CONTENTS

1 SAFETY

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

1.1 Protective Ground

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

1.2 Repair and Adjustment

Ensure that the instrument is disconnected from the AC power supply (switching off the front panel POWER switch is not sufficient) before the covers are removed or fuses are replaced, otherwise dangerous voltages are accessible. 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.

2 INTRODUCTION

2.1 Use of this Manual

This manual provides operating and service information for the Oxford Instruments Intelligent Temperature Controller model ITC4.

Sections 1-4 provide essential information and should be read before operating the instrument for the first time.

The remainder of the manual provides more detail on specific aspects and may be referred to as required. Section 16 attempts to identify some of the more common operating pitfalls and may be useful if problems are encountered.

ITC4 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 ITC4 **firmware.** The firmware is coded with a two part number (e.g. 2.04) where the first digit indicates a major version of the firmware and the second two digits cover minor revisions. This issue of the manual has been prepared to coincide with the introduction of Version 2 firmware. A small number of features of Version 2 are either not available on Version 1, or behave differently. These differences are described at the appropriate place in the manual.

2.2 Description of ITC4

ITC4 is a general purpose laboratory temperature controller, with a number of features specifically intended for use in cryogenic applications. In its most common application ITC4 will be used to control the temperature of some "sample", the properties of which are being investigated as a function of temperature. The sample will have a sensor monitoring its temperature, and a heater and/or some means of cooling, whereby its temperature may be varied. The whole will normally be surrounded by some form of thermal insulation to isolate the sample from its environment. In this manual the term "sample" will be used to refer to any object being controlled and the term "system" will be used to refer to the complete assembly.

The basic ITC4 includes a single input channel for one sensor. A further two independant input channels may be added for systems with more than one sensor.

For use in cryogenic applications ITC4 can accept a wide range of different temperature sensors and can provide up to 80W of heating power. In addition it contains internal logic to drive a motorised valve as a means of controlling sample cooling in a continuous flow cryostat.

ITC4 displays the sample temperature on a four and one half digit display, covering a range of up to -19999 to +19999.

Manual operation of the controller is by means of front panel push buttons and associated status lamps.

Remote computer control and monitoring is by means of a built-in RS232 interface.

The controller incorporates a number of safety features to prevent damage to the system if a fault should occur in the sensor or the controller itself. Where three sensors are fitted, all are continuously monitored for overtemperature, irrespective of which sensor(s) are selected for control and display.

Sensor calibration data and many of the controller operating parameters are held in a non-volatile memory, which is retained when the controller is switched off.

3 INSTALLATION

3.1 Supply Connection

Before applying power to the instrument, ensure that the voltage selector on the rear panel is correctly set for the intended supply 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:

100-120v	1.6A Type T (Slow Blow)
200-240v	0.8A Type T (Slow Blow)

3.2 Heater and Sensor Connections

Connections to the heater and sensor are by means of a 9 way D-socket on the rear panel. Where more than one input channel is fitted, separate connectors are used for each channel. The pin connections are the same for each channel and the heater connections are brought out in parallel on each channel.

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 Source +ve
5 Current Source -ve
6 Heater Output +ve
7 Heater Output -ve
8 Input Low for Thermocouples with RT Ref. Junction
9 Chassis Ground

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

	Thermo-couple	Metal Resistor	Ge/Carbon Resistor	Si/GaAs Diode
Input High	V+	V+	V-	V-
Input Low	V-	V-	V+	V+
Current +ve	n/c	I+	I+	I+
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 the room temperature compensating sensor is mounted at the rear panel of ITC4. 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 ITC4 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 RT sensor, positioned immediately to its right.

The Input connections are electrically isolated from the controller ground and the chassis ground. The Heater Output connections are electrically isolated from the input ground, the controller ground and from the chassis ground.

Where more than one input channel is fitted there is also electrical isolation between separate input channels.

3.3 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.

Pin connections at this socket are:

2	Received Data (From Computer)
3	Transmitted Data (To Computer)
4	Linked to 5
5	Linked to 4
6	+5V when ITC4 is powered up
7	Signal Ground
8	+5V when ITC4 is powered up

All other pins are open circuit.

Voltage levels for the transmitted and received data are:

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

Data protocols are:

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

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

3.4 Auxiliary Port Connections

The auxiliary port serves four separate functions.

1)It provides a stepper motor drive and sense input for use with an automatic gas flow control accessory (AutoGFS).

2)It provides an over-ride input to disable the heater output. This is intended for use with a separate over-temperature cut-out switch and displays the message "Hot 0".

3)It provides a pseudo-analogue output for use with a chart recorder. (An external passive filter is required).

4)It provides drive signals to one or more external heater select relays for systems with more than one heater. (Applies from firmware Version 2.03 onwards).

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 500mA from a supply of up to 25 volts maximum. When driving an inductive load, it is recommended that a diode is connected across the load to absorb the stored energy.

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

Heater-2 select relay is energised when controlling on Sensor 2. Heater-3 select relay is energised when controlling on Sensor 3. Neither relay is energised when controlling on Sensor 1. (Applies only to firmware Vesrion 2.03 onwards).

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

The AutoGFS sense input on K5, should be linked to +5v when an AutoGFS is connected. (Applies to firmware from Version 2.01 onwards)

If a thermal shut down device is connected to socket K7, it should be connected such that an overtemperature will pull the pin above 2.5 volts. The internal 100K resistor may be shunted by an external resistor, if required to match a sensor characteristic.

Pin connections at this 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	(Heater-2 Select Relay)
11	Output Bit 5	(Heater-3 Select Relay)
4	Output Bit 6	(Spare)
12	Output Bit 7	(Pseudo-Analogue o/p)
5	Input K4	(Auto GFS Sense)
13	Input K5	(Spare)
6	Input K6	(Spare)
14	Input K7	("Hot 0" Shutdown)
7	+5v	
15	Driver Protection / +11v unregulated.	
8	0v	

3.5 Analogue Output

The pseudo-analogue output on pin 12 of the auxiliary port is intended to drive a chart recorder for trend monitoring. The pin is alternately pulled to 0v and released with a time dependant waveform, the mean value of which represents the analogue output. To use the output, a pull-up resistor should be fitted to a suitable reference voltage (not greater than 25V) followed by a passive low pass filter +5 volts. A passive filter with a cut-off frequency of about 1Hz should be connected between this pin and the chart recorder input. A Recorder Output Lead, including a pull-up to +5V and a 2 stage passive filter, is available as an optional accessory if required.

The analogue output always indicates the value currently shown on the front panel display. Thus the DISPLAY SENSOR button may be used to select any sensor for trend monitoring.

