Operator's Handbook

Lambda Point Controller

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Warnings

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1 Warnings

1. ***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.***

2. ***High Voltage Hazard. Isolate this equipment by switching off the external AC electrical supply, disconnecting and removing the external supply cable.***

3. ***The AC electrical supply is considered to be the disconnect device for the equipment. Access to this must not be restricted at any time. The external AC electrical supply cable must remain accessible for disconnection of the equipment.***

4. ***Maintenance: Only qualified and authorised persons should carry out servicing and repair work on this equipment.***

5. ***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.***

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

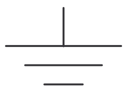
1. ***If you change set-up data and want it to be retained after power down, the data must be deliberately STORED as described in section 7.6***

2. ***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.***

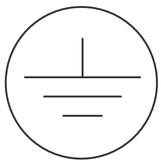
3. ***COOLING HAZARD. Internal components are air-cooled. Ensure the front lower ventilation space is not obstructed.***

Explanation of symbols used in the Instrument

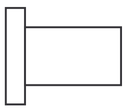
Attention; please refer to the manual



Functional earth



Protective earth



OFF

ON

3 Introduction

3.1 Safety

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

3.1.1 Protective Ground

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

3.1.2 Repair and Adjustment

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

Ensure that the instrument is disconnected from the AC power supply (switching off the front panel POWER switch is not sufficient) before the covers are removed or fuses are replaced, otherwise dangerous voltages are accessible. Capacitors inside the instrument and power connector filter, if fitted, may remain charged after removal of AC power. These should be discharged before starting work.

For fault finding and calibration, the AC Power supply may require reconnection. This work may only be carried out by skilled personnel who are aware of the hazard involved.

3.2 The B-T Environment Concept

This manual provides operating and service information for the Oxford Instruments Lambda Controller. B-T Environment is a generic name for a range of products based around computer control of a magnet. A minimum B-T Environment system includes the magnet itself, the set of computer controlled electronics required to energise it and monitor its operation, and the necessary software drivers required to control the whole system. In addition, B-T Environment will often incorporate additional hardware and software to control the temperature Environment of a sample within the magnetic field.

The essence of the B-T Environment concept is that B-T Environment provides the "x-axis" control for a scientific experiment, in a way which allows the user to add his own measurements to form the "y-axis", the whole resulting in a complete computer-controlled experiment.

3.3 Description of Lambda Controller

Computerised control of magnet energisation and sample temperature is easily achieved using Oxford Instruments standard Power Supplies and Temperature Controllers. The Lambda Controller complements these to provide computer control of the cryogenic Environment for the magnet. In particular it carries out control and monitoring functions associated with cooling the magnet below 4.2 K for operation at high field.

Many of the superconducting magnets supplied by Oxford Instruments have two maximum field specifications. There is a maximum field attainable with the magnet operating at 4.2 K (the boiling point of liquid helium at atmospheric pressure). There is often a second (higher) maximum field attainable with the magnet operating at 2.2 K. This temperature corresponds to the Lambda point, 2.17 K at which liquid helium becomes superfluid. Cooling to this temperature is achieved by means of a "Lambda Point Fridge", the operation of which is described briefly below in section 5.2. The Lambda Controller is able to monitor and control the operation of the Lambda Fridge. In addition, it monitors the magnet temperature, allowing the experimental control software to what field, the magnet may safely be energised.

The Lambda Controller is based upon the **ITC**500 series temperature controller family. However it is intended only for use as a computer interface and therefore carries no user controls other than its power switch and a status display indicating whether the instrument is active or in standby.

3.4 Scope of this Manual

The Lambda Controller is only intended to be used as part of a complete system and will always be controlled via software drivers supplied by Oxford Instruments. Hence this manual provides only sufficient detail to allow the controller to be put into service and operated via its computer interface. If more detail is required concerning the theory of its operation and use of non-standard sensors, reference should be made to the **ITC**502 Temperature Controller manual.

3.5 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 Installation

4.1 Supply Connections

Before applying power to the instrument, ensure that the voltage selectors on the rear of the equipment is correctly set for the intended supply voltage. The selectors cover four voltage options 100 V, 115 V, 200 V and 230 V. Selectors should be set to the same value nearest to the nominal local Mains AC voltage.

If necessary, open the voltage selector panel using the slot provided, withdraw the voltage selector and replace it in the correct orientation for the intended voltage. Check that the correct fuses are fitted, then close the voltage selector panel.

Fuse ratings are:

~100/115 V T2.0AH 250 V Type T (Slow Blow)

~200/230 V T0.8AH 250 V Type T (Slow Blow)

4.2 Classification

The Lambda Point Controller 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.

4.3 Environment

The following operating environment conditions must be observed;

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

4.4 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 °C
Relative humidity	30% to 75% (non- condensing)
Atmospheric pressure	700 to 1060 mbar

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

Ambient temperature	-40 to 45 °C
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

4.5 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

Every six months see CONNECTIONS below and if required contact the Oxford Instruments service department.

4.6 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.

4.7 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.

4.8 Mounting Instruction

The equipment is housed inside a 19 inch, 2U rack. The rack is usually placed on a bench or table with access to the rear for connections.

4.9 Sensor Connections

The Lambda Controller accepts inputs from three sensors. In a standard system, these are configured as:

CHANNEL 1	Lambda Fridge pump-line Pressure
CHANNEL 2	Magnet Temperature (Allen Bradley Resistor)
CHANNEL 3	Optional 2nd Temperature Sensor (Normally unused)

Each sensor connects to its own 9 way input connector

Pin connections are:

1	Input High
2	Input Low for Normal Applications
3	Input GND (Linked to pin 2, isolated from supply GND)
4	Current / Voltage Source +ve
5	Current / Voltage Source -ve
6	Not Used
7	Not Used
8	Input Low for Thermocouples with RT Ref. Junction
9	Chassis Ground

Connections between these sockets and the actual sensor will vary with the type of sensor in use, as shown in the table below.

For the pressure sensor (a Piezo strain gauge type) the pinouts given (1, 2, 3 and E) correspond to the 4 pin connector normally fitted to the sensor.

		Pressure Sensor
1	Input High	2 Output +
2	Input Low	3 Output -
4	Current +ve	1 Supply +ve
5	Current -ve	E Supply Gnd

For temperature sensors the connections are as shown below. The most commonly used magnet temperature sensor is an Allen Bradley carbon resistor, with wiring as shown for "Ge/Carbon Resistors".

	Thermo-couple	Metal Resistor	Ge/Carbon Resistor		Si/GaAs Diode
1	Input High	V+	V+	V-	V-
2	Input Low	V-	V-	V+	V+
4	Current +ve	n/c	I+	I+	I+
5	Current -ve	n/c	I-	I-	I-

Note that the polarity of the voltage input connections is reversed for semiconductor resistors and diodes. For these sensors, the sensor resistance or sensor voltage falls with increasing temperature.

For some thermocouple ranges a room temperature reference junction may be used (not recommended for cryogenic applications). It is important to note that the room temperature compensating sensor is mounted at the rear panel of Lambda Controller. To get accurate compensation it is essential that the thermocouple reference junction is at the same temperature. This in turn means that the cable linking the sensor to Lambda Controller must use thermocouple compensating cable. If the rear panel in the region of the connector is likely to be exposed to temperature fluctuations, it will be an advantage if a draught shield is placed around the plug, and the Room Temperature sensor, positioned immediately to its right.

The Input connections are electrically isolated from the controller ground and the chassis ground.

4.10 RS232 Serial Data Line Connections

The bi-directional serial data link from the computer is connected via a 25 way D-socket on the rear panel. Lambda Controller is configured as a DCE with the standard pin outs given below. The majority of computer RS232 interfaces are configured as a DTE and are fitted with a 25 way D plug. For this type of connector, a simple lead connecting pin 1 to pin 1, pin 2 to pin 2 etc. is all that is required. 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 Lambda Controller RS232 socket are:

Pin	Signal Name	Notes
1	FG	Linked to Chassis Ground in Lambda Controller
2	TD	Data from Computer to Lambda Controller
3	RD	Data from Lambda Controller to Computer
4	RTS	Linked to Pin 5 in Lambda Controller
5	CTS	Linked to Pin 4 in Lambda Controller
6	DSR	Linked to +5 V when Lambda Controller is powered
7	SG	Linked to Digital Ground in Lambda Controller
8	DCD	Linked to +5 V when Lambda Controller is p powered

All other pins are open circuit.

Lambda Controller does not require signals to be present on any of the "modem control" lines, RTS or DTR (pin 20). RTS is looped back as CTS and logic high levels are returned on DSR and DCD to ensure maximum compatibility with any requirement of the computer.

Voltage levels for the transmitted and received data are:

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

Data protocols are:

Baud Rate	9600
Tx Start Bits	1
Tx Data Bits	8
Tx Stop Bits	2
Rx Start Bits	1
Rx Data Bits	8
Rx Stop Bits	1 or 2
Parity	None

4.11 The Oxford Instruments ISOBUS

A unique feature of Lambda Controller 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 6.5.

4.12 GPIB (IEEE-488) Connection (Optional)

If the optional GPIB interface is fitted, connections to the GPIB are made via a standard 24 way GPIB connector. Assignment of the connector pins conforms to the standard IEEE-488.1. Connections should be made using a standard GPIB cable. **GPIB connections should never be made or broken whilst the controller 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 immediately below the GPIB connector, to assist in diagnosing any GPIB communication problems. The RED lamp lights whenever the Lambda Controller 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 controller 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 Lambda Controller was last addressed to talk or to listen.

Before any communication can occur, Lambda Controller must be given a unique GPIB address. By default, Lambda Controller is supplied with its address set to 24. 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 5.5.

4.13 The GPIB to ISOBUS Gateway

A Lambda Controller fitted with a GPIB interface 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 Lambda Controller. The adaptor is a symmetrical 25-way plug to 25-way plug link, with pin connections as shown below.

NOTE. Beware of using 25-way plug to 25-way plug adapters, sold as "DCE-linkers" by some suppliers. A variety of different conventions exist for these, not all of which will work as a Gateway Master Adaptor. The correct adaptor may be obtained from Oxford Instruments.

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

The necessary protocols for use as a Gateway Master are included as standard in Lambda Controller and are described in section 6.6.9.

4.14 Auxiliary Port Connections

The auxiliary port provides the connections required for a stepper motor, used to drive a motorised needle valve to control the operation of a Lambda Point Fridge.

Connections to the port are by means of a 15-way D-socket on the rear panel.

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

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

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

The Needle Valve sense input on K5, should be linked to +5 V when an automatically controlled Lambda Fridge needle valve is connected.

Pin connections at the Auxiliary socket are:

1	Output Bit 0	Stepper Motor
9	Output Bit 1	Stepper Motor
2	Output Bit 2	Stepper Motor
10	Output Bit 3	Stepper Motor
3	Output Bit 4	(Not Used)
11	Output Bit 5	(Not Used)
4	Output Bit 6	(Not Used)
12	Output Bit 7	(Not Used)
5	Input K4	Auto Needle Valve Sense
13	Input K5	(Not Used)
6	Input K6	(Not Used)
14	Input K7	(Not Used)
7	+5 V	
15	Driver Protection / +11v unregulated.	
8	0 V	

5 Functional Operation

5.1 Power Up

The Lambda Controller is switched on by means of the POWER ON/OFF switch. The green POWER lamp will light to indicate that power is applied. When first powered up the controller will be in STANDBY and the red STANDBY lamp will be lit. If the controller is connected to an automatic needle-valve, the STANDBY lamp will flash, whilst the needle valve is driven to its fully closed position in order to establish a reference setting for the valve. When this process is complete, the lamp will remain lit, without flashing. When the controller issues a "C1" command, to take control, the STANDBY lamp will extinguish and the ACTIVE lamp will light. If the computer issues this command before the valve reference setting has been establish, the ACTIVE light will flash until the reference setting is reached. Thereafter computer control is by means of commands as given in section 7.

