

Modular **IPS** Series

Superconducting Magnet Power Supplies

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1 Warning.

- 1. High Voltage Hazard. Isolate this equipment by switching off the external AC electrical supply, disconnecting and removing the external supply cable.**
- 2. Maintenance: Only qualified and authorised persons should carry out servicing and repair work on this equipment.**
- 3. High Voltage Hazard: High voltages are present inside this equipment. Isolate this equipment by switching off the external AC electrical supply, disconnecting and removing the external supply cable before any covers are removed.**
- 4. Heavy Load Hazard. Care must be taken when moving the unit. It must not be lifted by the small front handles. Always use appropriate lifting equipment which must be positioned under the unit.**
- 5. The equipment has the following AC voltage options 100 V, 115 V, 200 V and 230 V. Please make sure equipment is set to value nearest to the nominal local mains voltage.**
- 6. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.**
- 7. The equipment is not suitable for use with explosive or flammable gases. The equipment is not suitable for use in explosive, flammable or hazardous environments.**
- 8. The equipment does not provide protection against the ingress of water. The equipment should be positioned so that it will not be exposed to water ingress.**

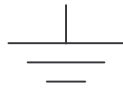
2 Cautions

- 1 **ELECTROSTATIC HAZARD:** *This equipment contains Electrostatic Sensitive Devices (ESSD). ESSD protective procedures in accordance with BS CECC00015 Part 1 and American National Standard EIA-541-1988 must be applied when installing or maintaining this product. Refer to guidelines in the preliminary pages.*
2. **COOLING HAZARD.** *Internal components are air-cooled. Ensure the front lower ventilation space is not obstructed.*

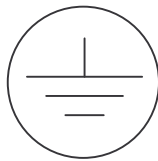
Explanation of symbols used in the Instrument



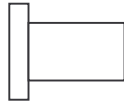
Attention; please refer to the manual



Functional earth



Protective earth



OFF



ON

3 Introduction

3.1 Use of this Manual

This manual provides operating and service information for the Oxford Instruments, IPS series of modular power supplies. 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.

3.2 Description of Equipment

An IPS modular power supply consists of a controller module and one or more power modules. These modules are mounted in an electronics rack, usually with space for other instruments to be fitted above the power supply.

There are two types of module: 120 amps, 10 volts and 60 amps, 20 volts. Module outputs are connected in parallel to busbars at the rear of the rack. The total current available is proportional to the number of modules connected.

The power supply is designed for energising and de-energising superconducting magnets. Current is delivered at a voltage up to +10 volts or +20 volts for magnet energisation. For de-energisation it is able to absorb energy at -10 volts or -20 volts.

The polarity of the current in the power supply can be selected, allowing magnets to be energised in a positive or negative direction. A separate output for a switch heater is provided for magnets incorporating a superconducting switch. Remote computer control of all power supply functions can be performed via RS232 and GPIB interfaces.

3.3 Model Names

The following table lists the current and voltage capabilities for each power supply:-

Model Name	Output Current	Compliance Voltage	Number of Modules
IPS240-10	+/- 240 A	+/- 10 V	2
IPS360-10	+/- 360 A	+/- 10 V	3
IPS120-20	+/- 120 A	+/- 20 V	2
IPS180-20	+/- 180 A	+/- 20 V	3
IPS240-20	+/- 240 A	+/- 20 V	4
IPS300-20	+/- 300 A	+/- 20 V	5

3.4 Warnings

Before you attempt to install or operate this equipment for the first time, please make sure that you are aware of the precautions that you must take to ensure your own safety. In particular please read the Safety section of this manual.

3.5 Important Note

This manual is part of the product that you have bought. Please keep it for the whole life of the product and make sure that you incorporate any amendments which might be sent to you. If you sell or give away the product to someone else please give them the manual too.

3.6 Disposal and recycling

Before disposing of this equipment, it is important to check with the appropriate local organisations to obtain advice on local rules and regulations about disposal and recycling.

You **must** contact Oxford Instruments NanoScience Customer Support (giving full product details) before any disposal begins.

4 Safety

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

4.1 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 disconnect the protective ground inside or outside the instrument.

There must always be a ground connection between the power supply and the cryostat, a suitable wire is included in the magnet current leads.

4.2 Magnet Terminals

Under no circumstances should the magnet cable be disconnected from the power supply or the magnet while current is flowing in the magnet. This may cause dangerously high voltages to appear on the magnet cables or terminals.

4.3 Repair and Adjustment

Under no circumstances is the user permitted to adjust or repair this unit while mains is connected.

Some internal adjustments can be made to the power supply. Although Oxford Instruments does not encourage you to make these adjustments we try to supply you with enough information to allow you to do it safely. Disconnect the AC power supply before you remove the covers or fuses, because dangerous voltages are accessible on the circuit board and other components. It is not sufficient to switch off the front panel power switch.

Fault finding within the large switch-mode power supply (SMPS), one inside each module, is not recommended. This is a specialist unit and should be returned to the factory for replacement or repair.

4.4 Safety Standards

This equipment is designed to meet the following safety requirement:

IEC1010-1 with Amendment 1: 2001

“Safety requirements for electrical equipment for measurement, control and laboratory use”.

5 Installation

The power supply consists of fan-cooled modules mounted in a rack. To avoid overheating, ensure that there is sufficient space for air to flow around it. There must be a gap of at least 100 mm behind the rack and an exit path for hot air from the fans.

5.1 Environment

The following operating environment conditions must be observed;

Maximum magnetic field	50 GAUSS
Ambient temperature	18 to 30 Celsius
Atmospheric pressure	700 to 1060 mbar(10 to 15 psi)
Relative humidity	30% to 75% non- condensing

5.2 Handling and Storage Including Transport

The module may be stored for up to 15 weeks in a storage environment as follows;

Ambient temperature	-20 to 45 Celsius
Relative humidity	30% to 75% (non- condensing)
Atmospheric pressure	700 to 1060 mbar

If storage is for less than 3 days then the following environmental restrictions apply;

Ambient temperature	-40 to 45 Celsius
Relative humidity	30% to 75% (non- condensing)
Atmospheric pressure	700 to 1060 mbar

Marking for packaging and handling complies with international standards ISO 780/BS2770.

5.3 Classification

The IPS is Class1 Equipment.

The equipment is not suitable for use in the presence of a flammable anaesthetic mixture with air or with oxygen or with nitrous oxide.

5.4 Maintenance

Preventive maintenance

Warning

Access within the equipment and removal of connecting cables is restricted to suitably skilled and competent persons. See WARNINGS and CAUTIONS.

Maintenance interval

Six months or as for cleaning if more frequent.

5.5 Cleaning

External cleaning

Interval between cleaning is as required by appearance.

Warning

Ensure that the AC supply to the equipment is isolated at the external disconnect device before cleaning. See WARNINGS and CAUTIONS.

To remove surface dust and light markings, the equipment may be wiped down using lint free cloth, barely moistened with clean water. For removal of heavy marks, the use of a proprietary aerosol foaming cleaner is permissible. Test carefully on a small inconspicuous area to ensure that the product does not damage the surface finish.

5.6 Connections

Warning

High voltage hazard. Ensure that the AC supply to the equipment is isolated at the external disconnect switch before accessing any connection.

Check all cables and connections to the equipment for mechanical security and ensure all covers are securely fixed in place.

Mains cord selection

In the EU, the mains supply cord shall be rated for the maximum current for the equipment. The cable used shall meet the requirements of IEC227 or IEC245, mains cords certified or approved by any recognised national test house are regarded as meeting this requirement.

In the USA the mains cord selected must be a listed mains cord set approved to the standard UL817 for Cord Sets and Power Supply Cords, the mains plug must be a separable plug (without a locking device). If the mains plug is to be a disconnecting device for the equipment, the mains cord must be less than 3 m in length. In Canada the cord set must be certified by CSA. The cord set must be suitable for use and of current rating at least 125% that of the equipment rating.

Green/Yellow covered conductors shall be used only for connection to protective conductor terminals.

5.7 Mounting Instruction (Rack Assembly)

5.7.1 Equipment Supplied

Before assembly, the power supply comprises the following items:-

- i) A 19 inch rack of appropriate height. Panels are fitted at the bottom, front and rear, for the mains connectors and output busbars. The rack is pre-wired with mains cables and connectors for the individual modules, and with heavy cables for connecting module outputs to the busbars.
- ii) A controller module. This module has front panel meters and buttons.
- iii) One or more power modules. The front panels of these modules have only an "ON/OFF" lamp.
- iv) For each power module, a ventilation grille 1U high.
- v) For each power module, a 15-way ribbon cable with D-connectors.
- vi) A 15-way D-plug with pins 8 and 15 linked.

5.7.2 Module Placement

Please note: before fitting modules into the rack, please read section 5.8 to ensure that the voltage settings are correct.

Slide a power module into the bottom of the rack immediately above the mains panels. Fit a ventilation grille above this module. Place additional power modules and ventilation grilles above these, and finally place the controller module above the last ventilation grille. There should be one grille between each module, to facilitate cooling.

5.7.3 Module Cables

Each module has two rear terminals fitted with 8 mm bolts. The rack has two output busbars, with cables pre-wired inside the rack. Use these cables to connect the MAGNET -ve terminals of each power module to the magnet -ve busbar, and the MAGNET +ve terminals to the Magnet +ve busbar.

Connect the single-phase mains connectors, pre-wired from the inside of the rear panel, to the circular connectors at the rear of each module.

On the rear of the controller module is a 15-way D-socket labelled "MASTER" Use a ribbon cable to connect this socket to the socket labelled "SLAVE" on the module below the controller.

Use any additional ribbon cables to connect the "MASTER" socket of each power module to the "SLAVE" socket of the module below.

Plug the D-plug with the linked pins into the "Master" socket of the module at the bottom of the rack.

5.8 Supply Connection and Voltage Adjustment

5.8.1 3 Phase Connection

The power supply rack is factory-wired for use with the operating voltage expected at the user's site. A 3 phase mains connector is supplied with the equipment. This connector is a large plastic socket which mates with the fixed plug at the rear of the power supply rack.

If the mains plug and socket are coloured red, then the rack is wired for use where the phase-to-neutral voltage is 200-240 Vac (346-415 Vac phase-to-phase), and the modules in the rack are connected to operate between phase-to-neutral wires. Make connections to the three phases and neutral and earth.

If the mains plug and socket are coloured blue, then the rack is wired for use where the phase-to-neutral voltage is 115-120 Vac (200-208 Vac phase-to-phase). Neutral is not used, and the modules in the rack are connected to operate between phase-to-phase wires. Make connections to the three phases and earth.

The power supply will not work if a red socket is connected to a 115-120 Vac mains. You should contact the factory if you have a red plug and socket and a phase-to-neutral voltage of 115-120 Vac.

The power supply will be extensively damaged if a blue socket is connected to 200-240 Vac mains (346-415 Vac phase-to-phase). You should contact the factory if you have a blue plug and socket and a phase-to-neutral voltage of 200-240 Vac.

5.8.2 Module Voltage Settings

In addition to checking the supply connector, check that the voltage label on each module indicates the correct supply voltage. Internal links must be set inside each module to match it to the mains voltage. This is normally done at the factory.

To change the module voltage settings, carry out the following procedure:-

The rack is wired so that the modules all operate from a voltage of 200-240 Vac.

Modules are set to the nearest or lower voltage from a choice of 200, 215 or 230 Vac.

For 240 Vac, the 230 Vac setting is used.

For 208 Vac phase-to-phase, the 200 V setting is used.

- i) Disconnect the rack from the mains supply before starting work.
Disconnect the cables from each module in turn and remove it from the rack, noting the position of the cables relative to the module rear panels.

- ii) For each module, remove the outer cover and find the mains assembly (on top of a transformer inside the front of the module). Remove the cover from the Mains PCB (CBL5750) and adjust the four links 1,2,3,4 to select the required voltage.

Mains Voltage	Link 1	Link 2	Link 3	Link 4
100 V	not fitted (not for modular systems)			
115 V	not fitted (not for modular systems)			
200V	A	B	B	A
215 V	B	B	B	A
230 V	B	B	B	B

- iii) The ratings of the fuses mounted on the Mains PCB are :-

F2, F4	T1.0AH 250V TYPE T
F5	T0.5 AH 250V type T

- iv) Replace the mains PCB cover and the module outer cover. Return the module to the rack and reconnect the cables. Please mark the new supply voltage on the rear of each module.

5.8.3 Rack Instruments

You should also check that any other instruments in the top of the power supply rack are correctly set, particularly if installing other instruments at a later date. The IEC mains outlet fitted within the power supply rack is wired for 200-240 Vac, in the same way as the power supply modules described above.

To summarise:

If the rack has a red mains connector then the other instruments should be set .for the phase-to-neutral voltage. If the rack has a blue mains connector then other instruments should be set .for the phase-to-phase voltage. Please refer to the relevant operating handbooks or manuals for details of how to change the mains settings of other instruments.

5.8.4 On / Off Switch

Once the mains supply is connected, turn on the two pole miniature circuit breaker (MCB) on the rear panel of each module. These breakers should normally be left in the "on" or up position. The single front panel "On / OFF" switch on the controller module is then used to turn all modules on and off simultaneously.

5.9 System Grounding

The power supply and magnet will frequently be used in a system with other test and monitoring instruments. It is important for the user to know how the power supply is connected to ground (to mains earth or chassis) in order to ensure that all interfaces are compatible. Incorrect grounding could damage the power supply or other instruments.

The metal case (chassis) of the power supply is connected to the earth wire of the mains cable. This connection is never broken, for safety reasons.

The signal returns of the computer interfaces (RS232 and IEEE) are joined to the MAGNET -VE busbar. This done inside the power supply and cannot be changed, else the power supply would not operate correctly.

The signal returns of the Parallel and Analogue Interfaces are also joined to the MAGNET -VE busbar inside the power supply, and so also is the +ve terminal of the switch heater output.

The power supply is normally shipped from the factory with the MAGNET -VE busbar linked to chassis. This is done using a solid metal ground link which is fitted outside the unit, underneath the MAGNET -VE busbar of the controller module (not on the power modules). This link can be seen from the rear of the power supply. The user should normally operate the power supply with the ground link fitted.

When the ground link is fitted, the Computer, Parallel and Analogue interface returns are all grounded to chassis. The ground link provides an important function - it will protect the power supply from damage if there is a fault inside the cryostat with an arc between the magnet and the cryostat. (For safety reasons it is also important that the cryostat has a high-current earth wire connected to the earth terminal on the rear of the power supply.)

In some installations it is necessary for the power supply output to be floating, not linked to ground. This occurs, for example, when more than one power supply is used to operate coils which are connected in series. The ground link may then be removed from the MAGNET -VE busbar. However, it is important to remember that the signal interface returns are internally joined to MAGNET -VE and that it may not be possible to connect a computer or other grounded instruments directly to the power supply without risking damage. In this situation, optically isolated interfaces are recommended, such as the Oxford Instruments ISOBUS section 5.12.

If the ground link is removed, the maximum voltage between chassis and either output busbar must never exceed ± 50 V. This limit is due to noise filter capacitors fitted between output and chassis.

It should be recognised that in the (rare) event of a severe magnet fault, there is more risk of damage to the power supply when the ground link is not fitted.

5.10 Magnet Connections

Connections to the main magnet current terminals are made via the busbar bolts on the rear panel. A suitable high current cable (normally supplied with the magnet), should be used.

The magnet cable should include an earth wire from the cryostat. Connect this to the earth terminal on the rear panel of the power supply (below the magnet terminals).

When making the connections, the power supply should be switched off to ensure that the output voltage is zero. Current polarity is defined as positive when current flows out of the MAGNET +VE busbar and returns to MAGNET -VE.

Danger On no account should these connections be made or broken unless both the voltmeter and the ammeter on the power supply are at zero

The small red and black terminals on the rear panel of the controller module provide connections to the heater of the superconducting switch on the magnet, if fitted.

5.11 Serial Data Line Connection

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 of the controller module. 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. For computers fitted with a 9 way D plug for RS232, (AT style COM port), a standard "AT lead" fitted with a 9 way socket and a 25 way plug is required.

Pin connections at the RS232 socket are:

Pin	Name	Notes
1	FG	Linked to Chassis Ground in power supply
2	TD	Received Data (From Computer)
3	RD	Transmitted Data (To Computer)
4	RTS	Linked to 5
5	CTS	Linked to 4
6	DSR	+5 V when unit is powered up
7	GND	Signal Ground
8	DCD	+5 V when unit is powered up

All other pins are open circuit.

The power supply does not require signals to be present on any of the "modem control" lines, RTS or DTR (pin 20). In other words, the power supply only requires pins 2,3 and 7 to be connected to a computer. However, to ensure maximum compatibility with any requirement of the computer, RTS is looped back as CTS and logic high levels are returned on DSR and DCD.

Voltage levels for the transmitted and received data are:

Transmitted Data High	> +5.5 V
Transmitted Data Low	< -5.5 V
Received Data High Threshold	< +2.6 V
Received Data Low Threshold	> +1.4 V
Max. Rx Input Voltage	± 30 V

Data protocols are:

Handshake	None required
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.

5.12 The Oxford Instruments ISOBUS

A unique feature of this power supply and other Oxford Instruments products, is the ability to connect a number of instruments simultaneously, to a single RS232 port on a computer and to control each one independently. This is done by means of an ISOBUS cable which carries a single MASTER connector (25-way D socket) and up to eight, daisy-chained SLAVE connectors (25-way D plugs). Each slave connector incorporates full optical isolation so that the slaves are all isolated from the master and from each other. The slaves connectors draw their power from the individual instruments, via the DCD signal on pin 8. The master connector may draw its power from either DTR or RTS signals from the computer.

To use ISOBUS, a special communication protocol is required, which is part of the command structure of Oxford Instruments products and is described in section 7.5.

5.13 GPIB (IEEE-488) Connection

Connections to the GPIB are made via a standard 24 way GPIB connector on the rear panel of the controller module. Assignment of the connector pins conforms to the standard IEEE-488.1. Connections should be made using a standard GPIB cable.

Caution GPIB connections should never be made or broken whilst the monitor or any of the instruments connected to the Bus are powered up. Failure to observe this precaution can result in damage to one or more instruments.

The GPIB interface complies fully with IEEE-488.1-1987 as a talker/listener, able to generate service requests and respond to serial poll and device clear commands. It does not support parallel polling and has no trigger function. Open collector drivers are used on the bus lines so it does not prevent parallel polling of other devices on the bus. Its complete GPIB capability is specified by the Capability Identification Codes:-

SH1 AH1 T6 L4 SR1 RL0 PP0 DC1 DT0 C0 E1

Two lamps are fitted to the rear panel of the controller module below the GPIB connector, to assist in diagnosing any GPIB communication problems. The RED lamp lights whenever the power supply is addressed to TALK and the GREEN lamp lights whenever it is addressed to LISTEN. The behaviour of the lamps is very dependent on the GPIB monitor in use. Some controllers un-address an instrument at the end of any transaction, in which case the lamps will just blink on for each transaction. Others leave instruments addressed between transactions in which case one or other lamp may remain lit depending on whether the power supply was last addressed to talk or to listen.

Before any communication can occur, the power supply must be given a unique GPIB address. By default, the power supply is supplied with its address set to 25. If this address is already in use by another instrument on the bus, it can be changed from the front panel via the Test Mode. This is described in section 11.6.

5.14 The GPIB to ISOBUS Gateway

The power supply has the ability to act as a GATEWAY to an ISOBUS cable, allowing other instruments to be linked to the GPIB without themselves requiring GPIB interfaces. This can enable other Oxford Instruments' products, for which an internal GPIB interface is not available, to be linked. It offers the additional advantage of optical isolation between these instruments and the GPIB.

To use the gateway, all that is required is GATEWAY MASTER ADAPTOR. This allows the 25 way ISOBUS MASTER socket to be linked to the 25 way RS232 socket on the power supply. The adaptor is a symmetrical 25-way plug to 25-way plug link, with pin connections as shown below.

Beware of using 25-way plug to 25-way plug adaptors, sold as "DCE-linkers" by some suppliers. Several different conventions exist for these, not all of which will work as a Gateway Master Adaptor. The connections required are given in the table below. A Gateway Master Adaptor providing these connections may be obtained from Oxford Instruments.

25 WAY PLUG	25 WAY PLUG
1	1
2	3
3	2
7	7
6	4
4	6

Note that the connections are symmetrical and the adaptor may be plugged in either way round.

The necessary protocols for the use of a power supply as a Gateway Master are described in section 7.6.9.

5.15 Parallel Interface Connections

The parallel interface port is a 15 way D-type connector on the rear panel of the controller module, marked "PARALLEL I/O" (which corresponds to SK2 on diagram CBL1202 sheet 2/3). It is a digital interface and provides three separate functions.

1. an input signal to force a superconducting magnet to de-energise.
2. an output confirming the output current is within a defined range.
3. several uncommitted input and output lines for computer control. (3 input, 7 output, see section 8.2)

The outputs are open-collector transistors (specification as for ULN2803A) and can sink up to 500 mA from a supply of up to 25 volt 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 500 mA may be drawn from this source.

The input lines on the parallel interface socket are suitable for either TTL level inputs (74 series, Transistor Transistor Logic) or contact closures to +5 V. The input device is a 74HC244 and 100 kohm pull-down resistors to 0 V are fitted. Pin connections at this socket are:-

Pin	Title	Function
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	+5 V	
15	+11 V unregulated. (Driver Protection)	
8	0 V	

5.15.1 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 11.10.

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 approximately 10 mA being drawn from pin 7 (at +5 V) 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.

5.15.2 Auto-Run-Down

Auto-run-down will automatically de-energise a magnet system. The function is described in section 9.

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

For example, low helium level can trigger an auto-run-down by using an Oxford Instruments ILM200 or HLM2 helium level meter. These meters contain relays which change state when the helium level drops below a user settable level.

In the case of the ILM200, connections should be made to a pair of terminals inside the ILM200 marked "COM" and "N/O".

In the case of the HLM2, connections should be made to a pair of terminals on the rear panel, marked "COM" and "LOW".

Refer to the relevant level meter manual for further details.

5.16 Analogue Interface Connections

The analogue interface port is a 9 way D-type connector on the rear panel, marked "ANALOGUE I/O" (see diagram CBL2902 sheet 3/3 and PL102 on CBL5302 sheet 1/7). It provides for analogue monitoring of power supply voltage and current and a modulation input which allows the magnet current to be adjusted slightly by means of an analogue control voltage or signal.

Pin connections at this socket are:

Pin	Function
1	test use only
6	test use only
2	Current Shunt
7	Current Shunt return
3	Current Monitor
8	Current Monitor return
4	Voltage Monitor
9	Voltage Monitor return
5	Not connected

All of the return pins are internally connected by 1 kohm resistors to the same 0 V as the digital interfaces.

