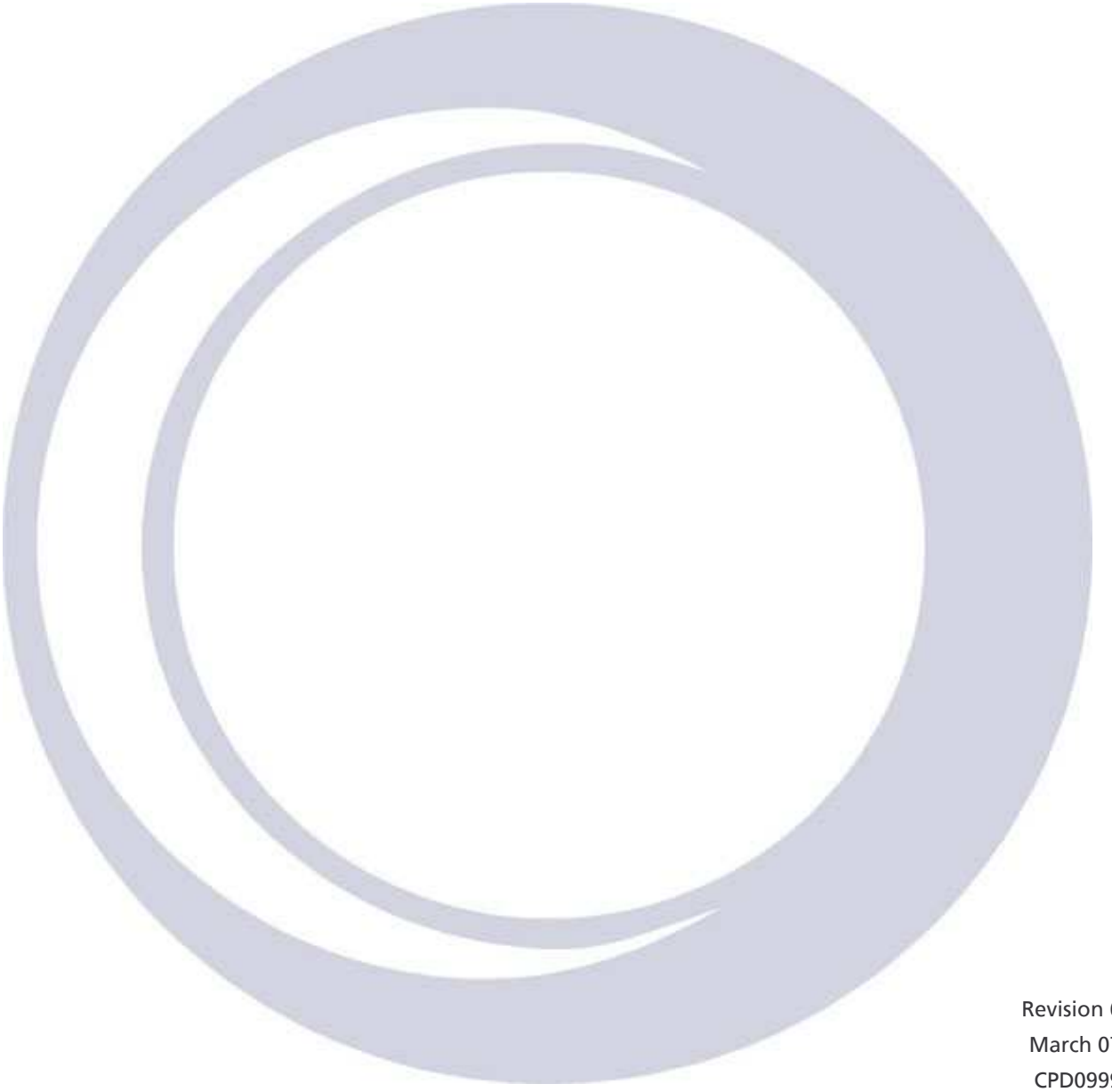
Operator's Handbook

SMC4

Stepper Motor Controller



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OXFORD INSTRUMENTS

Contents

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.

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 Disconnect Device for removal of the supply is considered to be either the Appliance Coupler or the Mains Plug. These must either be readily accessible or an alternative accessible disconnect device must be provided by the End – Use 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

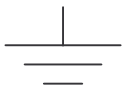
1 If you change set-up data and want it to be retained after power down, the data must be deliberately STORED as described in section 7.6.

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.

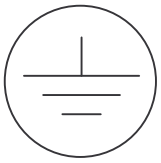
3 COOLING HAZARD. Internal components are air-cooled. Ensure the front lower ventilation space is not obstructed.

Explanation of symbols used in the Instrument

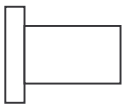
Attention; please refer to the manual



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.

3.2 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.

3.3 Use of this Manual

This manual provides operating and service information for the Oxford Instruments Four Axis Stepper Motor Controller model SMC4.

Sections 1-6 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.

3.4 Description of the SMC4

The SMC4 is an intelligent four axis stepper motor controller. It allows up to four stepper motors to be controlled from a single RS232 computer interface.

The SMC4 allows independent variable speed drive for each of the four motors. Two limit switches may be associated with each motor to define the limits of travel of a mechanism driven by the motor.

The SMC4 is able to drive both bipolar and unipolar motors and individual motors may be set to operate in either full-step or half-step modes. Motors are driven in constant current mode to maximise torque at high step rates. Motor currents may be individually preset to suit a particular motor. The maximum current available is 2 amps per phase. Current control is by means of pulse width modulation for best efficiency and the modulation method used may be selected for optimum performance for a given motor.

The SMC4 can provide automatic three stage acceleration and deceleration of a motor if requested, allowing operation at the motor's maximum step rate, without loss of steps during acceleration and deceleration.

Control of the SMC4 is by means of a 9600 Baud RS232 Serial link. This may be driven directly from the serial (or COM) port. Alternatively it may be driven by an Oxford ISOBUS cable, allowing a number of instruments to be controlled from a single serial port.

SMC4 is a microprocessor based instrument and is controlled by an operating program contained in a programmable memory chip (EPROM). This program is referred to as the SMC4 firmware. The firmware is coded with a two part number (for example 1.01) where the first digit indicates a major version of the firmware and the second two digits cover minor revisions.

4 Installation

4.1 Supply Connections

Before applying power to the instrument, ensure that the voltage selector 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 T2.0 AH 250 V Type T (Slow Blow)
~200/230 V T0.8 AH 250 V Type T (Slow Blow)

4.2 Classification

The SMC4 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;

The instrument is designed for indoor use only.

Altitude	2000 m
Atmospheric pressure	700 to 1060 mbar (10 to 15 psi)
Ambient temperature	18 to 30 °C
Maximum Relative humidity	80% non-condensing
Maximum magnetic field	50 Gauss
Rated Pollution Degree	Degree 2

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 3 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

Six months or as for cleaning if more frequent.

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 Motor Connections

Four separate 15 way D-plugs are provided on the rear panel for connection to the individual motors. All four channels are identical and correspond to the order of the channels on the front panel. Thus MOTOR 1 is associated with the left hand channel as viewed on the front panel etc. With the standard panel layout, channels are:

Z AXIS	MOTOR 1
Y AXIS	MOTOR 2
X AXIS	MOTOR 3
ROTATION	MOTOR 4

Caution: To avoid the risk of damage to the drive electronics, connections to the motors should never be made or broken whilst the SMC4 is switched on.

Pin connections on the motor plugs have been allocated to match those of the Time and Precision rotation and translation mechanisms used on a number of Oxford Instruments systems.

The coil connections given are for a 24 V bipolar motor. For use with a 12 V unipolar motor the coil common connections should be left unconnected and the coil ends treated as a pair of 24 V bipolar coils. For a 24 volt unipolar motor it is possible to operate at reduced efficiency, by using just one half of each of the coil, with the other half left open.

For all motors, it may be necessary to swap the "Start" and "End" connections of one of the coils to get the desired rotation direction.

The limit switches used should be normally-closed contacts, which open when the limit is reached. Internally, one end of each limit switch circuit is connected to the digital 0 V line (as indicated below). Either of these connections may be used as a limit switch common if required, to save one wire in the cable.

Pin connections at the MOTOR plugs are:

1	n/c
2	Motor Coil 1, Start
3	Motor Coil 2, Start
4	Motor Coil 1, End
5	Motor Coil 2, End
6	n/c
7	n/c
8	Limit Switch A
9	n/c
10	n/c
11	Limit Switch B (0 V)
12	Limit Switch B
13	Limit Switch A (0 V)
14	n/c
15	Shield (Chassis GND)

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. SMC4 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 SMC4 25 way RS232 socket are:

Pin	Signal	Notes
1	FG	Linked to Chassis Ground in SMC4
2	TD	Data from Computer to SMC4
3	RD	Data from SMC4 to Computer
4	RTS	Linked to Pin 5 in SMC4
5	CTS	Linked to Pin 4 in SMC4
6	DSR	Linked to +5 V when SMC4 is powered
7	SG	Linked to Digital Ground in SMC4
8	DCD	Linked to +5 V when SMC4 is powered

All other pins are open circuit.