5.2 Lambda Point Fridge

A lambda point fridge consists of a cooling loop mounted on a heat exchange plate immediately above the magnet that is to be cooled. Liquid helium is admitted from the main helium bath to the loop via an adjustable needle valve. The other end of the loop is connected via a pumping line to a rotary pump. A pressure sensor is mounted on the pumping line outside the cryostat. One or more temperature sensors are mounted on the magnet or in the helium bath near the fridge. Helium liquid flash evaporates at the needle valve producing cooling in the loop and hence cooling the helium in the main bath. The cooled helium, being more dense, sinks to the bottom of the cryostat and is replaced by liquid at 4.2 K. Cooling continues until the liquid below the lambda fridge (and hence the magnet which is immersed in this liquid) is all at 2.2 K. At this temperature liquid helium becomes superfluid. Hence further cooling does not produce any further fall in temperature at the magnet, instead the boundary between 2.2 K helium and 4.2 K helium starts to move further up the cryostat.

In operation the pump runs continuously and the needle valve is adjusted to control the rate of cooling. When the fridge is first started, the normal procedure is to run the pump with the needle valve shut. The pressure is monitored until a stable low value is achieved corresponding to a good roughing vacuum. This is taken as the baseline vacuum. The needle valve is then opened till the pressure rises to a target value in the 20 to 50 mbar region, known to give optimal cooling performance. As the magnet cools, the temperature immediately above it is monitored, whilst the computer controls the needle valve as required to keep the correct pressure in the pumping line. When the temperature reaches 2.2 K the needle valve may be closed to achieve a rather lower pressure and a lower cooling rate, sufficient to keep the magnet at 2.2 K whilst it is energised. This whole process is normally handled automatically by the B-T Environment software.

5.3 System Control

As well as implementing control of the lambda fridge, the B-T Environment Software monitors the reading of the Helium level meter. On the basis of measurements of helium level and magnet temperature, the B-T Environment software may allow no energisation of the magnet, energisation to the 4.2 K field or energisation to the 2.2 K field. In all this process, the decision making is carried out in the computer software. The Lambda Controller itself is responsible for collecting the temperature and pressure measurements and controlling the needle valve position.

5.4 Test Mode

The operations described so far are all part of the Lambda Controller normal **operating mode**. An additional **test mode** is available. This provides facilities to assist in testing the Lambda Controller, to configure it for use with specific sensors, to configure it for use with a specific Needle Valve and to set the GPIB address for use with the optional GPIB interface (if fitted). Since the Lambda Controller is always supplied as part of a complete system, it will have been fully configured before it leaves the factory.

To access and use test mode, it is necessary to remove the front panel. This is done by removing the six screws holding it in place. No mains voltage parts are accessible with the panel removed, so the instrument may be safely operated in this state. Removal of the panel will reveal a numeric display, three additional lamps, and six buttons. In the description that follows, these will be referred to by their component references as shown on the board. In addition, the functional name of the button or lamp will be given, as used on **ITC**502.

Test mode is entered from the front panel by holding the two buttons S406 (RAISE) and S405 (LOWER) pressed, whilst pressing and releasing S407 (LOC/REM). Lambda Controller will display the message:

tESt

to indicate that it is entering test mode. After a second this will change to;

t 00

indicating that Test 0 may now be performed (Test 0 in fact provides the exit from test mode and restarts Lambda Controller for normal operation). S406 (RAISE) and S405 (LOWER) may be used at this point to step through the 8 possible test functions, Test 0 to Test 7. When the chosen "t" number is displayed, S407 (LOC/REM) may be pressed to access the function. The following table lists the available functions. Tests 1, 2 and 4 are intended to assist in fault finding. Tests 3, 6 and 7 are described in the following sections.

Test 0	Restart Normal Operation
Test 1	Test Front Panel Display and Lamps
Test 2	Test Front Panel Buttons
Test 3	Set GPIB Address
Test 4	Set Front Panel Display Variable
Test 5	Unused
Test 6	Configure Needle Valve
Test 7	Configure Sensor Range

5.5 Setting the GPIB Address

The GPIB interface (if fitted) is normally supplied set to a GPIB address of 24. This may be changed using Test 3. On accessing Test 3, the display will now show G nn where nn is the current GPIB address. Use S406 (RAISE) and S405 (LOWER) to display the desired new address, then press S407 (LOC/REM) to select it. The instrument will revert to the t=0 state. Pressing S407 (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=3 mode and select a new non-zero address.

After the address has been changed, if the new address is to be retained on power down, it must be copied into the Non-Volatile memory by means of the STORE operation described below in section 5.9.

5.6 Needle Valve Configuration

In order to accommodate a variety of motorised needle valves, it is necessary to specify to the controller how many motor steps are required to move from fully closed to fully open. This may be specified in powers of 2 by a configuration parameter in the range 120 to 127. (This is referred to as the valve gearing parameter). The parameter is viewed and adjusted by selecting Test 6 (the parameter starts at 120 to maintain compatibility with a similar parameter used for needle valve control on **ITC**502).

The table below relates the number of motor steps for full travel, to this parameter. S406 (RAISE) and S405 (LOWER) may be used to vary the parameter. Note that it is possible to set this parameter to any value in the range 0 to 255, however the more significant bits of the number have no effect on needle valve operation in the Lambda Controller.

Needle Valve Gearing:

VALUE	VALVE STEPS
120	65536
121	32768
122	16384
123	8192
124	4096
125	2048
126	1024
127	512

After the Needle Valve Gearing has been changed, if the new value is to be retained on power down, it must be copied into the Non-Volatile memory by means of the STORE operation described below in section 5.9.

5.7 Sensor Range Configuration

Since the Lambda Controller is normally used with a specific set of sensors, for a for a single task, there should never be a requirement to reconfigure the sensor ranges after it leaves the factory. However, the firmware includes all the standard sensor ranges of **ITC**502 and these are listed, together with the configuration process in section 9.2.

If Test 7 is entered and the sensor configuration changed by mistake, provided the STORE operation described in section 5.9 below is **not** carried out, the original configuration may be restored by turning the Controller off, waiting 10 seconds and then turning it on again.

5.8 Sensor Calibration

To match Lambda Controller to the exact characteristics of a specific sensor, a calibration must be carried out at the two ends of the working range (do not forget to STORE the new calibration as described in section 5.9).

Calibration is carried out by means of the S415 (CAL) button. First use S416 (DISPLAY SENSOR) to display the sensor to be calibrated. The lamps LED417, LED416 and LED415 indicate that sensors 1, 2 or 3 respectively are being displayed.

5.8.1 Magnet Temperature Sensor

For the magnet temperature sensor (Sensor 2), cool the actual sensor to a known temperature as near to the bottom of the range as possible, (for example 4.2 K) or apply an equivalent input from a calibrator.

Press S415 (CAL) and whilst holding it pressed, use S406 (RAISE) and S405 (LOWER) to set the correct temperature reading. Lambda Controller will update the "ZERO" value stored in its memory.

Change to a temperature or calibrator input near the top of the range and repeat the process. Lambda Controller will update its stored "SPAN" value.

Repeat until both temperatures read correctly. The nearer the lower adjustment point is to the bottom of the range, the less interaction there will be.

Lambda Controller automatically decides whether to calibrate ZERO or SPAN depending on whether the input is in the lower or upper part of its range.

5.8.2 Pressure Sensor

The pressure sensor used is calibrated using a good rotary pump vacuum for the lower point, and atmospheric pressure for the upper point (an alternative sensor used on some early systems indicated "Gauge Pressure" rather than "Absolute Pressure"). In this case the display hardware read pressure in "arbitrary units" and was calibrated with a fixed voltage input of –40 mV to read 100.0 and 0 mV to read 900.) With the gauge currently used, the calibration points are:

INPUT	TO DISPLAY	CALIBRATES
Roughing Vacuum	000.1	ZERO
Atmospheric	999.8	SPAN

The calibration points are deliberately 1 unit above minimum reading and 1 unit below maximum reading to ensure that the displays are not on their "endstops". If the true atmospheric pressure (i.e. not a barometer reading corrected to read equivalent sea level pressure) is below 999.8 mbar when the gauge is calibrated, purists may prefer to calibrate to read this value. However the error in assuming atmospheric pressure always to be 999.8 mB will have no detectable effect on the operation of the Lambda fridge.

After changing the calibration, any changes must be STORED as described below.

5.9 Storing Calibration and Configuration

Whenever any data has been changed, which is intended to be retained after power down, this must be deliberately STORED. This write operation is achieved by holding S414 (STORE/LIMIT) in, whilst pressing and releasing S407 (LOC/REM). The display will briefly show **"Stor"** indicating that the data has been correctly stored. It is not necessary to hold S407 (LOC/REM) pressed, the complete RAM contents will always be written to the EEPROM.

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 a small two way Dual-in-Line switch SW2 on the motherboard. Set it to the "ON" position and try again. Only Switch No.1 of this switch has any effect but it will generally be easiest to move both parts of the switch together.

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.

Any changes that are to be retained after power down must be stored in this way. This includes changes to range data, span and zero calibration, needle valve configuration etc.

6 Computer Communication

6.1 Introduction

The Lambda Controller is always operated via its computer interface. The sections which follow describe the commands used to read the parameters monitored by the Lambda Controller and to set the Needle Valve for the Lambda Fridge.

6.2 Communication Protocols

Lambda Controller is always fitted with a Serial (RS232) interface. In addition, an optional GPIB (IEEE-488) interface may be fitted. Details of the hardware communication protocols for the two interfaces are given in sections 4.10 and 4.12 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 Lambda Controller.

Unless the command starts with a "$" (dollar) character, all commands will evoke a response from Lambda Controller. 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 one of the calibration buttons behind the front panel 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.

If the first character of a command is a "$", the command will be obeyed but no response will be sent (see section 6.5).

Lambda Controller will accept a command string at all times. If a computer linked by the serial (RS232) port, is unable to accept data from Lambda Controller at the full rate of the 9600 baud interface, the "W" command may be used to instruct Lambda Controller to send more slowly.

6.3 Commands and Responses

Commands to Lambda Controller all consist of a single letter, optionally followed by a numeric parameter, the whole being terminated by a Carriage Return. All commands are based on Upper Case letters with mnemonic significance. The response sent by Lambda Controller 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 Lambda Controller 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 Lambda Controller is in LOCAL control. If in doubt, the "X" command may be used to determine the current status.

6.4 Numeric Parameters

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

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

Thus to set the needle valve 20.0% open, the preferred command form is:

G200

The alternative:

G20.0

would be accepted and correctly obeyed, but the alternative:

G20

would result in a needle valve setting of 2.0 not 20.0. Hence unless you can be confident that your computer will always send a specific number of decimal places, it is preferable to convert all data to integers. For example in BASIC, the instruction:

LET N = INT(10*T)

might be used.

The same convention is adopted by Lambda Controller in returning numbers to the computer. Thus 23.09 would be returned as +02309. The convention of sending all numbers as integers has been adopted to maintain compatibility with the maximum number of computers. It avoids any problems caused by the various formats used by different machines, to represent floating point numbers.