3.6 IEEE-488 Interface

For use on the General Purpose Interface Bus. (GPIB, HPIB or IEEE-488) an IEEE-488 to RS232 conversion unit is available. This locates externally and is linked by a cable to the RS232 socket on ITC4. It requires a separate mains power supply. Operating instructions are supplied with this unit.

3.7 Room Temperature Thermocouple Reference

All thermocouples have at least two active junctions. The MEASURING junction is held at the temperature being measured whilst the REFERENCE junction is held at some known temperature. For some applications it is convenient to allow the reference junction to vary with room temperature (RT Reference). A separate sensor then monitors room temperature close to the reference junction and compensates for the effect of room temperature fluctuations. (RT Compensation).

For the highest precision work a fixed reference junction temperature is always preferable. However in many applications the convenience of an RT reference outweighs the slight loss of accuracy. In general, RT compensation is suitable for high temperature applications but **not recommended for cryogenic work.** There are three reasons for this:

i) Thermocouple sensitivity tends to fall at low temperatures so a small RT error will cause a larger low temperature error.

ii) A given temperature error (in degrees) is more likely to be significant at low temperature than at high temperature.

iii) The actual thermocouple wires must be taken all the way from the cryostat to the controller, since no compensating cable (see below) is available for common cryogenic thermocouples.

3.8 Use of RT Reference with Channel 1

The essence of accurate RT compensation is to keep the reference junction and the compensating sensor at the same temperature. ITC4 incorporates an RT sensor on the rear panel close to the SENSOR 1 connector. Thus the reference junction is assumed to be made at the connector. This is achieved by bringing the actual thermocouple wires back to the connector. Alternatively, a suitable thermocouple COMPENSATING CABLE may be used. This is cable having a thermal EMF which matches the thermal EMF of the actual thermocouple over a limited temperature range around room temperature. Its advantages are that it is less fragile than the thermocouple wire and unlike many thermocouples, need not be made from precious metals.

The ITC4 RT sensor is normally set to provide a 39uV/degree compensation, which is correct for Chromel/Alumel and Copper/Constantan thermocouples. Other values of compensation may be obtained by changing the value of R156 on the input PCB. (Value in Ohms equals uV/degree).

For use with RT compensation the sensor connections are made to pins 1 and 8, as given in section 3.2. For best results, the connector and the RT sensor should be enclosed within a draught shield.

When RT compensation is in use, the switch settings for SW1 and SW2 on the input card, will differ from settings for the same thermocouple with a fixed reference junction temperature. Section 11.2 lists the settings for a number of common configurations.

3.9 Use of RT Reference with Channels 2 & 3

ITC4 does not have a separate RT sensor for channels 2 & 3 (where fitted). Where RT compensation is required on only one channel of a multi channel instrument, Channel 1 should be employed for this purpose.

Where RT compensation is required on more than one channel, the Channel 1 RT sensor is employed for all channels. This is achieved by linking pin 2 on the SENSOR 1 connector to pin 2 on the SENSOR connector for any other channels requiring compensation. The -ve connections for all thermocouples are then linked to pin 8 of the SENSOR 1 connector, whilst the +ve connections are taken to pin 1 of the individual SENSOR connectors as usual. For best results all three connectors and the RT sensor should be within a single draught shield.

Different Switch settings for SW1 and SW2 as described above, will apply on all channels where RT compensation is used.

HEATER

The normal way in which ITC4 effects its control, is by applying power to a heater. In MANUAL control the heater voltage may be varied by RAISE and LOWER. In AUTOMATIC control the heater voltage is varied in response to the difference between a measured temperature and a set-point.

Where more than one sensor is fitted, the SENSOR button may be used to select which sensor is to be used for control. To avoid an inadvertant change of sensor whilst ITC4 is controlling, the SENSOR button will only operate whilst the heater is in MANUAL. (and in LOCAL control).

In general, sensors mounted on different parts of an apparatus are likely to be at different temperatures. Hence when switching between control sensors, a change in set point will be required. ITC4 performs this change automatically. Where control has been established on one sensor, the optimum set point for the new sensor is the prevailing temperature for that sensor at the point of switch over. This is the set point that ITC4 selects.

Pressing AUTO or MAN switches between the MANUAL and AUTOMATIC states. In either case, whilst the button is pressed the main display gives an approximate indication of the output voltage. (N.B. This is not a calibrated parameter. If a particular requirement needs an accurate value for the heater voltage, a meter should be connected to the heater leads). When ITC4 is in REMOTE control, switching between AUTO and MANUAL is disabled, but it is still possible to use the buttons to display the output voltage.

A 10 segment bar-graph is provided to give a continuous indication of heater operation, whilst the main display is showing temperature.

When the maximum heater voltage has been limited (see section 5), the main display will indicate the actual output voltage whilst AUTO and MAN are pressed. The bar-graph display will automatically be scaled so that an output on the limit will light all 10 bars.

GAS FLOW

Two buttons, with associated lamps, allow AUTOMATIC or MANUAL control of gas flow to be selected. These are provided for use with an automatic gas flow controller accessory (AutoGFS). They may be used to vary the flow of refrigerant in the same way that the heater controls are used to vary the heating power. If an AutoGFS accessory is fitted, the GAS MAN lamp will flash for a time after switch-on, whilst the controller establishes a reference position for the needle valve. During this time the Gas Flow Buttons will be disabled.

4 LOCAL OPERATION

4.1 Front Panel Controls

The front panel controls are grouped together in logically related blocks.

POWER

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

ADJUST

The red RAISE and LOWER buttons provide the main means of adjusting any parameter. They have no effect on their own but are always used in conjunction with one of the other buttons. Whenever a parameter is being adjusted, its current value is shown on the main display. Setting a value involves pressing RAISE and/or LOWER until the required value is shown.

Operation of the RAISE and LOWER controls has been designed to allow large changes to be made relatively quickly whilst at the same time enabling any value to be set exactly. Pressing RAISE or LOWER briefly will cause the value to change by one unit. If the button is held in, the last figure will start to change at about 5 units per second. After 2 seconds, an approximately 10-fold increase in rate will occur, followed after another 2 seconds by a further rate increase and so on. Altogether there are 4 different rates. Whenever RAISE or LOWER is released, the next lower speed will be selected. This allows the user to "home-in" on the required value most ergonomically.

CONTROL

Control of the instrument may either be LOCAL from the front panel, or REMOTE via the RS232 interface. The LOC/REM button may be used to switch between LOCAL and REMOTE.

When LOCK is lit, the instrument is locked into either local or remote control and the LOC/REM button has no effect. At power up, ITC4 is locked in LOCAL, since at that time the instrument has no way of knowing if there is a computer connected to the RS232 interface.