SMC4 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 SMC4 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 can draw its power from either DTR or RTS signals from the computer.

To use ISOBUS, a special communication protocol is required. It is part of the command structure of Oxford Instruments' products and is described in section 6.5.

4.12 GPIB Operation via an ISOBUS GATEWAY

The General Purpose Interface Bus (GPIB), also referred to as "IEEE-488", provides an alternative means of connecting instruments to a computer. SMC4 itself is not currently available with an internal GPIB interface. However, a number of Oxford Instruments products (for example the ITC500 family) are available with such an interface. Where one of these is present in a system, it may be used to link the SMC4 to the GPIB by means of an ISOBUS GATEWAY. As far as the SMC4 is concerned, the command protocol is as described for ISOBUS. Details of the GATEWAY are provided in the manual for ITC502 etc.

4.13 Auxiliary Port Connections

In common with all Oxford Instruments microprocessor based products, SMC4 incorporates an parallel I/O port, the connector labelled AUXILIARY at the rear of the instrument. This is unused on SMC4, but is available for user interfacing as described in section 6.

5 Setup and Calibration

5.1 Setting the DIP Switches

There is a pair of "DIP" (Dual In-line Package) switches SW101, SW201 etc., associated with each motor channel on the Driver Board (CPD0600). They allow the step mode and the current control mode to be set up to suit an individual motor. SW101 is associated with Motor 1, SW102 with Motor 2 etc. The two switches of each pair are labelled "1" and "2" and referred to as such, below.

Where the SMC4 has been supplied by Oxford Instruments as part of a system, the DIP switches will already have been set up for correct operation with the motors used and no change to these settings will be required.

5.1.1 Half Step / Full Step Switches

Motors can be operated in either Half Step or Full Step mode. In Half Step mode, twice as many steps are required to effect a given angular movement of the motor.

The "2" switch of each DIP switch (SW101/2 etc.) controls the step mode thus:

SW101/2 = OFF	HALF STEP
SW101/2 = ON	FULL STEP

For preference Half Step mode should be used whenever possible. It gives twice the angular precision and much quieter and smoother motor running. Unlike Full Step mode, it does not suffer from any noticeable motor resonance effects. Its only disadvantage is that the torque available from the motor at its maximum speed is lower than that attainable with Full Step mode.

Full Step mode can give the highest speed from a given motor at high torque. However, with many motors there will be severe resonance effects when used in Full Step mode. This can result in the motor having virtually no torque and refusing to operate at certain specific step rates below its maximum speed. In general Full Step mode should only be used where the motor will always be operating at a fixed high speed. Even then, resonance can be a problem, since the motor may lose one or more steps when accelerating through its resonant frequency.

5.1.2 Phase Chopping / Inhibit Chopping

To achieve high torque at high speed a stepper motor should be energised with a controlled current, rather than simply applying a fixed voltage to the windings. Current control is most efficiently achieved by chopping the current to the windings. The full supply voltage is applied to the windings and the winding current is sensed. The inductance of the windings will cause the current to rise at an approximately constant rate. When it reaches the required motor current, the drive to the motor is "chopped" (i.e. removed) and the current then starts to fall. A fixed time later (determined by the chopping frequency) the process repeats. The SMC4 employs a chopping frequency of 20 kHz, which is synchronised for all four motors.

The L297 integrated circuit used in the SMC4, offers two alternative ways in which the motor drive can be chopped, which determine the rate at which the motor current falls. If Inhibit Chopping is used, both the drive transistors are turned off and the motor current is returned to the power supply via two "flywheel" diodes. This gives a rapid current fall. If Phase Chopping is used, only one of the drive transistors is switched off and the motor current is allowed to circulate through the other transistor and one of the flywheel diodes. This gives a much lower rate of current fall and hence a longer current pulse.

The "1" switch of each DIP switch (SW101/1 etc.) allows either chopping mode to be selected, thus:

SW101/1 = OFF	PHASE CHOPPING
SW101/1 = ON	INHIBIT CHOPPING

However with most motors inhibit chopping will produce a faster current fall than the original current rise. This may give an unstable situation when used with a fixed chopping frequency. The fraction of the cycle for which the drive transistors are on will vary from one cycle to the next. In extreme cases the transistors will only turn on every second or third cycle. This results in the motor current having high components at some fraction of the chopping frequency. These will fall within the range of human hearing and will result in an annoying whistle from the motor. Hence, Phase Chopping is preferred for normal applications and the "1" switches left in the "OFF" position.

5.2 Setting the Motor Current

Four preset resistors RV101, RV201, RV301 and RV401 on the Driver Board (CPD0600), allow the current of the individual motors to be set. RV101 relates to Motor 1, RV201 to Motor 2 etc. Test points TP102, TP202, TP302 and TP402 are provided facilitate setting up these resistors.

Caution Setting these resistors requires operating the SMC4 with the top cover removed. Refer to Section 3.1 before attempting this.

To set the motor current, a DC voltmeter should be used to monitor the voltage at the test point, relative to 0 V (the latter can be found at test point T0 on the CPU Board CBD1200, near the front left hand corner of the instrument). The motor current per phase (in amps) is equal to twice the voltage monitored at TP102 etc. (in volts). Thus a voltage at TP102 of 0.5 V represents a motor current of 1 A per phase for motor 1. Note that on the Issue 1 version of the Driver Board, TP102 is not identified. It is located immediately to the left of U105, between C3 and R9. All other test points are identified.

The current should be set to the recommended value from the manufacturer's literature for the motor. However if a particular motor is not required to deliver its full rated torque, a lower value of current may be set. This will result in a lower operating temperature for the motor, which can help to prolong its life.

The maximum current which may be set is 2 A per phase. This is the full current rating of the SMC4.

6 Operation

6.1 Front Panel

The front panel carries a single control, the ON/OFF switch, and a number of status lamps. These are grouped into logical groups, one associated with each motor. The groups are labelled in accordance with the anticipated use of the motors.

6.1.1 Power

The main ON/OFF switch. A green lamp illuminates whenever the instrument is switched on.

6.1.2 Status Lamps

Three lamps are associated with each Axis.

LIMIT A Lights when the limit switch associated with low numbers is active. (i.e. the switch contacts have opened).

LIMIT B Lights when the limit switch associated with high numbers is active. (i.e. the switch contacts have opened).

ACTIVE Lights whenever a particular motor is rotating

6.2 Communication Protocols

All control of the SMC4 is by means of the RS232 serial interface. A series of commands is sent to SMC4 and these result either in motion of one or more of the stepper motors, or in the current motor positions and status being returned to the computer.

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 SMC4.

Unless the command starts with a "$" (dollar) character, all commands will evoke a response from SMC4. 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 the SMC4 is connected directly to a serial COM port on the computer, the response will be transmitted automatically as soon as it is available. If the connection is via a GATEWAY onto a GPIB interface, the response will be sent when the interface 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).

SMC4 will accept a command string at all times. If a computer linked by the serial (RS232) port, is unable to accept data from SMC4 at the full rate of the 9600 baud interface, the "W" command may be used to instruct SMC4 to send more slowly.

6.3 Commands and Responses

Commands to SMC4 all consist of a single letter, optionally followed by a numeric parameter, the whole being terminated by a Carriage Return. All common operational commands are based on Upper Case letters with mnemonic significance. The response sent by SMC4 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 SMC4 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.

6.4 Numeric Parameters

All numeric parameters are treated as signed integers and are sent as a string of decimal or hexadecimal digits. The range of acceptable numbers depends upon the specific command and is given below.

For positive numbers, the "+" sign is optional, as are leading zeros.

The same convention is adopted by SMC4 in returning numbers to the computer.

The numbers used to represent the position of the stepper motors (P command, T command and the response to the R0 and R1 commands) are all positive 6-digit hexadecimal numbers running from 000000H to FFFFFFH. These allow the total travel of the motor and gear train to be represented by a maximum of 16777216 steps (at 300 steps per second, this represents some 15 hours of movement!).

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. SMC4 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 Use via a GPIB GATEWAY

When being driven via a GATEWAY from another instrument connected to a GPIB, the protocols are unchanged. An individual ISOBUS address is allocated to each instrument and commands are sent with the standard ISOBUS prefixing.