6.5 Use with 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 0 to 8, 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 (note: this will only result in lost data. No hardware damage will be caused).

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

@n (At) addresses the command to instrument number n, where n is a digit in the range 0 to 8. This instrument obeys the command and returns its usual response. All other instruments ignore the command and send no reply.

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

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

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

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

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

!n (Exclamation) instructs the instrument that from now on its address is to be n. This command is included here since it is relevant to ISOBUS operation. However, for obvious reasons, it should not be sent when more than one instrument is powered up and connected to ISOBUS (it would result in all instruments having the same address!). The command is intended for initial setting up of instruments, one at a time. To avoid inadvertently changing addresses, the "!" command will only be obeyed following a "U" command with a non-zero password (see section 10). Note that the address set this way is the ISOBUS address, not the GPIB address. The latter cannot be set via the interface, since until an address is defined, GPIB communication is not possible.

6.6 The GPIB Interface

The GPIB Interface is an accessory allowing the Lambda Controller to be computer controlled by means of the General Purpose Interface Bus (GPIB), also known as HPIB and IEEE-488 interface.

When installed, it 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.

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 t=0 re-start) and ISOBUS addressing may be used if desired.

Provided the GPIB interface has not been deliberately DISABLED by setting its address to 0 (see section 5.5), 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 t=0 re-start.

6.6.1 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 Lambda Controller will accept commands at all times. Where commands produce a response message, this should be read before a further command is issued.

6.6.2 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.

6.6.3 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 TIMEOUT facility (see section 6.6.10). There are a number of ways by which the controller can determine when data is available. The simplest but least reliable, is to "know" from which command has been sent, whether a reply will be produced. 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 Lambda Controller interface will always respond to a serial poll and will return a status byte. Three bits in this byte have significance for Lambda Controller 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 SRQ 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 6.6.4).

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 SRQ 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 SRQ line. It will not be asserted again unless a further service request is issued.

Lambda Controller 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.

6.6.4 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 in 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.

6.6.5 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.

6.6.6 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 temperature control function.

6.6.7 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. By virtue of its use of open collector data buffers, it can however co-exist on the GPIB with other instruments which do have a Parallel Poll facility.

6.6.8 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 **ITC** 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).

6.6.9 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 SRQ 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 4.13.

No special command protocols are required to access the GATEWAY. All OI instruments 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).

6.6.10 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 TIMEOUT facility built in. The GPIB handshake sequence makes it all to easy for lost data to result in the bus hanging indefinitely. When a timeout occurs the controller should attempt to assess what is happening. In the case of the **ITC** 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.

7 Command List

A brief summary of the available commands is given below. Fuller details are given in the following section.

Commands fall into 4 categories:

MONITOR COMMANDS	which are always recognised.
CONTROL COMMANDS	which are only recognised when in ACTIVE state.
SYSTEM COMMANDS	which are only recognised after receipt of the correct "UNLOCK KEY".
SPECIALIST COMMANDS	which are primarily for use in conjunction with OI supplied high level system software. They provide a means to change the system configuration by computer control.

In the list which follows, "n" represents a decimal digit 0-9.

MONITOR COMMANDS (always recognised)

Cn	SET CONTROL TO ACTIVE OR STANDBY
Qn	DEFINE COMMUNICATION PROTOCOL
Rn	READ PARAMETER n
Unnnnn	UNLOCK FOR "!" AND SYSTEM COMMANDS
V	READ VERSION
Wnnnn	SET WAIT INTERVAL BETWEEN OUTPUT CHARACTERS
X	EXAMINE STATUS

CONTROL COMMANDS (recognised only in ACTIVE state)

Gnnn	SET GAS FLOW (by adjusting the NEEDLE VALVE)

SYSTEM COMMANDS (recognised only after correct Unnnnn command)

Ln	LOAD LINEARISER TABLE n
Y	LOAD ENTIRE RAM CONTENTS
Z	DUMP ENTIRE RAM CONTENTS
!	SET ISOBUS ADDRESS (See section 9.5)

SPECIALIST COMMANDS (all lower-case letters)

xnnn	SET TABLE POINTER x to nnn
ynnn	SET TABLE POINTER y to nnn
en	ENABLE/DISABLE CUSTOM TARGET VOLTAGE TABLE
gnnn	SET GAS FLOW CONFIGURATION PARAMETER
c	READ GAS FLOW CONFIGURATION PARAMETER

8 Command Syntax

8.1 User Commands

Cn COMMAND

The control command sets Lambda Controller allows the computer to take control of the needle valve by switching to the ACTIVE state. At power up Lambda Controller is in the STANDBY state, in which values may be read, but nothing may be changed. Allowed values are:

C0	STANDBY (Default State)
C1	ACTIVE

Qn COMMAND

Defines the communication protocol.

Currently only 2 values of n are significant:

Q0	"Normal" (Default Value)
Q2	Sends <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).

Rn COMMAND

The READ command allows the computer to interrogate any of a number of variables. The returned value is always an integer as defined in section 9.4. The allowed range of values for n is 0 to 15 but only the values listed in the table below are of significance for the Lambda Controller (R11 and above are intended as service diagnostics and are unlikely to be of use to the user).

R1	SENSOR 1 Pressure (arbitrary units)
R2	SENSOR 2 TEMPERATURE (Units of 0.1 Kelvin)
R3	SENSOR 3 (If used)
R7	NEEDLE VALVE POSITION (Units of 0.1% of travel)
R11	CHANNEL 1 FREQ/4
R12	CHANNEL 2 FREQ/4
R13	CHANNEL 3 FREQ/4

Unnnnn COMMAND

The UNLOCK command allows access to the SYSTEM commands. This set of 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 sent with 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	"L", "Y" & "Z" COMMANDS UNLOCKED

V COMMAND

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

Wnnnn COMMAND

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

(Note. the W command does not reduce the rate at which Lambda Controller can accept data from computer.)

X COMMAND

The EXAMINE command allows the computer to read the current Lambda Controller STATUS. The format for the status message has been kept the same as that used by **ITC**502 to provide software compatibility. Only the "C" parameter has any significance for the Lambda Controller. The X command requires no parameters and will return a message string of the form:

XnAnCnSnnHn

where the digits "n" have the following meaning:

Xn	SYSTEM STATUS	(Always zero for Lambda Controller)
An	ACTIVITY STATUS	(Normally zero. n=4 during Valve Initialise)
Cn	STANDBY/ACTIVE	(n as for C COMMAND)
Snn	SWEEP STATUS	(Always zero for Lambda Controller)
Hn	CONTROL SENSOR	(Always one for Lambda Controller)

Fnn COMMAND

The FRONT PANEL DISPLAY command sets the Numeric Display (behind the front panel) to show one of the internal parameters rather than the normal measured sensor value. Normal display operation may be restored by pressing S416 (SENSOR) button. The command is intended chiefly for use during test and fault diagnosis. n may take the same values as for the "R" command above, with the same significance.

Gnnn COMMAND

Controls the GAS FLOW through the Lambda Fridge by setting the Needle Valve to a defined value nnn. The "G" command will not be accepted during the initialisation of the needle valve, whilst ACTIVE or STANDBY are flashing.

Ln COMMAND

The LINEARISER LOAD command loads one of the three customisable non-volatile data tables with linearisation for a particular sensor. See **ITC**502 manual for details of custom range design.

Yn COMMAND

The Y command allows the contents of the RAM memory to be loaded in binary, via the serial interface. It is not intended as a user command. If n is omitted or has the value 2, only the first 2 kilobytes of the memory are loaded. If n has the value 8, the entire 8 kilobytes are loaded (in general all calibration parameters of interest are held within the first 2 kB). Note that after loading the memory in this way, the new content will be lost at power-down, unless it has been saved by a STORE sequence as described in section 5.9.

Zn COMMAND

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

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 version 1.0 firmware but the commands will not necessarily be retained in this form in future versions of the firmware.

Note that if any parameters changed by these commands are to be retained after power down, the STORE procedure must be used as usual.

gnnn COMMAND (Set Needle Valve Gearing Configuration Parameter)

The g command sets the value of this parameter (See section 5.6 for details).

c COMMAND (Read Gas Flow Configuration Parameter)

The converse of the g command.

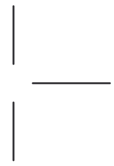
9 Sensor Range Configuration

9.1 Introduction

Each sensor input channel of Lambda Controller may be configured to a range suitable for use with a specific sensor. Normally an instrument is supplied with the specified range(s) configured ready for use. However it is possible to reconfigure it for use with different sensors should this be required.

Pressure is normally configured as a **Lin**ear range, so the data which follows is only likely to be needed if non-standard sensors are to be used to monitor the magnet temperature.

The existing configuration may be determined by the code(s) displayed when the DISPLAY SENSOR button is pressed. Limitations of a 7-segment display, mean that the characters are a rather stylised mixture of upper and lower case. "K" is particularly obscure and is shown as:



Lambda Controller comes with data for many of the most commonly used ranges included in the program memory. A further three ranges may be accommodated as custom calibrations in the non-volatile memory. For some sensors, ranges are available with either a Centigrade or Kelvin display. To identify these, the sensor code for all Centigrade ranges has an extra decimal point following the final digit.

The table in section 9.2 shows range details for the standard ranges included within the program memory of Version 1.0 firmware (the standard ranges may be changed from time to time in response to variations in sensor popularity). The temperature range listed is the useful working range. On many ranges Lambda Controller will continue to indicate slightly outside this range.

The remainder of this section shows how to configure the instrument for use on one of these installed ranges. Section 12 takes configuration a stage further and shows how a completely new custom range may be designed and installed. In the following description, abbreviated component references are used. Thus SW1 refers to SW301 on channel 1, SW501 on channel 2 and SW401 on channel 3.

9.2 Range Data

CODE	SENSOR	RANGE	Tref	SW1 (Rear Switch)	SW2 (Front Switch)
Lin	Linear Range	0-999.9		(As required, See Note 2)	
Null	Centre Zero	+/-19999		(As required, See Note 2)	
Con 1	Conductance	0-19.999mS		00001 11110	01001 01010
TG 5	AuFe 0.03/Chr	2-500K	4.2K	11000 11111	00000 11000
TG 5	AuFe 0.03/Chr	2-500K	77K	11000 11100	00000 11000
TG 5	AuFe 0.03/Chr	2-500K	273K	11000 10100	00000 11000
TG 57	AuFe 0.07/Chr	2-500K	(Tref and Switches as for AuFe 0.03)		
CN 3	Cernox Resistor	1.5-300K		01100 11010	01001 01010
TT 5	Copper/Const.	20-500K	77K	10100 11111	00000 11000
TT 5	Copper/Const.	20-500K	RT	10100 11111	00000 10100
TT 4.	Copper/Const.	-250-400C	77K	10001 10111	00000 11000
TT 4.	Copper/Const.	-250-400C	RT	10001 11100	00000 10100
TK 10	Chromel/Alumel	0-1000C	0C	01111 10111	00000 11000
TK 10	Chromel/Alumel	0-1000C	RT	01111 10111	00000 10100
TK 13	Chromel/Alumel	-200-1370C	0C	01110 10100	00000 11000
TK 13	Chromel/Alumel	-200-1370C	RT	01110 11111	00000 11000
CR 1	Ruthenium Oxide	0.250-9.990K		00100 10010	00101 01000
RF 52	RhFe Resistor	1.5-500K		01111 11111	10010 10000
RP 1.	Plat Resistor	-200-+100C		10110 11111	01010 10100
RP 5	Plat Resistor	20-500K	Pure	10010 11111	01010 10000
RP 51	Plat Resistor	50-500K	Ballasted	10010 11111	01010 10000
RL 3	CLTS	2-300K		10111 01111	01010 10100
DS 32	Si Diode (OI)	2-300K		00010 00000	00110 11000
CC 35	C-Glass CR500	2-300K	(Typ only)	00001 11011	10001 01010
CA 21	100R Allen Brad	4-250K		00111 11000	01001 01010
CA 22	270R Allen Brad	4-250K		00011 10010	01001 01010
CS 01	470R Speer	0.250-9.999K		00011 11010	00101 01010