When ITC4 is in REMOTE, many of the front panel controls are inoperative. Those controls which only affect the display, will still work but those which could change the operation of the instrument are disabled.

SWEEP

The ITC4 incorporates a programmable sweep facility. This is controlled by a single RUN/PROGRAM button with three lamps. It is described in detail in section 6.

DISPLAY

The main display normally indicates the measured temperature. Where more than one input channel is fitted, the SENSOR button may be used to switch between input sensors. This affects only the displayed temperature, and so remains operational even in REMOTE control. Whilst the button is pressed, the display switches to indicate the range code for the sensor being selected. This merely serves as a reminder of which sensor has been associated with which channel.

Pressing the SET button switches the display to indicate the set temperature. Provided the controller is in LOCAL, the RAISE and LOWER buttons may be used to adjust the set point.

Similarly, pressing the PROP, INT and DERVI buttons allows the value of the corresponding control terms to be displayed and modified.

The display block includes two additional buttons LIMIT and CAL. These are rarely used controls and are recessed behind the front panel to prevent inadvertent operation. They may be operated using a pointed object, such as the point of a pencil. Their operation is described in sections 5 and 7 respectively.

4.2 First Time Operation

Switch on the instrument by means of the POWER switch. Check that the green POWER lamp lights.

After about one second the word "PASS" will appear on the display. This indicates that the ITC4 has completed its self test and initialisation.

After a further pause the internal SAFETY RELAY will will close. This links the heater to the controller output. At the same time, the display will show the measured temperature for Channel 1.

If an AutoGFS accessory is fitted, the GAS MAN lamp may continue to flash for several minutes whilst the needle valve is reset. During this period, Gas Flow control is disabled, but all other functions operate normally. (Firmware Version 2.01 onwards).

The ITC4 will now be under LOCAL control from the front panel, with the HEATER and GAS FLOW in MANUAL and the heater voltage at zero.

4.3 Sensor Selection

Pressing the DISPLAY SENSOR button will cycle the display round the three possible input sensors. (If only one channel is fitted the display will still switch between channels but will not give a meaningful reading for sensors 2 and 3.

Similarly the HEATER SENSOR button may be used to select which of the three sensors is to be used for automatic control. This button is disabled unless ITC4 is in LOCAL and the heater is set to MANUAL. When changing control sensors ITC4 will automatically reset the SET temperature as described in section 4.1 under HEATER. If a Heater Select relay accessory is fitted, the appropriate heater will be selected as the control sensor is changed

4.4 Setting a Desired Temperature

Press the SET button to display the desired temperature. Whilst holding SET pressed, RAISE and LOWER may be used to change the set point.

The range of adjustment is normally determined by the full range of the sensor in use. However a set point limit may be applied if required (see section 5.3). After setting the required value, release SET then press it again. If the value set was above the limit, ITC4 will have automatically reduced it to the limit.

When in REMOTE control, the SET button may still be used to display the set point, but this cannot be adjusted by means of RAISE and LOWER.

4.5 Manual Heater Control

Press the Heater MAN button to select manual heater control. Whilst the button is pressed the display will indicate the approximate output voltage. (Note that this is an uncalibrated parameter and will vary to some extent with the heater loading).

Whilst MAN is pressed, the output voltage may be varied by means of RAISE and LOWER.

If the controller is in REMOTE it will not be possible to switch from AUTO to MANUAL from the front panel. However if the controller is already in MANUAL, pressing MAN will allow the output voltage to be displayed, though RAISE and LOWER will have no effect.

ITC4 incorporates "bumpless" AUTO to MANUAL and MANUAL to AUTO transitions. This means that if the the controller is operating in AUTO and is switched to MANUAL the heater voltage is held constant at its existing value. Similarly if the controller is operating in MANUAL with the measured temperature equal to the set point and is switched to AUTO, the heater voltage will remain unchanged. (If the measured temperature is not at the set point, the heater voltage will of course change when switched to AUTO as the controller attempts to bring the temperature to the set point).

4.6 Automatic Heater Control

Press the Heater AUTO button to select automatic heater control. As for manual control, whilst the button is pressed the display will indicate the approximate output voltage. The heater output will be varied by the controller such that the measured temperature is brought towards the set point.

When in REMOTE, switching from MANUAL to AUTO is prevented, but pressing AUTO whilst the controller is in AUTO will allow the output voltage to be displayed.

4.7 Setting P, I & D Control Terms

The control terms may be displayed and set by means of the PROP, INT and DERIV buttons.

PROP indicates the PROPORTIONAL BAND as a percentage of the input span, covering a range of 0 to 199.9% in steps of 0.1%.

INT indicates the INTEGRAL ACTION TIME in minutes, covering a range of 0 to 140 minutes in steps of 0.1 minute.

DERIV indicates the DERIVATIVE ACTION TIME in minutes, covering a range of 0 to 273 minutes (Though values beyond 70 minutes are unlikely to be required in practice.).

RAISE and LOWER may be used to vary the control terms whilst in LOCAL control. Once a set of values has been chosen, they will be retained in the ITC4's non-volatile memory and will not need resetting at switch on.

The P, I and D terms cover a large range of values to cover systems ranging from a small laboratory cryostat to a large furnace. For most laboratory applications a PROPORTIONAL BAND of 2 to 20% will be appropriate, with an INTEGRAL TIME of 1 to 10 minutes.

The main purpose of DERIVATIVE action is to reduce overshoot, when approaching a new set temperature. For many small systems derivative action will not be required and may be left at zero. (Hold LOWER pressed for a second after 0.000 is displayed to ensure that there is not a small residual setting of less than 0.05 mins which will show as zero)

The PROP and INT controls should not normally be set to zero, since this would correspond to ON/OFF control (See section 14).

Section 14 covers the theory behind P,I,D control. However the following procedure gives a good rule-of-thumb for setting the controls to a value that is close to optimum.

1. Set INT for a time much longer than the expected response time of the system.

2. Set DERIV to zero.

3. Select AUTO and reduce PROP until the temperature starts to oscillate above and below some mean value (not necessarily the set point).

4. Time the period of oscillation. This is a measure of the response time of the system.

5. Set INT to a value approxiately equal to the response time and increase the PROP setting to a point where oscillation just ceases, then double this value. This gives a good starting point for THE PROP and INT control terms.

6. Test how the system responds to step changes in the SET point and modify the PROP and INT settings for a reasonably fast response without excessive overshoot.

7. If overshoot remains a problem following a large step change in SET, try the effect of adding some DERIVITAVE action. A good initial setting is half to one third of the system response time measured above. This will probably require PROP to be re-optimised for best results.

8. When optimisng P, I and D the aim should be to achieve the lowest values of all three terms, consistent with no oscillation and an acceptably small amount of overshoot. This will give the fastest response for the system.