7 Command List

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

Commands fall into two categories:

OPERATIONAL COMMANDS	Used for normal control of the stepper motors and which are always recognised.
SYSTEM COMMANDS	Used for diagnostic and configuration purposes and which are only recognised after receipt of the correct "UNLOCK KEY".

In the list which follows, "n" represents a decimal digit 0-9 and "h" represents a hexadecimal digit 0-F. Many of the commands apply to the **current motor**, as specified by the "M" command, so that a command sequence may typically involve selecting a current motor, then applying a further sequence of commands to it.

OPERATIONAL COMMANDS

An	**A**CTIVATE / DE-ACTIVATE MOTOR
B	APPLY **B**RAKING TO MOTOR
Cn	SET **C**ONTROL MODE (IGNORED)
Dnnn	SET **D**ELAY BETWEEN ACCELERATE / BRAKING STEPS
En	**E**NABLE / DISABLE MOTOR
Fn	SET / CLEAR THE GLOBAL ENABLE **F**LAG
G	**G**ET MOTOR POSITIONS
H	SET MOTOR TO **H**OME POSITION
I	**I**NCREASE SPEED OF MOTOR
Mn	SELECT **M**OTOR (Note value of n will not be as expected)
Phhhhhh	SET MOTOR **P**OSITION
Qn	DEFINE COMMUNICATION PROTOCOL
Rn	**R**EAD PARAMETER n FOR CURRENT MOTOR
Snnn	SET **S**PEED OF MOTOR
Thhhhhh	SET **T**ARGET POSITION FOR MOTOR
Unnnnn	**U**NLOCK FOR "!" AND SYSTEM COMMANDS
V	READ **V**ERSION
Wnnnn	SET **W**AIT INTERVAL BETWEEN OUTPUT CHARACTERS
X	E**X**AMINE STATUS

SYSTEM COMMANDS (recognised only after correct Unnnnn command)

Y	LOAD ENTIRE RAM CONTENTS
Z	DUMP ENTIRE RAM CONTENTS
!	SET ISOBUS ADDRESS (See section 9)

8 Command Syntax

8.1 Operational Commands

An COMMAND

Activates or Deactivates the current motor.

A1	ACTIVATE MOTOR
A0	DE-ACTIVATE MOTOR

Activation affects whether the SMC4 will attempt to control the motor. A motor will be automatically deactivated if it is about to run outside the position count range.

B COMMAND

Brake the current motor. The motor will decelerate to a standstill in three stages each reducing the step rate by a third of its initial value and being separated by a delay set by the D command. This command can only operate on one motor (the current motor) at a time, and does not return the acknowledgement letter until the braking process is complete. The motor is left deactivated once it has stopped.

Cn COMMAND

This command is provided for compatibility with other Oxford Instruments products that may be run on an ISOBUS network. The SMC4 will accept and acknowledge the command, but since it is always remotely controlled, the command will have no effect.

Dnnn COMMAND

Set delay between acceleration or braking steps. Acceleration or braking occurs in three steps with a delay between each. The delay is specified in milliseconds in ASCII decimal format, For example.

D50	Set delay to 50 ms

En COMMAND

Enable or Disable the current motor.

E1	Enable motor
E0	Disable motor

This command tells the SMC4 whether to energise the motor windings. With the windings de-energised, the motor will move freely and may be operated by hand. Since it is not possible to step the motor in this state, disabling a motor will also deactivate it.

Fn COMMAND

Set or Clear Global Enable Flag. The Global Enable Flag operates on all motors. By default it is set on. If it is necessary to move two or more motors simultaneously and starting simultaneously, then they can be set up and enabled with the Global Enable Flag off. Switching the flag on will then start the motors together.

F0	Set Global Enable Flag off (all motors suspended)
F1	Set Global Enable Flag on (default state)

G COMMAND

Get Motor Positions. This command updates all the values returned by the R command simultaneously, enabling the user to obtain the relative positions of the motors to a higher accuracy.

H COMMAND

Set current motor to home position. This command causes the motor windings to be energised in state one. Since this is implemented by the stepper driver IC, the motor step count will by inaccurate after the H command has been used. It is therefore suggested that this command only be used when calibrating a motor against its limit switch.

I COMMAND

Increase the speed of the current motor. This command accelerates the current motor in three stages to a specified or maximum velocity from a standstill. As with the B (Brake) command, the three equal speed increments are separated with a delay specified by the D command. It is not necessary to activate the motor before accelerating it. As with the B command, the acknowledgement letter is returned once the acceleration is complete - hence only one motor may be accelerated at a time.

I	Accelerate motor to maximum velocity
I16	Accelerate motor to CLOCK/16

Mn COMMAND

Select current motor. Most of the SMC4 commands operate on only one motor at a time, known as the 'current' motor. The M command allows the user to select which motor is the 'current' motor. Note that there is an inconsistency between the value of "n" used in this command and the numbering of the motors on the rear panel and the component numbering on the circuit board.

M1	Select **Rotation Axis Motor**	(Motor 4)
M2	Select **X-Axis Motor**	(Motor 3)
M3	Select **Y-Axis Motor**	(Motor 2)
M4	Select **Z-Axis Motor**	(Motor 1)

Phhhhhh COMMAND

Set the position for the current motor. The SMC4 stores the position of each motor as an unsigned 24 bit number in the range 0 to 16777215, and updates this as the motor is moved. For calibration purposes it will be necessary to drive the motor to one of its limit switches in order to fix a position, and then tell the SMC4 what the position is. The position is sent as an ASCII HEX number, optionally prefixed by a + sign, but containing no symbols other than numerals and spaces.

P+FFFFFF	Set position to 16777215

Note that care must be taken to ensure that the position is set such that a legal positive value exists for all the desired motor positions, as the SMC4 will not allow motor movement outside the range of its position counter.

Qn COMMAND

Defines the communication protocol. Currently only two possible values 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 communication buffer).

Rn COMMAND

Send Reading. Allows interrogation of variables relating to the current motor. All variables are returned as positive ASCII HEX integers, preceded by the letter R. Thus the format of the returned response is:

Rhhhhhh

Valid parameters are:

R0	Target motor position
R1	Current motor position
R2	Status of motor
R3	Direction of motor
R4	Speed of motor
R5	Main motor clock

The values returned will be those at the time when the last G (Get) command was issued. This enables an accurate comparison of the relative positions etc. of all the motors at a precise instant. If the R command returned the value at the time the command was issued, the readings obtained for the separate motors would all correspond to slightly different times.

For **R0** and **R1**, the three byte (24 bit) number returned represents the motor position in number of steps from "home".

For **R2** the three bytes are composed as follows

1st Byte (MS)	Not used
2nd Byte	Limit Switches: Bit 0 Limit A Bit 1 Limit B
3rd Byte (LS)	Motor Status: Bit 0 Active Flag Bit 1 Enabled Flag Bit 2 Position Error Flag

For **R3** three bytes are sent but only the LS byte is valid and is composed as follows:

3rd Byte (LS)	Direction
Bit 0	Towards Limit Switch A
Bit 1	Towards Limit Switch B

For **R4** again, only the LS byte is valid and gives the clock divisor as set by the "S" command.

For **R5** again, the LS Byte is valid and can be used to calculate the interrupt clock frequency as follows:

If LS Byte is 'x', then

f = 4 MHz / (16 * x)

Snnn COMMAND

Set the speed for the current motor. The speed is a decimal number between 1 and 255 which is used to divide the 1 kHz internal clock to obtain the step rate. The exact step rate can be determined using the R command (note that the SMC4 cannot tell whether a motor is able to follow a particular step rate, it is the user's responsibility to ensure the S parameter is large enough to stay within the maximum step rate for a given motor).

S0	Move at clock rate
S1	Move at clock rate
S2	Move at clock / 2
S3	Move at clock / 3
.	.
.	.
S255	Move at clock / 255

Since this divisor controls the step period, it is not proportional to step rate, that is,. S2 is half the speed of S1 but S255 is only slightly slower than S254.

Thhhhhh COMMAND

Set target position for current motor. If a motor is active, and not against a limit switch, it will move until its position matches its target position. The syntax for the T command is the same as for the P command.

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.

Thus the allowed values of U are:

U0	LOCKED (Power-up Default)
U1	"!" COMMAND UNLOCKED
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 SMC4 via the computer interface. This allows SMC4 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 the SMC4 can accept data from computer.)

X COMMAND

The EXAMINE command allows the computer to read the current SMC4 STATUS. It requires no parameters and will return a message string of the form:

XMn

where the digit "n" indicates the "current" motor. Note that the motor numbering convention here follows that of the "M" command.

Y 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.