5.16.1 Current Shunt

This output and its return provide a direct monitoring connection to the 120 amp shunt used to control the output current in the controller module. A 1 kohm resistor is fitted in series with each pin. This function is of limited use in multi-module systems since the currents in the power modules are not included.

+/-120 mV represents an output current of +/-120 A
(to within +/-1%)

5.16.2 Current Monitor

This output provides a 10 V monitor of the output current, note that the monitor polarity is the inverse of the output current. Output impedance is 2 kohm in addition to a 1 kohm resistor in the return line.

-/+10 V represents +/- full-scale current of the power supply
(to within +/-0.2%)

5.16.3 Voltage Monitor

This output provides a 10 V monitor of the output voltage. Output impedance is 2 kohm in addition to a 1 kohm resistor in the return line.

+/-10 V represents for 10 V power supplies an output voltage of +/-10 V
+/-10 V represents for 20 V power supplies an output voltage of +/-20 V
(to within +/-1%)

5.17 Configuring the Power Supply for the Magnet

If the power supply is provided as part of a magnet system, then values such as the correct ratio of amps to tesla will have been loaded at the factory. However if the power supply is shipped on its own, then certain parameters should be set.

All the configurable parameters are accessed through "test mode", see section 11. There are many parameters that may be set but the most important are listed below:-

Test 06 Magnet System Configuration. typically set to:
0 if there is no persistent switch fitted to the magnet.
1 if there is a persistent switch fitted to the magnet.

Test 07 Superconducting Magnet System.
S 01 Define amps / tesla.
S 02 Define power supply current limit.
S 11 Define magnet inductance.
S 15 Define switch heater current.

6 Local Operation

6.1 Front Panel Controls

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

6.1.1 POWER

The main ON/OFF switch. When the instrument is switched on, the green POWER lamps are lit on the controller and all power modules.

6.1.2 ADJUST

The red RAISE and LOWER buttons are used to adjust a 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 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 digit. 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 6 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.

6.1.3 CONTROL

Control of the instrument may either be LOCAL from the front panel, or REMOTE via the RS232 or GPIB 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, see section 9.

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 whether there is a computer connected to a digital 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 9.

6.1.4 SWITCH HEATER

This controls the heater supply for a superconducting switch on the magnet (if fitted). The SELECT and CONFIRM lamps together indicate that the heater is on and the superconducting switch is open, allowing the magnet to be energised. When the lamps are off, the heater is un-powered and the superconducting switch is closed.

The SELECT lamp indicates the selected state of the switch heater and the CONFIRM lamp shows when current is actually flowing in the heater circuit. CONFIRM detects a heater current of approximately 5 milliamp or more. If SELECT is on and CONFIRM is off then check that the switch heater leads are correctly connected.

The associated button allows the heater to be switched on and off. This button will only function when the output current is stable, it is disabled whilst the output is sweeping. Please note, It is usually necessary to wait several seconds after operating the button before the superconducting switch changes state.

In order to prevent inadvertent damage to the magnet system, the switch heater will only turn on if the power supply current matches the 'persistent magnet current' in both magnitude and polarity (+/- zero amps are considered equal). The 'persistent 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 the 'persistent magnet current' does not match the power supply current then the 'persistent magnet current' is displayed for as long as the switch heater button is depressed. This safety feature gives a warning that the magnet system could be damaged if the switch is opened. The operator should change the power supply current to match the 'persistent magnet current' before attempting to energise the switch heater. If the operator is confident that no damage will be done, then the 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 the power supply current.

The current flowing through the switch heater may be adjusted to suit different switches by setting a parameter in test mode (see section 11.10). If the power supply was supplied with a magnet, the switch heater current will have been set to an optimum value at the factory. The current is normally set to the minimum value at which the switch will open reliably after 10-15 seconds.

6.1.5 SWEEP CONTROL

HOLD, GOTO ZERO and GOTO SET buttons may be used to control the power supply output current. Three lamps indicate which state is selected. A fourth state, clamped, is possible and is indicated in the DISPLAY box along with other lamps that show when the power supply is not in normal sweep mode.

HOLD

Unclamping a magnet. The clamped state can only be left by pressing HOLD. The output clamp relays open and the magnet is connected to the power electronics.

The modular power supply system is not able to unclamp if there is too much current in the magnet leads, the error message "Err C" will be displayed. The user must wait for the current to decay before the clamp will open. The limit is set by the maximum current that any one module can carry. A 10 volt power supply will unclamp when the current in the leads is less than 120 amps, a 20 volt power supply will unclamp when the current is below 60 amps.

Stopping a sweep. The power supply output current will remain at the same value indefinitely. This extends into the voltage limiting mechanism, which is inhibited while the HOLD button is pressed, see section 6.2.

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

- i) The "Hot", "Fault" and "Quenched" states are cleared.
- ii) With a finger on HOLD, pressing SET POINT will cause the last recorded "Trip Current" or "Trip Field" to be displayed. See section 6.2.
- iii) With a finger on HOLD, pressing RAISE or LOWER will cause "FASt" or "SLO" 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. SLO is an alternative set of maximum sweep rates. There is no significance in the two names, they only serve to distinguish the profiles. The limiting rates are variables, see section 11.10.

GOTO ZERO

Causes a sweep towards zero current or field.

GOTO SET

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

Sweep Mode and Immediate Mode

The sweep can proceed in one of two modes, "sweep mode" and "immediate mode" the power supply automatically makes this decision depending on what load the power supply is connected to. There are three possible loads:-

- i) There is no superconducting switch fitted to the magnet. All power supply current must pass through the magnet. The sweep proceeds in "sweep mode".
- ii) There is a superconducting switch fitted but it is "open", the magnet is non-persistent. Changes in the power supply current will all pass through the magnet. The sweep proceeds in "sweep mode".
- iii) The magnet is persistent because the superconducting switch has been closed. Changes in the power supply current will all pass through the leads and persistent switch only, not the magnet. The sweep proceeds in "immediate mode".

The power supply knows if there is a switch fitted because of a flag set in the "Configuration", see section 11.9. If there is a switch fitted, the state is determined by the state of the switch heater; if the heater is on then the switch is "open", if the heater is off then the switch is "closed".

The immediate mode sweep rate is fast, the default setting is from zero to full rated current in 30 seconds, but this can be modified, see section 11.10. The sweep mode rate will be 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, explained later in this section.

Note that 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 6.2.

6.1.6 DISPLAY

The four lamps on the right of the display indicate deviations from the normal sweep modes.

OUTPUT CLAMPED

At switch on, the power supply is in a clamped state, and the OUTPUT CLAMPED lamp is on. 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.

PERSISTENT MODE

A superconducting magnet is put into persistent mode by closing the superconducting (or persistent) switch which is fitted in parallel with the windings to complete the superconducting circuit. The power supply current is then decreased to zero, so that all of the magnet current flows through the switch.

This lamp indicates that the power supply lead current is zero, that the magnet is persistent, and that the current in the magnet is non-zero. If there is zero current in the magnet or the magnet is not persistent, then the lamp will not light. To discover the current (or field) in a persistent magnet, press the MAGNET STATUS button.

SWEEP 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 pre-set 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 for one of two reasons. Firstly to protect a magnet from damage caused by sweeping it too fast or secondly to prevent the power supply from being swept so fast as to touch the voltage limits (see section 6.2). To change a limit see Sup 05 to Sup 09 in section 11.10.

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.

The threshold at which a quench is triggered depends on the magnet inductance. The inductance can be adjusted by the user, see section 11.10. If the inductance is set too low, the power supply will not detect a quenching magnet. If the inductance is set too high, then a quench may be falsely triggered by normal operation.

A magnet quenches when part of the windings goes normal, or resistive. the energy dissipated by the current flowing through this resistive part of the coil generates heat. The heat usually causes the normal region to propagate rapidly through the whole magnet.

For some magnets there is a possibility that a small winding (for example a cancellation coil) 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. Also, damage may occur to a persistent magnet switch if after the quench the power supply outputs a large voltage which heats up the switch while there is no liquid helium left to cool it.

For these reasons a "QUENCH" will cause the power supply to go to zero amps +1V. 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". To display the trip current, press and hold the MAGNET STATUS (or HOLD) button and then press the SET POINT button.

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

Numeric Display

The numeric 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 power supply is in voltage limit mode (see section 6.2) 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.

The display may be switched to show 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.

"Hot" Message

It is possible that the display may read "Hot" instead of a number, this indicates that the transistor bank has overheated in one of the modules. 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). Pressing the HOLD button will restore normal operation but only if the overheated part has cooled down.

"Fault" Message

It is possible that the display may read "Fault" instead of a number, this indicates a fault condition which may include the following:-

- (a) Loss of a mains phase.
- (b) Disconnection of a module mains connector.
- (c) Circuit breaker (MCB) switched off at the rear of a module.
- (d) Ribbon cable disconnected.
- (e) Circuit failure within a module.

The user should check for (a) to (d) before investigating a module failure.

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. Please note that the amps/tesla coefficient must be correctly set for the magnet. If the power supply was supplied with a magnet, then the coefficient was set at the factory.

OUTPUT VOLTS

The voltage across the (inductive) magnet is proportional to the rate of change of current, so depends on the magnitude and sign of the sweep rate. The displayed voltage includes the voltage drop due to the magnet cables, proportional to current and typically 1 volt at full output current.

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 11.10.

MAGNET STATUS

Press this button and the power supply will display the current (or field) that the power supply believes to be in the magnet.

In the case of an magnet that has not been fitted with a persistent switch the display will not change. If the magnet does have a persistent switch but it is 'open' then the display will not change. If however the persistent switch is 'closed' then the display will change to display the current (or field) in the magnet when it was last put persistent.

With a finger on MAGNET STATUS, pressing SET POINT will cause the last recorded "Trip Current" or "Trip Field" to be displayed. See section 6.2.

SET RATE

Displays the sweep rate in amps per minute or the equivalent tesla per minute. The range of possible values that may be set depends on the current specification of the power supply, please refer to section 12. Whilst sweeping, the SET RATE may exceed the maximum magnet sweep rate, in which case the sweep rate will be limited and SWEEP LIMITING will be illuminated (refer to page 27). 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 6.2.

Note that the SET RATE is only observed when in sweep mode (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. 30 seconds from zero to full current, or less if the limit has been reduced, see section 11.10.

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 full current, or 0 and the maximum magnet current if a current limit has been installed, see section 11.10.

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.

With a finger on HOLD, pressing (display) SET POINT will cause the last recorded "Trip Current" or "Trip Field" to be displayed, see section 6.2.

CHANGE POLARITY

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 the set point corresponds to the polarity of the target current.

6.2 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 or +/-20 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. Pressing the HOLD button will temporarily disable voltage limiting.

When the power supply first reaches a voltage limit, the power supply output is recorded as the trip current, displayed by pressing MAGNET STATUS (or HOLD) and SET POINT (see above). When a magnet has been "caught" the power supply is left in its HOLD state and the (persistent) magnet current is updated (thus an accurate record of magnet current is kept even if a superconducting switch closes at a current different from that when the operator last turned off the switch heater).

For some (unswitched) magnet systems, the catch mechanism is accidentally triggered at the beginning (or end) of a fast sweep. This transient or voltage overshoot is due to a low frequency resonance between the magnet and the output capacitors of the power supply. The catch mechanism can be told to ignore the first 2 seconds of voltage limiting, it will only trigger if voltage limiting persists for longer than this time. To make the power supply ignore transients, a switch must be set in the "configuration", see section 11.9.

Software voltage limits are not commonly used. They are intended to protect magnets at the end of long or very resistive leads. The power supply continuously monitors the magnet lead resistance and calculates the voltage drop across them, subtracting this voltage from the voltage measured at the power supply terminals results in the voltage at the magnet.

If the software voltage limits are required, they should be set to be just below the voltage of the magnet protection network, the power supply firmware will then make allowance for the voltage drop across the leads. If the power supply exceeds this limit then some of the current must be flowing in the protection circuit, if the condition persists for more than a pre-set period (e.g. 2 seconds), the magnet will be "caught".

6.3 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.

Warning Connections to the magnet should never be broken unless both meters are at zero.

The Output Current scale is marked POSITIVE and NEGATIVE 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 conditions the display will flash, to warn the operator.

The current value displayed is the true sum of the currents from all modules. This is useful, for example, in diagnosing a fault where one module is not delivering the correct current.

The Output Voltage scale is marked POSITIVE and NEGATIVE. Note that at higher currents, the lead resistance will introduce an offset voltage of about 1 volt at full current.

If the field magnitude is increasing, both the voltage and current meters will show the same polarity. When the field is decreasing towards zero, then the voltage polarity will be the opposite of the current.

6.4 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.

CAUTION The power supply is designed for use with a magnet and will not function correctly with a small inductive load. The load should only be either a short-circuit or an inductance of 0.2 - 1000 henries.

Switch on the miniature circuit breakers mounted on the rear panels of the controller and all of the power modules, it is marked "ISOLATION". These switches should now be left in the "on" position. The front panel ON/OFF switch is for every-day use.

Switch on the instrument by means of the ON/OFF switch on the front panel, the green POWER lamp illuminates on each module.

After about one second a message such as "PS3.01" will appear on the display. This shows the firmware version and indicates that the power supply has completed its self test and initialisation. This message is closely followed by a "G" and a number, indicating the GPIB address of the instrument. The second message clears and the display will show the output current.

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

Decide whether 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 down the appropriate SET button.

If the magnet has a superconducting switch fitted, 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.

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

7 Remote Operation

7.1 Introduction

The power supply may be remotely operated by means of its RS232 or GPIB 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.

7.2 Communication Protocols

The power supply is always fitted with both Serial (RS232) and GPIB (IEEE-488) interfaces. Details of the hardware communication protocols for the two interfaces are given in sections 5.11 and 5.13 respectively.

The same command protocols are used for the Serial and GPIB interfaces.

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. With the Serial Interface in use, the response will be transmitted automatically as soon as it is available. With the GPIB interface, the response will be sent when the instrument is next addressed to talk.

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, then the response may appear to be incomplete or chaotic. In this case, the "W" command may be used to instruct the power supply to send more slowly, see page 43.

If the first character of a command is a "\$", the command will be obeyed but no response will be sent, see section 7.5.

7.3 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.

7.4 Numeric Parameters

All numeric parameters are treated as signed decimal numbers and are sent as a string of decimal digits with an appropriately placed decimal point. Note that this is **not the same convention as the PS120-10 or ITC4** where all numbers were treated as signed integers.

The format of all numbers exactly matches that displayed on the front panel. However the resolution can be extended by an extra decade if set by the "Qn" command, see page 41.

7.5 Use of the Oxford Instruments ISOBUS

The Oxford Instruments 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, held in non-volatile memory.

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)n addresses the command to instrument number n, where n is a digit in the range 0 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 whether 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 page 42

To retain the new Isobus address after the instrument is switched off, the data must be stored. This is done either by sending the "~" command, as described on page 48, or by exiting test mode, as described in section 11.3

Note that the address set this way is the ISOBUS address, not the GPIB address. The later cannot be set via the interface, since until an address is defined, GPIB communication is not possible.

7.6 The GPIB Interface

The GPIB Interface allows the power supply to be computer-controlled by means of the General Purpose Interface Bus (GPIB), also known as HPIB and IEEE-488 interface.

The GPIB Interface supplements rather than replaces the RS232 Serial Interface. It allows an instrument to be controlled either by GPIB or RS232 (not both simultaneously). In addition when operating under GPIB control, the RS232 interface may be used as a GATEWAY to further OI instruments, not themselves fitted with a GPIB interface.

An Oxford Instruments power supply is normally supplied set to a GPIB address of 25. To change the address, the user must enter test mode, see section 11.6.

The instructions which follow assume some basic familiarity with the concepts of the GPIB. This will typically be provided as part of the documentation supporting a GPIB controller card for a computer etc.

Even with the GPIB interface fitted it is still possible to communicate with the instrument via the RS232 interface in the standard way. This is the default condition after power up (or a re-start when exiting test mode) and ISOBUS addressing may be used if desired.

Provided the GPIB interface has not been deliberately DISABLED by setting its address to 0, it may be switched to the GPIB IN-USE state at any time. This occurs automatically when a GPIB Controller asserts the REN line and addresses the interface either to talk or listen at the GPIB address selected. Once it has been put into the GPIB IN-USE state, it remains in that state until power down or until a re-start on exit from test mode.

7.6.1 Sending Commands via the GPIB

Commands sent via the GPIB follow exactly the same syntax as for the RS232 interface. Commands must be terminated by a Carriage Return <CR> character, (ASCII 13). A Line Feed <LF> may be sent if desired but is not needed and will have no effect. (Your GPIB controller may send <CRLF> by default). Provided it is operating (as opposed to being in TEST mode) the power supply will accept commands at all times. Where commands produce a response message, this should be read before a further command is issued.

7.6.2 Accepting Responses via the GPIB

Messages returned via the GPIB consist, by default, of an ASCII character string, terminated by a <CR>. If your controller expects <LF> as a terminating character, this may be achieved by sending an initial "Q2" command after power up. Note that the "Q2" command itself produces no response message but that all subsequent messages are terminated by the <CRLF> pair. The interface never asserts the EOI line at the end of a message, instead allowing either <CR> or <LF> to be used as the End-of-String (EOS) character.

7.6.3 The Status Byte, Use of a Serial Poll

One of the problems with a GPIB interface is knowing when a message is available to be read. If a device is addressed to TALK but has no data available, it will wait indefinitely, unless the controller includes a TIME-OUT facility (see section 7.6.10). There are a number of ways by which the controller can determine when data is available. The simplest, but least reliable way is to "know" from the command which has been sent, whether a reply is to be expected. This is fine until something unexpected happens.

A better alternative is to read a STATUS BYTE from the instrument by conducting a SERIAL POLL of it. The power supply interface will always respond to a serial poll and will return a status byte. Three bits in this byte have significance for the power supply as follows.

Bit 6 (Value 64 decimal)	RQS (Requesting Service)
Bit 4 (Value 16 decimal)	MAV (Message Available)
Bit 1 (Value 2 decimal)	BAV (Byte Available)

The bit positions for the RQS and MAV bits are as specified in IEEE-488.1 and IEEE-488.2 respectively. (Note the convention here is that the Least Significant Bit is Bit 0. This is sometimes referred to as data line D1. Thus lines D1 to D8 correspond to Bits 0 to 7.)

The BAV bit is set as soon as at least one byte is available to be read. The MAV bit is set when a complete message up to and including the <CR> or <LF> character is available to be read. The RQS bit indicates that the instrument has requested service by asserting the GPIB SRQ line true (see section 7.6.4).

The status byte may be read as many times as the controller wishes. The MAV and BAV bits will reflect the current status of the interface at the time the byte is read (but see below). Hence once set, they will remain set until the message has been read. The RQS bit behaves differently (in accordance with IEEE-488.1). The first time the status byte is read after the interface has requested service, it will be set. The act of reading the status byte clears the service request bit and at the same time allows the interface to release the Service Request Line (see below). It will not be asserted again unless a further service request is issued.

The power supply updates the status byte every millisecond. Thus if the status byte is read within 1 ms of reading data from the interface, the MAV and BAV bits may not yet have been cleared, even though all available data has been read. If these bits are found to be unexpectedly set immediately after a data read, a second read of the status byte at least 1 ms later will confirm whether there really is data remaining.

7.6.4 Use of the Service Request Line

The interface will issue a service request (by pulling the SRQ line), at the point a complete message becomes available to be read, (i.e. at the point at which MAV is first set), unless the interface is already addressed to TALK at that point. In the latter case no service request is required since the controller is already waiting to read the data or is in the process of doing so.

Hence use of the SRQ line allows a suitably equipped controller to handle all data from the interface on an interrupt basis. If the controller is not equipped to do this, it may simply ignore the SRQ line and poll the status byte on a regular basis until the MAV bit indicates data is available.

7.6.5 Use of the Device Clear Function

When the GPIB interface receives a Device Clear message from the controller, it responds by clearing all the communication buffers to their empty, power-up state. It does not reset any of the temperature control functions to the power-up state. Device Clear may thus be safely used to empty the buffers if these have been filled with a number of unread messages. Device Clear may be sent by either the GPIB DCL message (which clears all connected devices), or by means of the SDC message addressed specifically to its address.

Note that if an ISOBUS GATEWAY is in use, only the buffers in the MASTER instrument are cleared. If data is currently being transmitted from a SLAVE instrument to the MASTER, this will be read into the buffer after it has been cleared.

7.6.6 Use of the Interface Clear (IFC) Function

Receipt of the single line IFC message clears the GPIB interface functions as specified by IEEE-488.1. It does not clear any pending data in the buffers. Nor does it have any effect on operation of the power supply's control functions.

7.6.7 Non-Implemented Features of the GPIB

The GPIB Remote Enable (REN) line is used only to alert the interface to the presence of an active controller. It is not used for LOCAL/REMOTE switching which is carried out by the simpler "C" command, for compatibility with RS232 operation. Similarly the GPIB LOCAL LOCKOUT command and GOTO LOCAL commands have no effect. This functionality too is a part of the "C" command.

The interface does not respond to a Parallel Poll request. However since it uses open collector data buffers, it can co-exist on the GPIB with other instruments which do have a Parallel Poll facility.

7.6.8 Compatibility with IEEE-488.2

Compatibility with certain aspects of this extension to the original standard has already been mentioned in a number of places (for example the format of the Status Byte). However details of the command sequences and formats within messages, error handling and status reporting all follow the existing power supply syntax and protocols used on RS232. This precludes complete compliance with the rather more complex IEEE-488.2 syntax. In particular there is no attempt to support the "Standard Commands for Programmable Instruments" (SCPI).

7.6.9 Use of the GPIB Interface as a GATEWAY to ISOBUS

When the interface is operating in the GPIB IN-USE state, all characters received via the GPIB are echoed back out on the RS232 line. Similarly any characters received on the RS232 are made available to be read by the GPIB controller (with MAV, BAV and RQS being set appropriately as above). This allows one or more other instruments to be connected to the first instrument using the Oxford Instruments ISOBUS. These may share the benefits of being controlled by the GPIB controller, whilst at the same time enjoying the advantages of optical isolation provided by ISOBUS. To use this GATEWAY, requires only a GATEWAY MASTER ADAPTOR, as described in section 5.14.

No special command protocols are required to access the GATEWAY. All Oxford Instruments products fitted with RS232 can be accessed in this way. The command strings sent to individual instruments when used in this way are simply prefaced by their ISOBUS ADDRESSES as described above. Note the distinction between the GPIB address which is common to all the instruments on the GATEWAY and their individual ISOBUS addresses which form a part of the message string, preceded by the "@" character. The ISOBUS GATEWAY MASTER (i.e. the instrument actually fitted with the GPIB interface) always has the ISOBUS address "@0". This must be used when addressing this instrument, since a command sent with no "@" prefix would be seen by all instruments (just as for a simple ISOBUS system).