When adjusting the control terms remember that <u>reducing</u> the PROPORTIONAL BAND <u>increases</u> the controller gain. This can cause some confusion when the concept of PID control is first encountered.

4.8 Gas Flow Control (Requires AutoGFS and Version 2 firmware)

The AutoGFS accessory allows ITC4 to control a needle valve, regulating the flow of cryogen used to cool a sample. With an AutoGFS connected, the GAS FLOW MAN lamp will flash following switch-on and the controller will drive the valve towards its closed position for approximately 4.5 minutes. This ensures that the valve is fully closed (A slipping clutch operates when the closed position is reached.) During this period the HEATER controls may be operated normally, but the GAS FLOW controls will be inhibited.

Once the closed position has been established, the GAS FLOW controls may be used to control the valve, in much the same way as the HEATER controls are used. When either Gas Flow AUTO or MAN is pressed, the display will show the current position of the valve, as a percentage of fully open. Operating RAISE and LOWER in conjunction with MAN will allow any valve position to be set. Note that since the new value can be set faster than the valve can follow, the valve will continue to drive after MAN is released, until the selected position is achieved. If MAN is pressed again during this process, the display will show the position the valve has currently reached and it will stop driving at this point. If further valve motion is required, RAISE or LOWER should again be used to specify a new target setting.

Automatic gas flow control may be selected by pressing Gas AUTO. Automatic Gas flow may be used either on its own at a fixed heater setting, or more ususally in conjunction with automatic heater control. (Since the control response to the gas flow regulator is much slower than that to the heater, it is normally possible to achieve a more stable control with the heater and gas flow both under automatic control).

The values of the PROP, INT and DERIV settings required for best control will not necessarily be the same for automatic gas control as for automatic heater control. Having decided upon the control mode required, the PID values should be optimised as described in section 4.7 of the ITC4 manual.

When automatic gas control is used on its own, ITC4 attempts to control at the desired set temperature in the usual way. When automatic gas flow is used in conjunction with automatic heater control, the latter takes over responsibility of achieving the desired temperature, whilst the gas flow control attempts to maintain a specific target heater power. This target heater power is itself a preset function of the set temperature, and has been chosen to give the best balance between control stability and cryogen usage.

5 LIMITS

Limits may be placed on a number of the controller parameters, either as a means of improving control performance, or to ensure the safety of the system being controlled.

5.1 Limiting Maximum Heater Output

The normal full output of the controller is 40v which is capable of delivering up to 80W into a 20 ohm load. When controlling, it is generally desirable to achieve an approximate balance between heating and cooling such that the rate at which the temperature rises with the heater full-on is approximately the same as the rate at which it falls with the heater off. At low temperatures this can be achieved by means of a limit on the heater voltage. Once set, the limit cannot be exceeded in either AUTO or MAN.

To set a heater power limit, first ensure that the controller is in LOCAL and is switched to MAN, preferably with the heater volts set to zero. Press the recessed LIMIT button and hold it pressed. Now press the heater MAN button and release it. The display will switch to show the heater limit in volts (approximate value). RAISE and LOWER may then be used to adjust this, whilst LIMIT remains pressed.

A special case exists where the value of the limit is set to zero. In this case the controller will dynamically vary the limit on the basis of the selected set point. Thus a higher limit will be provided at higher temperatures and a reasonably constant balance between heating and cooling should be possible over the whole range.

5.2 Limiting Sensor Temperatures

A limiting value may be placed on the measured temperature. Where more than one sensor is in use, separate limits may be placed on each. All the sensors will be continuously checked against their respective limits, irrespective of which sensor is used for display or control.

The limits are set in the same way as that for output power described above. First use the DISPLAY SENSOR button to select the sensor whose limit is to be set. Press LIMIT and hold it pressed, then briefly press and release the DISPLAY SENSOR button, to indicate that a display sensor is to be adjusted. The current limiting value will be displayed and RAISE and LOWER may be used as usual to modify it. The same sequence may be repeated for each of the other sensors.

The limits should normally be set a little above the maximum operating temperature for the system.

If any limit is exceeded the ITC4 will immediately display one of the messages:

Hot 1 Hot 2 Hot 3

indicating which sensor has detected the over-temperature. At the same time the heater output voltage will be set to zero. If this causes the temperature to fall below the limit, the message will clear and normal operation will resume. If the heater is in AUTO, heater voltage will be reapplied as necessary to achieve the SET temperature. (In MAN, the heater voltage will remain at zero until a new value is selected).

If after 10 seconds the temperature is still above the limit, ITC4 will assume that a fault may have occurred in the heater circuit. It will therefore open its output safety relay, completely isolating the heater from the controller output. If this occurs the display will remain latched in the "Hot n" state, even after the system has cooled. To restore normal operation, it will be necessary to switch ITC4 off and on again.

By setting a wrong limit, it is possible to end up in a situation where the "Hot n" message is displayed from switch-on. If this occurs, refer to section 16.

5.3 Limiting Set Temperature

The Set Temperature, is automatically limited to the Sensor Limit described above, for the control sensor in use. It is possible to place an additional **temporary** limit (below the Sensor limit) on the set temperature. However this limit will be automatically cleared whenever the Control Sensor is changed, and will also be cleared at power up.

To set this limit, the SET button is pressed briefly whilst holding LIMIT. Then RAISE and LOWER are used as above.

5.4 System Over-Temperature Shutdown

An external over-temperature limit may be connected to the AUXILIARY socket, as described in section 3.4. If this device detects an over-temperature the message:

Hot 0

will be displayed. The same protocol applies. If the condition disappears within 10 seconds, normal operation will resume. If it does not, the safety relay will open and the instrument will remain latched in the "Hot 0" state.

6 SWEEP

6.1 Purpose of Sweep

The sweep facility allows the set point to be programmed to follow a fixed temperature/time profile. The profile consists of a series of constant temperature steps joined by linear ramps.

A program may consist of up to 16 ramps and 16 steps. Each ramp and step may last for a period programmable from 0.1 minute to 24 hours. Once programmed, the same sequence may be repeated as often as required and is retained in non-volatile memory when ITC4 is switched off.

The sweep is controlled from the front panel by a single RUN/PROGRAM button, operable only in LOCAL control.

6.2 Starting a Sweep

Press the RUN/PROGRAM button and release. The display will show

run

whilst the button is pressed and providing a program is present, the SWEEP lamp will light when the button is released. The set point will start to ramp towards the value selected for the first program step. When the first sweep time is complete, the temperature will have reached its programmed set point. The SWEEP lamp will go out and the HOLD lamp will light. This sequence will be repeated for each of the programmed steps. After the 16th step has been completed, both lights will go out and the controller will be left with the set point equal to that of the 16th step. Any steps with sweep and hold times set to zero will be bypassed. (If neither SWEEP nor HOLD lamp lights when RUN/PROGRAM is released, it means that all 16 steps have zero for both sweep time and hold time.)