Z 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.

r COMMAND

Read parallel interface port. This commands reads the state of the four input lines on the PARALLEL I/O connector, providing the facility to use the SMC4 as a general purpose digital interface to the computer communications port. The command takes no parameters: the response is in the form of an integer in the range 0 to 15. The decimal number corresponds to the binary value presented to the bit 3 to bit 0 inputs of the PARALLEL port.

The input pins require 0-5 V logic levels and are TTL compatible. The CMOS circuits will be damaged by larger voltages unless appropriate buffering is provided. The port includes pins for 0 V return and for 5 V supply, which may be used with pull-up resistors.

snnn COMMAND

Set parallel interface port. This command sets the state of the 8 output lines on the PARALLEL connector, providing the facility to use the SMC4 as a general purpose digital interface to the computer communications port. The parameter nnn is an integer value in the range 0 to 255. The decimal number corresponds to the binary number presented to the bit 7 to bit 0 outputs of the PARALLEL port. Note that these data bits are then inverted by the output buffer, before reaching the connector pins.

The open-collector outputs require an external pull-up resistor. The port includes pins for 0 V return and for 5 V and 12 V supplies, which may be used with pull-up resistors.

9 Servicing

9.1 Circuit Description

The SMC4 is built on two main circuit boards, with a separate front panel display board and power supply unit. Circuit diagrams are provided for the individual boards and for the overall interconnection of the boards.

9.1.1 Microprocessor Board

The SMC4 is controlled by a Z80A microprocessor (CPU). In addition to the CPU, the microprocessor board contains EPROM, RAM, CTC and UART chips. The stepper motor driver board is mapped directly as an I/O device on the CPU bus and all the system timing is derived from a 1 mS interrupt generated by the CTC chip.

Battery backed non-volatile RAM is used to retain the SMC4 ISOBUS Address and the position of the four motors during power down. The latter may be helpful during brief power-outs but in general the motor position cannot be relied on since the CPU has no way of determining whether the motor has been moved whilst power was off.

9.1.2 Display Board

Three LEDs provide visual indication of the status for each motor on the front panel. LED1, 4, 7 and 10 indicate motor movement. The RC network and inverter lengthen and negate the clocking pulses supplied by the Microprocessor to the driver board. LED2, 3, 5, 6, 8, 9, 11, and 12 are driven by the limit switches to indicate the ends of motor travel. LED13 gives visual indication of power.

9.1.3 Driver Board

The Driver Board carries four Stepper Motor Controller IC's type L297 and four Stepper Motor Driver IC's type L298N. The latter are mounted directly onto the rear panel heat sink. The construction of the SMC4 is such that the driver board and the heat sink may be removed as an assembly for servicing. To do so, it is only necessary to remove the two bolts supporting the front of the board and the four bolts securing the heat sink to the rear panel. The whole assembly may then be removed backwards through the rear panel.

Component references on the Driver Board are prefixed 100, 200, 300 or 400 for the four motor channels. Components common to all four motors have part numbers less than 100.

Partial I/O decoding is provided by the microprocessor board CBD1200 in the form of the ~IORD and ~IOWR signals. U1 further decodes these to provide addresses for two input and two output ports. Only one of the input ports is actually used and this is fed by the limit switches for the four motors. The limit lines are normally grounded and active open. When open the pull up resistor network RN1 brings the inputs to logic high. R1-8 give protection to the input buffer U2, and provision is made on the PCB for capacitors to ground for each line, should this be necessary. The two output latches U3 and U4 supply step, direction, reset and enable signals to the four motor controller IC's U105, 205, 305 and 405.

C3 and R9 are the timing components for the internal clock oscillator of U105. The SYNC pin on all the controller IC's is linked so that the clock of U105 drives the other three controllers. R115 and RV101 etc. generate reference voltages which set the peak motor current for each controller IC. S101 etc. set full or half step mode and step or inhibit switching.

U106 etc. are the motor driver IC's. R111 and R112 are the current sensing resistors for the two phases of each motor. Note that two metal film resistors are used in parallel, rather than a single wire-wound resistor. This is necessary to keep the inductance low at this point. If it is necessary to replace these resistors, ones of a similar type should be used.

The flywheel diodes D101 to D108 etc. **must be high speed** types. Replacing the UF5404 devices fitted with a "standard" speed device such as 1N5404 will result in very high power dissipation in the associated L298N driver and the probable destruction of this device.

9.1.4 Power Supply

This is a standard linear power supply. A regulated +5 V supply is provided for the logic circuitry and an unregulated 24 V supply powers the stepper motors. The supplies are initially taken to the Controller/Driver board and the microprocessor board in turn receives its power through the ribbon cable connecting the two boards.

(Note that the SMC4 power supply appears superficially similar to that used on the ITC range of temperature controllers. However, it employs a differently specified mains transformer and the supplies are therefore not interchangeable between the two instruments).

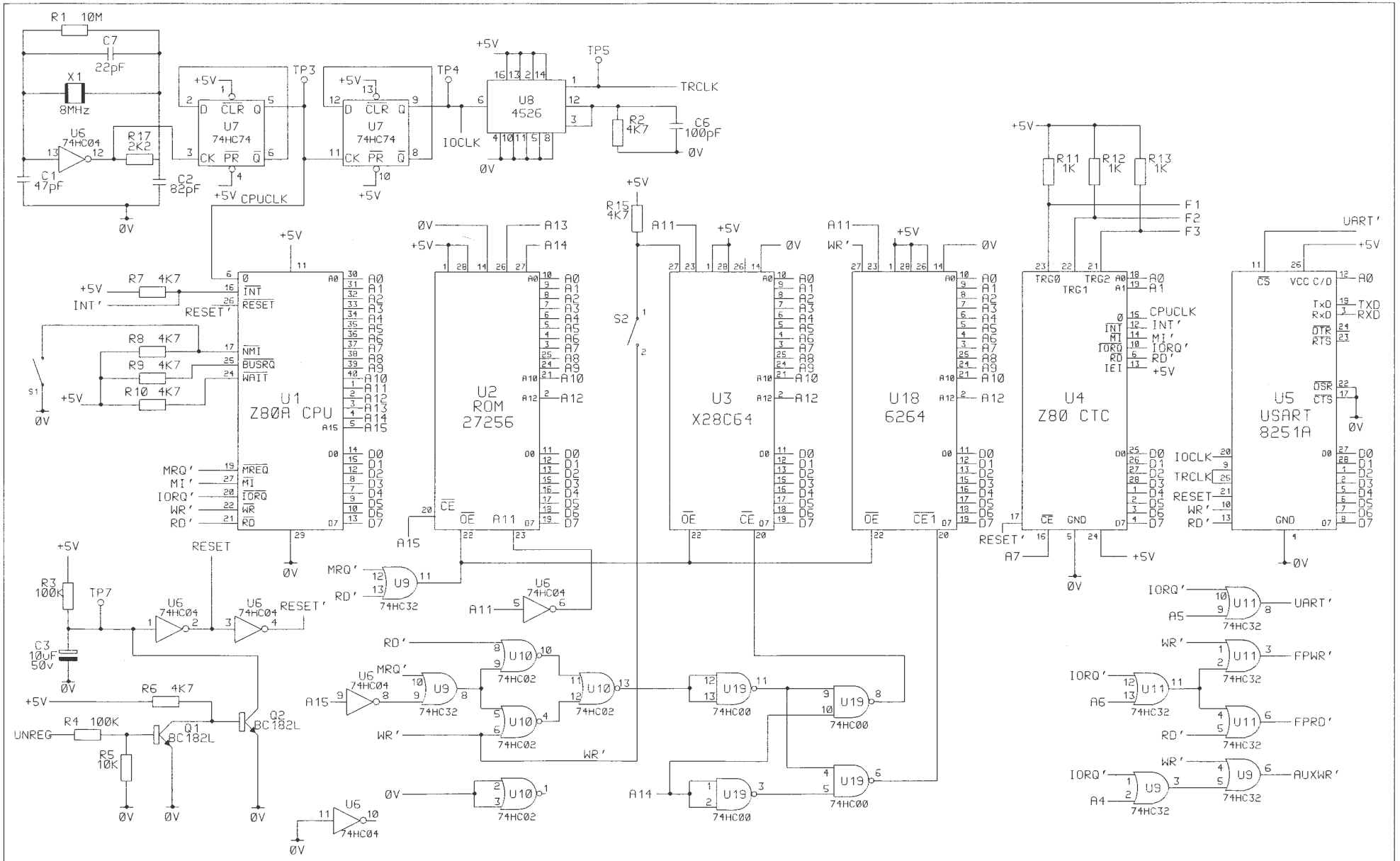
10 Specification

OUTPUT CHANNELS	Control for four motors, 2 phases each
OUTPUT CURRENT	Up to 2 amps per phase (variable for each motor)
OUTPUT POWER	Total output power available is approx. 80 W
POSITION LIMITING	Inputs for two limit switches per motor
DRIVE SPEED	Up to 1000 steps per second (variable)
RS232 INTERFACE	Configured as DCE
HANDSHAKE	None Required
BAUD RATE	9600 Baud
DATA BITS	8
STOP BITS	2
PARITY	None
CONTROL LANGUAGE	Commands enable motors to be positioned individually or simultaneously at variable speeds. Position and status of motors can be requested. Motors can be position calibrated against limit switches. Motor windings can be switched off to allow manual positioning. The Oxford Instruments ISOBUS protocol is supported.
CONNECTORS	
POWER IN	IEC 3 pin
MOTORS	15 way D plug (4 off)
AUXILIARY I/O	15 way D socket
RS232	25 way D socket
POWER REQUIREMENTS	100/115/200/230 V, 50/60 Hz
POWER CONSUMPTION	120 VA approx.
FUSE RATING	100/115 V T2.0AH 250 V 200/230 V T0.8AH 250 V
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