Notes:

a) Switch settings in this table are intended as a guide only. In particular the span and zero settings defined by SW1 may change for different sensors. In the case of thermocouples, the zero switch setting will vary with the reference junction temperature. Settings are given above for some of the more common combinations. Others may easily be obtained empirically.

b) The Lin and Null ranges are general purpose ranges and may be set up for any desired span and zero. Both provide a linear relationship between input and display. One provides a unipolar display, whilst the other is centre zero.

c) Note that whilst it is theoretically possible to use a Room Temperature reference junction with a cryogenic thermocouple such as AuFe/Chromel, this is not recommended. The accuracy and stability obtained are unlikely to be acceptable for cryogenic applications.

d) The spread of 27 Ohm Rhodium Iron Sensors is such that two typical curves are included. Curve A should be used for those sensors having a 4.2 K resistance of 2 ohms or greater, whilst Curve B should be used for sensors with a 4.2 K resistance less than 2 ohms. Use of the appropriate curve should result in linearisation errors of less than 1K over the full temperature range. For a more accurate fit to a specific sensor, a custom calibration should be ordered.

e) Two platinum ranges are provided, one for a pure platinum element, the other for a ballasted element to BS1904/DIN43760. The latter element is more readily available but its performance below 73 K is currently unspecified (the data between 50 K and 73 K is based on BS1904:1964 rather than BS1904:1984).

9.3 Access to Configuration Controls

Configuring Lambda Controller involves setting switches on the input board and selecting the appropriate linearisation data table. To carry out this work the top cover of the instrument must be removed. Before attempting this, read the Safety Information in Section 3.1 of this manual.

To remove the top cover, first remove the 4 screws securing it. The cover may then be slid towards one side, until the opposite side may be lifted clear of the side casing.

The second input board fitted for channels 2 and 3 locates over the channel 1 board. The switches on the channel 1 board are placed at the edge of the board such that they remain accessible. On the upper board, the switches are associated with the two channels in a logical manner, such that the channel 3 switches are nearer the left hand side of the instruments. On all boards SW1 is nearer the rear panel. Note. The full component references used on the PCB for SW1 are SW101, SW501 and SW401 for channels 1-3 respectively. Except when referring to a specific channel, the first digits are omitted here.

9.4 Hardware Configuration

Configuring the input stage hardware involves setting up the correct pattern on the two sets of DIP switches associated with the channel being configured. The preceding table gives the correct pattern for each of the standard ranges. In each case a "1" represents a switch in the "ON" position (nearer the left side of the instrument) SW1 is the set of switches nearest the rear panel.

It is not necessary to know the function of the switches, in order to set them correctly. However a brief indication may prove helpful.

SW1 is split into two sections each of five switches. SW1/1 to SW1/5 define the input span, whilst SW1/6 to SW1/10 define the input zero. The pattern on the switches may be regarded as a binary number with the highest numbered switch being the least significant bit. The all "ON" position gives the smallest span and zero whilst the all "OFF" position gives the largest.

SW2/1 to SW2/3 define the magnitude of the sensor energisation current, when required.

SW2/4 selects constant current energisation for metallic resistance thermometers.

SW2/5 selects constant voltage energisation for semiconductor resistance thermometers.

SW2/6 selects normal voltage sense operation. It is set to OFF for semiconductor resistance thermometers.

SW2/7 selects a negative zero offset for suppressed zero ranges.

SW2/8 selects a positive zero offset for elevated zero ranges.

SW2/9 selects a small zero offset for use with semiconductor resistance thermometers.

SW2/10 halves the input sensitivity for use with Gallium Arsenide diodes.

9.5 Linearisation Configuration

To select the correct software data table, proceed as follows. Remove the front panel preparatory to entering Test Mode (See section5.4). Switch the instrument on and ensure that the DISPLAY SENSOR lamp is showing the channel which is to be configured (LED417=Ch1, LED416=Ch2, LED415=Ch3). If necessary press S416 (SENSOR) to change channels.

Now hold the S406 (RAISE) and S405 (LOWER) buttons pressed, whilst pressing and releasing the S407 (LOC/REM) button. The message

tESt

will appear followed shortly by:

t 00

Press S405 (LOWER) and release, to display:

t 07

Then press S407 (LOC/REM). The display will show

LOAd

followed shortly by:

Lin

which is the code for the first one of the available standard ranges.

Press S406 (RAISE) or S405 (LOWER) to cycle through the available ranges until the code for the required range is displayed. Custom ranges that have not had data installed, will show as a blank display.

Press S407 (LOC/REM) and the range will be configured. Lambda Controller will then leave the test mode and start normal operation with the "PASS" message.

After re-configuring a range, it will be necessary to carry out the calibration described in section 5.8.

10 Servicing

10.1 Circuit Description

The majority of the circuitry involved in Lambda Controller is conventional and can be readily understood from the circuit diagrams. The notes which follow cover those areas where some additional explanation may be required.

The power supply is totally conventional, providing a high power DC heater supply and a separate 5 V supply for the logic. The raw 11 volts from which the 5 V is obtained, is used on the main PCB to monitor mains volts. Should this fall below 8 volts, a RESET is performed. If the Lambda Controller is operated on very low mains volts, it may keep resetting. It will be found to revert to STANDBY, without a command from the computer. If the front panel is removed, this condition may be identified by the "PASS" message reappearing during use.

The main transformer also generates an 18 V AC supply for the input circuits. A separate transformer on the input board splits this into separate isolated supplies for the input amplifier and the current source. Regulated reference supplies of ± 6.2 V are generated on the input board.

The input amplifier uses a chopper stabilised amplifier for best stability. This incorporates internal protection against electro-static discharge (ESD) and further protection is provided by the input filter and the fully floating supplies.

The ladder networks associated with SW1 have been designed to give approximately equal ratios of 0.7 between steps.

The sensor current source U103A floats on its own power supply. However it derives its reference supply from the main input stage reference rails, using the three amplifier instrumentation configuration U103 B, C & D, to provide the necessary common mode rejection.

Note when testing the current source, there must be some electrical path between the current source and the input amplifier, to ensure that this remains within the common mode range of the amplifier. In use, this path is provided via the sensor leads. For testing, it is suggested that pins 3 and 5 of the input connector should be linked.

Referencing the current source from the main input reference permits an easy re-configuration for a true 4-wire conductance measurement. This is achieved by opening SW2/6 and SW2/4 and closing SW2/5. The main amplifier now operates open loop and the overall feedback loop is closed via the current source. The normal zero network is used to define an expected sensor voltage and the feedback loop now slaves the sensor current to achieve this. A capacitor across SW2/6 ensures AC stability in this configuration.

The high level signal from the input stage is fed via a filter to a voltage to frequency converter and thence via a high speed opto-isolator to a counter on the microprocessor board.

The microprocessor circuit is conventional and incorporates CPU, EPROM, RAM, CTC and UART chips. The keyboard and display are mapped directly as i/o ports on the microprocessor bus and the CPU handles all the display decoding and multiplexing in software.

An EEPROM U3, is used to retain data when the instrument is powered down. When a STORE operation is performed, the entire RAM content is written to this chip. Its content is automatically copied back to the RAM at power up. The EEPROM used requires a specific code sequence to be sent before any write operation is permitted. This prevents corruption of the EEPROM data should the normal CPU operation be disturbed by a mains transient or ESD. Should this IC require replacing, an exact equivalent from the same manufacturer should be used, or advice sought from Oxford Instruments. Not all manufacturer's "equivalent" EEPROMs support this Software Data Protection. Further protection is provided by switch S2 in the write enable line. When switched off, this prevents all EEPROM writes.

The GPIB sub-board (if fitted), employs a dedicated GPIB interface IC type uPD7210. This supports all the GPIB protocol. The bus transceivers are type 75160 and 75161 and are fitted in sockets to allow easy replacement. (GPIB transceivers can be damaged if GPIB connections are made or broken whilst instruments are powered up!).

The sub-board links to the main board via the U5 UART socket. The UART is included on the GPIB board and a PAL on this board maps both the GPIB chip and the UART into the original UART i/o space.