Remember that the sweep facility programs the ITC4 set point. The measured temperature will tend to lag behind the set point by an amount dependant upon the response time of the system. Remember also that ITC4 must be set to AUTO if the actual temperature is to be varied!

6.3 Monitoring the Progress of a Sweep

At any time during a sweep, the HOLD and SWEEP lamps will indicate whether the set point is being ramped or held.

The SET button may be pressed at any time to indicate the current value of the set point.

If RUN/PROGRAM is pressed briefly, whilst the sweep is running, the display will indicate:

P nn

where nn is the current program step number in the range 1 to 16.

* WARNING *

Do not hold RUN/PROGRAM too long, or the sweep will be terminated, see below.

6.4 Stopping a Sweep

If left uninterrupted, a sweep program will continue till all steps have been completed. If required it can be terminated before it is complete by pressing RUN/PROGRAM, and holding it until the display changes to:

End

The sweep program will be aborted and the set point will be left at the value it had reached when the sweep was terminated.

6.5 Programming the Sweep

A Sweep Program may be entered from the front panel, starting with the controller in LOCAL. The method is as follows:

Press RUN/PROGRAM and hold it in.

Wait till the display changes from "run" to "Pro", then release the button. ITC4 is now in the program mode and the display will indicate

P 01

showing that the first program step is to be examined. (If you wait too long with the "P 01" display, ITC4 will automatically leave the program mode and resume normal operation.)

Press and hold RUN/PROGRAM and the PROGRAM lamp will light and the programmed set point for the first step will be displayed. It may be adjusted if required, in the usual way, by means of RAISE and LOWER.

Release RUN/PROGRAM and press it again. SWEEP will now light, and the sweep time taken by the controller to reach this programmed set point, will be displayed. The time is displayed in minutes with a resolution of 0.1 minute (6 seconds). RAISE and LOWER allow this to be adjusted between zero and 1440.0 minutes (24 hours).

Note that for the first step, this will be the time taken to sweep to the first set point from the set temperature when the program run commences. Thus the actual sweep rate will be recomputed for each run.

Releasing RUN/PROGRAM and pressing it again will cause HOLD to light and will display the hold time at the first temperature, again in minutes. After this has been set, RUN/PROGRAM may be released and the display will again show "P 01". If any of the settings require further modification, the sequence can be repeated as often as desired.

If RAISE is pressed whilst "P 01" is displayed, the display will change to "P 02". The same sequence may then be followed to set the programmed temperature and sweep and hold times for this step.

All 16 steps may be programmed in the same way. It is not necessary to examine or program the steps in any order. Once the "P nn" display is shown, RAISE and LOWER may be used to select any step. The display rolls round from 16 to 1, so that pressing LOWER when "P 01" is displayed gives a quick way of getting to "P 16".

Where a program of less than the full 16 steps is required, the SWEEP and HOLD times for all the unused steps should be set to zero. When the program is run, ITC4 will automatically bypass these steps.

The programmed temperature of step "P 16" has a special significance. This is the temperature at which the set point will remain when the sweep is completed and should be set accordingly.

To escape from the sweep programming mode, simply leave the controller with no buttons pressed and "P nn" displayed. After about 5 seconds, ITC4 will switch back to a normal operating mode and display the measured temperature.

N.B. To achieve maximum accuracy, the sweep temperature steps are held internally as a fraction of the full temperature range of the control sensor in use. Thus if an ITC4 has more than one sensor, covering different ranges, the intended control sensor should be selected before the sweep is programmed. If a different control sensor is selected after programming and the sweep parameters are inspected, all the temperatures will be found to have changed. However restoring the original control sensor will also restore the original sweep parameters.

7. CALIBRATION

7.1 Sensor Calibration

To match ITC4 to the exact characteristics of a specific sensor a calibration must be carried out at the two ends of the working range. This is achieved by means of the recessed CAL button.

Use DISPLAY SENSOR to select the sensor to be calibrated.

Cool the sensor to a known temperature as near to the bottom of the range as possible, or apply an equivalent input from a calibrator.

Press CAL and whilst holding it pressed, use RAISE and LOWER to set the correct temperature reading. ITC4 will update the "ZERO" value stored in its non-volatile memory.

Change to a temperature or calibrator input near the top of the range and repeat the process. ITC4 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.

ITC4 automatically decides whether to calibrate ZERO or SPAN depending on whether the input is in the lower or upper half of its range.

8. REMOTE OPERATION

8.1 Introduction

ITC4 may be remotely operated by means of its RS232 interface. This allows a computer to interrogate the instrument and if required, to take control of it.

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

8.2 Communication Protocols

All dialogue with ITC4 is in 9600 baud serial form.

Data sent by ITC4 is in the form of 1 start bit, 8 data bits and 2 stop bits.

Data sent by ITC4 during normal operation has the 8th (parity) bit always set to zero. When receiving normal data, ITC4 ignores the parity bit. (In the "Y" and "Z" diagnostic commands, all 8 bits are used for data).

All commands consist of a string of printing ASCII characters, terminated by a Carriage Return character. A Line Feed character may optionally be sent after the Carriage Return but is ignored by ITC4.

Unless the command starts with a "$" (dollar) character, all commands will evoke a response from ITC4. The response will consist of a string of one or more printing ASCII characters and will be terminated by a Carriage Return Character. This may optionally be followed by a Line Feed character.

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

If the first character of a command is a "$", the command will be obeyed but no response will be sent. (See section 8.4).

None of the RS232 Modem control lines are required by ITC4, though signals are returned on some of the more common ones for maximum compatibility with other equipment.

ITC4 will accept a command string at all times. If a computer is unable to accept data from ITC4 at the full rate of the 9600 baud interface, the "W" command may be used to instruct ITC4 to send more slowly.

8.3 Commands and Responses

Commands to ITC4 all consist of a single upper-case letter, optionally followed by a numeric parameter, the whole being terminated by a Carriage Return. The response sent by ITC4 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 ITC4 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 ITC4 is in LOCAL control. If in doubt, the "X" command may be used to determine the current status.

8.4 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 preceeded by a "#" (hash) symbol. Numbers outside this range will give an error.

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

Thus to set a temperature of 20.0 the preferred command form is:

T200

The alternative:

T20.0

would be accepted and correctly obeyed, but the alternative:

T20

would result in a set temperature 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 ITC4 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.