7.6.10 Writing a "Rugged" GPIB Control Program

A lot of effort has been put into making the design of the GPIB interface as tolerant as possible. However in any computer interface designed to operate unattended for periods of time, it is essential to assume that data corruption may occur at any time. Usually this is due to static, power line surges, operator error etc. Any controller program should be designed to cope with this. In particular all attempts to write data to or read data from any instrument should have a TIME-OUT facility built in. The GPIB handshake sequence makes it all too easy for lost data to result in the bus hanging indefinitely. When a time-out occurs the controller should attempt to assess what is happening. In the case of the power supply GPIB interface this is best done by means of a serial poll. If this too times out, the next recourse should be to reset the interface by means of the Interface Clear (IFC) line. If a serial poll is still unable to get a response, the controller must assume that the instrument has been switched off, failed or a connector has fallen out. As a last resort it should attempt to alert an operator and/or if possible continue operating the remaining instruments.

8 Command Syntax

For a more detailed explanation of the power supply states, the user should refer to section 6, Local Operation.

Commands fall into four categories:

Monitor Commands

which are always recognised.

Control Commands

which are only recognised when in REMOTE control.

System Commands

which are only recognised after receipt of the correct Unn command or "unlock key".

Specialist Commands

Which are all lower case letters. They are primarily for use with OI supplied high level system software or as an aid to control algorithm development.

In the Lists which follow "n" & "m" represent decimal digits 0-9. A number represented by "nn" is not constrained to be a single digit.

8.1 Monitor Commands

Cn Set Control

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

In the C3 state, buttons such as SET POINT and SET RATE, can be used to examine values on the display, but RAISE and LOWER cannot be used to change these values. However the LOC/REM button is active and can be used to switch to the C2 state in order to change values. While any buttons are held pressed in the C3 state, the instrument will not respond to any remote commands. Instead these are held pending and acted upon when the button is released. Computer programs should either be written to tolerate this delay or should put the instrument into the C1 state to completely disable the front panel controls.

Qn Set Communications Protocol

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

- Q0 "Normal" (Default Value)
- Q2 Sends <LF> after each <CR>
- Q4 Extended Resolution.
- Q6 Extended Resolution. Send <LF> after each <CR>.

Note that unlike all other commands, the Q command does not produce an echoed response to the computer. (Having changed the communication protocol, it automatically clears the communications buffer.)

The <LF> option is for use with computers that require an <LF> as an input message terminator.

Extended resolution increases the resolution of the power supply's currents and fields and associated rates by one order of magnitude. For example the IPS120-10 set point current resolution is increased from 0.001 amp to 0.0001 amp.

Note that the Q command is volatile, when the power supply is switched off and on, the communication protocol reverts to the default value of Q0.

Rnn Read Parameter

The READ command allows the computer to interrogate any of a number of variables. The returned value is always a number as defined in section 7.4. Allowed values for n are listed below. The name of the parameter is followed by the units and the letters E.R. if the parameter can be sent at extended resolution, see the "Qn" command on page 41. Variables marked with a "*" are intended as service diagnostics and are unlikely to be of use to the user.

R 0	Demand current (output current)	amp	E.R.
R 1	Measured power supply voltage	volt	
R 2	Measured magnet current	amp	
R 3	Unused		
R 4 *	Demand current (duplicate of R0)	amp	E.R.
R 5	Set point (target current)	amp	E.R.
R 6	Current sweep rate	amp / minute	E.R.
R 7	Demand field (output field)	tesla	E.R.
R 8	Set point (target field)	tesla	E.R.
R 9	Field sweep rate	tesla / minute	E.R.
R 10 *	DAC zero offset	amp	E.R.
R 11 *	Channel 1 freq./4		
R 12 *	Channel 2 freq./4		
R 13 *	Channel 3 freq./4		
R 14 *	Demand current (duplicate of R0)	amp	E.R.
R 15	Software voltage limit	volt	
R 16	Persistent magnet current	amp	E.R.
R 17	Trip current	amp	E.R.
R 18	Persistent magnet field	tesla	E.R.
R 19	Trip field	tesla	E.R.
R 20	Switch heater current	milliamp	
R 21	Safe current limit, most negative	amp	
R 22	Safe current limit, most positive	amp	
R 23	Lead resistance	milliohm	
R 24	Magnet inductance	henry	

Unn Unlock System Commands

The UNLOCK command allows access to the SYSTEM commands. These commands are intended for diagnostic and configuration purposes and have the power to erase or modify the contents of the memory. The U command must be followed by the correct KEY parameter before these commands may be used. The KEY value for these commands is 9999.

A lower level of key protection is provided for the "!" command, to avoid accidental errors. Any non-zero value will unlock this command.

Two additional special key values are significant. These are intended specifically to allow a GATEWAY MASTER instrument to be used to load RAM data (via a "Y" command) to a SLAVE instrument, without the data being "obeyed" as commands, by the MASTER. A value of U1234 puts the MASTER to SLEEP, until the specific sequence U4321 is detected. Whilst it is asleep, all data received via the GPIB interface is passed on to the slave but ignored by the master.

Thus the allowed values of U are:-

U0	Locked (power-up default)
U1	"!" command unlocked
U1234	Sleep
U4321	Wake up
U9999	"Y" and "~" commands unlocked

V Read Version

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

For example: "IPS120-10 Version 3.04 © OXFORD INSTRUMENTS 1999"

Wnn Set Wait Interval

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 nn specifies the delay in milliseconds. It defaults to zero at power-up, the maximum delay is 32767 milliseconds.

Note that 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

Note that the length of the returned string is fixed (at 15 characters).

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
m=8	Fault
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 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 Magnet at Zero	(switch closed)
	n=1	On	(switch open)
	n=2	Off Magnet at Field	(switch closed)
	n=5	Heater Fault	(heater is on but current is low)
	n=8	No Switch Fitted	
Mmn	Mode	(m as for M command)	
		<u>Display</u>	<u>Magnet Sweep</u>
	m=0	Amps	Fast
	m=1	Tesla	Fast
	m=4	Amps	Slow
	m=5	Tesla	Slow
	n=0	At rest	(output constant)
	n=1	Sweeping	(output changing)
	n=2	Sweep Limiting	(output changing)
	n=3	Sweeping & Sweep Limiting	(output changing)

The active states "SWEEPING" and "SWEEP 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 SWEEP 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, SWEEP LIMITING will also be indicated.

Pmn	Polarity	<u>Desired</u>	<u>Magnet</u>	<u>Commanded</u>
m=0		Positive	Positive	positive
m=1		Positive	Positive	negative
m=2		Positive	Negative	Positive
m=3		Positive	Negative	Negative
m=4		Negative	Positive	Positive
m=5		Negative	Positive	Negative
m=6		Negative	Negative	Positive
m=7		Negative	Negative	Negative
n=1		Negative contactor closed		verification flags
n=2		Positive contactor closed		verification flags
n=3		Both contactors open		verification flags
n=4		Both contactors closed		verification flags

For the IPS series power supplies, the polarity flags are superseded by signed numbers for currents and fields, but they are included here for compatibility with the earlier PS120-10. The customer is advised to ignore these flags.

An Set Activity

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 instrument 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 Display Parameter

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

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 is equal to the present power supply output current. Both current magnitude and polarity are considered but +/- zero amps are considered equal.

Caution The H2 command performs no such check, and will open the switch regardless of any apparent conflict

Please note the following points:

- 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, for example 30 seconds from zero to full current, 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.

Inn Set Target Current

The I command sets the SET POINT (target) current to which the power supply will sweep. The parameter nn is the required current sent as a number in accordance with section 7.4. The resolution of the set current is 0.001 amp, or 0.0001 amp if Extended Resolution has been selected, see the "Qn" command on page 41. If the maximum output current of the power supply is more than 199 amps, then the resolution is reduced to 0.01 and 0.001 amps.

Jnn Set Target Field

The J command sets the SET POINT (target) field to which the power supply will sweep. The parameter nn is the required field sent as a number in accordance with section 7.4. The resolution of the set field is typically 0.0001 tesla, or 0.00001 tesla if Extended Resolution has been selected, see the "Qn" command on page 41.

Mn Set Mode

The MODE command selects CURRENT or FIELD mode for the display and selects FAST or SLOW 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:

	<u>Display</u>	<u>Magnet Sweep</u>	
M0	Amps	Fast	(M2 is also accepted)
M1	Tesla	Fast	(M3 is also accepted)
M4	Amps	Slow	(M6 is also accepted)
M5	Tesla	Slow	(M7 is also accepted)
M8	Amps	Unaffected	
M9	Tesla	Unaffected	

Fast/Slow This facility protects the magnet from damage due to 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. Slow is an alternative set of maximum sweep rates. There is no significance in the two names, they only serve to distinguish the profiles, when selected from the front panel, the names of the sweeps are displayed as "FASt" and "SLo". The limiting rates are variables, see section 11.10.

Pn Set Polarity

The POLARITY command is not necessary for operation of the IPS series but is included here for compatibility with the earlier PS120-10 power supply.

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 Positive Current
P2	Set Negative Current
P4	Swap Polarity

Snn Set Current Sweep Rate

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 nn is the required sweep rate sent as a number in accordance with section 7.4 The range of possible values that may be set depends on the current specification of the power supply, please refer to section 12, but in each case the resolution is increased by a factor of x10, if Extended Resolution has been selected, see the "Qn" command on page 41.

The sweep rate selected will only apply when the power supply is operated in SWEEP mode, for example, 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.

Tnn Set Field Sweep Rate

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 nn is the required sweep rate sent as a number in accordance with section 7.4; to a resolution of, for example, 0.001 tesla per minute, or 0.0001 tesla per minute if Extended Resolution has been selected, see the "Qn" command on page 41.

The sweep rate selected will only apply when the power supply is operated in SWEEP mode, for example, 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.

Yn Load RAM Contents

The Y command allows the entire contents of the RAM memory to be loaded in binary, via the serial or GPIB interface. It is not intended as a user command and will only be obeyed after a correct "U" password. If n is omitted or has the value 2, only the first 2 kilobytes of the memory will be loaded. If n has the value 8, the entire 8 kilobytes are loaded. Note that after loading the memory in this way, the new content will be lost at power-down, unless it has been saved by the "~" command or by a STORE sequence as described in section 11.3.

Zn Dump RAM Contents

The Z command allows the entire contents of the RAM memory to be dumped in binary, via the serial or GPIB interface. It is not intended as a user command. Like the Y command, omitting n or setting it to 2 results in a 2 kilobyte dump. Setting n to 8 gives a full 8 kilobyte dump.

! Set ISOBUS Address

See section 7.5

~ Store Data

The ~ (tilde) command stores any changes made to the calibration data in the power supply, otherwise the changes will be lost after power down. It will only be obeyed after the correct "U" password.

The front panel display of the instrument will show the message "Stor" if the store command is successful, if a "Prot" message is displayed, then the hardware write-enable switch is in the OFF position, see section 11.3.

8.2 Specialist Commands

In general the commands in this section are not intended for customer use. They have been provided for engineering use during algorithm development and to interface with certain Oxford Instruments application software. The details which follow are provided for interest only. They are correct for this version of firmware but future versions will not necessarily retain the commands in the same form. A command letter followed by ".." indicates that a numeric value should be appended to the command.

a Read Auto-Run-Down Status

No further description here.

c Read Damping Parameter

No further description here.

d Read Damping Coefficient

No further description here.

e.. Set Damping Coefficient

No further description here.

g **Send Hex Reading**

Send the internal value of a displayable variable. This allows the user to inspect the value of an variable to the full 24 bit resolution of the power supply. The x pointer should be set to "nn" where "Rnn" is the equivalent READ PARAMETER command. The y pointer must be set to 99. The response is sent as an (unsigned) 6 digit hexadecimal number.

h.. **Set Hex Variable**

Set the internal value of a displayable variable. This allows the user to set the value of a variable to the full 24 bit resolution of the power supply. The x pointer should be set to "nn" where "Rnn" is the equivalent READ PARAMETER command. The y pointer must be set to 99. The number must be sent as an (unsigned) 6 digit hexadecimal number.

Caution This command must be used carefully. As well as the numbers being difficult to relate to actual currents etc., the power supply makes no checks (such as current limits) before accepting the new value.

r **Read Parallel Interface Port**

Read the state of the 3 "free" input lines to the PARALLEL I/O port. This command allows digital signals to be passed transparently through the power supply to the communication interfaces.

The response is in the form of an integer in the range 0 to 7. The decimal number corresponds to the binary number presented to the bit 0 to bit 2 input pins of the Parallel I/O Port.

s.. **Set Parallel Interface Port**

Set the state of the 7 "free" output input lines to the PARALLEL I/O port. This command allows digital signals to be passed transparently through the power supply from the communication interfaces.

The command should be in the form of an integer in the range 0 to 127. The decimal number corresponds to the binary number presented to the bit 0 to bit 7 output pins of the Parallel I/O Port.

x... **Set x Pointer**

y.. **Set y Pointer**

The x and y commands set pointers into tables for loading and/or examining data values in the table. The sequence of operations is to load either or both pointers as appropriate, then issue the command to load or examine the data. The number following 'x' or 'y' is a decimal integer in the range 0 to 128. If a command is issued with incorrect values set for x or y, that command will not be obeyed and an error response will be returned.

At power-up x and y are set to zero. None of the tables hold data at x=0, y=0; so it is good practise to leave x and y set to zero after use. This will ensure that if one of the "table" commands is issued inadvertently, it will always be rejected and produce an error response.

9 Auto-Run-Down

Auto-run-down will automatically de-energise a magnet system in response to an external signal. 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 or magnet switch from damage should the helium level in the magnet cryostat drop too far.

Caution This function can only operate if the power supply is left switched on

The auto-run-down function is invoked via the rear panel connector on the controller module marked "PARALLEL I/O", see section 5.15.

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 power supply performs the following sequence of actions fully automatically during auto-run-down:-

- i) If the power supply is clamped, then unclamp the magnet.
- ii) If the switch heater is off, then quickly sweep the leads to where the magnet was last put persistent.
- iii) If the switch heater is off, then wait 20 seconds and turn the switch heater on.
- iv) De-energise the magnet in a low-voltage mode (± 1 volt for a 10 volt power supply or ± 2 volt for a 20 volt power supply).
- v) 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).

The operator cannot regain control of the power supply until the external signal is cleared (or disconnected).

10 Fault Conditions

This section includes only those faults which are indicated by the power supply being in an unusual state. Faults concerning the magnet system as a whole are not described here, the user should refer to the magnet system handbooks or manuals.

10.1 Fault Index

Faults may be caused by internal or external conditions. The power supply overheating is an example of an internal fault and mains failure is an example of an external fault. There are some other conditions that are not strictly faults but are mentioned here for completeness.

Most of the faults are not fully described in this section but the following table indexes them all.

Fault	Power Supply Symptoms	Refer to:
Voltage Limiting	Numeric display flashing	Section 6.2
Can not unclamp	Numeric display reads "Err C"	Page 24
Sweep Limiting	SWEEP LIMITING lamp is on	Page 27
Quench	QUENCH lamp is lit	Page 27
Hot (overheating)	Numeric display reads "Hot"	Page 28
Fault	Numeric display reads "FAULT"	Page 28
Auto-Run-Down	LOCK / REMOTE / LOCAL lamps flashing	Section 9
Mains Failure	One or more "ON/OFF" (green) lamps off	Section 10.2

10.2 Mains Failure

If the mains supply fails, or if the power supply is suddenly switched off, the magnet terminals are immediately clamped by mechanical contacts. The analogue meter continues to show the output current.

A magnet with the switch heater on (or without a persistent switch), will slowly run down.

A persistent magnet (zero lead current) with the switch heater off will remain persistent.

When the mains is reconnected the power supply will remain in the clamped state with the switch heater off. The operator can resume control by pressing HOLD to unclamp the output.

If the magnet was persistent then the power supply will remember the magnet current at the time when the power failure occurred. Operation can resume as though no interruption had occurred.

If the magnet was not persistent at the time of the power failure, then the output will typically go to the voltage limits and be caught as described in section 6.2. Turn on the switch heater and wait long enough for the switch to open before continuing with interrupted operations.

11 Test Mode

11.1 Entry to Test Mode

When switched on, the power supply performs a basic self test of the microprocessor and memory before displaying the firmware version message e.g. "PS3.01" followed by the GPIB address "G 25". A more detailed hardware test mode is available that includes procedures to calibrate the power supply and to adjust limits etc..

Test mode is accessed by one of two methods, either press the internal RED button, SW1, on the digital circuit board; or, 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 from test mode and it also provides the STORE procedure for this instrument, see section 11.3.

Caution 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.

11.2 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 Exit test mode (and store changes in EEPROM)
- t 01 Test front panel display and lamps
- t 02 Test front panel buttons
- t 03 Set the GPIB address
- 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)

All the tests are described below.

11.3 Test 00 Exit (and Storing Calibration Data)

This option should be used for exit from test mode. On exit the user is prompted to STORE any data that has been changed in test mode.

The power supply contains several types of memory circuits. Changes to any of the parameters in test mode will be retained while the power supply is switched on. If the changes are not stored then when the unit is switched on again, the original calibration parameters will be restored.

On entry to test 0, the display reads "Stor.y" press RAISE or LOWER and the display toggles to "Stor.n". Press LOC/REM to exit test 0 and return to the normal mode. If on exit, the display reads "Stor.y", then the calibration data will be stored. If the display reads "Stor.n", then the new data will not be stored. It is unlikely that a user will require the "Stor.n" option.

If "Stor.y" has been selected, the display will briefly show "Stor" indicating that the data has been correctly stored. If instead of showing "Stor", the display shows "Prot", this indicates that the memory is protected by the hardware WRITE-ENABLE switch being in the OFF position. This is Switch 1 of a small 2 way Dual-in-Line switch SW2 on the digital circuit board (CBL1200). Set it to the "ON" position and try again. The switch need only be returned to the OFF position if it is desired to prevent any possibility of the data being changed by someone tampering with the front panel. When the power supply leaves the factory, this switch is normally ON, allowing changes to be stored.

11.4 Test 01 Test Front Panel Lamps

Lights each LED or display segment in turn, then pulls each of the auxiliary (parallel interface) output lines low in turn. When the test is complete, the unit returns to the test menu.

11.5 Test 02 Test Front Panel Buttons

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.

11.6 Test 03 Setting the GPIB address

An Oxford Instruments power supply is normally supplied set to a GPIB address of 25. On accessing Test 3, the display will now show G.nn where nn is the current GPIB address. Use RAISE and LOWER to display the desired new address, then press LOC/REM to select it. The instrument will revert to the t.00 state. Pressing LOC/REM again will restart the instrument, with the new address in operation. Any address in the range 1 to 30 may be selected. (Although 31 may be selected, it is not a valid GPIB address since it is reserved for the UNTALK, UNLISTEN functions). Setting the GPIB address to 0 has a special significance. It DISABLES the GPIB interface ensuring that only RS232 operation is possible. To ENABLE it again it is only necessary to return to the t.03 mode and select a new non-zero address.

11.7 Test 04 F (Front Panel Display) 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 on page 45, 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 24 for front panel display. The options are as given in the list for the "Rnn" command on page 42. 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. The options are listed below:-

F 0	Demand current (output current)	amp
F 1	Measured power supply voltage	volt
F 2	Measured magnet current	amp
F 3	Unused	
F 4 *	Demand current (duplicate of R0)	amp
F 5	Set point (target current)	amp
F 6	Current sweep rate	amp / minute
F 7	Demand field (output field)	tesla
F 8	Set point (target field)	tesla
F 9	Field sweep rate	tesla / minute
F 10 *	DAC zero offset	amp
F 11 *	Channel 1 freq./4	
F 12 *	Channel 2 freq./4	
F 13 *	Channel 3 freq./4	
F 14 *	Demand current (duplicate of R0)	amp
F 15	Software voltage limit	volt
F 16	Persistent magnet current	amp
F 17	Trip current	amp
F 18	Persistent magnet field	tesla
F 19	Trip field	tesla
F 20	Switch heater current	milliamp
F 21	Safe current limit, most negative	amp
F 22	Safe current limit, most positive	amp
F 23	Lead resistance	milliohm
F 24	Magnet inductance	henry

Variables marked with a "*" are intended as service diagnostics and are unlikely to be of use to the user.

11.8 Test 05 PSU (Power Supply) Menu

This 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.

Caution The "Psu" menu changes the calibration of the power supply and magnet.

"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.

Note that the power supply may prevent casual entry to the Psu menu. If the user tries to enter this mode and the power supply current is not zero, a "not 0 Error" message will be displayed and the display returns to "t 00". This check is to protect the magnet system from damage as the output will be clamped on entry to the PSU menu and this may cause problems! The safety feature may be overridden by pressing and holding LOC/REM whilst the error message is displayed.

These are the available options.

P 00	Return to test menu
P 01	Not used
P 02	Define power supply current range
P 03	Adjust power supply zero correction
P 04	Step through DAC outputs
P 05	Test output damping
P 06	Not used
P 07	Not used
P 08	Not used
P 09	Not used
P 10	Calibrate voltage monitor at negative voltage limit
P 11	Calibrate voltage monitor at positive voltage limit
P 12	Auto-calibration of current monitor
P 13	Not used
P 14	Auto-zero power supply
P 15	Not used

Psu 02 Define Power Supply Current Range.

Caution 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 test 7, Sup 2, define power supply current limit?

On entry, the display shows "I CAL" (current calibrate), press LOC/REM again and the power supply returns to the menu. To display or adjust the current range, display I CAL then press RAISE, LOWER and LOC/REM.

The number is set to the rated output current of the power supply, for example, 120.000 for a normal IPS120-10. Initially, 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.

Psu 03 Adjust Power Supply Zero Correction

This is a software trim for the zero current of the power supply. On entry, the present value is displayed as a number of amps, depressing LOC/REM allows this value to be adjusted over a small range. The default setting is 00.000

For the duration of this test, the output of the power supply is unclamped, thus the offset current can be measured between the power supply's 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 volt/mA.

Psu 04 Step Through DAC Outputs

This test is intended for checking the output of the power supply's DAC. For the duration of this test, the output of the power supply is clamped. Therefore no current will flow between the magnet terminals and the output of the DAC can be safely measured at test point TP303 on the analogue pcb (mounted upside down in the top of the power supply).

On entering Psu 04, the display will briefly read "d 00" followed by -10.0000 volts. This display indicates approximately what voltage the DAC should output. Pressing RAISE or LOWER will cycle the DAC from "d 01" to "d 16", while the button is depressed the display will read "d nn", indicating which data line to the DAC is made active. When the button is released, the calculated DAC output voltage will be displayed. To exit Psu 04, press LOC/REM.