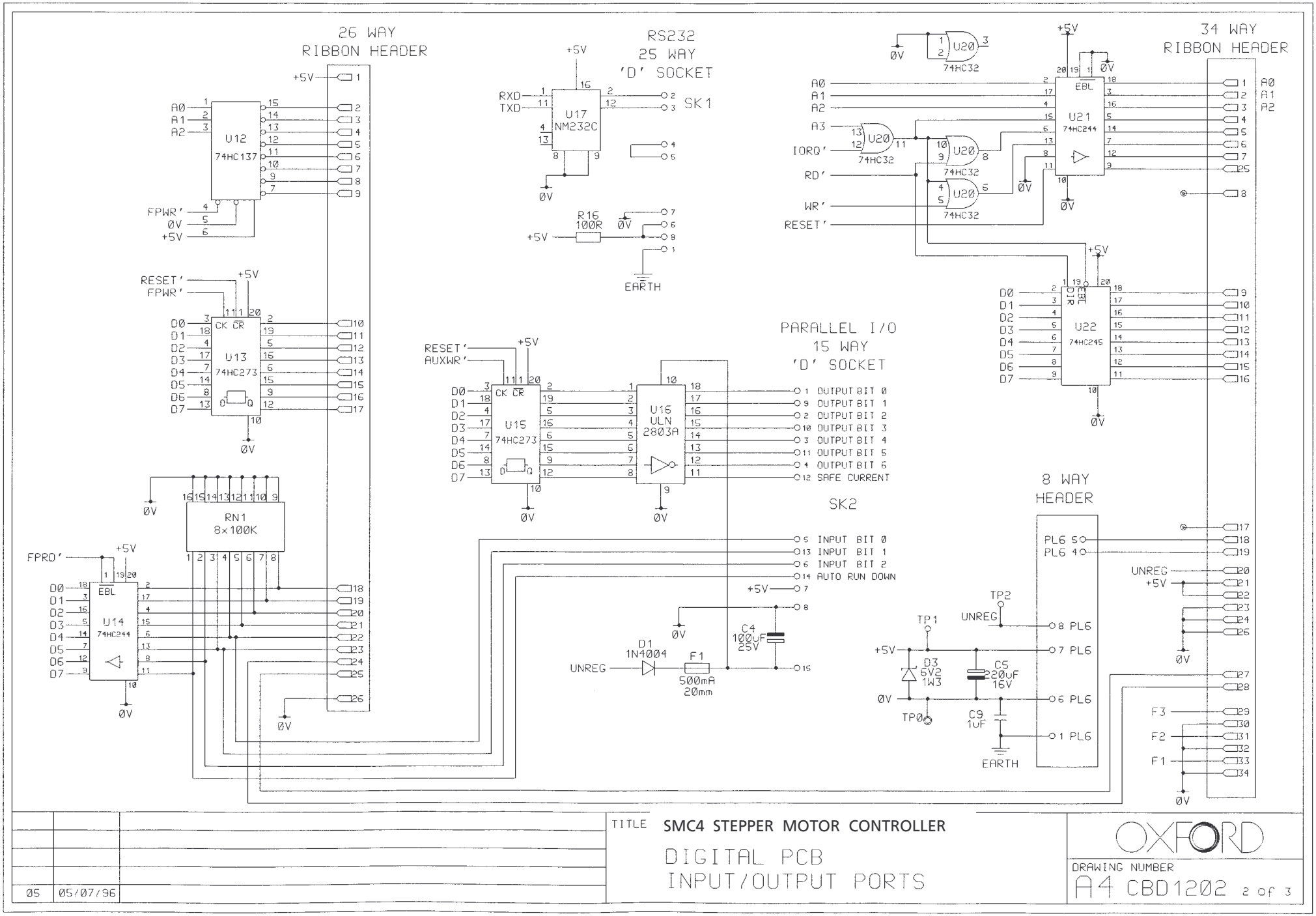
11 Circuit Diagrams

The following circuit diagrams are included.

Drawing Number	Number of sheets	Description
CBD1202	3	CPU BOARD
CPD0502	1	DISPLAY BOARD
CPD0602	3	DRIVER BOARD
CPD0702	1	POWER SUPPLY
CPD0902	1	WIRING LOOM



			TITLE SMC4 STEPPER MOTOR CONTROLLER
			DIGITAL PCB CPU, MEMORY AND TIMING
05	05/07/96		OXFORD DRAWING NUMBER A4 CBD1202 1 of 3