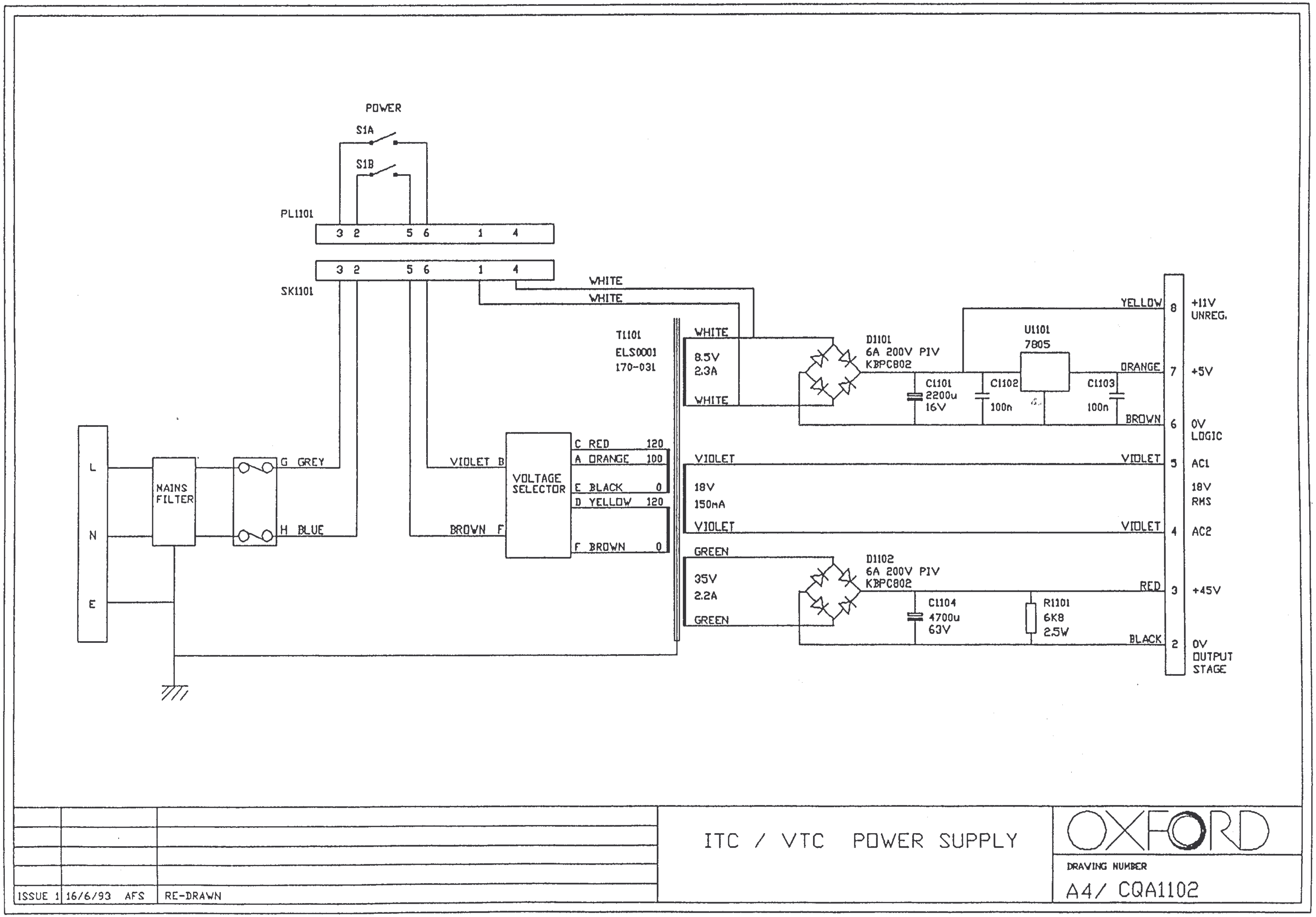
11 Specification

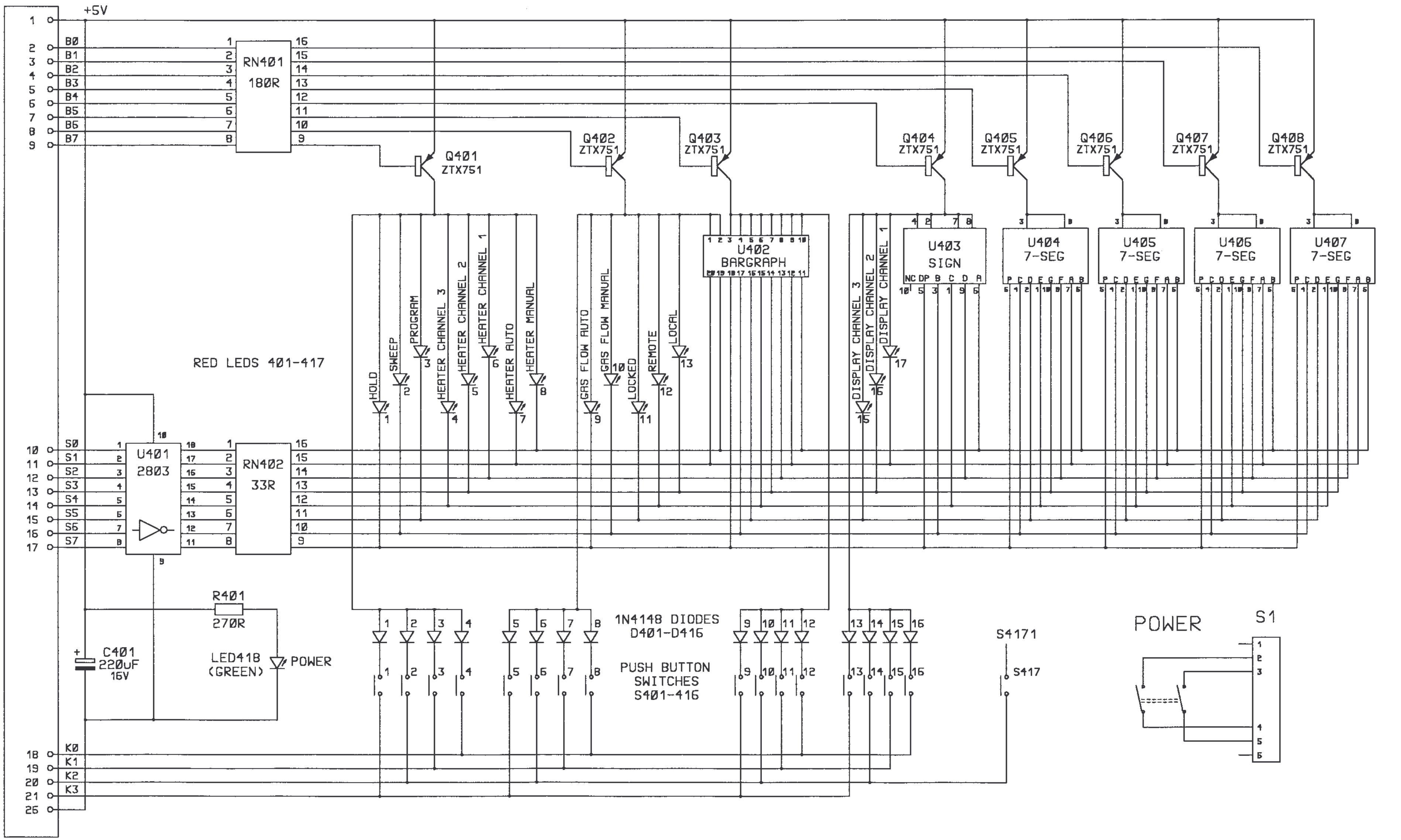
INPUT CHANNELS	3 (Normally Pressure, Temperature and Spare)
INPUT RANGE	5 mV to 2 V FSD
INPUT OFFSET	-2 V to +2 V
CURRENT SOURCE	10 uA, 100 uA, 1 mA (± 10%)
SENSOR TYPES	
Voltage Input	5 mV to 2 V FSD
Resistance Input	4-wire, 5 Ohm to 200 K Ohm FSD
Thermocouple	See List. (RT comp. on Celsius ranges)
Pt, RhFe Resistor	4-wire resistance measurement
Ge, Carbon Resistor	4-wire conductance measurement
Si, GaAs Diode	Volts sense at constant current
AUXILIARY I/O	For Lambda Fridge Control
DISPLAY TYPE	0.56 inch RED LED (Internal, for Test Only) DISPLAY
RANGE	-19999 TO +19999
SAMPLE RATE	4 Hz
INPUT RESOLUTION	16 Bit
RS232 INTERFACE	Configured as DCE
HANDSHAKE	None Required
BAUD RATE	9600 Baud
IEEE-488 INTERFACE	Optional Internal Interface
CONNECTORS	
POWER IN	IEC 3 pin
SENSOR INPUT	9 way D socket
AUXILIARY I/O	15 way D socket
RS232	25 way D socket
POWER REQUIREMENTS	~100/115 /200/230 V, 50/60 Hz
FUSE SPECIFICATION	~100/115 V T2.0AH 250 V
	~200/230 V T0.8AH 250 V
POWER CONSUMPTION	100 W Max.
CASE STYLE	Free-standing Metal Case
	Optional Rack Mount Ears
DIMENSIONS	
FREE-STANDING	446 mm x 106 mm x 298 mm
RACK MOUNT	19 inch x 2U x 298 mm
WEIGHT	6.5 kg

12 Circuit Diagrams

The following circuit diagrams are included, covering Lambda Controller itself, together with its accessories:

Drawing Number	**No. of pages**	**Description**
CQA1102	(1 sheet)	POWER SUPPLY
CQB0102	(1 sheet)	KEY / DISPLAY BOARD
CQB0202	(4 sheets)	CPU / DIGITAL CONTROL BOARD
(Not all components are fitted for Lambda Controller). Note Labelled "1 of 4", "2 of 4" and "3 of 4" (sheet 4 of 4 covers the **ITC**502 o/p stage not included in the Lambda Controller).		
CQB0302	(2 sheets)	INPUT AMPLIFIER BOARD
CVA0002	(1 sheet)	OXFORD INSTRUMENTS ISOBUS CABLE
CVG0102	(1 sheet)	GPIB INTERFACE


POWER
S1A
S1B
PL1101
SK1101
3 2 5 6 1 4
WHITE
WHITE
T1101
ELS0001
170-031
L
N
E
MAINS FILTER
G GREY
H BLUE
VIOLET B
BROWN F
VOLTAGE SELECTOR
C RED 120
A ORANGE 100
E BLACK 0
D YELLOW 120
F BROWN 0
WHITE
8.5V
2.3A
WHITE
D1101
6A 200V PIV
KBPC802
U1101
7805
C1101
2200u
16V
C1102
100n
C1103
100n
YELLOW
ORANGE
BROWN
VIOLET
18V
150mA
VIOLET
GREEN
35V
2.2A
GREEN
D1102
6A 200V PIV
KBPC802
C1104
4700u
63V
R1101
6K8
2.5W
RED
BLACK
8 +11V UNREG.
7 +5V
6 0V LOGIC
5 AC1
18V RMS
4 AC2
3 +45V
2 0V OUTPUT STAGE
ISSUE 1 16/6/93 AFS RE-DRAWN
ITC / VTC POWER SUPPLY
OXFORD
DRAWING NUMBER
A4/ CQA1102



REV	DATE	DESCRIPTION
07	7/6/99	C731 U403 CHANGED BACK TO SIGN
06	3/2/98	400 ADDED TO IDENTS, U403 WAS SIGN DISPLAY
05	21/6/93	DRAWING NUMBER CORRECTED (WAS CQC0102 IN ERROR)
04	1/7/91	REDRAWN

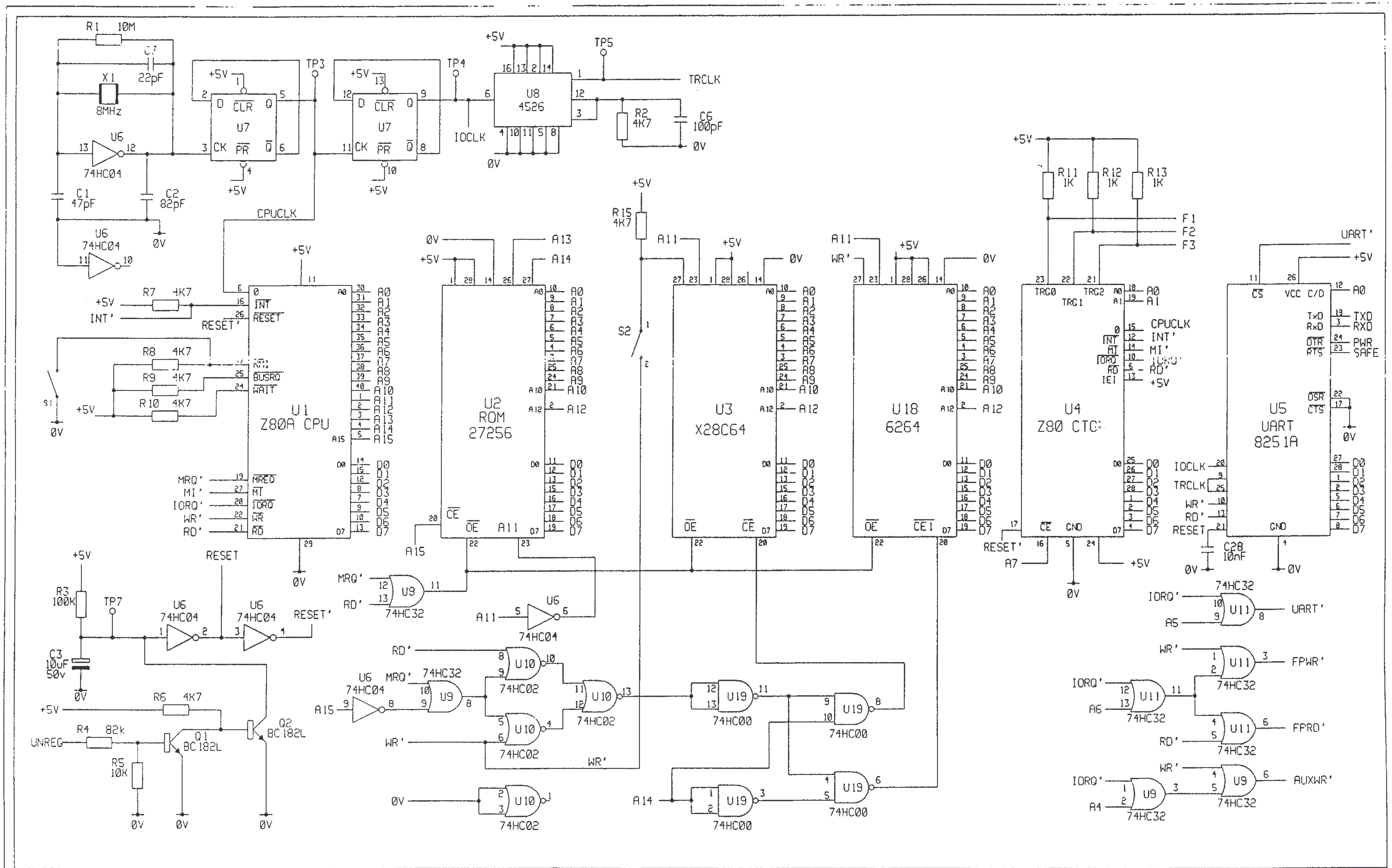
TITLE

ITC KEY/DISPLAY BOARD

OXFORD

DRAWING NUMBER

A4/CQB0102 SHT 1 OF 1



05	5/6/97	C586 R220 ADDED
04	22:11:93	U6 PIN 11 TAKEN TO 0V
03	21:8:93	C28 ADDED
02	16:3:93	PRODUCTION ISSUE
01	29:1:93	ORIGINAL