Psu 05 Test Output Damping

This test is intended for checking the components which provide filtering and damping of the output. For this test, connections to the "magnet" terminals must be removed. The output is made to oscillate between the hardware voltage limits, and the display shows the average period of the oscillation (the units are seconds). Press LOC/REM repeatedly and the output will oscillate at two different rates, then exit.

Psu 10 Calibrate Voltage Monitor at the Negative Limit

Psu 11 Calibrate Voltage Monitor at the Positive Limit

These tests calibrate the power supply voltage monitor. Psu 10 calibrates the measured voltage at the negative (hardware) voltage limit, normally -10 or -20 volts. Psu 11 calibrates the measured voltage at the positive (hardware) voltage limit, normally +10 or +20 volts.

These tests require existing connections to the "magnet" and "switch heater" terminals to be removed. A voltage meter set to read at least ± 10 or ± 20 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 may 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 (mounted upside down in the top of the power supply). To adjust the negative limit, enter Psu 10 as described above and adjust RV301 to set the required limit. To adjust the positive limit, enter Psu 11 as described above and adjust RV302 to set the required limit.

Psu 12 Auto-Calibration of Current Monitor

This test automatically calibrates the measured lead current of the power supply. All existing connections to the "magnet" and "switch heater" terminals must be removed. A busbar 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 Auto-Zero Voltage and Current Monitors

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 wire link or busbar 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 output link is correctly placed.

11.9 Test 06 Magnet System Configuration

The "configuration" defines what type of magnet system will be used with the power supply.

On entry to test 6, a number in the range 0 to 255 is displayed, this represents the "configuration" and may be adjusted by pressing LOC/REM and using RAISE and LOWER, releasing LOC/REM returns to the test menu. Certain "configurations" are not allowed, the power supply will reject these, display "ConF Error", then display the previous configuration.

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.

Should be set if a superconducting switch is fitted to the magnet. If this bit is set then the switch heater button is enabled.

Bit 1 Add output filter current compensation.

Adds a correction term to the output current to compensate for the effect of the power supply's output filter. This function may not be selected if the magnet is fitted with a superconducting switch.

The output of the magnet power supply is fitted with a network of large capacitors, these are needed to reduce the voltage noise generated by the combination of a current source (the power supply) and a very large inductance (the magnet). If the output current is constant or the output is changing at a constant rate, then there is no current into the capacitors. However at the beginning and end of a sweep, the capacitors must be charged to the voltage on the magnet. If this function is selected, then the power supply calculates this charge current and adds it to the normal output current.

The accuracy of this function relies on the magnet inductance being set correctly, see Sup 11 on page 63.

Bit 2 Ignore voltage transients.

Set this bit to avoid the magnet "catching" routine being triggered by voltage transients caused by the beginning or end of a sweep. The catch mechanism will then ignore the first 2 seconds of voltage limiting, it will only trigger if voltage limiting persists for longer than this time.

The transient is due to a low frequency resonance between the magnet and the output capacitors of the power supply. For unswitched magnets, setting Bit 1 may help reduce the transient.

Bit 3 Unipolar version of the power supply.

If an IPS power supply is configured as unipolar at the factory, a plug is disconnected from pins 11 & 12 of PL501 on the analogue pcb (mounted upside down in the top of the power supply). This ensures that the positive current contactor remains closed and negative currents are impossible. The user may reconfigure the unit as bipolar by reconnecting this plug and changing bit 3 to zero as described above.

The following are the most commonly required configurations:

- 0 No persistent switch fitted to magnet
- 1 Persistent switch fitted to magnet
- 2 No persistent switch, add correction current.
- 4 No persistent switch, ignore voltage transients.
- 6 No persistent switch, add correction current, ignore voltage transients.
- 8 Unipolar power supply, no switch fitted.
- 9 Unipolar power supply, switch fitted.

11.10 Test 07 SUP(superconducting magnet) Menu

The "Sup" menu provides access to a set of operations designed to be carried out when initially setting up a magnet system. 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.

These are 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, "SLO" (slow) run
S 10	Define software voltage limit
S 11	Define magnet inductance
S 12	Not used
S 13	Not used
S 14	Not used
S 15	Define switch heater current

- * Menu options that are marked with a "*" allow fast setting to their maximum or minimum values. Press LOC/REM to display the current value then press LOWER to display the minimum value and while pressing LOWER, press LOC/REM again to latch and adjust it. Pressing RAISE displays (and adjusts) the maximum value for the variable.

Sup 01 Define Amps/Tesla

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.

Sup 02 Define Power Supply Current Limit

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 Define Safe Current Monitor, Negative Limit

Sup 04 Define Safe Current Monitor, Positive Limit

These tests define a range of 'safe' power supply output currents. If the measured current is outside these limits, the safe current output signal will not be given, see page 20.

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.

Sup 05 Define Current Breakpoints for Rate Limiting

This test sets the current breakpoints marking the end of each maximum rate of change segment. See SWEEP LIMITING on page 27 for an explanation of these limits. 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.

Press RAISE or LOWER to display the maximum or minimum values for breakpoint current. Depressing LOC/REM a second time allows the user to adjust the selected current with RAISE and LOWER. The adjustment will start from whatever number is displayed when LOC/REM is pressed, this allows the numbers to be changed rapidly from one end of the range to the other. 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 Define Limiting Rate for Leads, Magnet at Zero

For when the magnet system has a superconducting switch fitted, and the magnet is persistent at zero field.

Sup 07 Define Limiting Rate for Leads, Magnet at Field

For when the magnet system has a superconducting switch fitted, and the magnet is persistent at a non-zero field.

Sup 08 Define Limiting Rate for Leads, "FAST" run

For running current into a magnet. Sup 8 defines the limiting rates observed when "FAST" magnet sweep rate limits are selected.

Sup 09 Define Limiting Rate for Leads, "SLO" (slow) run

For running current into a magnet. Sup 9 defines the limiting rates observed when "SLO" (slow) magnet sweep rate limits are selected.

Sup 06, Sup 07, Sup 08 and Sup 09 define the maximum rate of change of current in amps/minute for each maximum rate segment as defined in Sup 5. See SWEEP LIMITING on page 27 for an explanation of these limits. Each of the four Sup options set limiting rates for particular conditions:

Each record "r n" in the rate (r) table sets 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 sweep rate in amps/minute.

Press RAISE or LOWER to display the maximum or minimum values for rate of change of current. Depressing LOC/REM a second time allows the user to adjust the selected sweep rate with RAISE and LOWER. The adjustment will start from whatever number is displayed when LOC/REM is pressed, this allows the numbers to be changed rapidly from one end of the range to the other. 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 10 Define Software Voltage Limit

defines the characteristics of the software voltage limits. These limits are usually inhibited and are primarily intended to be used to protect magnets at the end of long or very resistive leads. 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 '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 'catch' mode (see section 6.2). The spell is defined in units of 1/4 second and can be adjusted by depressing LOC/REM and using RAISE AND LOWER. The spell can be set to any value between 2 and 254 inclusive (between 1/2 second and about 1 minute), trying to set the spell to < 2 will display the error message "2 Error". If the spell is set to 255 (the maximum value) this function will be completely disabled.

10 V power supplies are usually shipped with the software voltage limit set to 12.49 volts and the 'spell' set to 255 (inhibited). For 20 V power supplies the default voltage limit is 24.99 volts.

Sup 11 Define the Magnet Inductance.

The control firmware used in this power supply requires a value of inductance for 'quench detection', refer to QUENCH on page 27. The magnet inductance can be set from 0.0 to 1745.9 henries, the default setting is 0.0.

Sup 15 Define the Switch Heater Current.

On entry, the switch heater is turned on and the present switch heater current is displayed in units of milliamps. The switch heater current can be set from 0.0 to 119.1 milliamp, the default setting is 0.0.

If the power supply has been supplied with a magnet, the switch heater current will have been set to an optimum value at the factory. This current may need adjusting for different magnet. The current is normally set to the minimum value at which the switch will open reliably after 10-15 seconds.

Ambient Temperature	0-40 °C.
Cooling	Forced Air, 1500 W maximum per module
Power Requirements	Three phase, 50/60 Hz either 200-240 V phase to neutral or 200-240 V phase to phase
Power Consumption	3.3 kVA maximum per module + 6 A auxiliary power outlet
Module Dimensions	Height 223 mm Width 482 mm Depth 530 mm
PSU Dimensions, Rack Mounted	6U per module + 2U extra
Module Weight	35 kg

13 Quick Reference Guide

13.1 Front Panel Controls

OUTPUT VOLTS	Display power supply output voltage
CURRENT / FIELD	Toggle the display between showing current (in amps) and the equivalent field (in tesla).
MAGNET STATUS	Display current (or field) in the magnet.
MAGNET STATUS	Display trip current (or field), saved when voltage limiting. + SET POINT
SET RATE	Display sweep rate. To adjust use RAISE & LOWER.
SET POINT	Display set point current (or field). Adjust using RAISE, LOWER and CHANGE POLARITY.
CHANGE POLARITY	Use with SET POINT.
HOLD	Unclamp the power supply. Stop the power supply from sweeping. Clear fault conditions ("Hot" and QUENCH)
HOLD + RAISE	Set FAST sweep rate profile.
HOLD + LOWER	Set SLOW sweep rate profile.
GOTO ZERO	Sweep power supply towards zero current.
GOTO SET	Sweep power supply towards the SET POINT current.
HEATER	Toggle the switch heater on and off. If magnet persistent at different current to power supply, then display 'MAGNET STATUS' and refuse to open switch.
LOC / REM	Toggle Local (front panel) and Remote (computer) control.
RAISE	Increase the value of a displayed variable.
LOWER	Decrease the value of a displayed variable.
LOC / REM	Enter test mode. + RAISE + LOWER

An	Set Activity clamp	A0 hold, A1 goto set point, A2 goto zero, A4
Cn	Set Control unlocked	C0 local, C1 remote locked, C3 remote
Fnn	Set Front Panel to Display Parameter	see section 0
Hn	Set Switch Heater:	H0 off, H1 on, H2 force on
Inn	Set Target Current (amps)	
Jnn	Set Target Field (tesla)	
Mn	Set Mode:	M8 amps, M9 tesla
Pn	Set Polarity	
Qn	Set Communications Protocol	Q0 normal, Q4 high resolution
Rnn	Read Display Parameter	see section 0
Snn	Set Current Sweep Rate (amps/minute)	
Tnn	Set Field Sweep Rate (tesla/minute)	
Unn	Unlock System Commands	
V	Read Version	
Wnn	Set Wait Interval	
X	Examine Status:	XmnAnCnHnMmnPmn
Yn	Load RAM Contents	
Zn	Dump RAM Contents	
!	Set ISOBUS Address	
~	Store Data	

Specialist Commands

a	Read Auto-Run-Down Status
c	Read Damping Parameter
d	Read Damping Coefficient
e..	Set Damping Coefficient
g	Read Hex Reading
h..	Set Hex Variable
r	Read Parallel Interface Port
s..	Set Parallel Interface Port
x..	Set x Pointer
y..	Set y Pointer

13.2 Test Mode

Note that if any parameters are changed in test mode, then to be retained after power down, the STORE procedure must be used, see section 11.3.

- t 00** Exit (& store in EEPROM)
Toggle "Stor.y" and "Stor.n" using RAISE or LOWER, exit using LOC /REM.
- t 01** Test front panel display and lamps
- t 02** Test front panel buttons
- t 03** Set the GPIB address from 1 to 30 (0 to 31).
- t 04** Select "F" menu, set front panel display, see section 0
- t 05** Select "P" menu, power supply calibration
 - P 00** Return to test menu
 - P 02** Define power supply current range
 - P 03** Adjust PSU zero correction
 - P 04** Step through DAC outputs
 - P 05** Test output damping
 - 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 14** Auto-zero power supply
- t 06** Magnet system configuration
 - 0 No persistent switch fitted to magnet
 - 1 Persistent switch fitted to magnet
 - 2 No persistent switch, add correction current
 - 4 No persistent switch, ignore voltage transients
 - 8 Unipolar power supply, no switch fitted
 - 9 Unipolar power supply, switch fitted
- t 07** Select "S" menu, superconducting magnet calibration
 - 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, "slow" run
 - S 10** Define software voltage limit
 - S 11** Define magnet inductance
 - S 15** Define switch heater current

13.3 Display Parameters

These numbers identify the display variables for the two computer interface commands, **Fnn** and **Rnn**. The test mode, **t 04**, sets the front panel display using the same numbers.

Some parameters are marked E.R., if the computer interface has been set to extended resolution mode, then the reply to the Rnn command includes an extra decade.

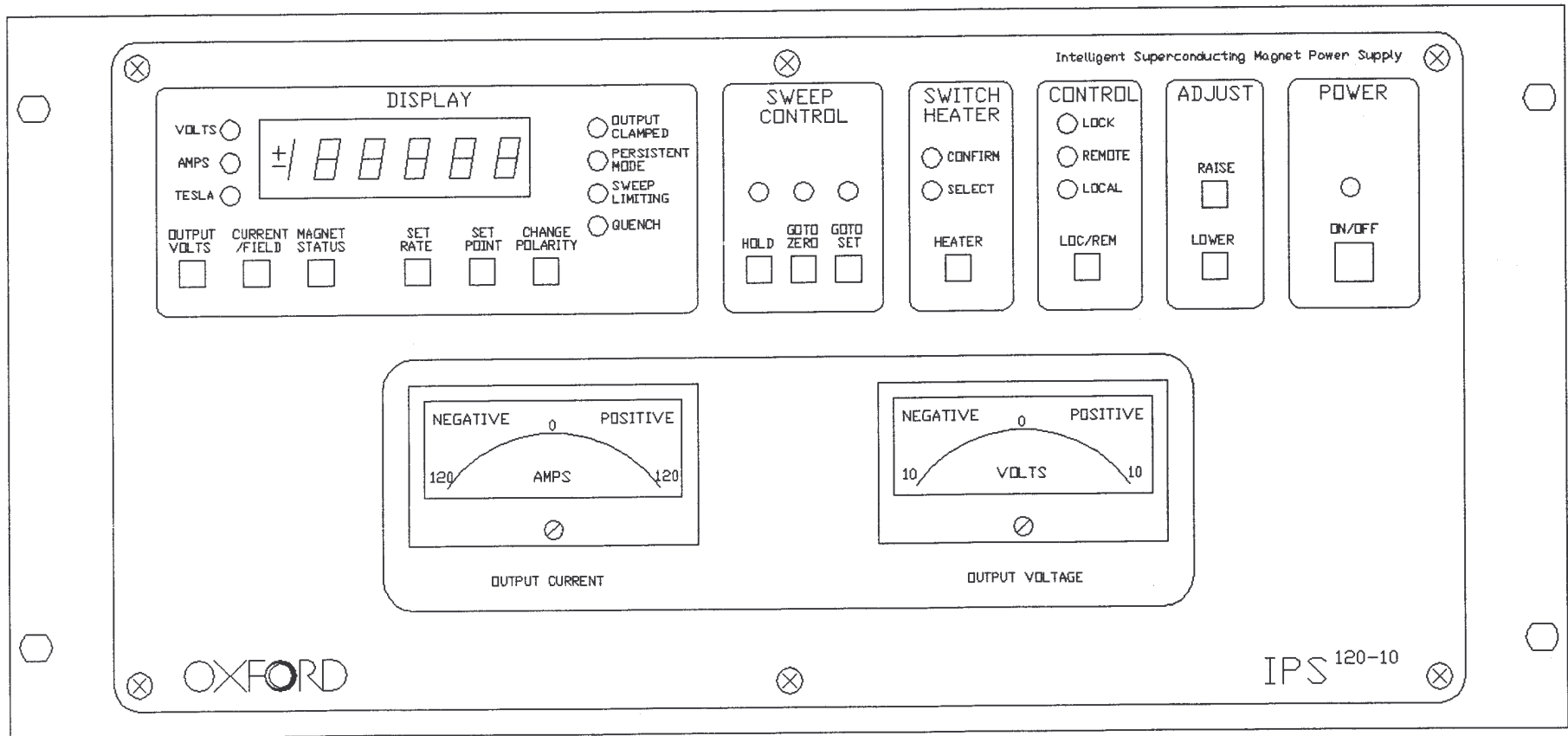
0	Demand current (output current)	amp	E.R.
1	Measured power supply voltage	volt	
2	Measured magnet current	amp	
3	Unused		
4	Demand current (duplicate of R0)	amp	E.R.
5	Set point (target current)	amp	E.R.
6	Current sweep rate,	amp / minute	E.R.
7	Demand field (output field)	tesla	E.R.
8	Set point (target field)	tesla	E.R.
9	Field sweep rate,	tesla / minute	E.R.
10	DAC zero offset	amp	E.R.
11	Channel 1 freq./4		
12	Channel 2 freq./4		
13	Channel 3 freq./4		
14	Demand current (duplicate of r0)	amp	E.R.
15	Software voltage limit	volt	
16	Persistent magnet current	amp	E.R.
17	Trip current	amp	E.R.
18	Persistent magnet field	tesla	E.R.
19	Trip field	tesla	E.R.
20	Switch heater current	milliamp	
21	Safe current limit, most negative	amp	
22	Safe current limit, most positive	amp	
23	Lead resistance,	milliohm	
24	Magnet inductance	henry	

14 Circuit Diagrams

The circuit diagrams that follow are listed below.

Drawing Number	No of pages	Description
CBL0980	1 of 1	Front Panel (for the similar IPS120-10)
CBL1102	1 of 1	Key / Display PCB
CBL1202	1 of 4 2 of 4 3 of 4 4 of 4	Digital PCB CPU, Memory and Timing Digital PCB Input / Output Ports Digital PCB RS232 and GPIB Interface Digital PCB De-Coupling Capacitors etc.
CBL1402	1 of 1	Pass Bank PCB
CBL4602	1 of 1	Rack Connection Diagram
CBL4612	1 of 2 2 of 2	Rack Mains Wiring 10 kVA Phase / Neutral Rack Mains Wiring 10 kVA Phase / Phase
CBL5002	1 of 1	Module Block Diagram
CBL5302	1 of 7 2 of 7 3 of 7 4 of 7 5 of 7 6 of 7 7 of 7	Analogue PCB Connection Diagram Analogue PCB Digital Interface Analogue PCB Control Amplifiers Analogue PCB Power Control and Switch Heater Analogue PCB Reversal Control and Relay Drivers Analogue PCB Reversal Bridge Analogue PCB DAC Alternatives
CBL5502	1 of 1	Master / Slave Interface PCB
CBL5702	1 of 1	Auxiliary Power Supply
CBL5772	1 of 1	Output Clamp and Filter PCB
CBL5902	1 of 4 2 of 4 3 of 4 4 of 4	IPS Module Mains Wiring IPS Module Low Voltage Wiring IPS Module Ribbon Cables IPS Module Interface PCB Wiring

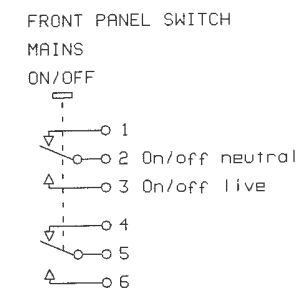
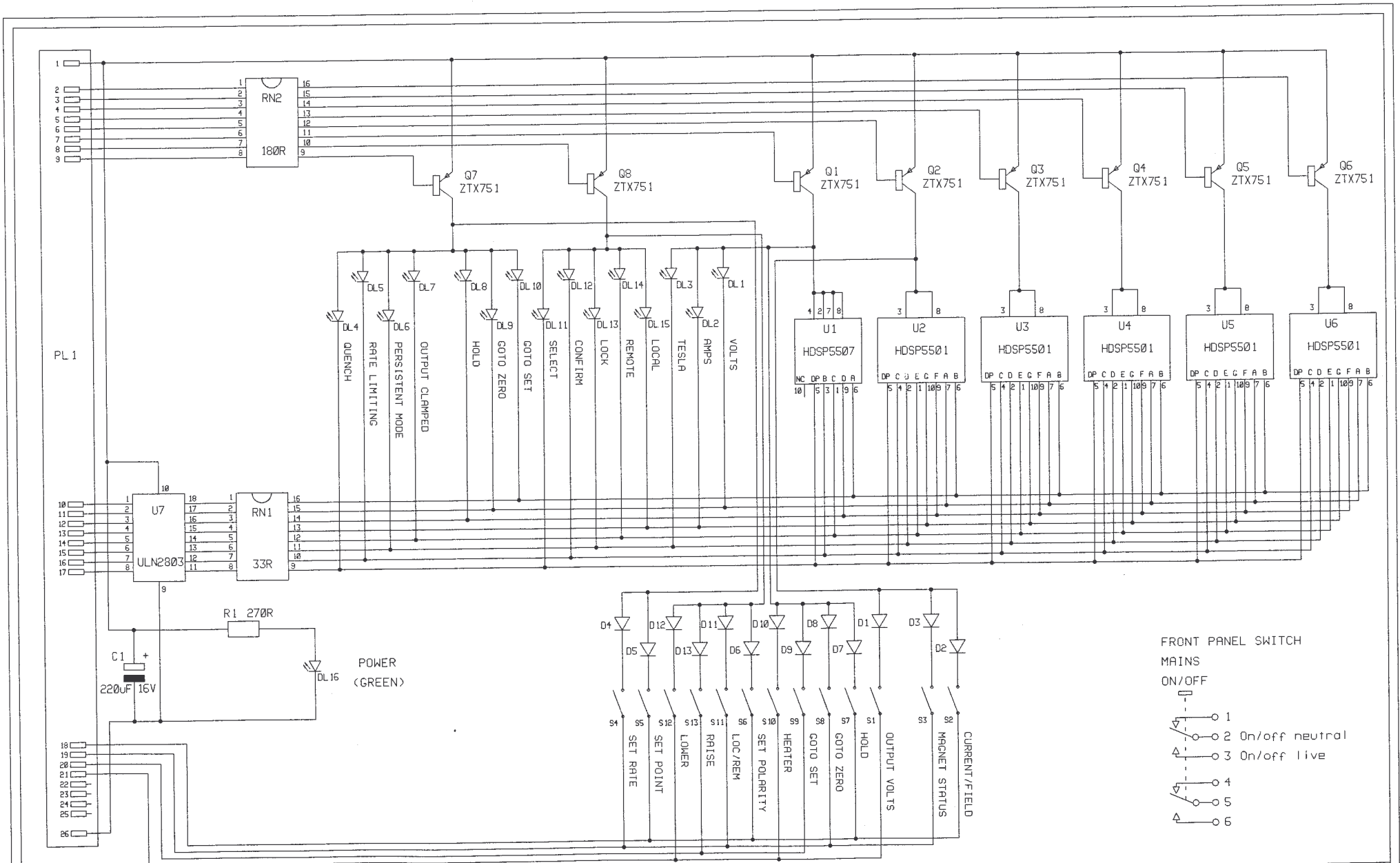
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01	4/6/94	SCALE 1:2
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IPS120-10 POWER SUPPLY
FRONT PANEL