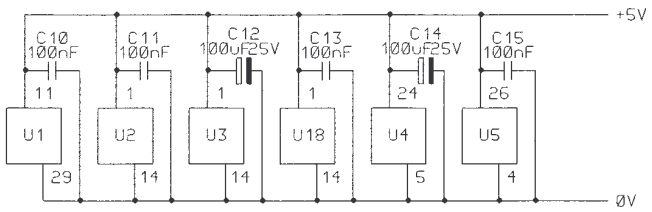
05	05/07/96	

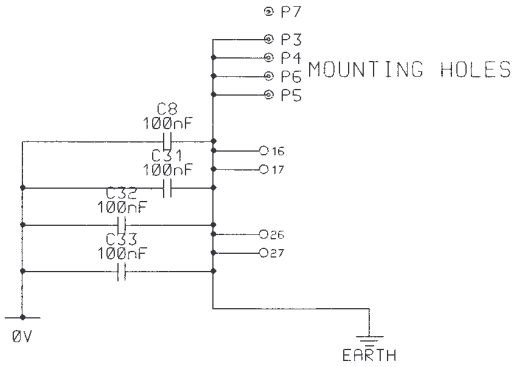
TITLE **SMC4 STEPPER MOTOR CONTROLLER**

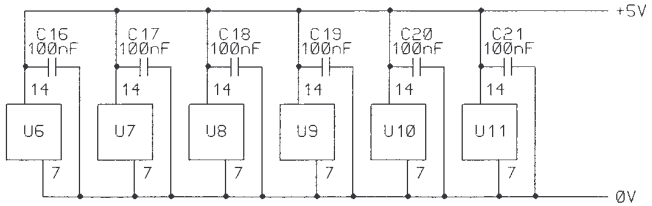
DIGITAL PCB
INPUT/OUTPUT PORTS

OXFORD

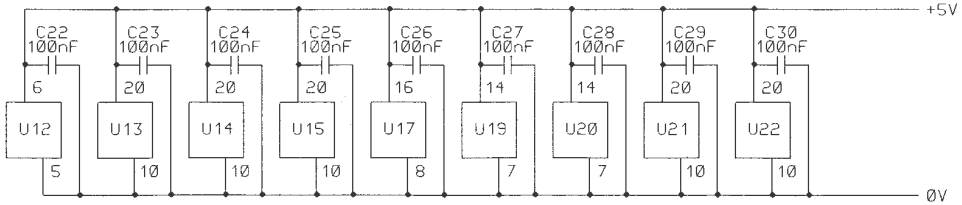
DRAWING NUMBER
A4 CBD1202 2 of 3



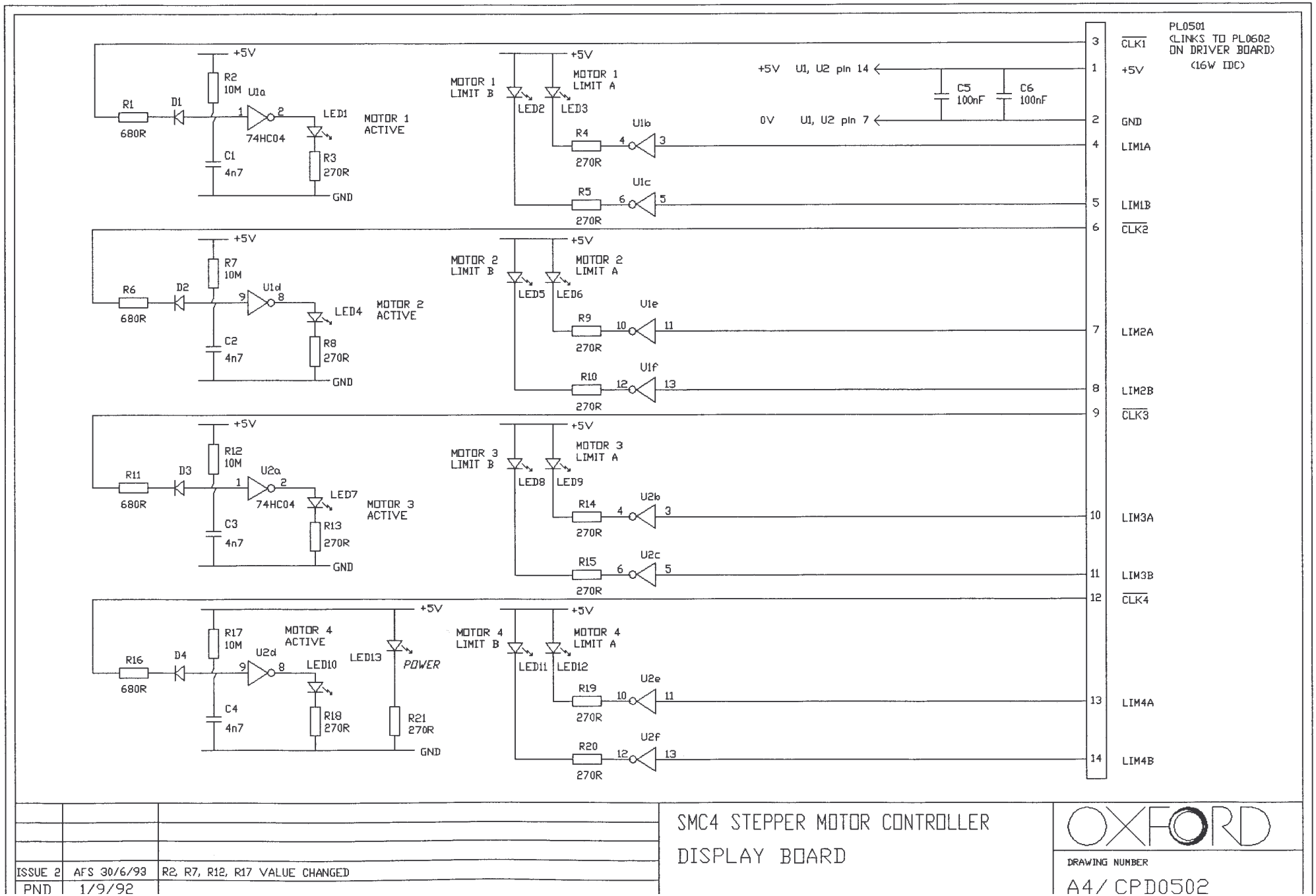




DECOUPLING CAPACITORS TO BE CLOSE
TO THE RELEVANT COMPONENT.



			TITLE: SMC4 STEPPER MOTOR CONTROLLER DIGITAL PCB DE-COUPLING CAPACITORS etc.
			OXFORD DRAWING NUMBER A4 CBD1202 3 of 3
05	05/07/96		