TITLE

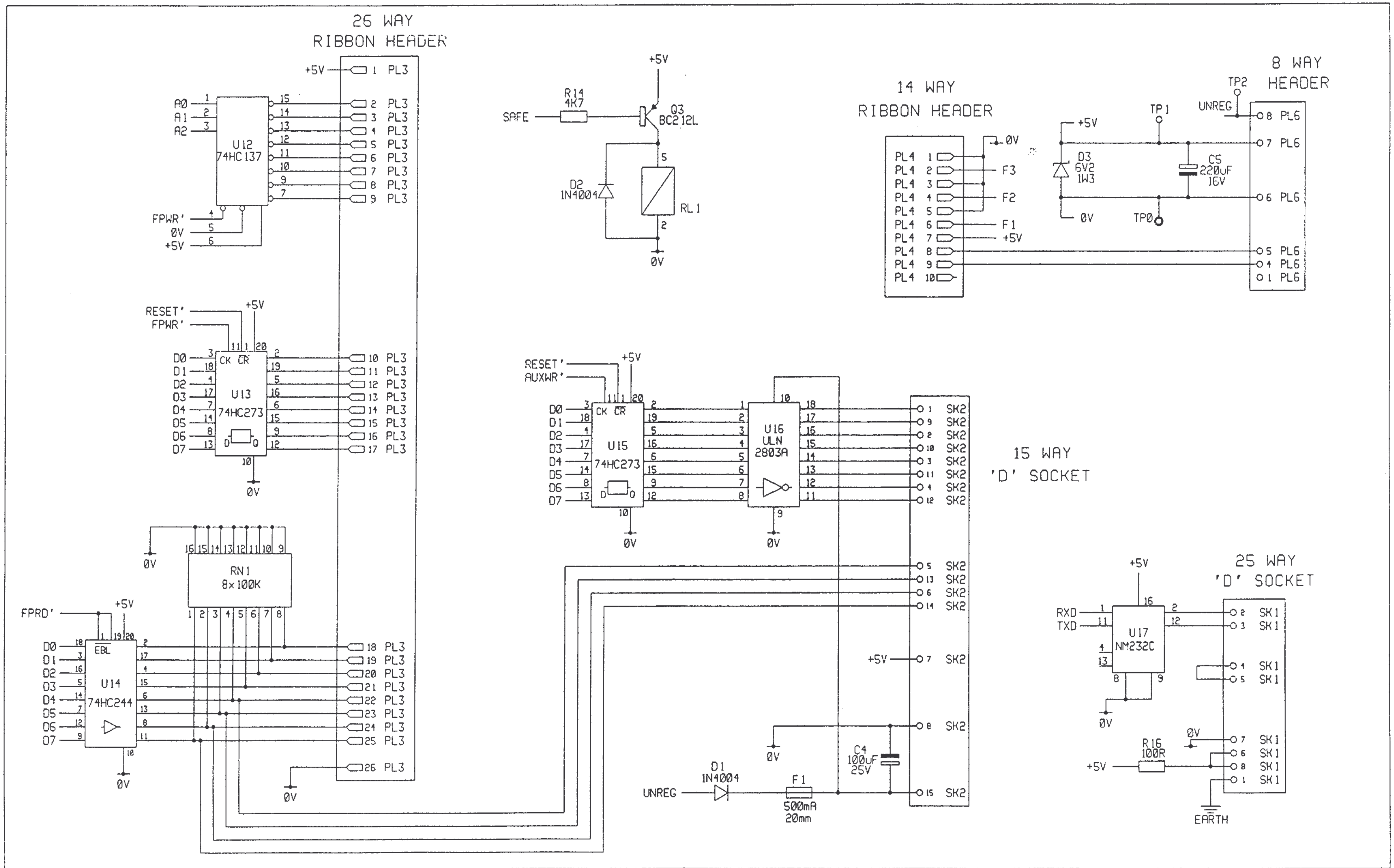
CPU/DIGITAL CONTROL PCB

MEMORY AND TIMING

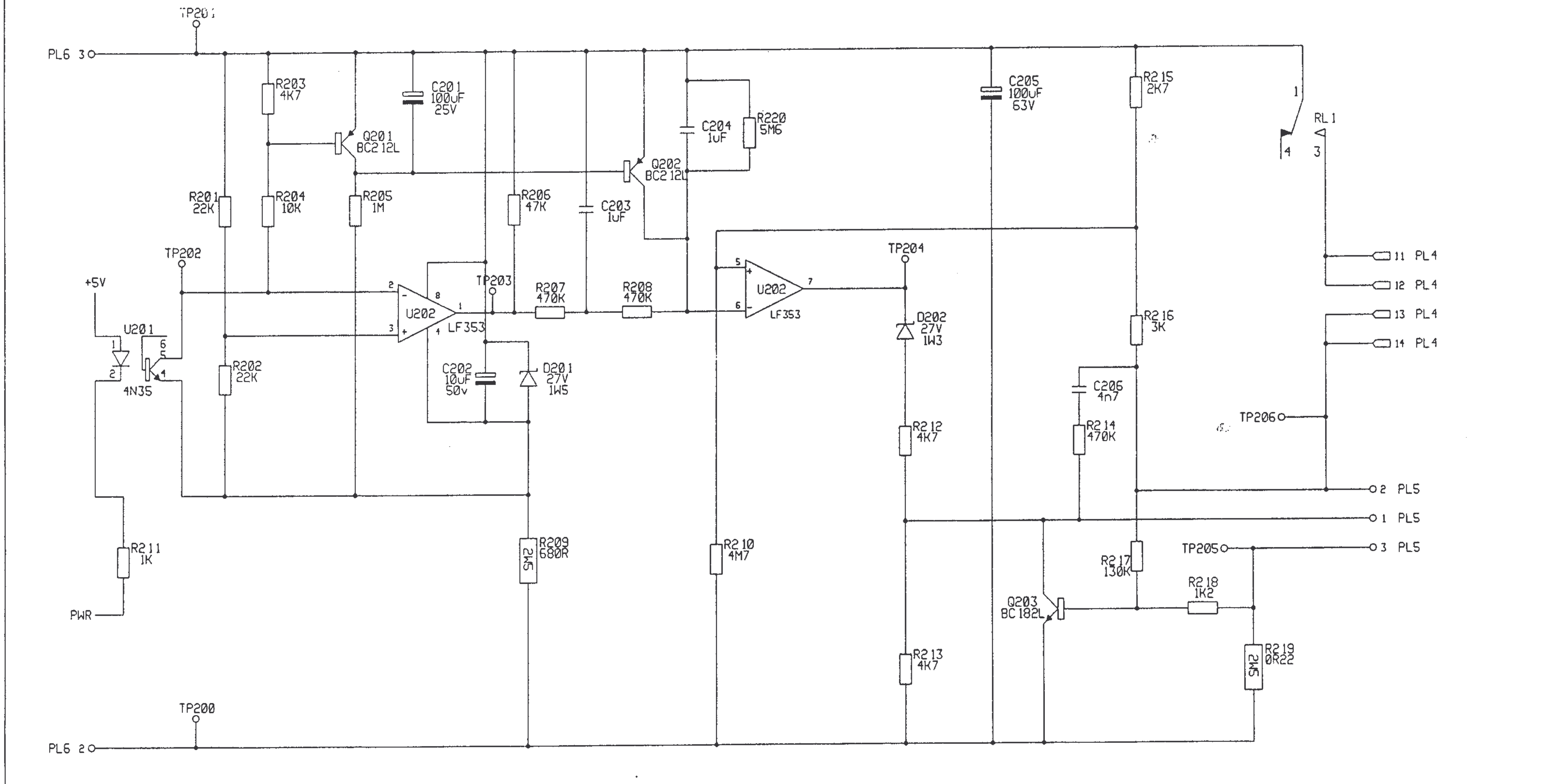
OXFORD

DRAWING NUMBER

A4 CQB0202 1 of 4



			TITLE	
05	6/6/97	C586 R220 ADDED	CPU/DIGITAL CONTROL PCB	OXFORD
04	22:11:93	U6 PIN 11 TAKEN TO 0V		DRAWING NUMBER
03	21:8:93	C28 ADDED	INPUT & OUTPUT PORTS	A4 CQB0202 2 of 4
02	16:3:93	PRODUCTION ISSUE		
01	29:1:93	ORIGINAL		



05	6/6/97	C586 R220 ADDED
04	22:11:93	U6 PIN 11 TAKEN TO 0V
03	21:8:93	C28 ADDED
02	16:3:93	PRODUCTION ISSUE
01	29:1:93	ORIGINAL