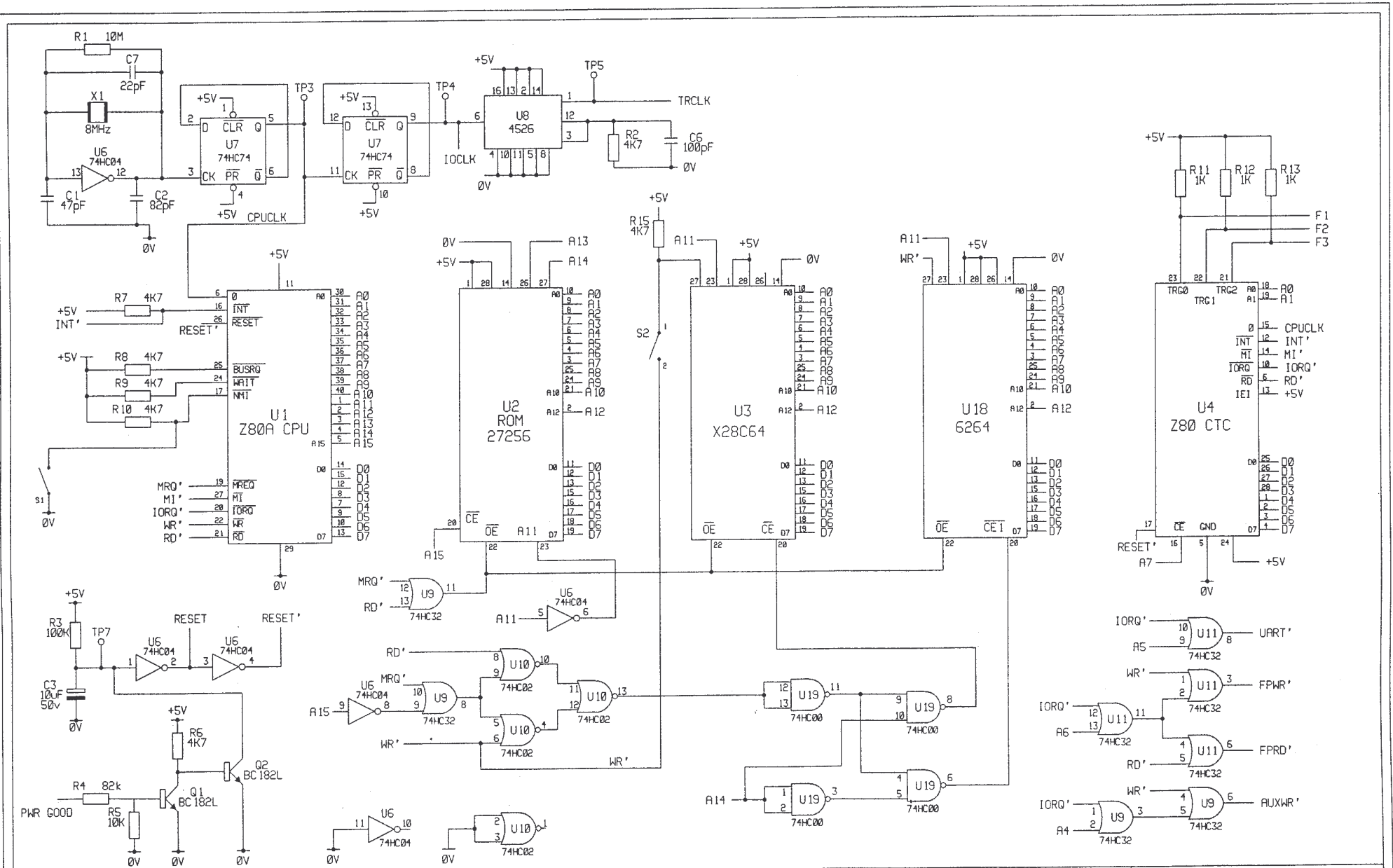
OXFORD
DRAWING NUMBER
A4/ CBL0980



01	14/1/94
----	---------

TITLE
 IPS120-10 POWER SUPPLY
 KEY/DISPLAY PCB

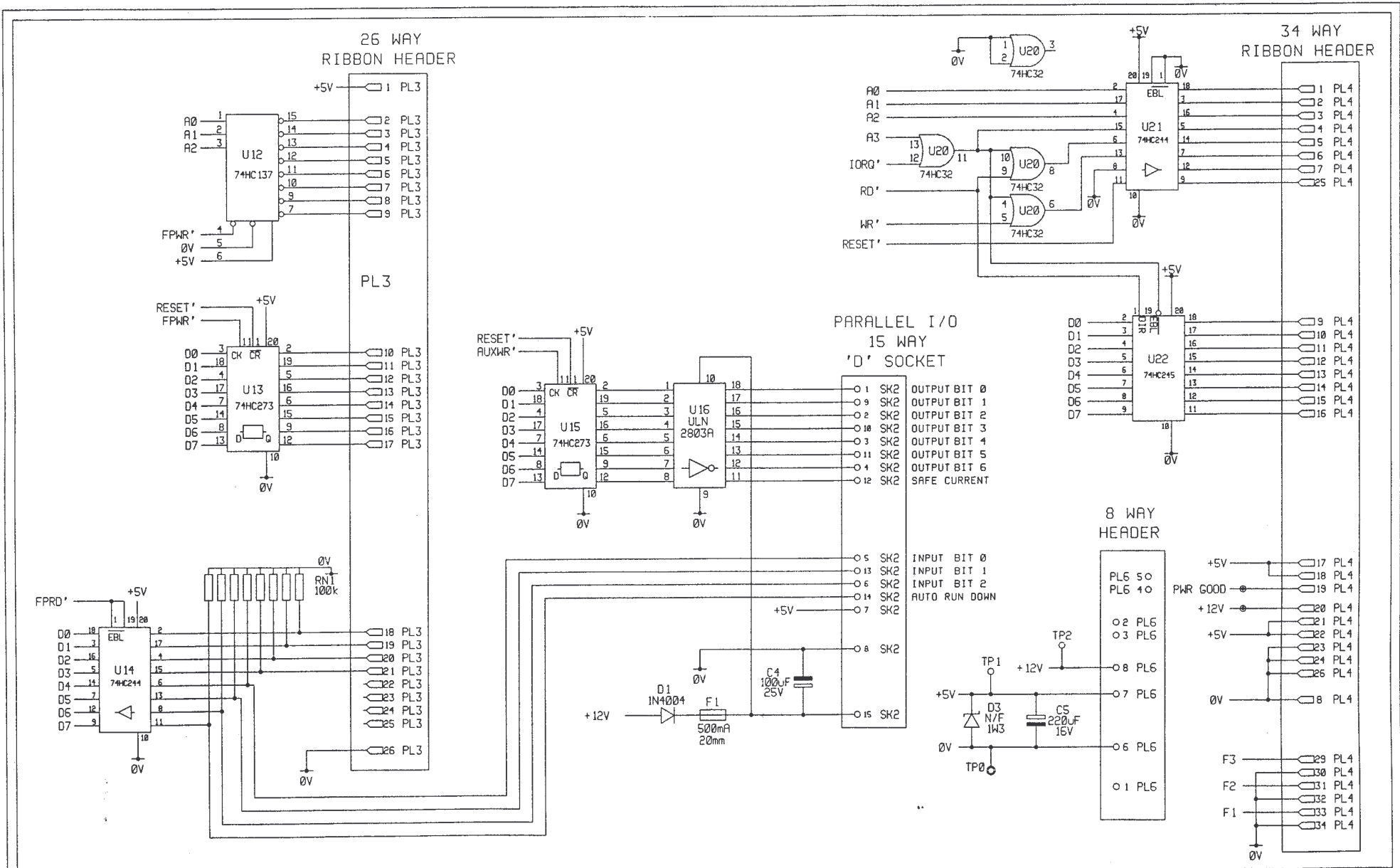
OXFORD
 DRAWING NUMBER
 A4 CBL1102 1 of 1



3	14/8/95	
02	17/5/94	
01	RJM	

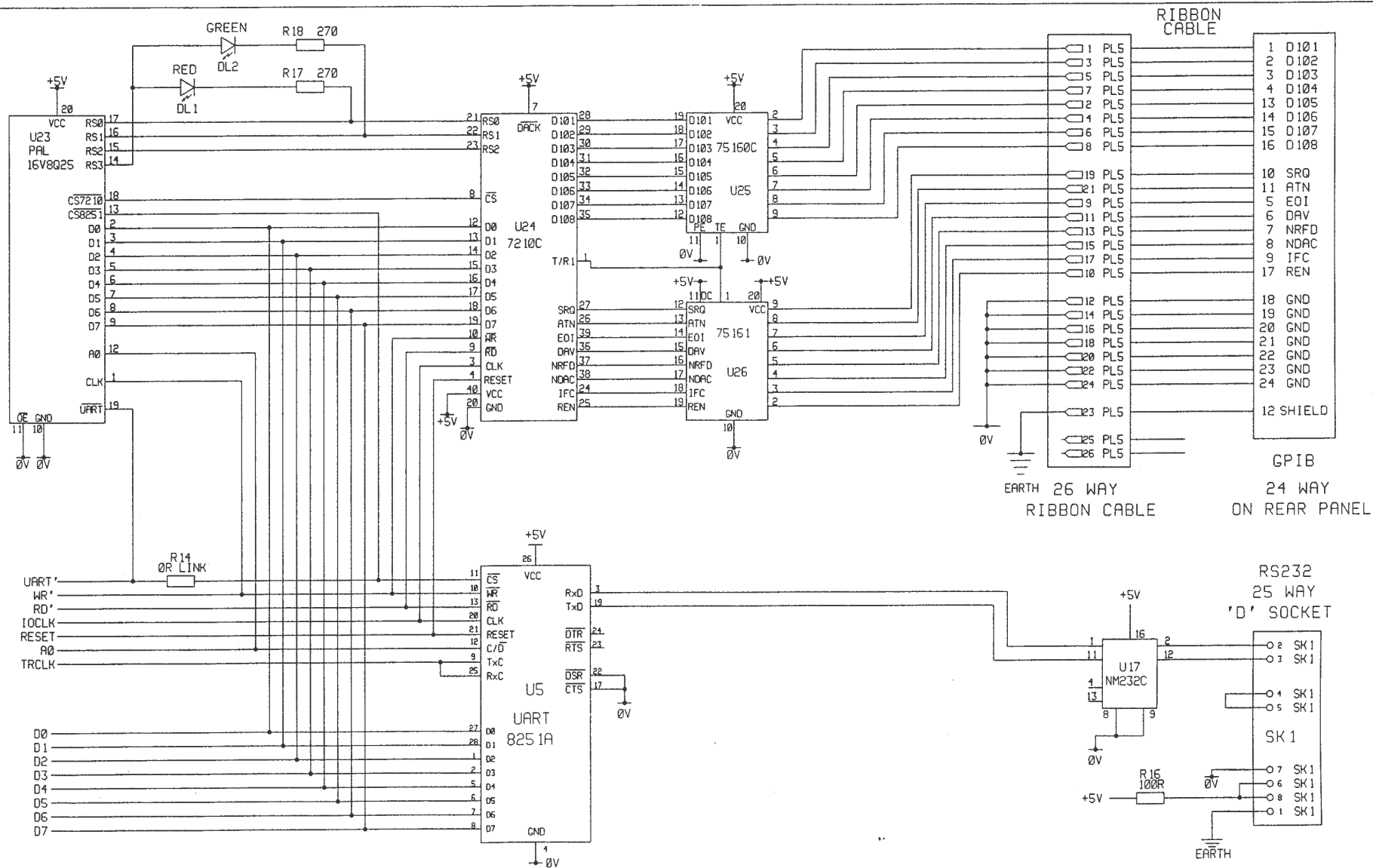
TITLE
 IPS120 DIGITAL PCB
 CPU, MEMORY AND TIMING

OXFORD
 DRAWING NUMBER
 A4 CBL1202 1 of 4



			TITLE
3	14/8/95	EMC MODS C9 DELETED	IPS120 DIGITAL PCB INPUT / OUTPUT PORTS
02	17/5/94		
01	RJM		

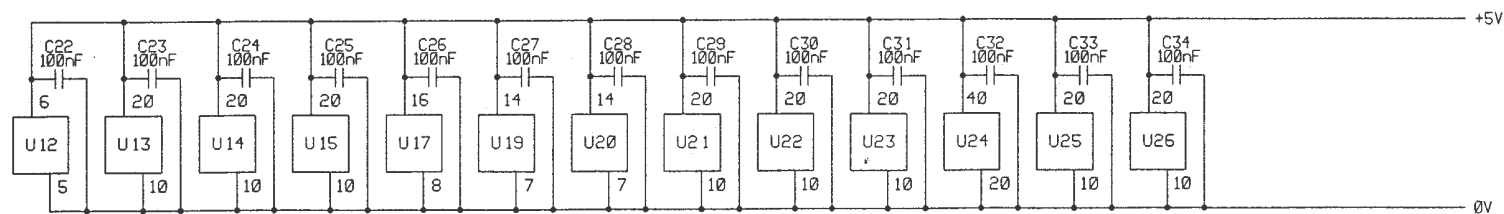
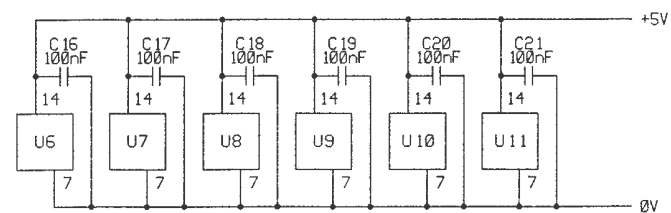
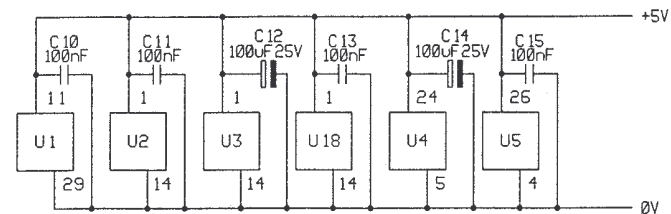
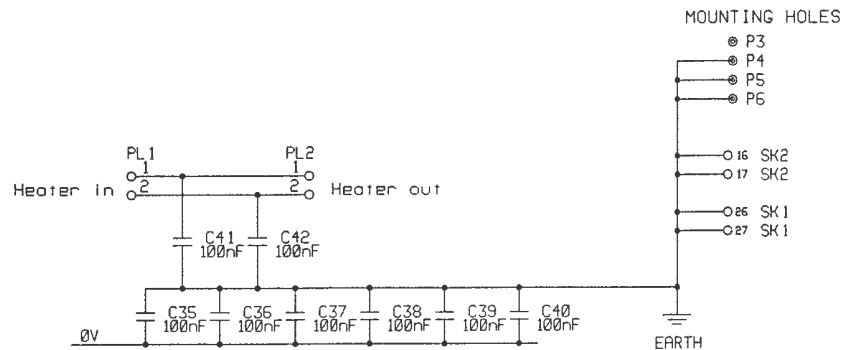
OXFORD	
DRAWING NUMBER	
A4 CBL1202	2 of 4



3	14/8/95	EMC MODS
02	17/5/94	
01	RJM	

TITLE
 IPS120 DIGITAL PCB
 RS232 AND GPIB INTERFACE

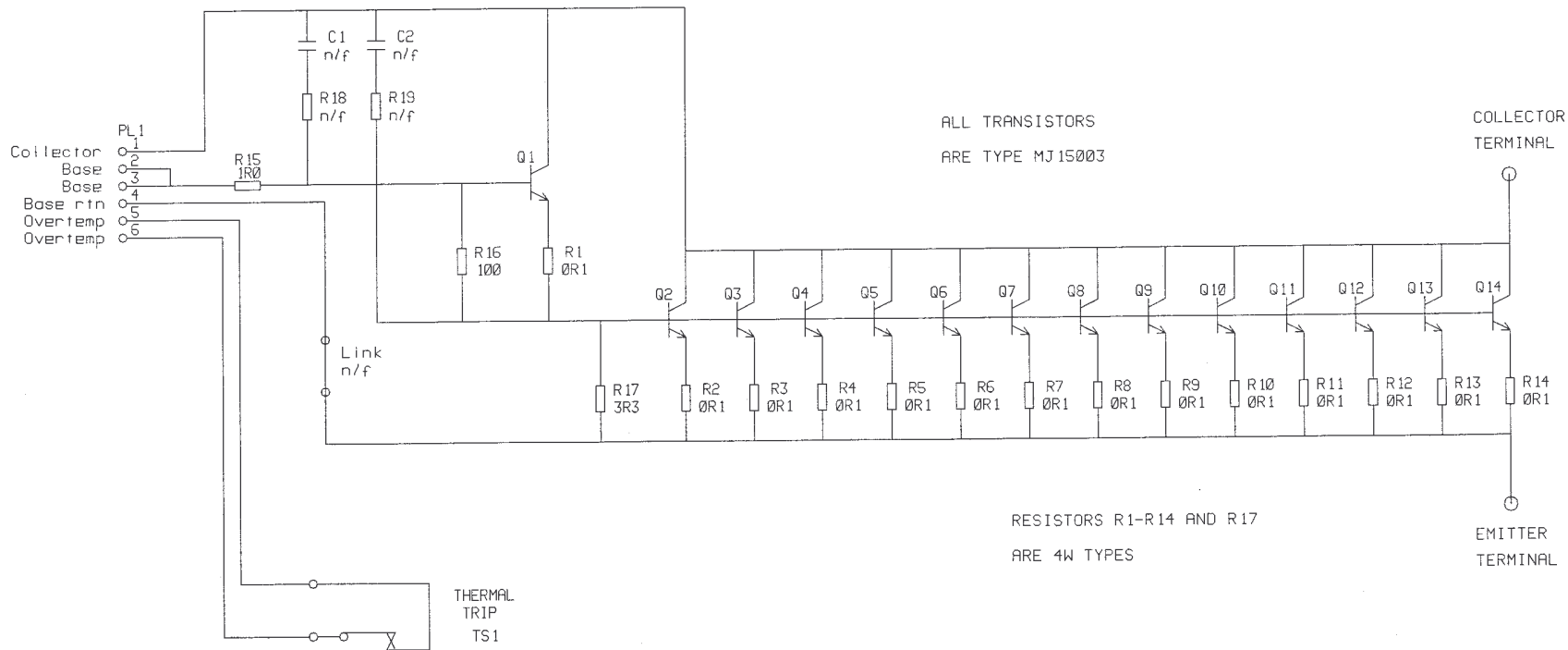
OXFORD
 DRAWING NUMBER
 A4 CBL1202 3 of 4



3	14/8/95	EMC MODS C35-42, PL1-2
02	17/5/94	
01	RJM	

TITLE
 IPS120 DIGITAL PCB
 DE-COUPLING CAPACITORS etc.