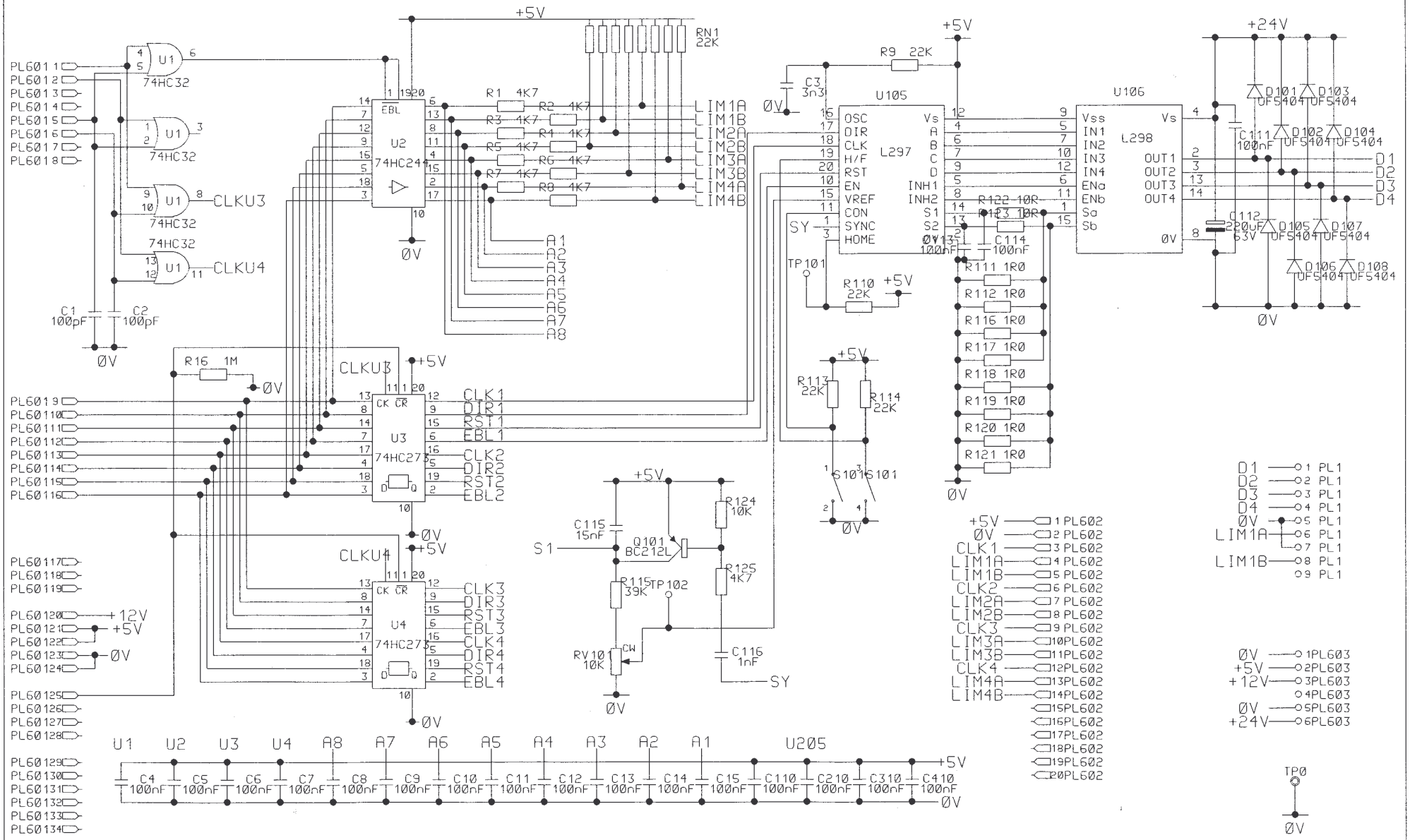


ISSUE 2	AFS 30/6/93	R2, R7, R12, R17 VALUE CHANGED
PND	1/9/92	

SMC4 STEPPER MOTOR CONTROLLER
DISPLAY BOARD

OXFORD

DRAWING NUMBER
A4/CPD0502

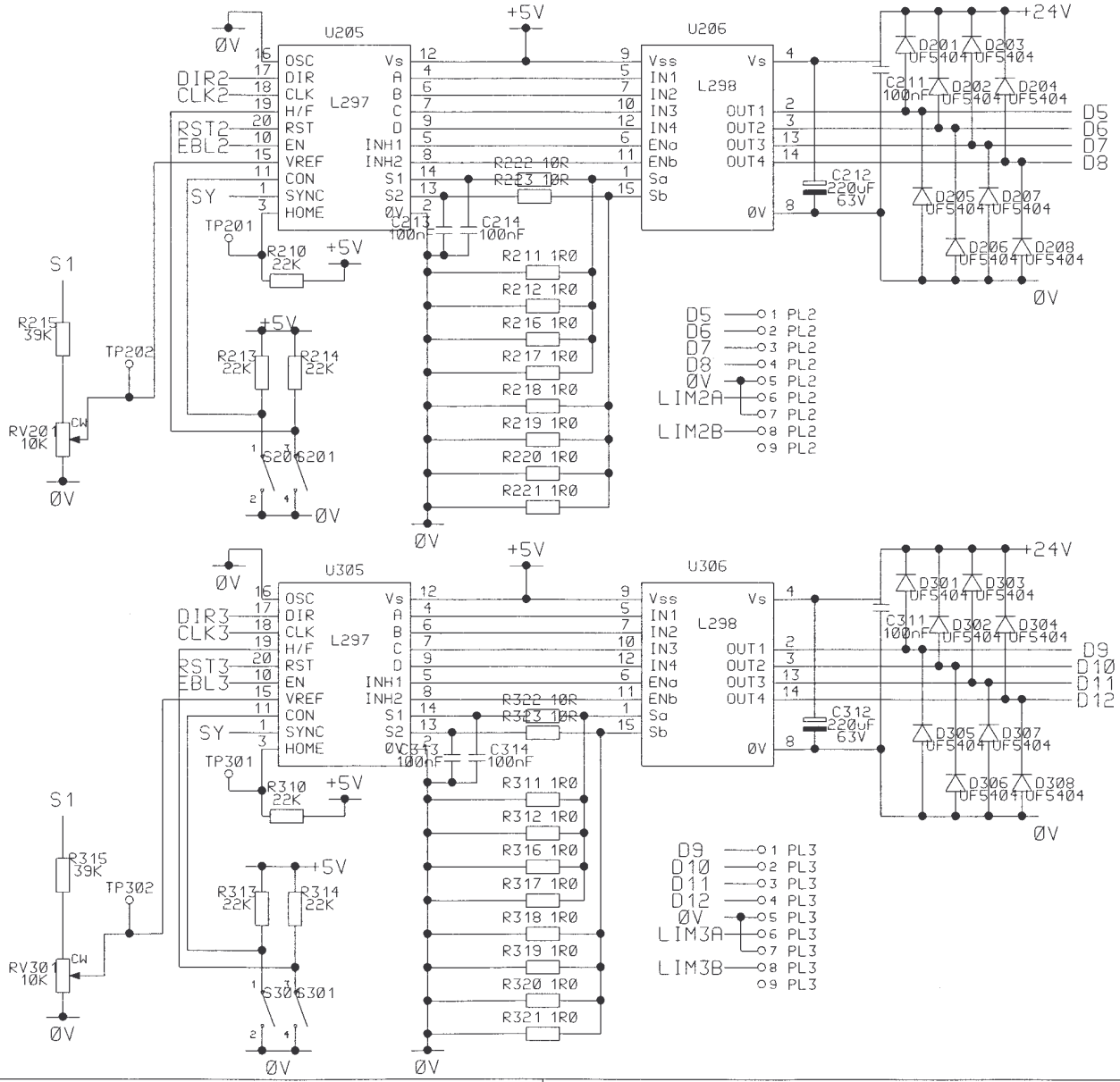


05	6/9/96	C489 TPØ ADDED, CAPS CHANGED, DIODES MOVED
04	1/7/96	C442 EMC MODS
02	27/6/96	CIRCUIT PUT ON RANGER2
01	1/9/92	PND