8.5 Use with OXFORD ISOBUS

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

To allow separate instruments to be distinguished, each is allocated a unique address in the range 1 to 8. Depending on the instrument this may be set up in hardware, or held in non-volatile memory. In the case of ITC4 the latter option is used.

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

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

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

@n (At) addresses the command to instrument number n, where n is a digit in the range 1 to 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. ITC4 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 relevent 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 inadvertantly changing addresses, the "!" command will only be obeyed following a "U" command with a non-zero password. (See section 9).

9. COMMAND LIST

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

Commands fall into 3 categories:

MONITOR COMMANDS which are always recognised.

CONTROL COMMANDS which are only recognised when in REMOTE control.

SYSTEM COMMANDS which are only recognised after receipt of the correct "UNLOCK KEY".

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

MONITOR COMMANDS (always recognised)

Cn	SET CONTROL LOCAL/REMOTE/LOCK
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 REMOTE)

An	SET AUTO/MAN FOR HEATER & GAS
Dnnnn	SET DERIVATIVE ACTION TIME
Fn	SET TO DISPLAY PARAMETER n
Gnnn	SET GAS FLOW (in MANUAL only)
Hn	SET SENSOR FOR HEATER CONTROL
Innnn	SET INTEGRAL ACTION TIME
Mnnn	SET MAXIMIUM HEATER VOLTS LIMIT
Onnn	SET OUTPUT VOLTS (in MANUAL only)
Pnnnn	SET PROPORTIONAL BAND
Sn	START/STOP SWEEP
Tnnnnn	SET DESIRED TEMPERATURE

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 8.5)

10. COMMAND SYNTAX

Cn COMMAND

The control command sets ITC4 into LOCAL or REMOTE and determines whether the LOC/REM button is LOCKED or active. At power up ITC4 defaults to the C0 state. Allowed values are:

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

Qn COMMAND

Defines the communication protocol.

Currently only 2 values of n are significant:

Q0	"Normal" (Default Value)
Q2	Sends <LF> after each <CR>

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 8.4. Allowed values for n are listed below. (R11 and above are intended as service diagnostics and are unlikely to be of use to the user).

R0	SET TEMPERATURE
R1	SENSOR 1 TEMPERATURE
R2	SENSOR 2 TEMPERATURE
R3	SENSOR 3 TEMPERATURE
R4	TEMPERATURE ERROR (as % of sensor span)
R5	HEATER O/P (as % of current limit)
R6	HEATER O/P (as Volts, approx.)
R7	GAS FLOW O/P (arbitrary units)
R8	PROPORTIONAL BAND
R9	INTEGRAL ACTION TIME
R10	DERIVATIVE ACTION TIME
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 non-volatile memory. The U command must be followed by the correct KEY parameter before these "dangerous" commands may be used. The value of the KEY is given in section 12.7 of this manual. The whole of section 12 should be read before any attempt is made to use the key!

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

U0	LOCKED (Power-up Default)
U1	"!" COMMAND UNLOCKED
Unnnnn	"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 <u>before</u> each character is sent from ITC4 via the serial interface. This allows ITC4 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.

(N.B. the W command does not reduce the rate at which ITC4 can accept data from computer.)

X COMMAND

The EXAMINE command allows the computer to read the current ITC4 STATUS. It requires no parameters and will return a message string of the form:

XnAnCnSnn

where the digits "n" have the following meaning:

Xn	SYSTEM STATUS	(Always zero currently)
An	AUTO/MAN STATUS	(n as for A COMMAND but see below)
Cn	LOC/REM/LOCK STATUS	(n as for C COMMAND)
Snn	SWEEP STATUS	(nn=0-32 as follows)
	nn=0	SWEEP NOT RUNNING
	nn=2P-1	SWEEPING to step P
	nn=2P	HOLDING at step P

On systems fitted with AutoGFS, the digit following "A" will be increased by 4, during the initial calibration period whilst the GAS MAN lamp is flashing.

An COMMAND

The AUTO/MANUAL command allows the heater and gas flow control functions to be set to AUTO or MANUAL. Allowed values are:

A0	HEATER MANUAL,	GAS MANUAL
A1	HEATER AUTO,	GAS MANUAL
A2	HEATER MANUAL,	GAS AUTO
A3	HEATER AUTO,	GAS AUTO

N.B. "MANUAL" in the context of REMOTE control means that the HEATER or GAS FLOW may be set directly by an "O" or "G" computer command.

"A2" and "A3" commands will not be accepted during the initial AutoGFS calibration phase, whilst GAS MAN is flashing.

Pnnnn, Innnn & Dnnnn COMMANDS

Set PROPORTIONAL, INTEGRAL and DERIVATIVE control terms. The values taken by n correspond to those given in section 4.7.

Fn COMMAND

The FRONT PANEL DISPLAY command sets the display to show one of the internal parameters rather than the normal measured temperature. Normal display operation may be restored by pressing the 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

Sets the GAS FLOW to a defined value nnn. (For use with AutoGFS). The "G" command will not be accepted during the initial AutoGFS calibration phase, whilst GAS MAN is flashing.

Hn COMMAND

The HEATER SENSOR command defines the sensor to be used for automatic control. n may take the values 1-3 corresponding to the three input channels.

Mnnn COMMAND

The MAXIMUM HEATER command sets the maximum heater voltage that ITC4 may deliver, under automatic control or in response to an "O" command. This performs the same function as the Output Limit described in section 5.1. nnn is specified in units of 0.1 volt, and is approximate.

"M0" may be used to specify a dynamically varying limit as described in section 5.1.

Onnn COMMAND

Sets the required heater output in MANUAL. The parameter nnn is expressed as a percentage of the maximum heater voltage set by the "M" command in units of 0.1%. Hence range of nnn is 0 to 999.

Sn COMMAND

The SWEEP command may be used to start and stop a sweep remotely.

S0	STOPS SWEEP
S1	STARTS SWEEP

Values of n from 2-32 may also be sent and have the effect of entering the sweep program part way through. The value of n has the same significance as for the S part of the status message (see above). Note however that if n is an odd number other than 1, the set point will immediately change to the programmed temperature for the preceeding step and start its sweep from there.

Tnnnnn COMMAND

The TEMPERATURE command sets a set point temperature. The parameter is the required temperature, sent as an integer in accordance with section 8.4.

Note that if a sweep is running, the temperature set by the T command will be over-ridden by the sweep.

Ln COMMAND

The LINEARISER LOAD command loads one of the three customisable non-volatile data tables with linearisation for a particular sensor. See section 12.

Y COMMAND

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

Z COMMAND

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

11. SENSOR RANGE CONFIGURATION

11.1 Introduction

Each sensor input channel of ITC4 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.