OXFORD
 DRAWING NUMBER
 A4 CBL1202 4 of 4



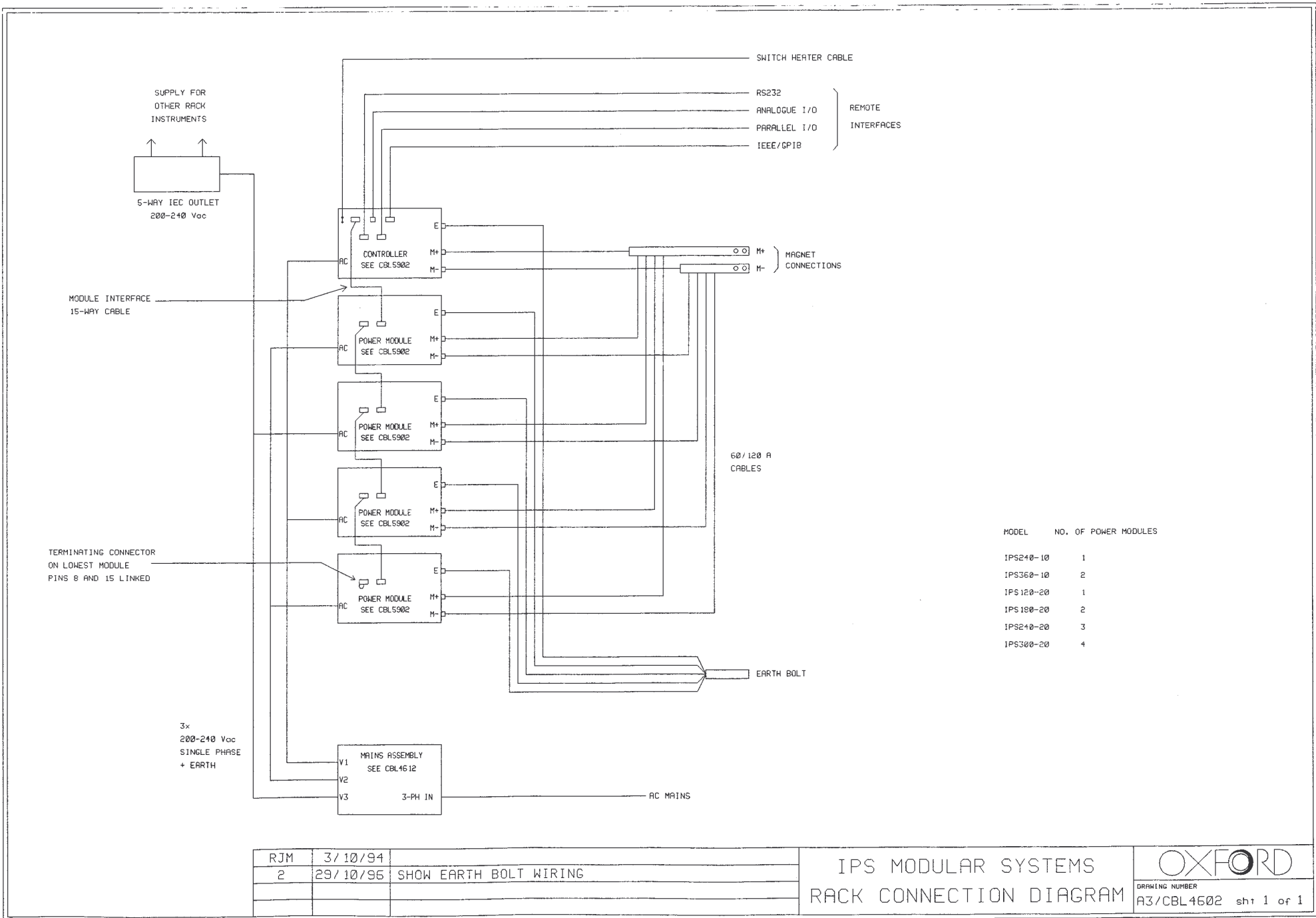
THIS ASSEMBLY IS ONE OF TWO IDENTICAL UNITS
MOUNTED ON THE HEATSINK

RJM	9/2/94	
2		MJ15001 CHANGE TO 15003

IPS 120 POWER SUPPLY
PASS-BANK PCB

OXFORD

DRAWING NUMBER
A4/CBL1402 sht 1 of 1

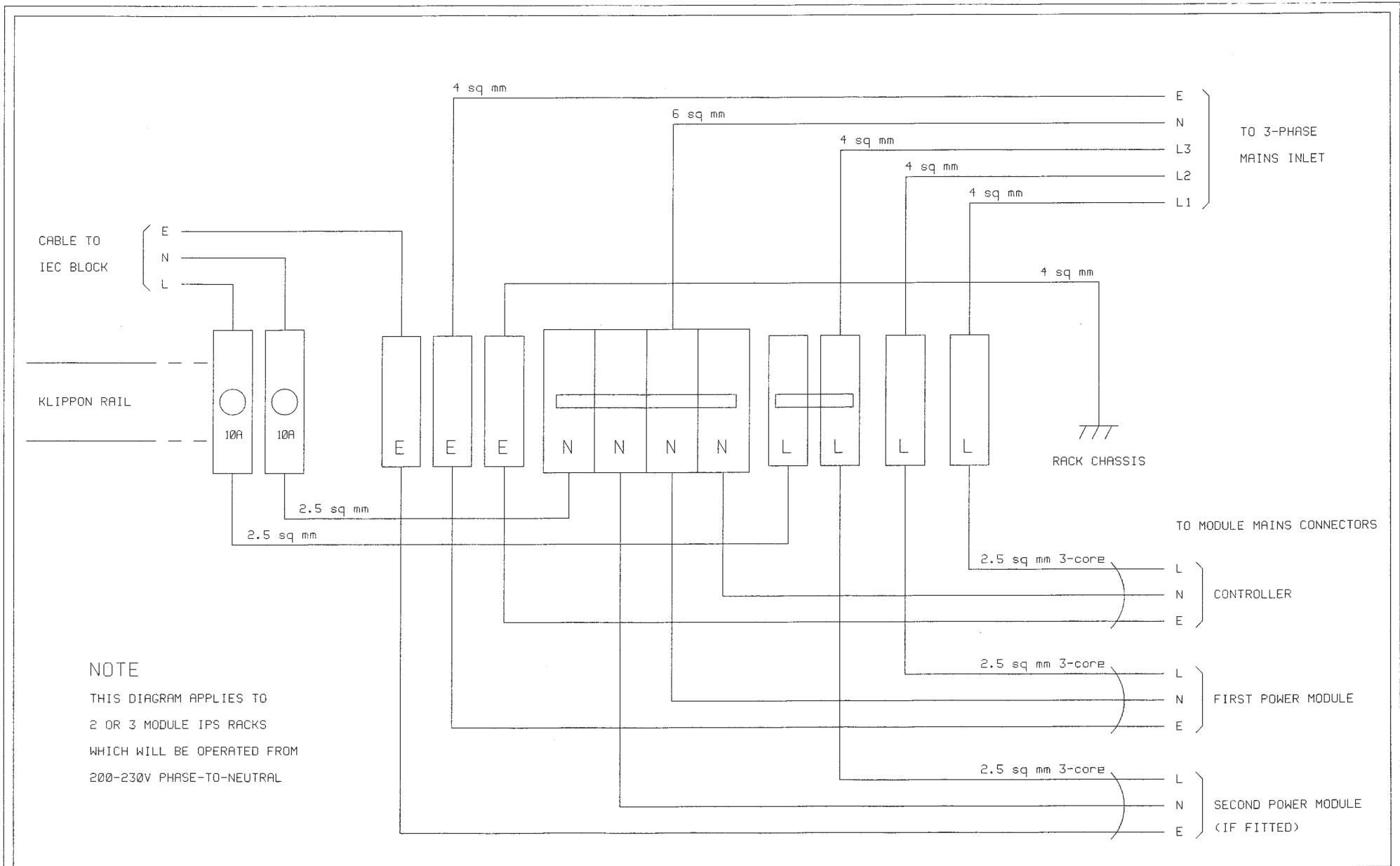


RJM	3/10/94	
2	29/10/96	SHOW EARTH BOLT WIRING

IPS MODULAR SYSTEMS
RACK CONNECTION DIAGRAM

OXFORD

DRAWING NUMBER
A3/CBL4602 sh1 1 of 1



NOTE

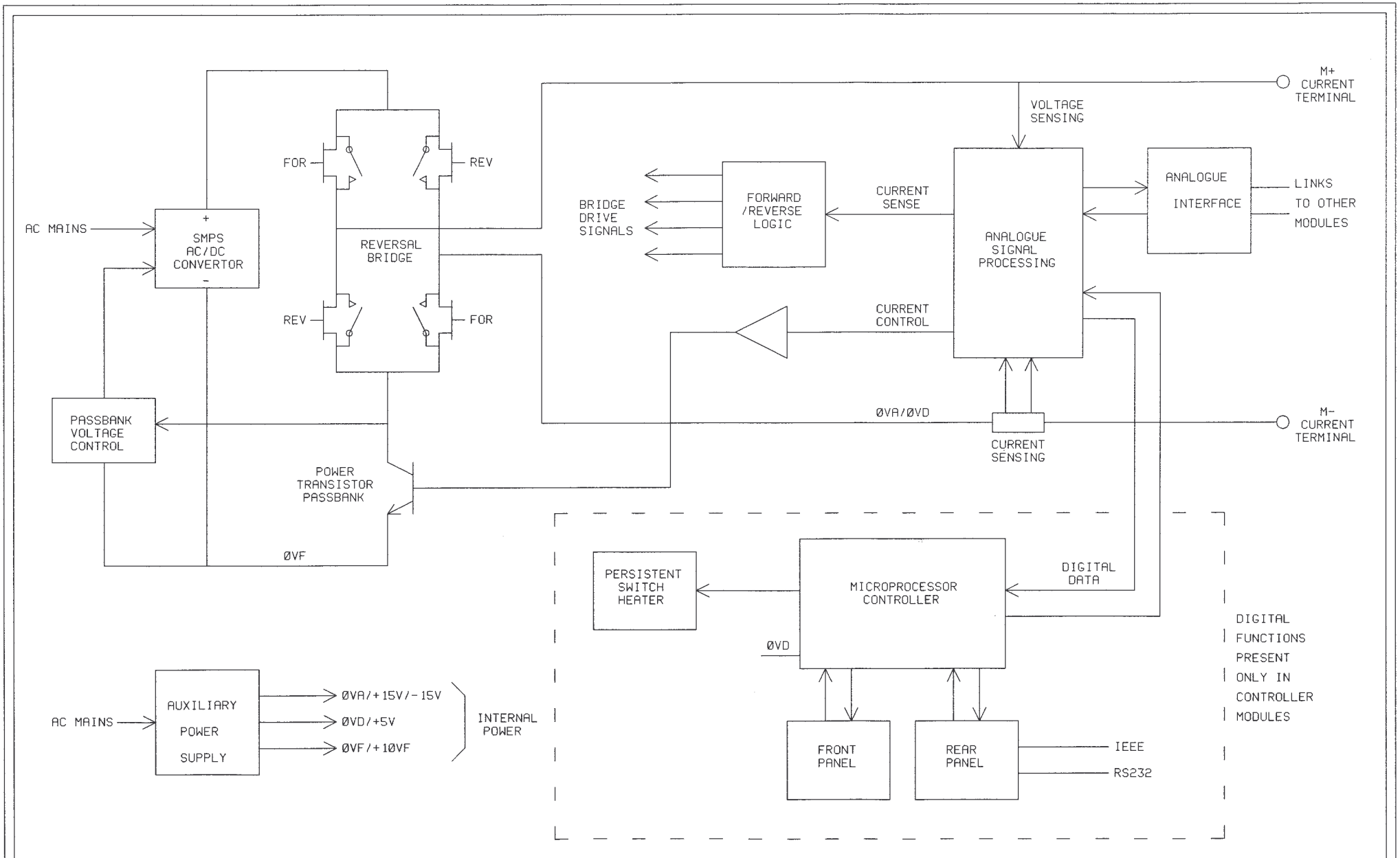
THIS DIAGRAM APPLIES TO
2 OR 3 MODULE IPS RACKS
WHICH WILL BE OPERATED FROM
200-230V PHASE-TO-NEUTRAL

RJM	21/9/94	
2	22/2/95	REAR PANEL EARTH
3	29/10/96	REROUTE PANEL EARTH VIA MODULES

IPS RACK MAINS WIRING
10kVA PHASE/NEUTRAL

OXFORD

DRAWING NUMBER
A4/CBL4612 sht 1 of 2



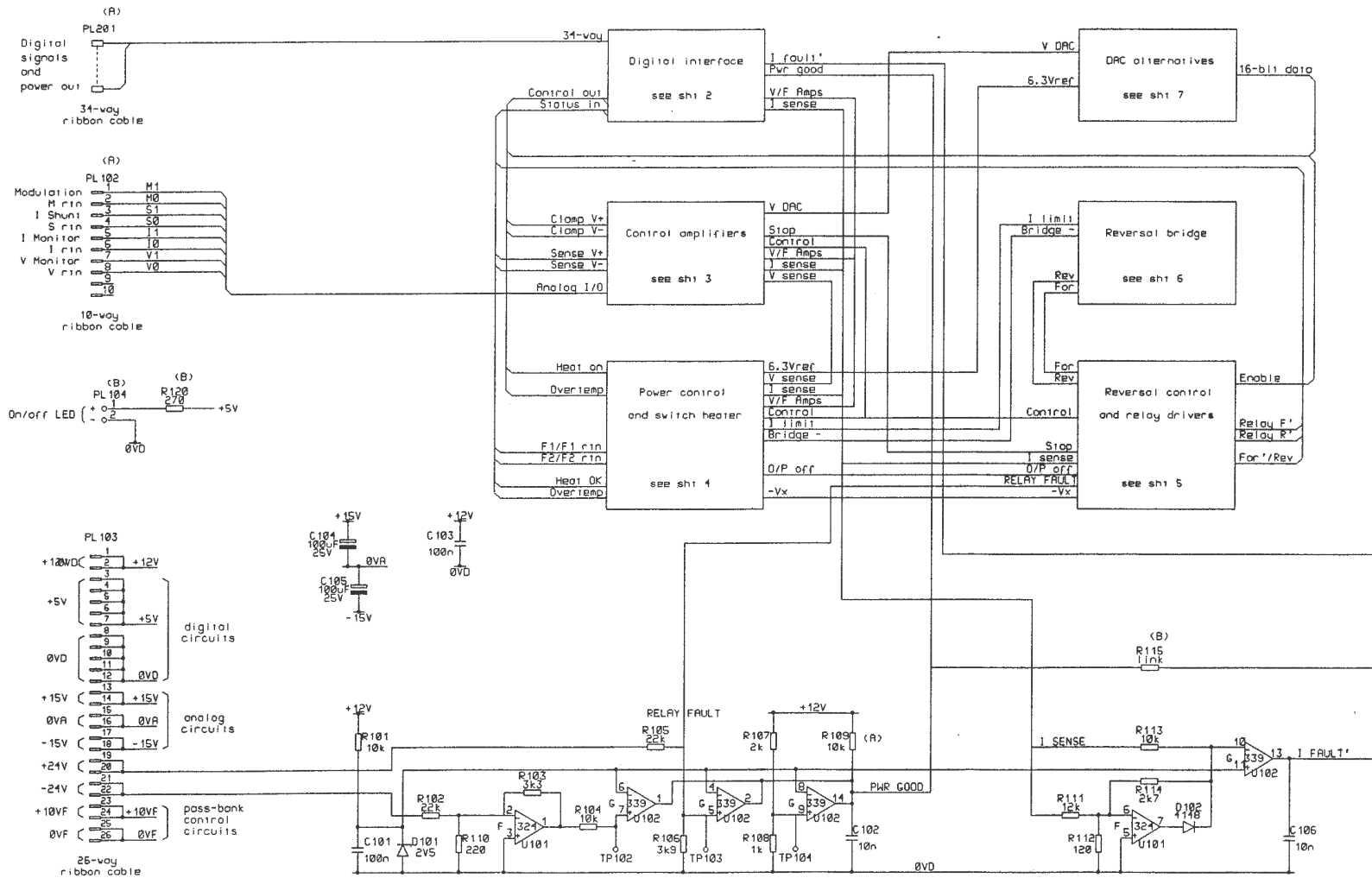
RJM 25/10/94

IPS MODULE BLOCK DIAGRAM

OXFORD

DRAWING NUMBER

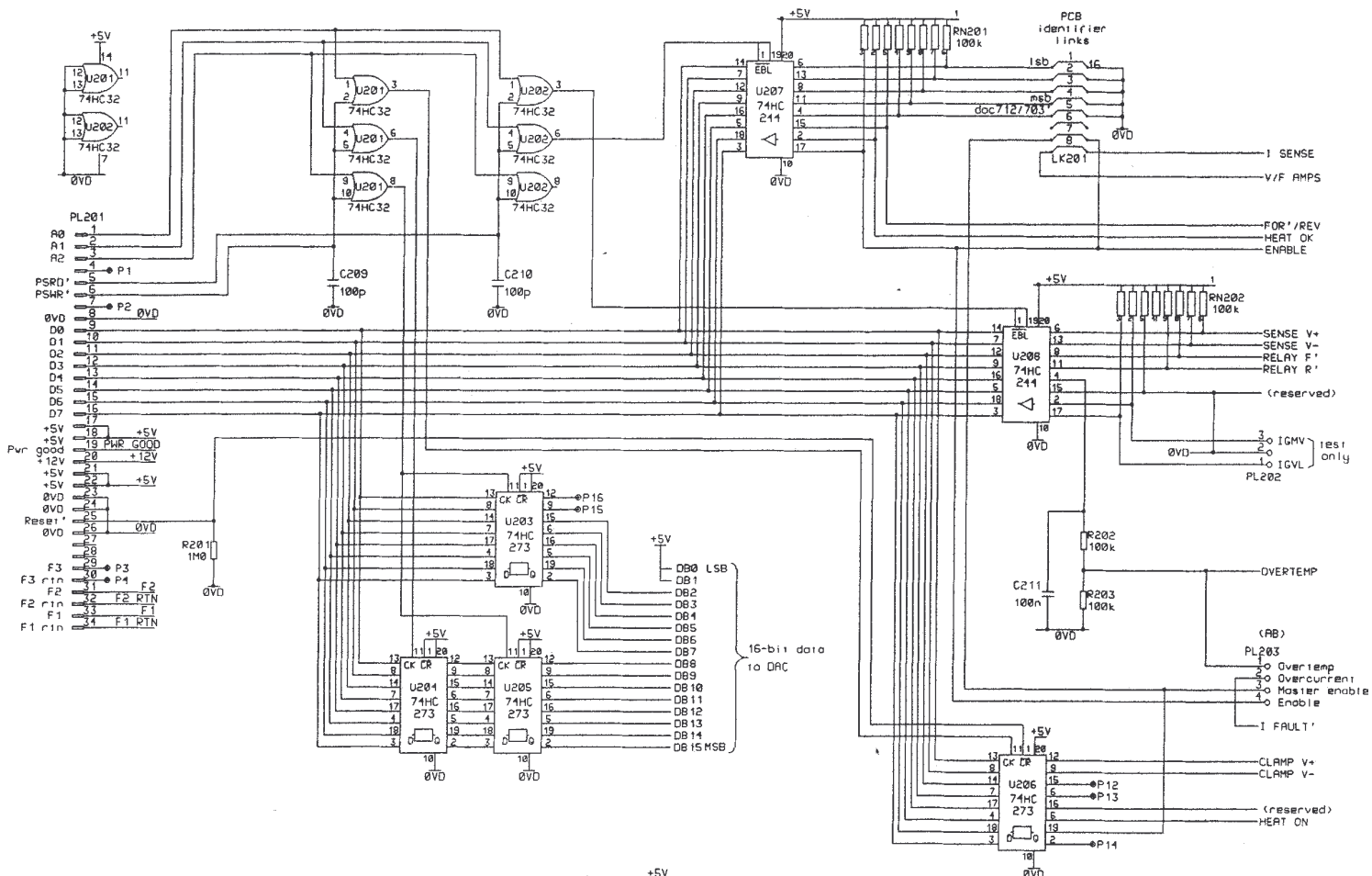
A4/CBL5002 sht 1 of 1



- NOTES
1. NEGATIVE LOGIC SIGNALS DENOTED BY '.
 2. POWER SUPPLY VARIANTS:
 (A) FITTED IN CONTROLLER ONLY.
 (B) FITTED IN POWER MODULE ONLY.
 OTHER COMPONENTS FITTED IN ALL UNITS.

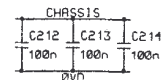
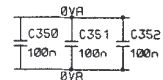
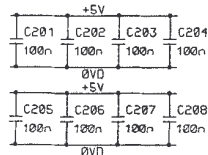
06	10/9/96	C176 RELAY FAULT LINE ADDED
05	19/1/96	C398
04	5/10/95	C383
03	14/8/95	C305
2	15/2/95	C287 PROTOTYPE CHANGES INCLUDED.
RJM	8/9/94	CBL1302 WITH MASTER/S�AVE COMPONENTS ADDED

07	1/5/97	SEE SHEETS 4 AND 5
IPS ANALOGUE PCB CONNECTION DIAGRAM		
		DRAWING NUMBER A3/CBL5302 sh 1 of 7



NOTES

1. NEGATIVE LOGIC SIGNALS DENOTED BY '.
2. POWER SUPPLY VARIANTS:
ALL COMPONENTS THIS PAGE ARE NOT FITTED IN POWER MODULES.
EXCEPT FOR (AB)



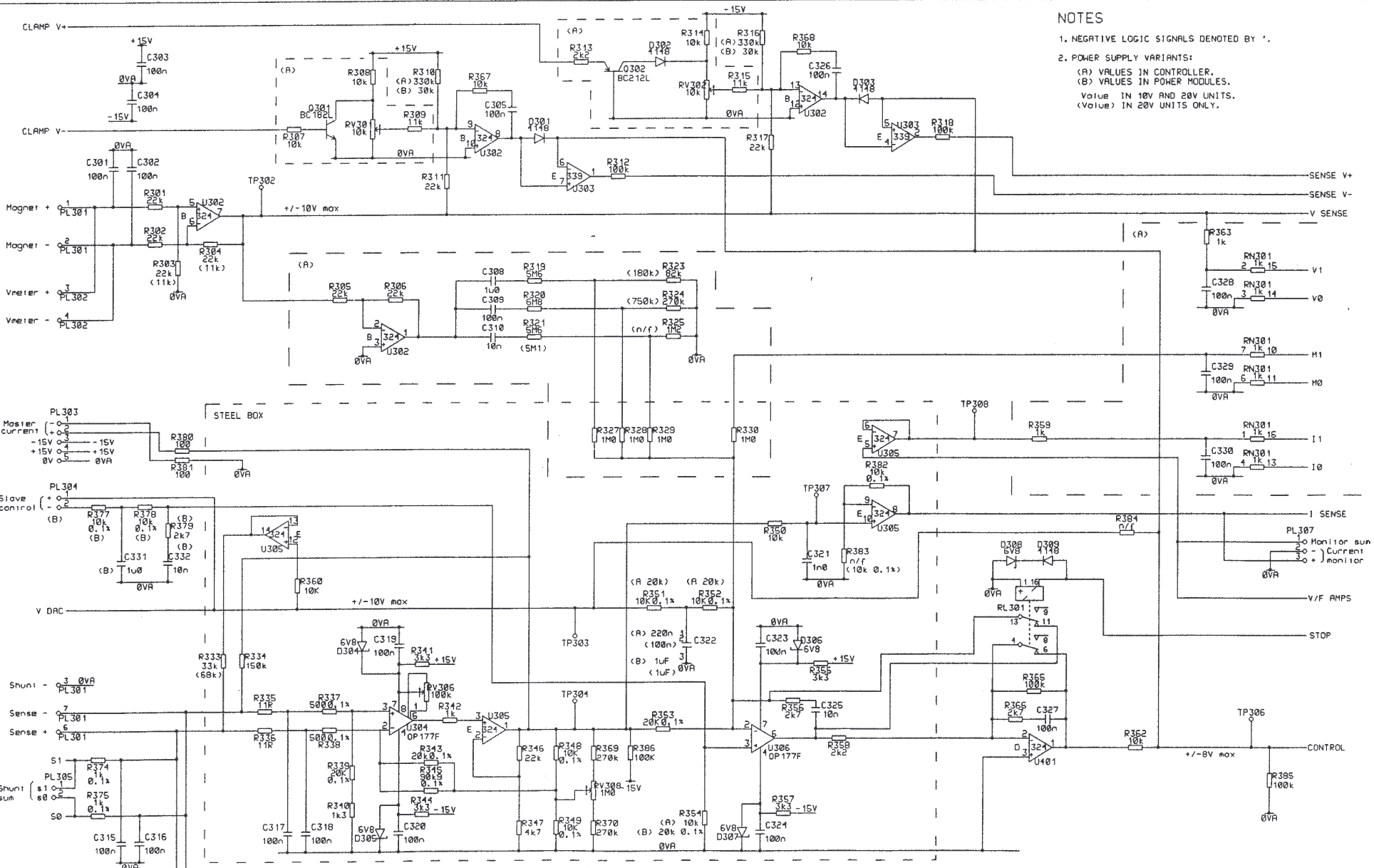
05	10/9/96	C475
05	19/1/96	C398
04	5/10/95	C383
3	14/8/95	C305 EMC MODS C211-214, C350-352
2	15/2/95	C287 PROTOTYPE CHANGES ADDED.
RJM	8/9/94	CBL1302 WITH MASTER/SLAVE COMPONENTS ADDED

07	1/5/97	SEE SHEETS 4 AND 5
----	--------	--------------------

IPS ANALOGUE PCB
DIGITAL INTERFACE

OXFORD

DRAWING NUMBER
A3/CBL5302 sht 2 of 7



NOTES

1. NEGATIVE LOGIC SIGNALS DENOTED BY ' .

2. POWER SUPPLY VARIANTS:

(A) VALUES IN CONTROLLER.
 (B) VALUES IN POWER MODULES.
 Value IN 10V AND 20V UNITS.
 (Value) IN 20V UNITS ONLY.