TITLE

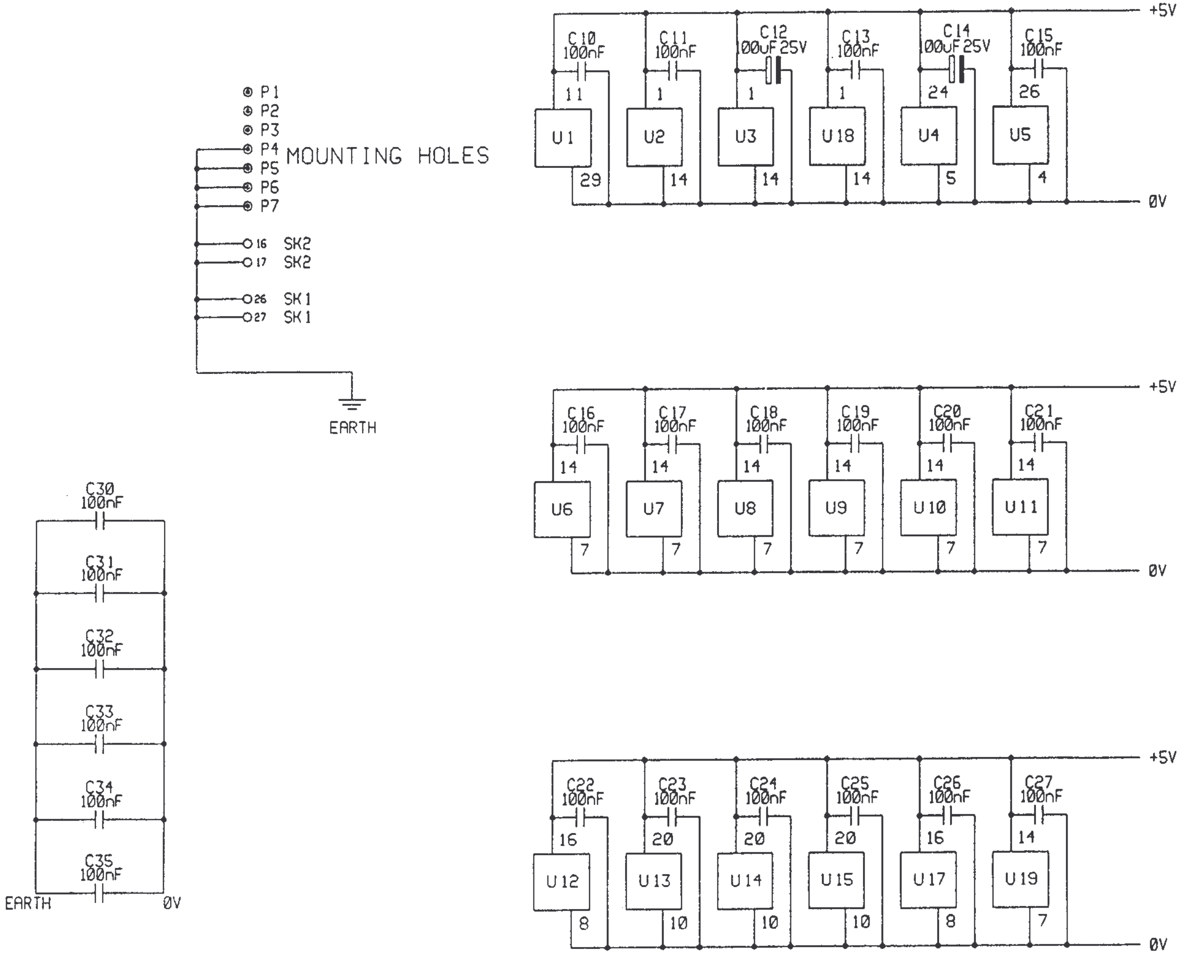
CPU/DIGITAL CONTROL PCB

HEATER OUTPUT

OXFORD

DRAWING NUMBER

A4 CQB0202 3 of 4



DECOUPLING CAPACITORS TO BE CLOSE TO THE RELEVANT COMPONENT.

05	6/6/97	C586 R220 ADDED
04	22:11:93	U6 PIN 11 TAKEN TO 0V
03	21:8:93	C28 ADDED
02	16:3:93	PRODUCTION ISSUE
01	29:1:93	ORIGINAL

TITLE

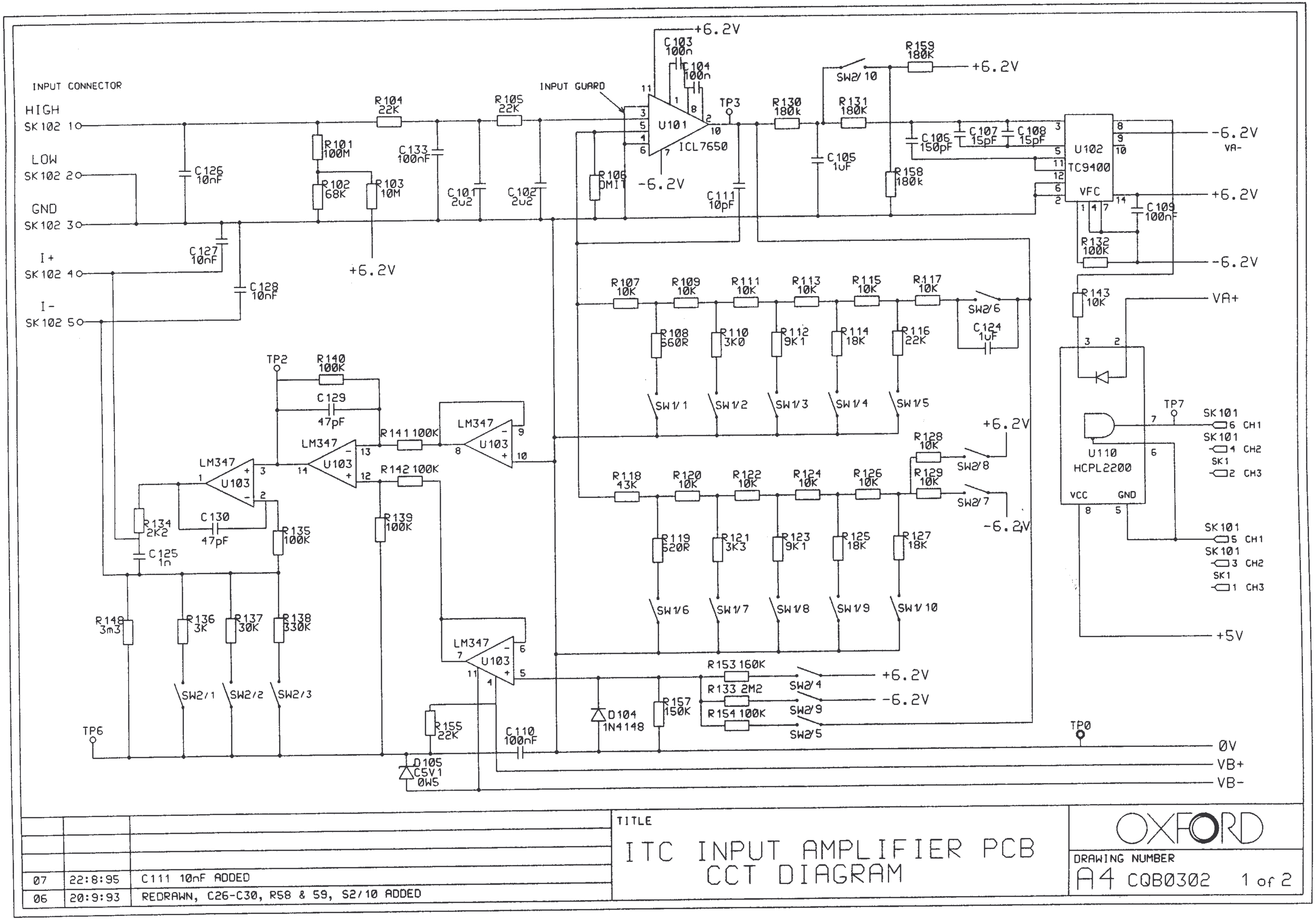
CPU/DIGITAL CONTROL PCB

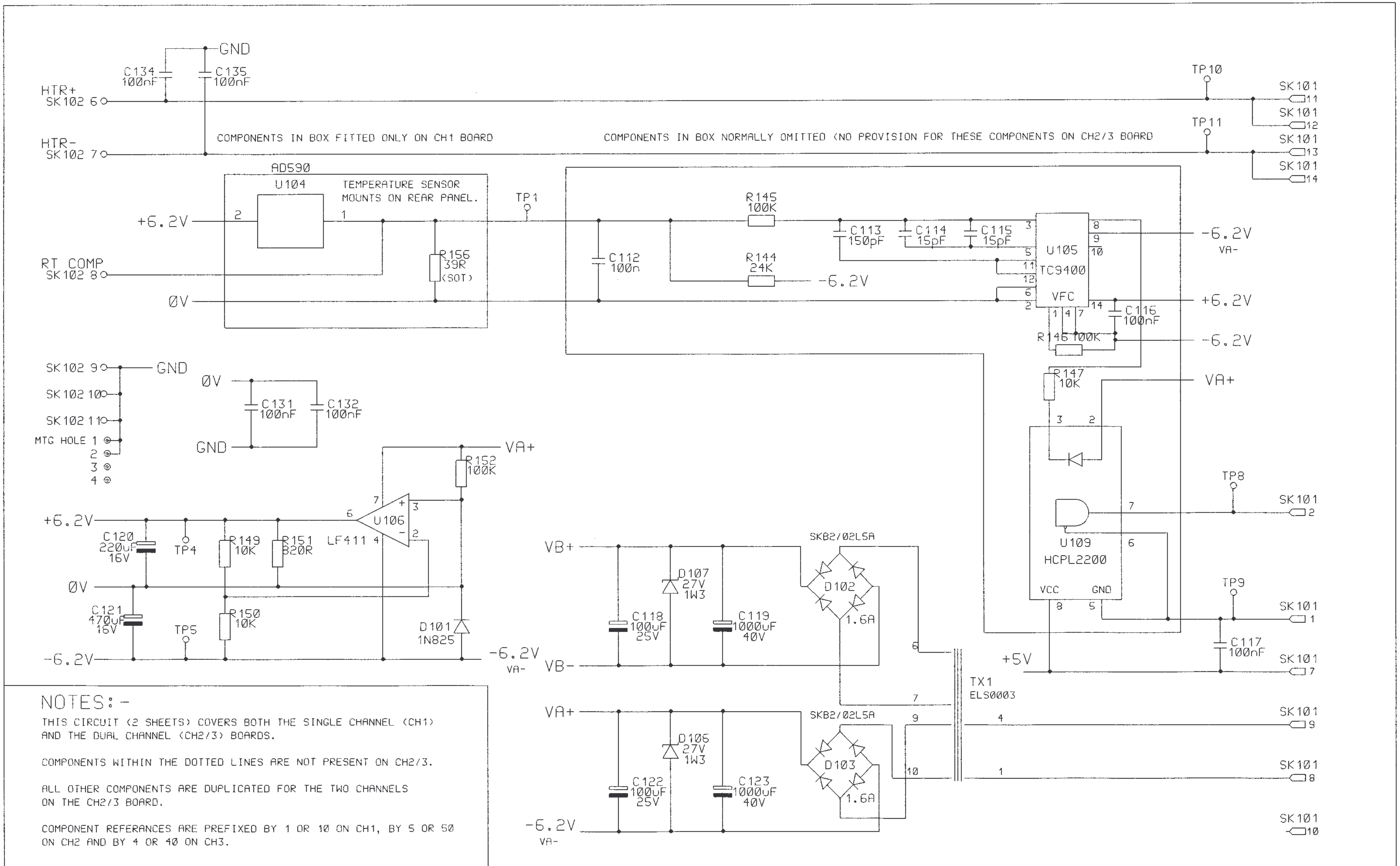
DECOUPLING CAPACITORS

OXFORD

DRAWING NUMBER

A4 CQB0202 4 of 4


INPUT CONNECTOR
HIGH
SK102 1
LOW
SK102 2
GND
SK102 3
I+
SK102 4
I-
SK102 5
INPUT GUARD
+6.2V
-6.2V
C103 100n
C104 100n
U101
ICL7650
TP3
R104 22K
R105 22K
R101 100M
R102 68K
R103 10M
R106 OMIT
C126 10nF
C127 10nF
C128 10nF
C133 100nF
C101 2u2
C102 2u2
C111 10pF
R130 180k
R131 180K
R159 180K
SW2/10
C105 1uF
R158 180k
C106 150pF
C107 15pF
C108 15pF
U102
TC9400
VFC
C109 100nF
R132 100K
VA-
VA+
R143 10K
R107 10K
R109 10K
R111 10K
R113 10K
R115 10K
R117 10K
SW2/6
C124 1uF
R108 560R
R110 3K0
R112 9K1
R114 18K
R116 22K
SW1/1
SW1/2
SW1/3
SW1/4
SW1/5
R128 10K
R129 10K
SW2/8
SW2/7
R118 43K
R120 10K
R122 10K
R124 10K
R126 10K
R119 620R
R121 3K3
R123 9K1
R125 18K
R127 18K
SW1/6
SW1/7
SW1/8
SW1/9
SW1/10
TP7
U110
HCPL2200
VCC
GND
SK101
6 CH1
4 CH2
SK1
2 CH3
5 CH1
3 CH2
1 CH3
+5V
TP2
R140 100K
C129 47pF
LM347
U103
R141 100K
R142 100K
R139 100K
R134 2K2
C130 47pF
R135 100K
C125 1n
R148 3m3
R136 3K
R137 30K
R138 330K
SW2/1
SW2/2
SW2/3
TP6
R155 22K
D105 C5V1 0W5
C110 100nF
D104 1N4148
R157 150K
R153 160K
R133 2M2
R154 100K
SW2/4
SW2/9
SW2/5
TP0
0V
VB+
VB-
07 22:8:95 C111 10nF ADDED
06 20:9:93 REDRAWN, C26-C30, R58 & 59, S2/10 ADDED
TITLE
ITC INPUT AMPLIFIER PCB
CCT DIAGRAM
OXFORD
DRAWING NUMBER
A4 CQB0302 1 of 2



NOTES:-

THIS CIRCUIT (2 SHEETS) COVERS BOTH THE SINGLE CHANNEL (CH1) AND THE DUAL CHANNEL (CH2/3) BOARDS.