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:

ITC4 comes with data for many of the most commonly used ranges included in the program memory. A further 3 ranges may be accommodated as custom calibrations in the non-volatile memory. (Version 2 firmware allows space for many more standard ranges than version 1).

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. (This convention only applies from the introduction of version 2 firmware).

The table in section 11.2 shows range details for the standard ranges included within the program memory of Version 2.03 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 ITC4 will continue to indicate slightly outside this range.

The remainder of section 11 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.

11.2 Range Data

CODE	SENSOR	RANGE	Tref	SW1 (Rear Switch)	SW2 (Front Switch)
STANDARD RANGES				(See Note 1)	
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)		
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
RF 5	RhFe Resistor	1.5-500K	Curve-A	01111 11111	10010 10000
RF 51	RhFe Resistor	1.5-500K	Curve-B	01111 11111	10010 10000
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 3	Si Diode (OI)	2-300K		00010 00000	00110 11000
DS 31	Si Diode (LS)	2-300K		00000 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:

1. 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 (see section 12.5).

2. 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.

3. 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.

4. 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 4.2K resistance of 2 ohms or greater, whilst Curve B should be used for sensors with a 4.2K 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.

5. 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 73K is currently unspecified. (The data between 50K and 73K is based on BS1904:1964 rather than BS1904:1984).

11.3 Access to Configuration Controls

Configuring ITC4 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 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.

Where a second input board is fitted for 2/3 channel use, this will locate over the channel 1 board. The switches on the channel 1 board are placed at the edge of the board such that they remain accessable. 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. N.B. The full component references used on the PCB for SW1 are SW301, SW501 and SW401 for channels 1-3 respectively. Except when referring to a specific channel, the first digits are omitted here.

11.4 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 5 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.

SW2/7 selects a negative zero offset for supressed 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 is unused.

11.5 Linearisation Configuration

To select the correct software data table, proceed as follows.

Switch the instrument on and ensure that the DISPLAY SENSOR lamp is showing the channel which is to be configured. If necessary press SENSOR to change channels.

Now press the RED button SW1 on the main printed circuit board. The message

tESt

will appear followed shortly by:

t 00

Press LOWER and release, to display:

t 07

Then press 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 RAISE or 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 LOC/REM and the range will be configured. ITC4 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 7.

12. SENSOR RANGE DESIGN

12.1 Introduction

The preceding section described how to configure ITC4 to use a range already installed in either the program or non-volatile memories. This section describes how a range may be designed and loaded into one of the non-volatile memory tables. To load the data requires entering some 260 numbers, without error. It is strongly recommended that the numbers be prepared as a data table on a computer and loaded automatically. That way errors may be corrected without having to start again at the beginning.

Before installing a new range, check that the data table to be loaded is not already in use. Once new data is loaded, the old data will be irretrievably lost (See section 11.5).

12.2 Types of Sensor

The first stage in designing a range is to decide what type of sensor is to be used.

The various sensors may be divided into a number of classes on the basis of the input configuration they require.

Thermocouples act as voltage sources and their output voltage is measured.

Metallic Resistance Thermometers have a resistance which rises approximately linearly with temperature. ITC4 passes a constant current through the sensor and measures the voltage produced (4-wire resistance measurement).

Semiconductor Resistance Thermometers have a resistance which falls very non-linearly with temperature. By measuring the sensor conductance, a function is obtained which rises with increasing temperature and is more nearly linear. ITC4 achieves a 4-wire conductance measurement by controlling the sensor current in such a way that the voltage across the sensor is held constant. The sensor current is then measured to indicate temperature. Apart from providing a more linear measuring function, this method has the added advantage that sensor dissipation is automatically reduced as the temperature falls.

Semiconductor Diodes have a voltage which falls with rising temperature. ITC4 provides a constant current energisation for these, as for metallic resistance thermometers, but the connections to input high and low are reversed, so that input high still receives a voltage which rises with increasing temperature.

12.3 Selecting Input Configuration

Having decided upon the sensor type the input stage configuration may be determined and the settings for SW2/4 to SW2/9 established.

	SW2/4	SW2/5	SW2/6	SW2/7	SW2/8	SW2/9
THERMOCOUPLE	OFF	OFF	ON	(See Below)		OFF
METAL RESISTOR	ON	OFF	ON	ON	OFF	OFF
SEMI. RESISTOR	OFF	ON	OFF	ON	OFF	ON
SEMI. DIODE	ON	OFF	ON	ON	OFF	OFF

SW2/7 and SW2/8 set the polarity of the zero offset. For thermocouples the setting of these is determined by the relation between the bottom end of the range and the thermocouple reference junction temperature. Where the reference junction temperature is close to or above the bottom of the range, SW2/7 should be ON. Where it is substantially below the bottom of the range, SW2/8 should be ON.

Where a thermocouple range is intended for use with a compensated room temperature reference, SW2/8 should be ON.

12.4 Selecting Sensor Energisation

For resistance thermometers and diodes the preferred sensor energisation may be set by SW2/1 to SW2/3.

For Metal Resistors and Diodes, constant current energisation is used and the possible currents are:

	SW2/1	SW2/2	SW2/3
10 uA	OFF	OFF	ON
100 uA	OFF	ON	OFF
1 mA	ON	OFF	OFF

Note that these currents are nominal values and there will be up to 10% variation between instruments.

For semiconductor resistors, the current reduces with falling temperature. The current to select, is that which may flow at the highest operating temperature. This is determined by SW2/1 to SW2/3 in accordance with the table above.

12.5 Selecting Zero and Span

Remember that SW1/1-5 and 6-10 correspond to binary numbers defining the span and zero respectively, in a logarithmic sequence (Section 11.4). To set these it is necessary to be able to simulate the sensor input conditions whilst monitoring the voltage between TP3 and TP0 on the input board.

First establish a zero switch setting SW1/6-10 by trial and error, such that with an input corresponding to the bottom of the range, the voltage at TP3 is as close to zero as possible, whilst remaining positive. (Typically this will be around 0.5 volts).

Now change to an input for the top of the range, and set SW1/1-5 to achieve a voltage as close to 5 volts as possible, without exceeding 5.25 volts. (Typically 4.5 - 5.0 volts).

There will be some interaction between the two sets of switches and a second iteration may be found to be necessary.

12.6 Calculation of Linearisation Data

Take the raw sensor data; voltage, resistance or conductance as appropriate; and split it into 256 equal intervals. Work out the temperature for each point defining these intervals (257 points in all counting first and last).

Note the actual values of the first point T(0) and last point T(256). These will be needed shortly.