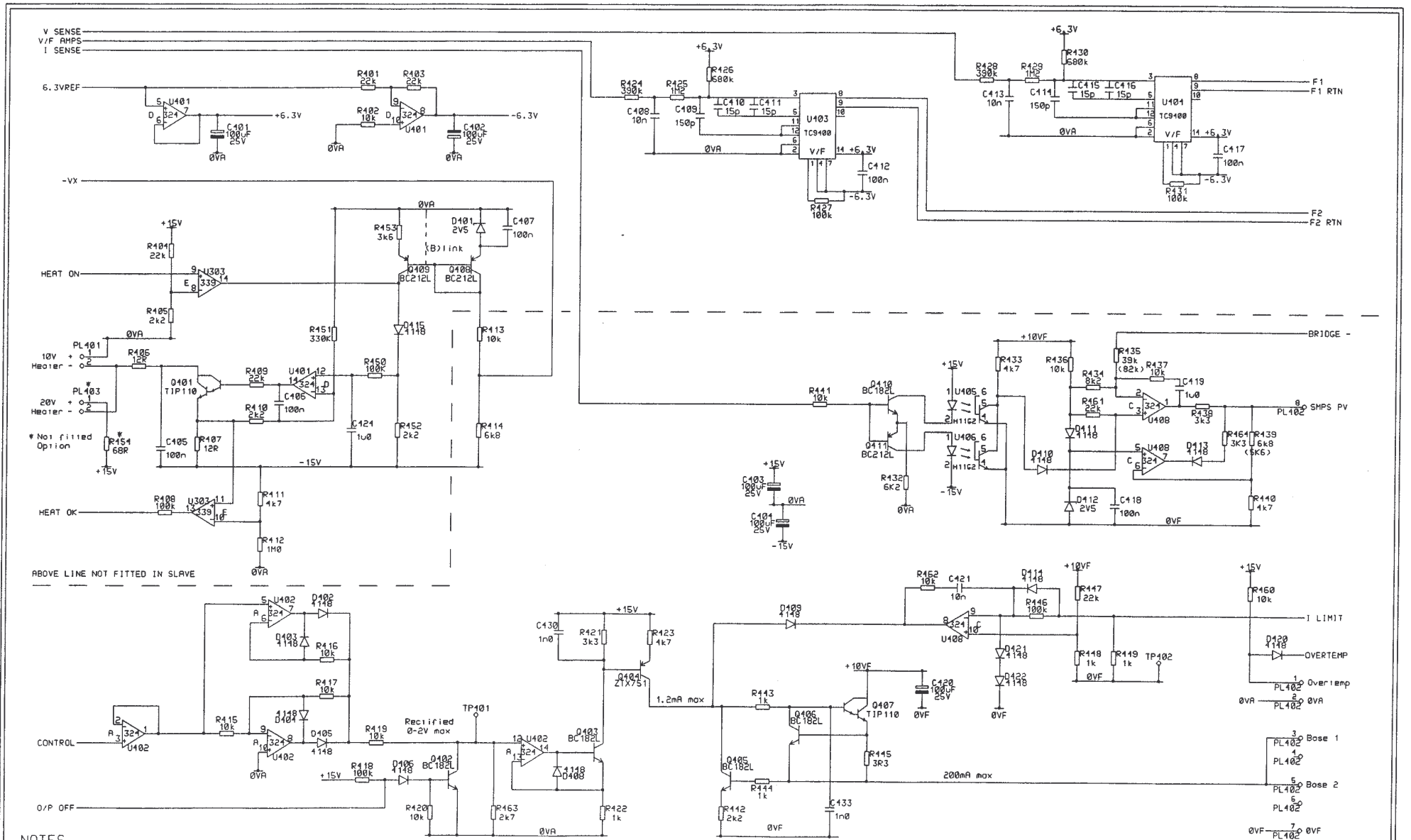
06	10/9/96	C478 R360 ADDED
05	19/1/96	C398
4	30/11/95	C383 R358, C327 VALUE. D310-3, R360-1 n/f.
3	14/8/95	C305 R309, R315, R384
2	15/2/95	C287 PROTOTYPE CHANGES ADDED.
RJM	8/9/94	CBL1302 WITH MASTER/SLAVE COMPONENTS A800R085.

07 1/5/97 SEE SHEETS 4 AND 5

IPS ANALOGUE PCB
 CONTROL AMPLIFIERS

OXFORD

DRAWING NUMBER
 A3/CBL5302 sh1 3 of 7



NOTES

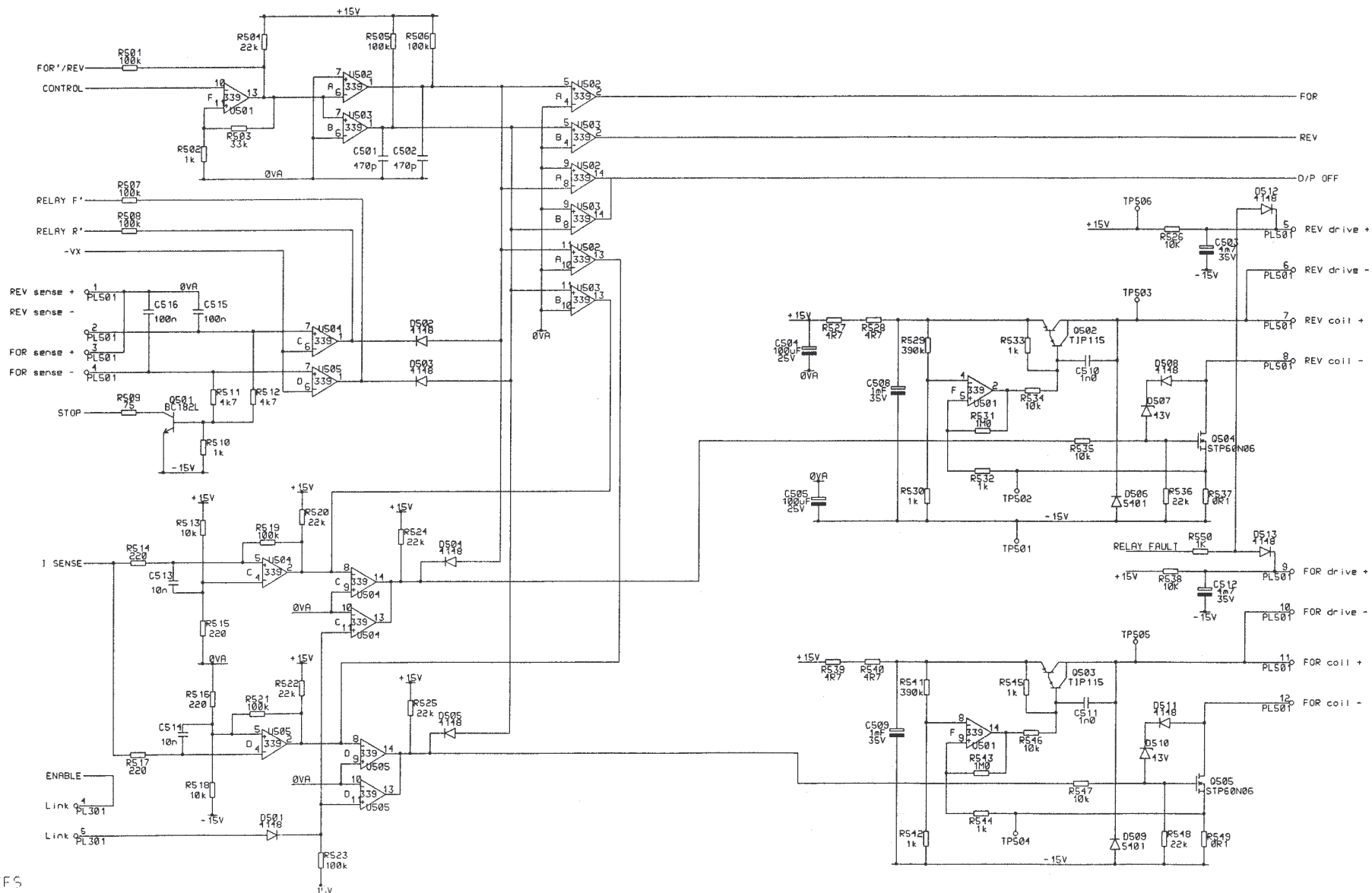
1. NEGATIVE LOGIC SIGNALS DENOTED BY '•'.
2. COMPONENTS ABOVE THE DASHED LINE ARE NOT FITTED IN POWER MODULES.
3. POWER SUPPLY VARIANTS:
 (A) VALUE IN CONTROLLER ONLY.
 (B) VALUE IN POWER MODULE ONLY.
 (value) IN 20V UNITS ONLY.

06	10/9/95	C476 R464 ADDED
05	19/1/96	C398
4	30/11/95	C383 R463 REPLACES D407.
3	14/8/95	C305 ADD C432, D421-2. DEL C422-3.
2	15/2/95	C287 PROTOTYPE CHANGES ADDED.
RJM	8/9/94	CBL1302 WITH MASTER/SLAVE COMPONENTS ADDED

07	1/5/97	ADD C433. DELETE C432.
----	--------	------------------------

IPS ANALOGUE PCB
 POWER CONTROL
 AND SWITCH HEATER

OXFORD
 DRAWING NUMBER
 A3/CBL5302 sh1 4 of 7



NOTES

1. NEGATIVE LOGIC SIGNALS DENOTED BY '-'

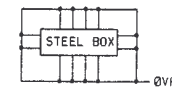
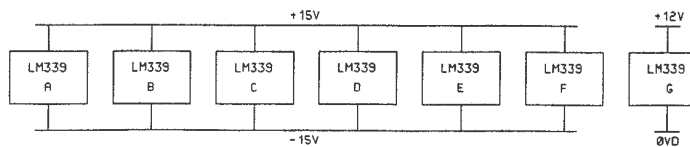
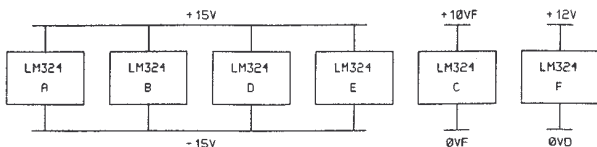
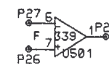
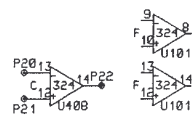
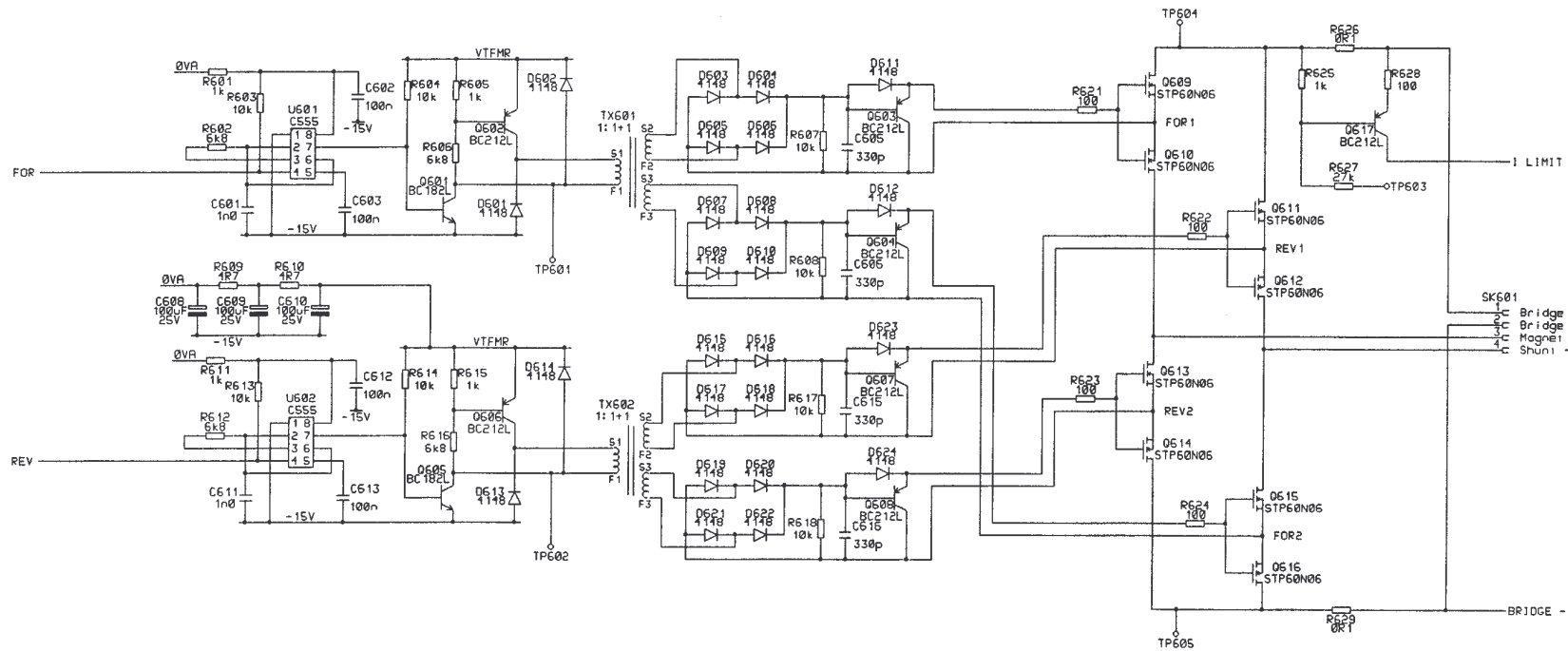
06	10/9/96	C478 D512,513 & R550 ADDED
05	19/1/96	C398
01	5/10/95	C383
3	14/8/95	C305 C515-6
2	15/2/95	C287 PROTOTYPE CHANGES ADDED.
RJM	8/9/94	CBL1302 WITH MASTER/S�AVE COMPONENTS ADDED

07 1/5/97 R503 CHANGE FROM 1M0 TO 33k

IPS ANALOGUE PCB
REVERSAL CONTROL
AND RELAY DRIVERS



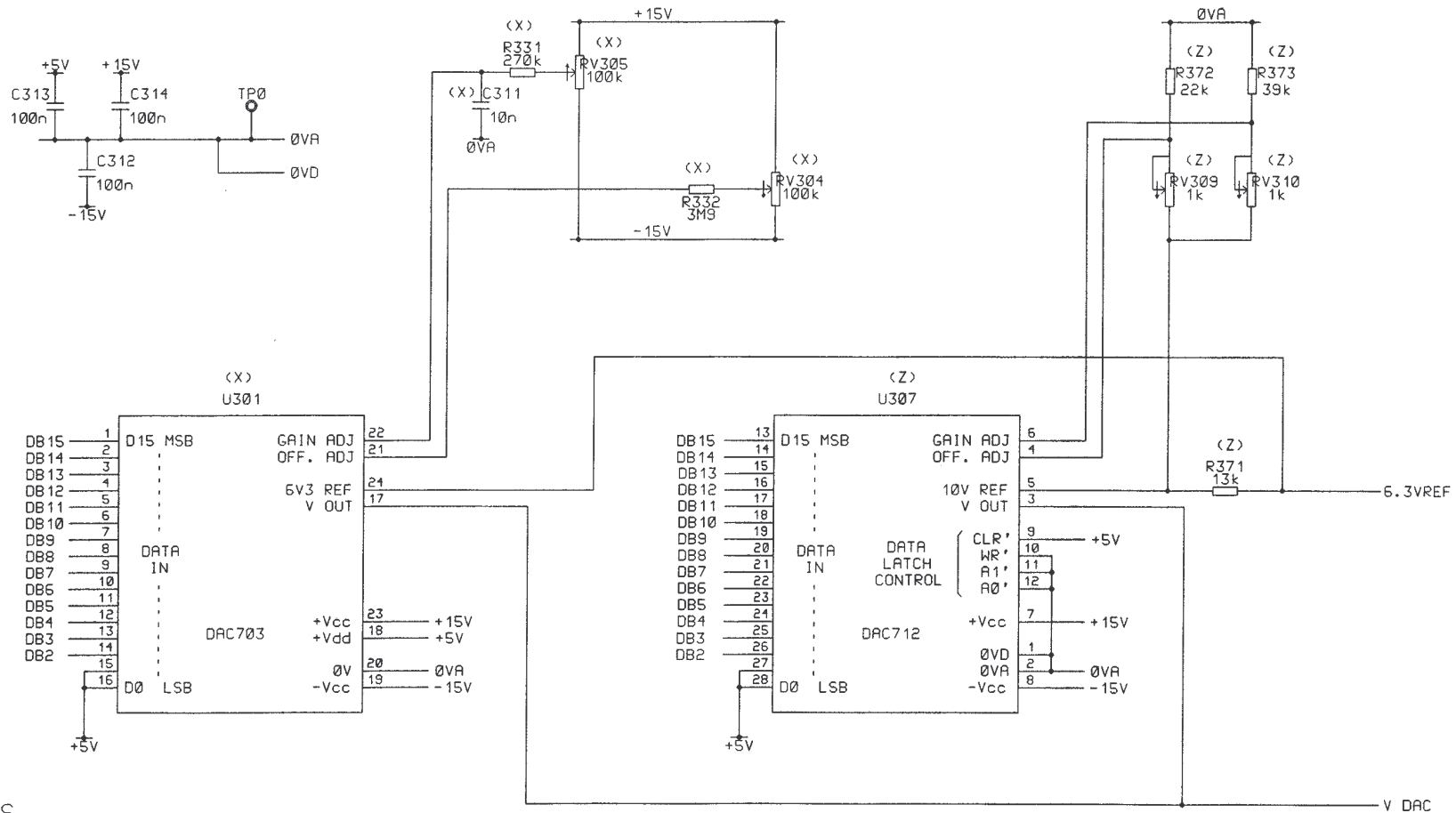
DRAWING NUMBER
A3/CBL5302 sh1 5 of 7



F3P3P3P3P37
F3P3P40
CHASSIS

06	10/9/96	C175
05	19/1/96	C398
04	5/10/95	C383
03	14/8/95	C305
2	15/2/95	C287 PROTOTYPE CHANGES ADDED
RJM	8/9/94	CBL1302 WITH MASTER/S�AVE COMPONENTS ADDED

07	5/1/97	SEE SHEETS 4 AND 5
IPS ANALOGUE PCB		OXFORD
REVERSAL BRIDGE		
DRAWING NUMBER		A3/CBL5302 sh1 6 of 7



NOTES

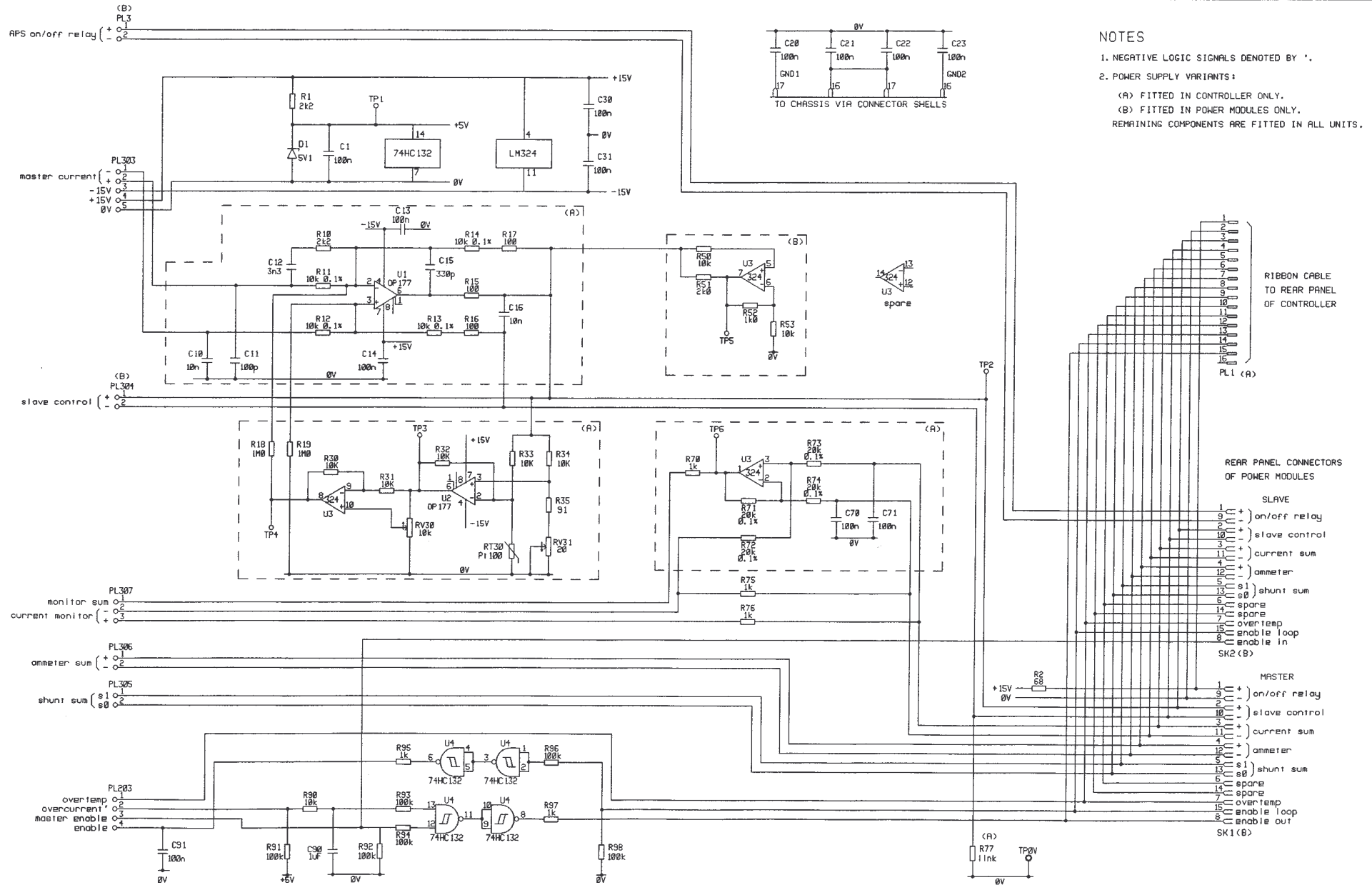
1. ALL COMPONENTS THIS PAGE ARE NOT FITTED IN POWER MODULES.
2. COMPONENTS MARKED (X) FITTED ONLY WITH DAC703
3. COMPONENTS MARKED (Z) FITTED ONLY WITH DAC712

07	1/5/97	SEE SHEETS 4 AND 5
06	10/9/96	C476
05	5/10/95	C398
04	5/10/95	C383
03	14/8/95	C305
2	15/2/95	C287 PROTOTYPE CHANGES ADDED.
RJM	8/9/94	CBL1302 WITH MASTER/SLAVE PARTS

IPS ANALOGUE PCB
DAC ALTERNATIVES

OXFORD

DRAWING NUMBER
A4/CBL5302 sht 7 of 7

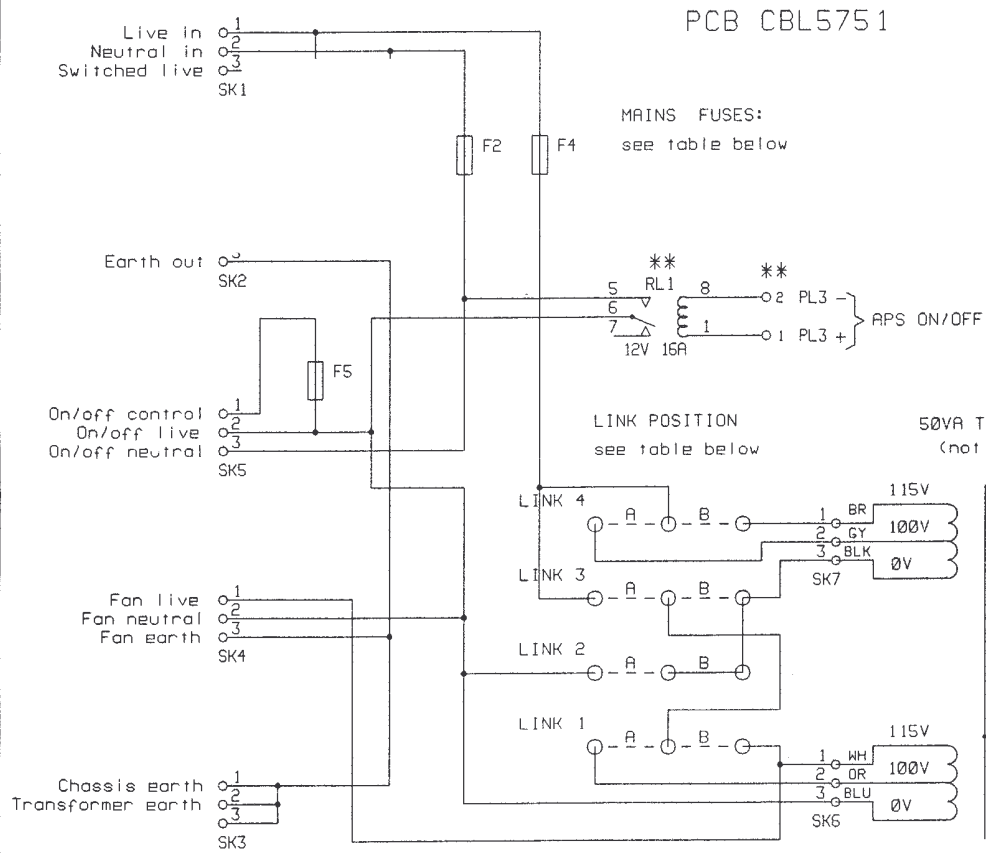


- NOTES**
1. NEGATIVE LOGIC SIGNALS DENOTED BY '-'
 2. POWER SUPPLY VARIANTS:
 - (A) FITTED IN CONTROLLER ONLY.
 - (B) FITTED IN POWER MODULES ONLY.
 REMAINING COMPONENTS ARE FITTED IN ALL UNITS.