SMC4 STEPPER MOTOR CONTROLLER
I/O DECODING, CONTROLLER & DRIVER PCB
CIRCUIT DIAGRAM

OXFORD

DRAWING NUMBER
A4/ CPD0602 sht 1 of 3

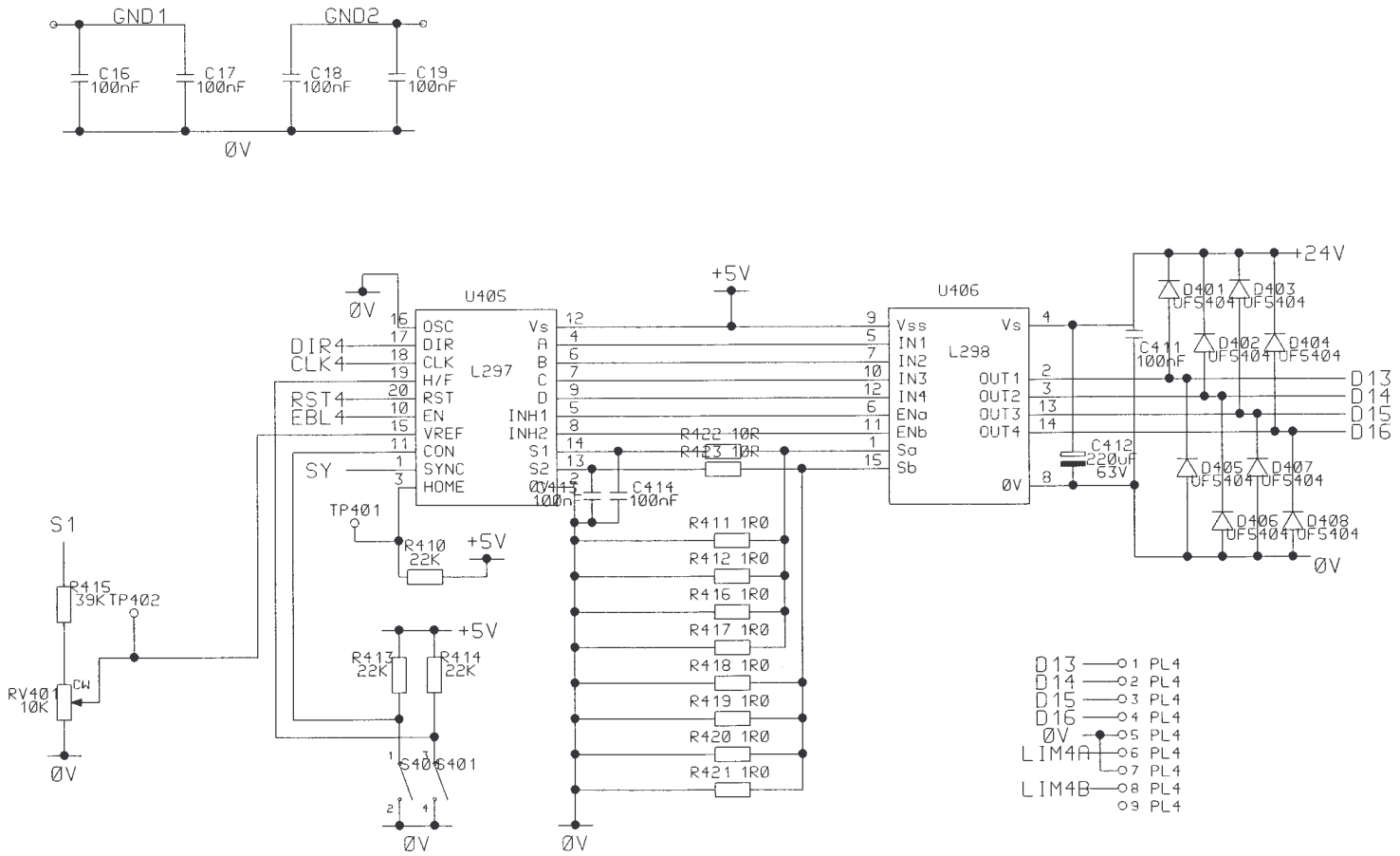


04	1/7/96	C442 EMC MODS

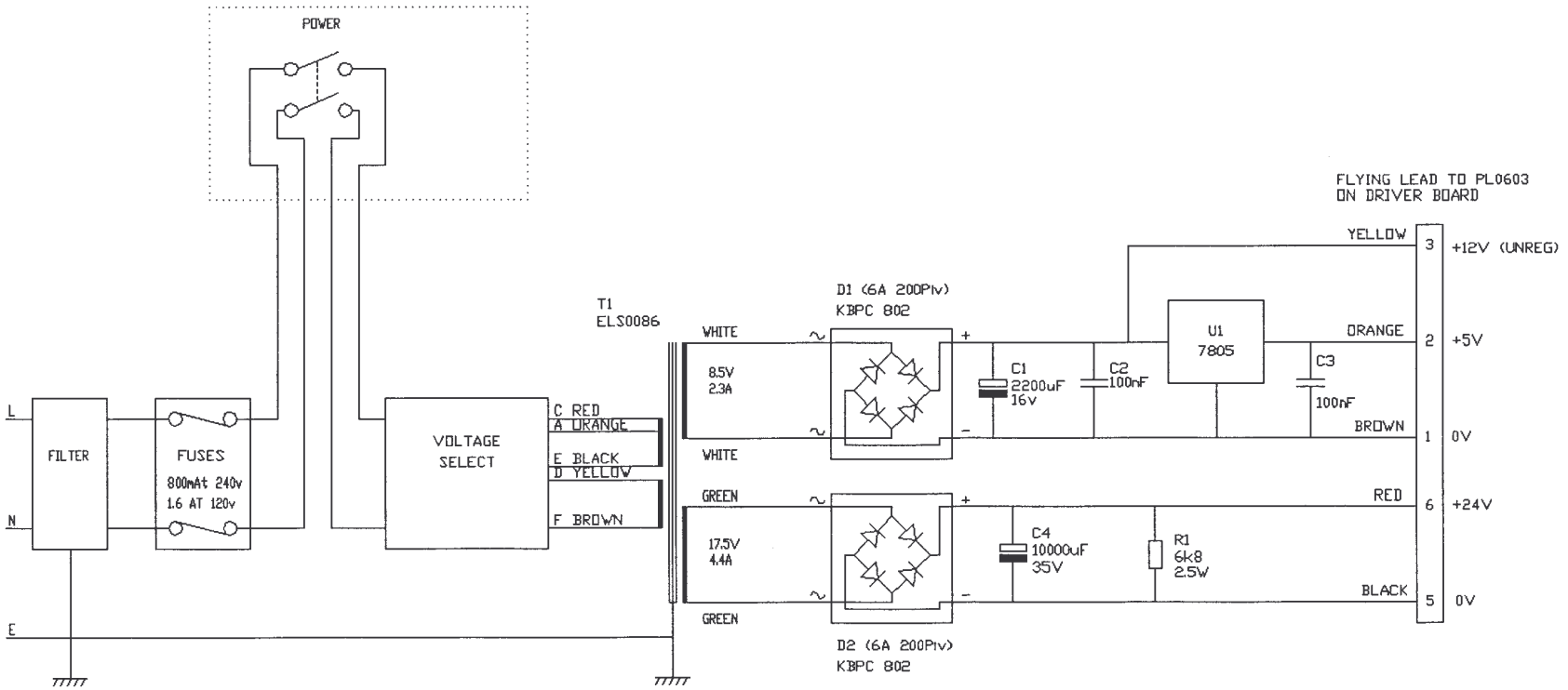
SMC4 STEPPER MOTOR CONTROLLER
CIRCUIT DIAGRAM

OXFORD

DRAWING NUMBER
A4/CPD0602 sht 2 of 3



			SMC4 STEPPER MOTOR CONTROLLER CIRCUIT DIAGRAM	OXFORD DRAWING NUMBER A4/CPD0602 sht 3 of 3
04	1/7/96	C442 EMC MODS		

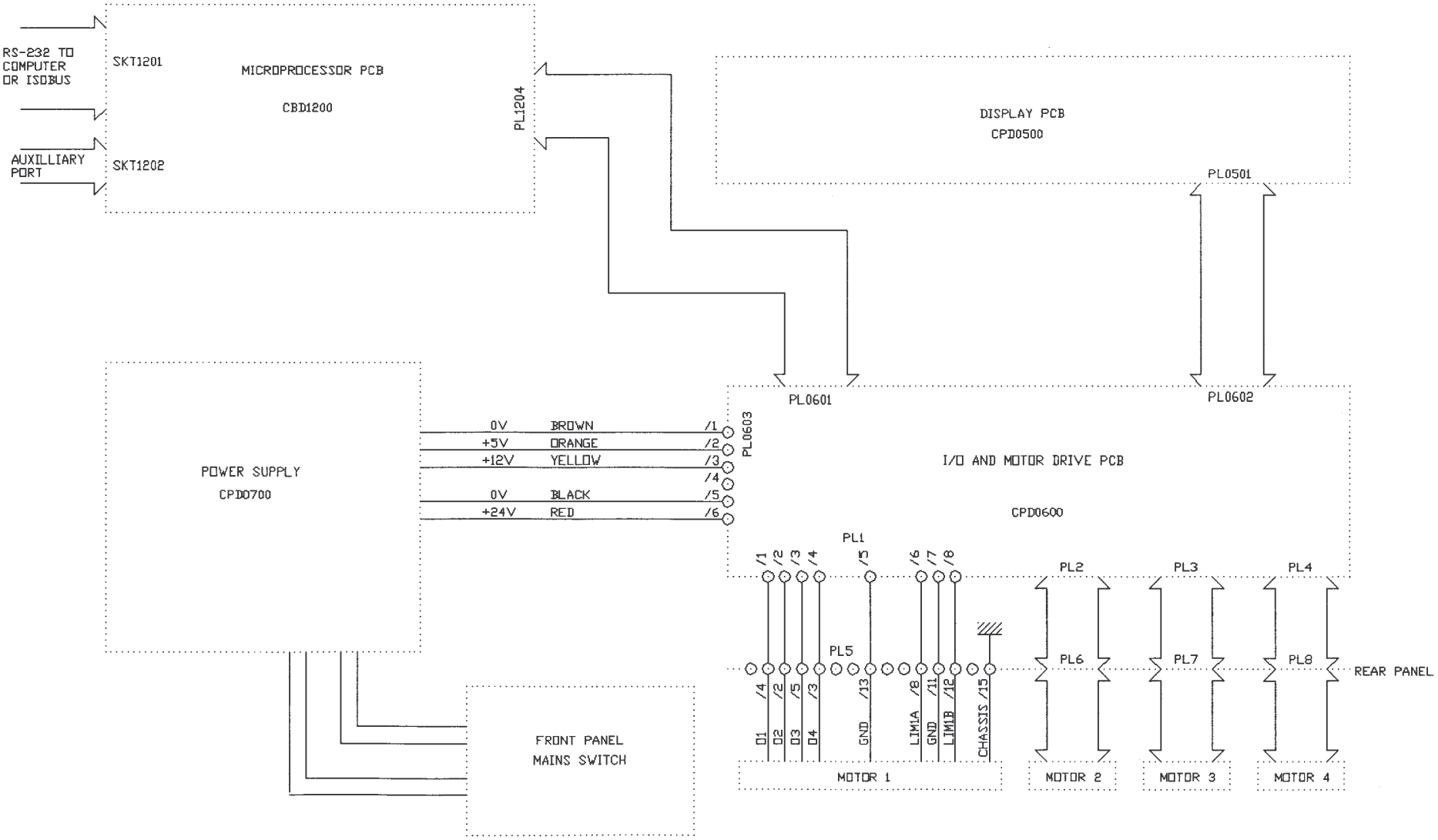


ISSUE 2	AFS 1/7/93	CONNECTOR ASSIGNMENTS REVISED. POLARITY OF C1, C4 CORRECTED.
PND	1/9/92	DOTTED LINE ....., MARKS CONNECTORS AND COMPONENTS NOT ON CPD0200

SMC4 STEPPER MOTOR CONTROLLER
POWER SUPPLY

OXFORD

DRAWING NUMBER
A4/CPD0702



ISSUE 2	AFS 1/7/93	CONNECTOR PINOUTS REVISED
PND	1/9/92	

SMC4 STEPPER MOTOR CONTROLLER
WIRING LOOM

OXFORD

DRAWING NUMBER
A4/ CPD0902

12 Restriction of certain Hazardous Substances Statement

European Union

Under the provisions of the Restriction of certain Hazardous Substances (RoHS Under 2002/95/EC) Directive, as applied to products manufactured and sold in the UK and Europe by Oxford Instruments NanoScience (OINS). OINS has been advised that the product(s) to which this manual relates is exempt under category 6 of the RoHS Directive because it is, or will form part of, a large-scale stationary industrial tool.

China

The Chinese regulations on RoHS require that the product manual has a table stating whether the product and its sub-assemblies contain any of the restricted materials. The table below is included to meet this requirement.

TABLE LISTING RESTRICTED SUBSTANCES /受限物质列表

Product SMC 4	**Toxic Hazardous Substances and Elements** 有害物质及元素

Part Name 部件名	**Description** 描述	**Pb** 铅	**Hg** 汞	**Cd** 镉	**Cr(VI)** 六价铬	**PBB** 多溴联苯	**PBDE** 多溴联苯醚
59-CBD1200	DISPLAY PCB 显示电路板	X	O	X	O	O	X
59-CPD0500	STEPPER DISPLAY PCB 步进器显示板	X	O	X	O	O	X
59-CPJ0200	REAR PANEL 后面板	O	O	O	X	O	O
59-CPJ0300	HEATSINK ASSEMBLY 热浴部件	X	O	X	X	O	X
59-CPJ0700	TX MTG ASSY TX MTG 部件	X	O	X	X	O	O
59-CQR1400	REAR PANEL 后面板	O	O	O	X	O	O

Key: X = substance present （含此物质）
O = substance NOT present （不含此物质）

Rest of World

There are currently no other countries or communities mandating compliance with any RoHS legislation.