COMPONENTS WITHIN THE DOTTED LINES ARE NOT PRESENT ON CH2/3.

ALL OTHER COMPONENTS ARE DUPLICATED FOR THE TWO CHANNELS ON THE CH2/3 BOARD.

COMPONENT REFERANCES ARE PREFIXED BY 1 OR 1Ø ON CH1, BY 5 OR 5Ø ON CH2 AND BY 4 OR 4Ø ON CH3.

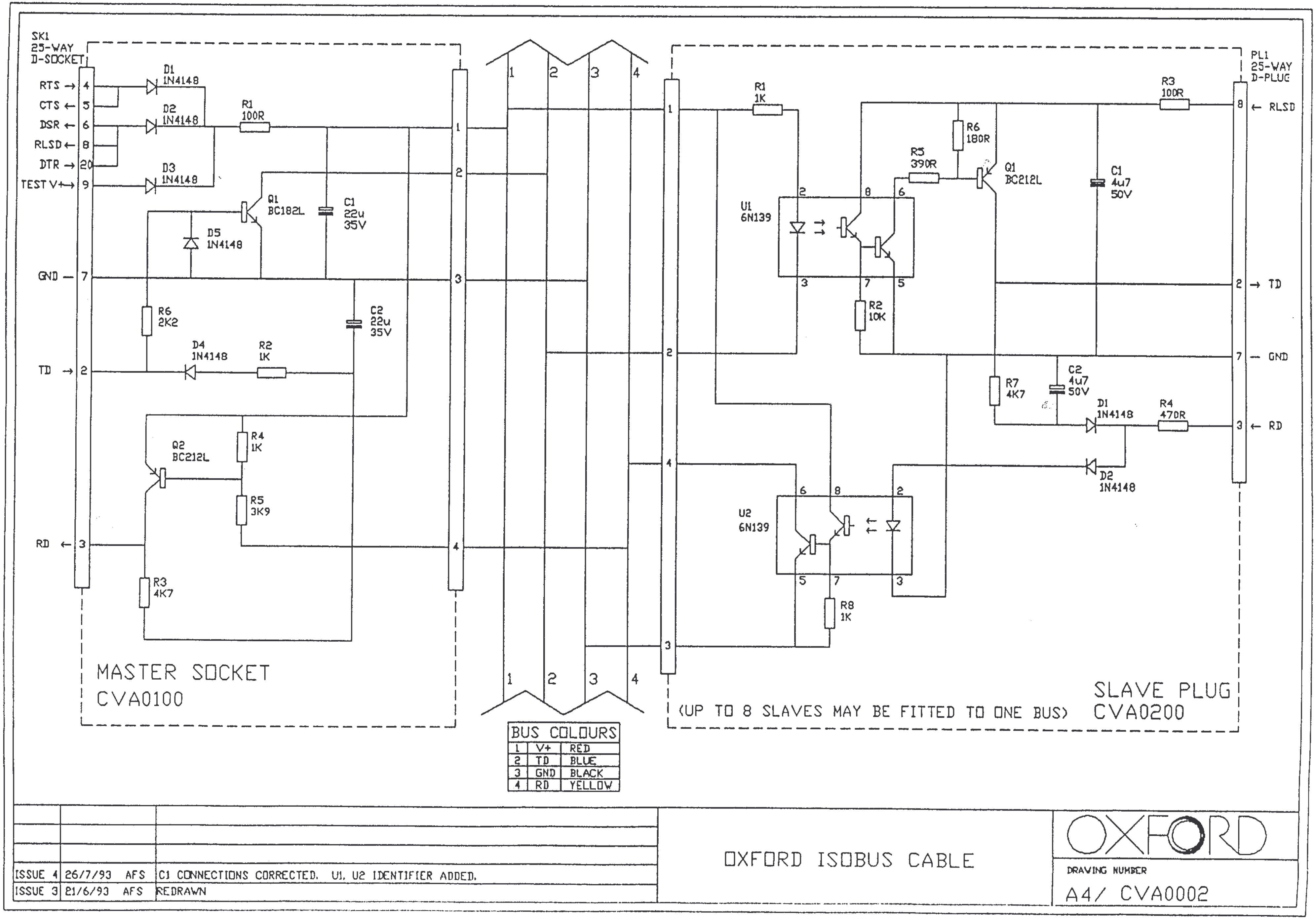
Ø7	22:8:95	C111 1ØnF ADDED
Ø6	20:9:93	REDRAWN, C26-C3Ø, R58 & 59, S2/1Ø ADDED

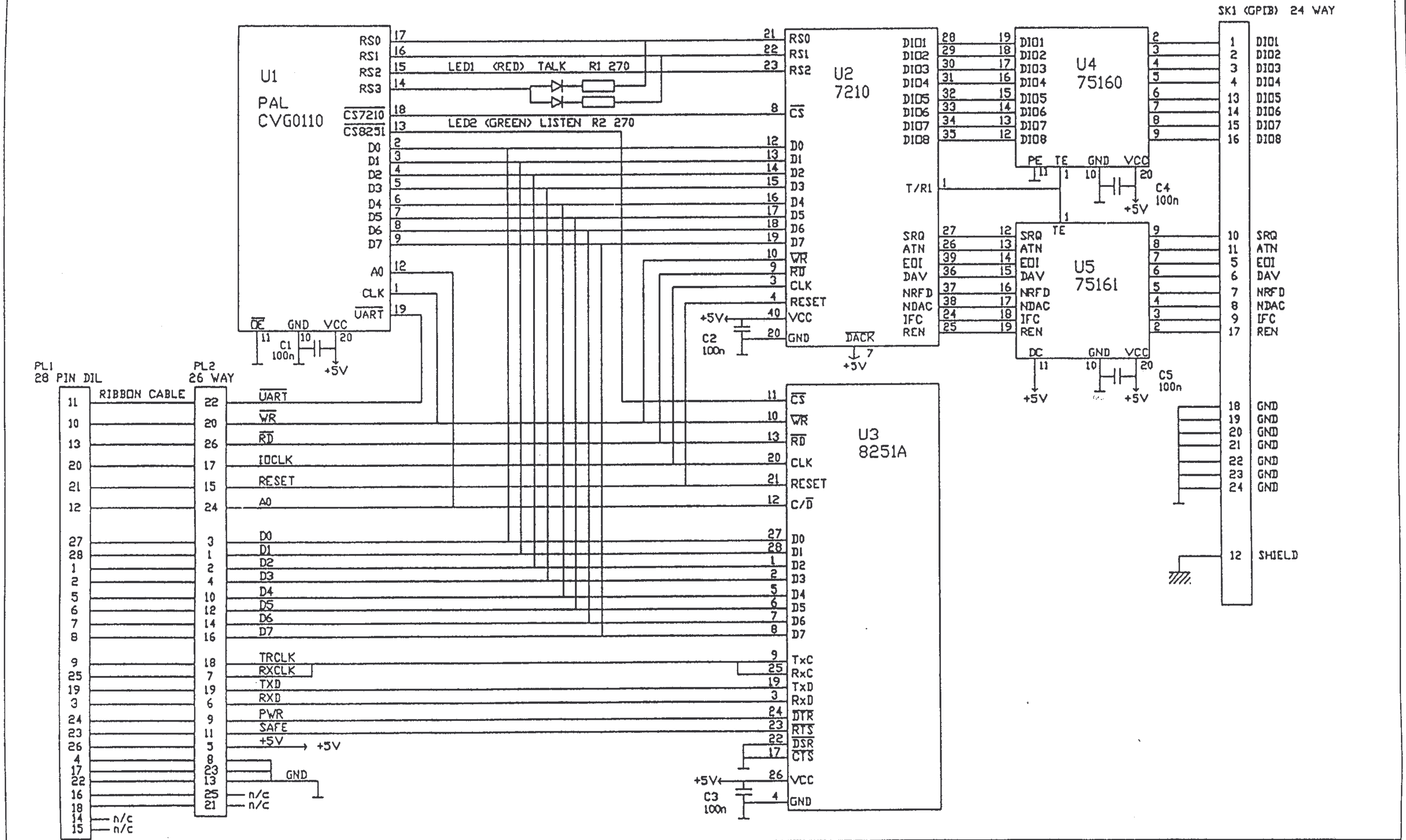
TITLE

ITC INPUT AMPLIFIER PCB CCT DIAGRAM

OXFORD

DRAWING NUMBER A4 CQBØ3Ø2 2 of 2


SK1
25-WAY
D-SOCKET
RTS
CTS
DSR
RLSD
DTR
TEST V+
GND
TD
RD
D1 1N4148
D2 1N4148
D3 1N4148
D4 1N4148
D5 1N4148
R1 100R
R2 1K
R3 4K7
R4 1K
R5 3K9
R6 2K2
Q1 BC182L
Q2 BC212L
C1 22u 35V
C2 22u 35V
MASTER SOCKET
CVA0100
PL1
25-WAY
D-PLUG
R1 1K
R2 10K
R3 100R
R4 470R
R5 390R
R6 180R
R7 4K7
R8 1K
Q1 BC212L
C1 4u7 50V
C2 4u7 50V
D1 1N4148
D2 1N4148
U1 6N139
U2 6N139
SLAVE PLUG
CVA0200
(UP TO 8 SLAVES MAY BE FITTED TO ONE BUS)
BUS COLOURS
1 V+ RED
2 TD BLUE
3 GND BLACK
4 RD YELLOW
ISSUE 4 26/7/93 AFS C1 CONNECTIONS CORRECTED. U1, U2 IDENTIFIER ADDED.
ISSUE 3 21/6/93 AFS REDRAWN
OXFORD ISOBUS CABLE
OXFORD
DRAWING NUMBER
A4/ CVA0002



ISSUE 3	16/3/93 AFS	LED 1 & 2 POLARITY REVERSED, U5 PIN NUMBERING CORRECTED
ISSUE 2	16/2/93 AFS	PL2 RENUMBERED
ISSUE 1	29/1/93 AFS	ORIGINAL

GPIB INTERFACE

OXFORD

DRAWING NUMBER

A4/ CVG0102