RJM	7/9/94	
2	14/2/95	C11 VALUE CHANGE.
3	1/11/95	C20-23 ADDED.

IPS MASTER/SLAVE
INTERFACE PCB

OXFORD
DRAWING NUMBER
A3/CBL5502 sht 1 of 1



PCB CBL5751

MAINS FUSES:
see table below

LINK POSITION
see table below

50VA Transformer
(not on PCB)

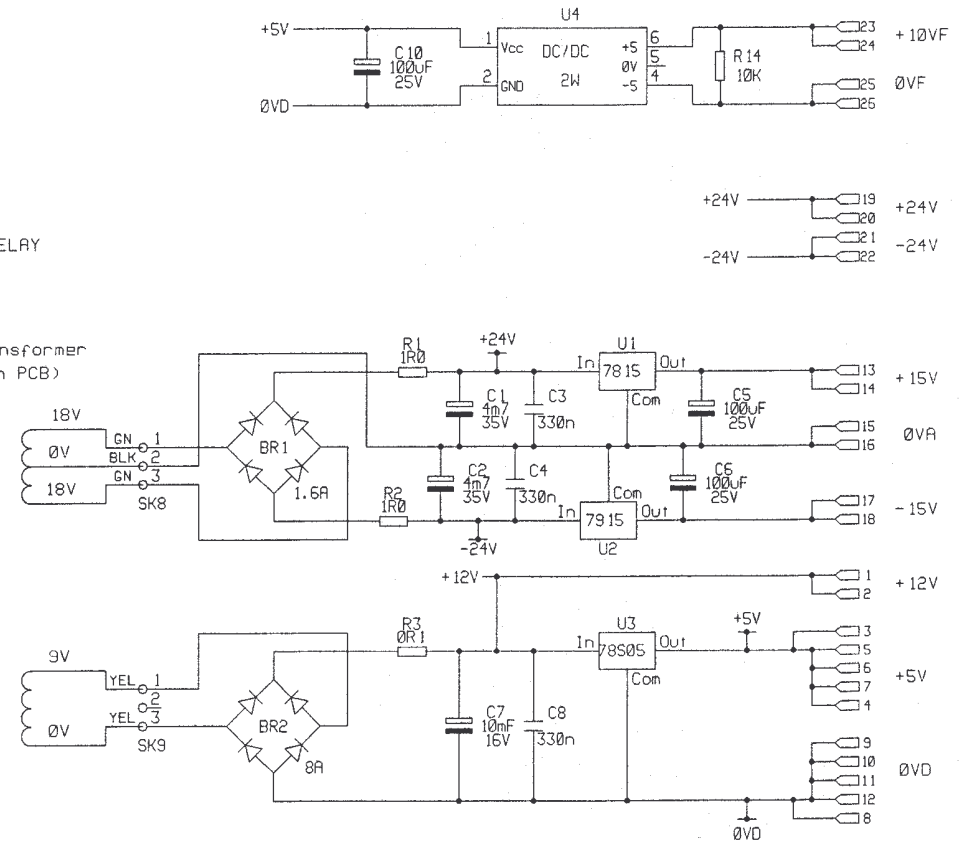
FUSE RATINGS

	100/115V	200/230V
FS2/FS4	2.0A A/S	1.0A A/S
FS5	500mA A/S	500mA A/S

SELECT MAINS VOLTAGE LINKS

	100V	115V	200V	215V	230V
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

PCB CBL5701



MTG HOLES

- Ø P1
- Ø P2
- Ø P3
- Ø P4
- Ø P5
- Ø P6
- Ø P7
- Ø P8 COVER
- Ø P9 MTG HOLES
- Ø P10

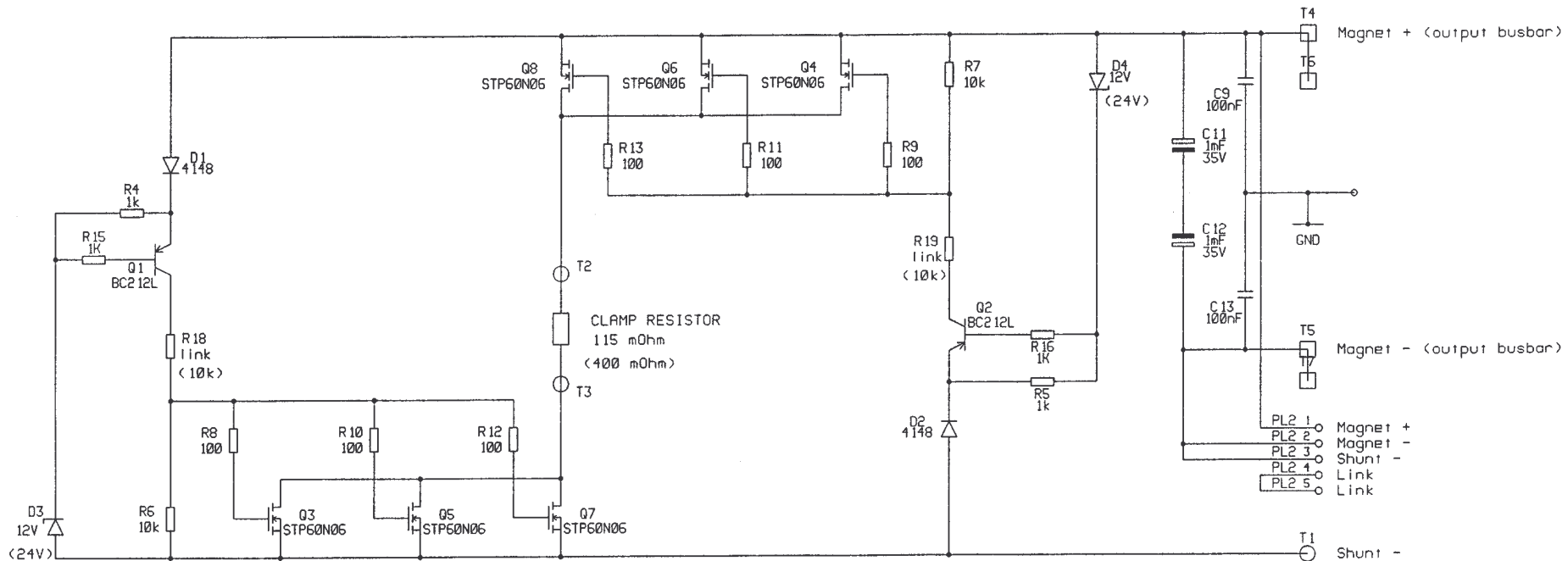
** COMPONENTS FITTED ONLY
IN SLAVE UNITS.

IPS 120 AUXILIARY
POWER SUPPLY

OXFORD

DRAWING NUMBER
A4/CBL5702 sht 1 of 1

Ø5	13/6/97	C576 TRACKING CHANGES
Ø4	7/10/96	C506 PL2 CONNECTIONS CHANGED
Ø1	6/9/94	RJM C217 FROM CBL1702 + RL1 AND PL3



NOTES

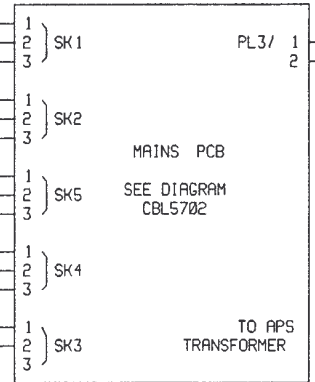
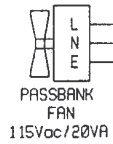
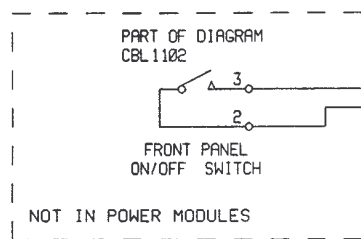
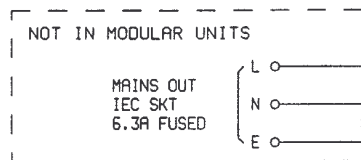
- 1. VALUES IN BRACKETS ARE FITTED FOR 20V UNITS.

Ø4	7/10/96	C506 PL2 CONNECTIONS CHANGED
RJM	14/9/94	FROM CBL2612 20V PARTS ADDED

IPS 120 OUTPUT CLAMP
AND FILTER PCB

OXFORD

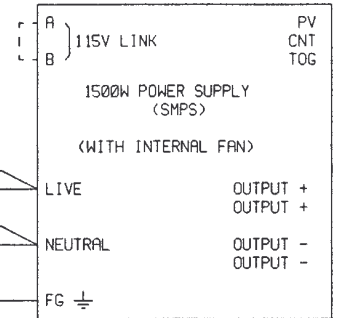
DRAWING NUMBER
A4/CBL5772 sht 1 of 1



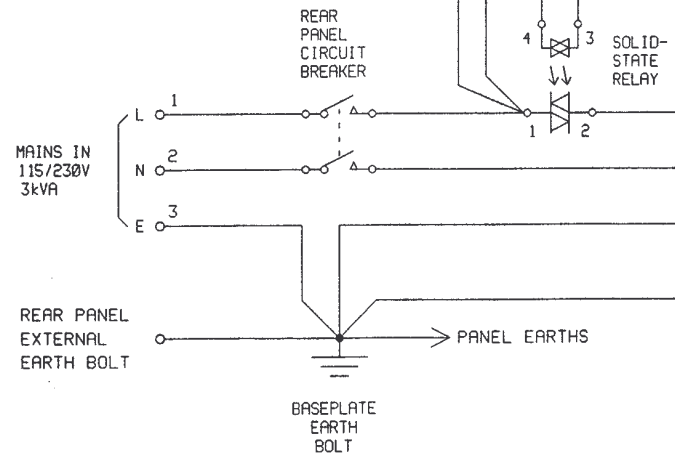
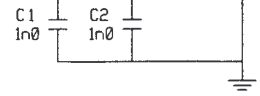
SEE SHEET 4
POWER MODULES ONLY
INTERFACE PCB PL3

SEE SHEET 3

→ APS TRANSFORMER EARTH



SEE SHEET 2

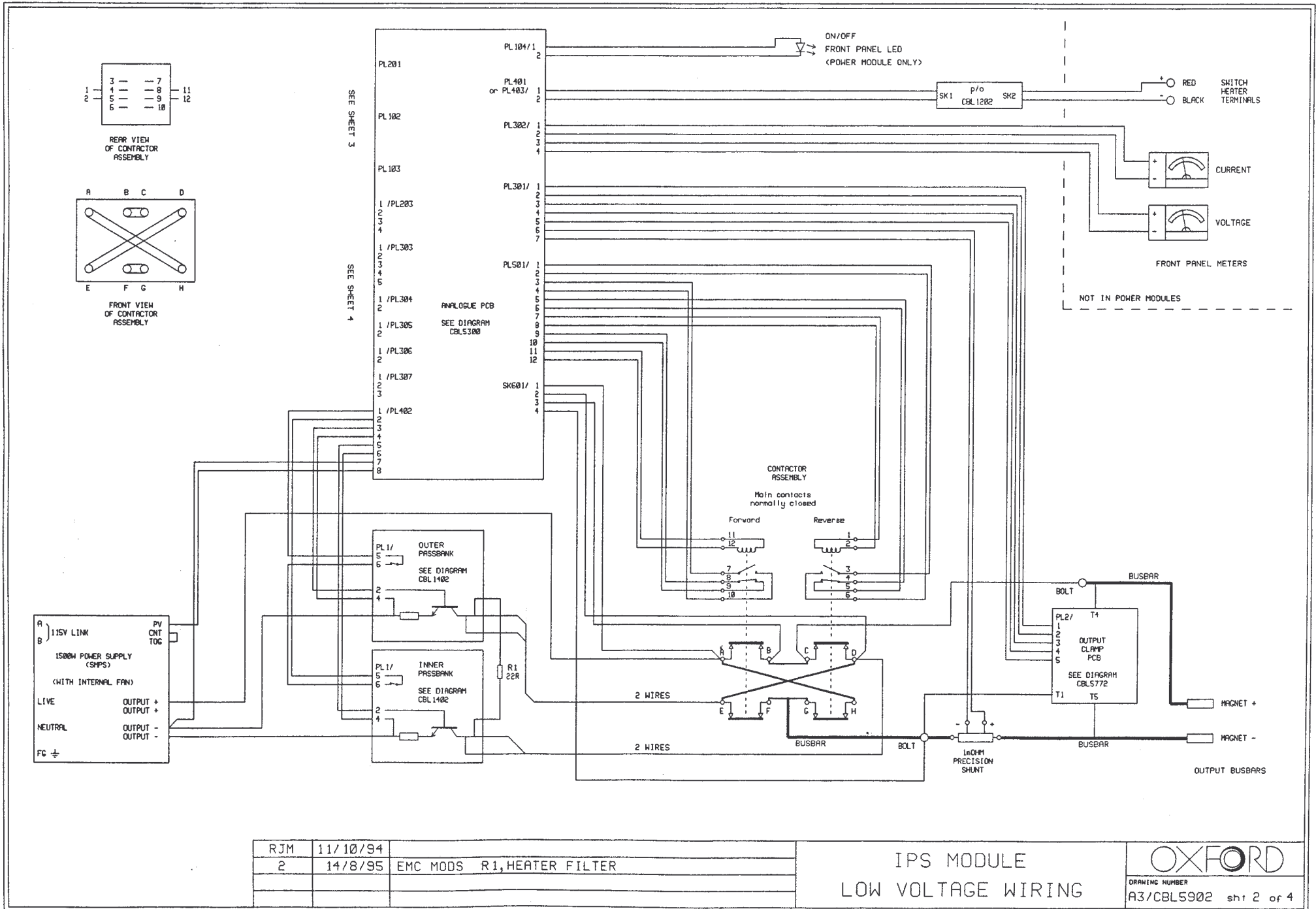


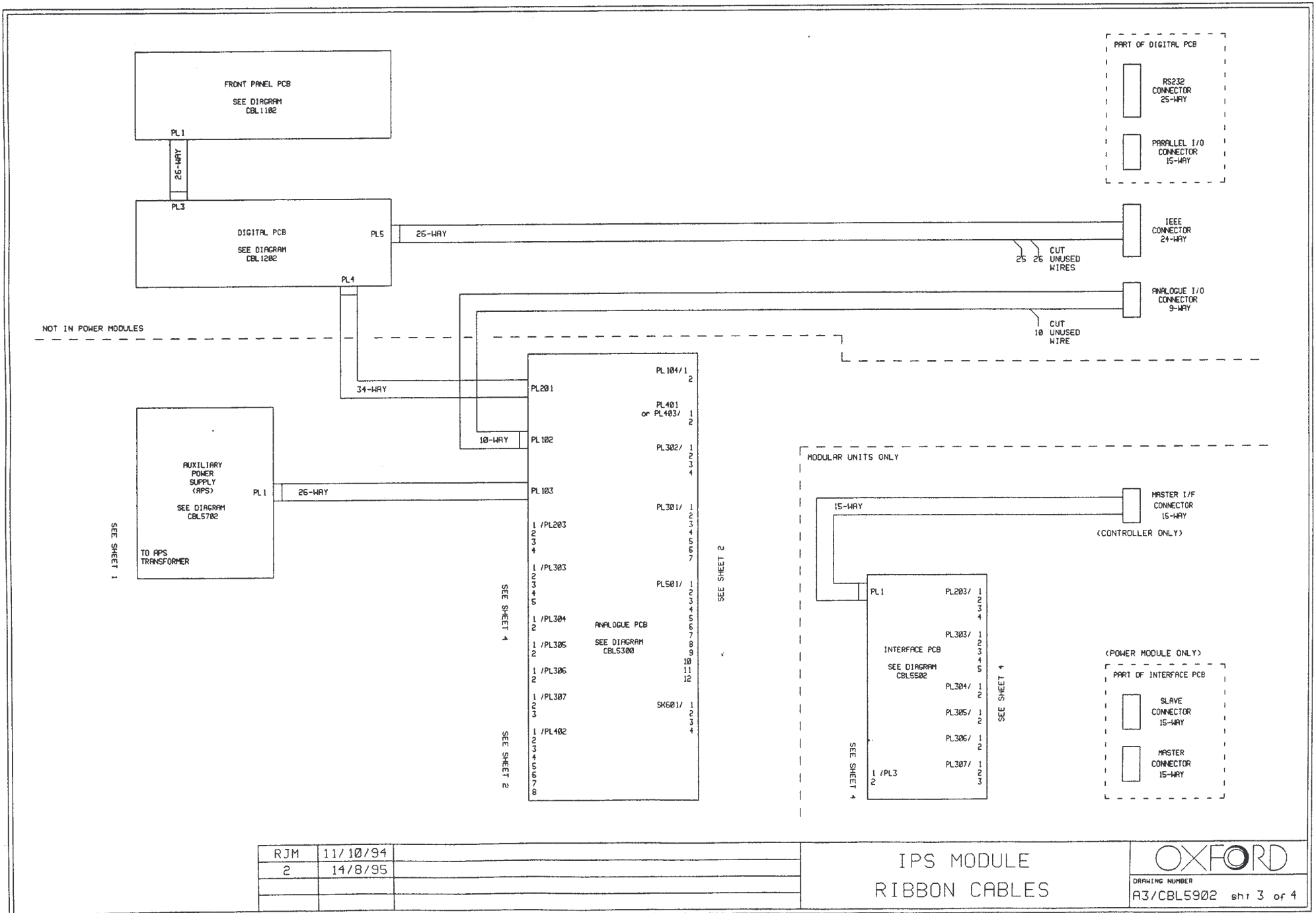
RJM	11/10/94	
2	14/8/95	EMC MODS C1,C2

IPS MODULE
MAINS WIRING

OXFORD

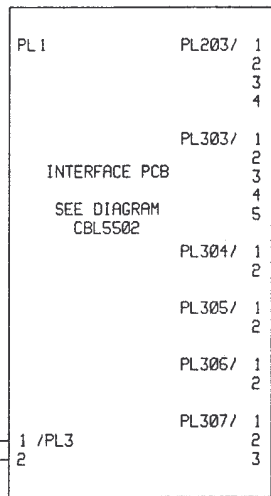
DRAWING NUMBER
A4/CBL5902 sht 1 of 4



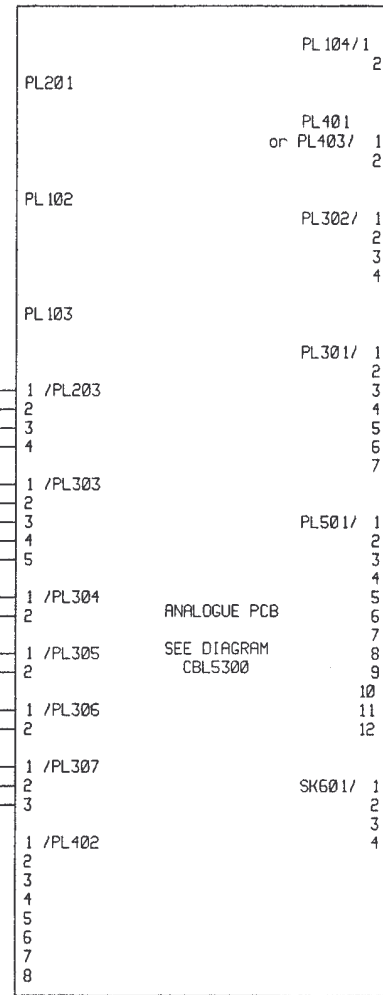


THESE WIRES FITTED ONLY
IN MODULAR UNITS

SEE SHEET 1
POWER MODULES ONLY
MINS PCB PL3



<POWER MODULES ONLY>



RJM	11/10/94
2	14/8/95

IPS MODULE
INTERFACE PCB WIRING

OXFORD

DRAWING NUMBER
A4/CBL5902 sht 4 of 4