Now normalise the data such that the first point is zero and the last is 65535. If T(0) is the first and T(256) the last, each point T(i) may be normalised to give N(i) by:

$$N(i)=(T(i)-T(0))*65535/(T(256)-T(0))$$

Use T(0) and T(256) to calculate a display offset, and display gain:

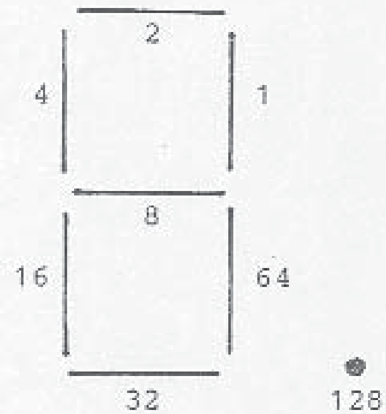
$$N(offs) = 32768 + T(0)$$
$$N(gain) = (T(256)-T(0))/2$$

N.B. T(0) and T(256) should be integral multiples of the intended least significant digit.

Now select a decimal point code N(decimal) using the following list:

N(decimal)	Number of Decimal Places
0	No Decimal Point
1	0
2	1
4	2
8	3
16	4

Finally compute values for the sensor display codes N(code1) to N(code4) for the four characters, by adding together the values of all the segments to light, using the diagram below to asign a value to each segment.



Combine these into two pairs by:

N(code12) = 256*N(code1) + N(code2)
N(code34) = 256*N(code3) + N(code4)

12.7 Loading Linearisation Data

First unlock the memory protection with the command "U9999". (This is the elusive key !)

Then send "Ln" where n is a number in the range 1-3 and determines which of the 3 custom linearisation tables is to be loaded.

Now send the following 264 numbers in the order listed below. Each number must be preceded by a #(hash) and terminated by a carriage return. (Note only the number is sent, not the text "N(0)" etc.).

Number	Example	Notes
N(0)	#0	Will always be 0
N(1)	#200	
N(2)	#387	
-	-	
- etc.	-	
-	-	
N(255)	#65300	
N(256)	#65535	Will always be 65535
N(gain)	#5000	
N(offs)	#32768	
N(decimal)	#2	For 1 decimal place
N(code34)	#28220	For "st"
N(code12)	#15422	For "te"
0	#0	Spare, must be zero
0	#0	Spare, must be zero

The data is now loaded. To install this data, follow the procedure given in section 11 to locate and load the code for the new sensor.

13. THEORY OF CALIBRATION AND LINEARISATION

In the interests of long term stability and ease of adjustment, ITC4 contains no conventional calibration presets. Instead the calibration constants are held in the non-volatile memory and "adjusted" to match a particular sensor by means of the front panel controls. This section covers the theory behind this.

13.1 Hardware Calibration

The input signal is amplified to produce a signal within the range 0 to 5 volts at TP3 on the input board.

The role of the span and zero switches SW1 is to ensure that a given input range occupies as much as possible of this 0 to 5 volt range without ever going outside it. The ratio between successive switch positions is never less than 0.7 so it is always possible to fill at least 70% of the 0 to 5 volt range.

The 0 to 5 volt signal is passed to the following voltage to frequency converter, where it is converted into a frequency in the range 0 to 65kHz approx. This is read as a 16 bit number by the microprocessor.

13.2 Input Software Calibration

The raw frequency count has a ZERO value added and is multiplied by a SPAN, to convert it to a number which runs from 0 to 65535 for the full working range. This serves two purposes. It allows interpolation between the switch steps and it allows variation between individual sensors to be calibrated out. When RAISE and LOWER are operated with the CAL button pressed, it is the values of ZERO and SPAN which are adjusted.

13.3 Linearisation

The lineariser proper takes the 16-bit (0-65535) number from the input calibration and remaps it to a new 16-bit number corrected for sensor non-linearity. This is achieved by defining 256 equally spaced linear segments. The correct segment is established and a linear interpolation performed within this segment.

Use of a set of linear segments requires much greater memory storage than would be required for example for a polynomial fit. However it is quicker to calculate, in real time and given the "kinked" nature of many cryogenic sensor calibrations, generally gives a better fit.

It is the linearised 16-bit number which is used within ITC4 for control purposes.

13.4 Display Calibration

To produce the required physical representation of the 16-bit number for display purposes a further multiplication and zero shift now takes place using the GAIN and OFFSET parameters. These map the 0-65535 to the required signed number expressed as degrees. The values of GAIN and OFFSET are determined as part of the range calibration (as described in section 12.6). It is only at this final stage that the accuracy of the numbers may be reduced by rounding. Internally within ITC4 all arithmetic is done on the full 16-bit number.

14. THEORY OF CONTROL

14.1 General

The aim of a controller is to maintain the temperature of a system as close as possible to some desired temperature (the SET POINT) and as far as possible to eliminate the effect of changes in the heat loss from the system. When a steady state is established, the heating provided by the controller will exactly balance the heat lost by the system to its surroundings. A further function of the controller is to follow any changes in the set point as rapidly as possible. Thus the criteria for good control are:

CONTROL ACCURACY	The mean temperature of the system should be as close as possible to the desired temperature.
CONTROL STABILITY	The fluctuations above and below the mean temperature should be small.
CONTROL RESPONSE	The system should follow changes in the set point as rapidly as possible.

In the following sections a number of possible control systems of increasing complexity are described, culminating in 3-TERM or P.I.D. control, as used in ITC4.

14.2 Open Loop Operation

In an open loop system, a fixed heater power is applied and the system is allowed to come to equilibrium. There is no control as such, since the heater power can only be changed by the intervention of a human operator. The system takes a long time to reach equilibrium and any changes in the heat loss from the system, produce corresponding changes in the system temperature. The hot plates on a domestic cooker form an example of this form of "control". This mode of operation can be obtained with ITC4 in its MANUAL mode.

14.3 On-Off Control

In an on-off (or "bang-bang") control system the heater power is either full on, if the temperature is below the set point; or off, if it is above. The control accuracy and response can be made very good with this form of control and the system can be made largely immune to changes in heat loss. However the control stability can never be made very good since the system temperature must always cycle above and below the set point. The magnitude of the temperature fluctuations depends on the thermal properties of the system. For some systems, where temperature fluctuations are not important, this is a perfectly satisfactory and simple system of control. (e.g. the domestic electric oven).

14.4 Proportional Control

A proportional control system overcomes the problems of temperature cycling by allowing the heater power to be continuously varied. The heater voltage at any instant is proportional to the error between the measured and desired temperatures. Thus a large negative error will produce a large heater voltage in order to correct that error.

If the output voltage were proportional to the error over the whole range of the instrument, a negative error equal to half the total span of the instrument would be required in order to generate a full output voltage. Thus, although the control stability might be good, the accuracy would be very poor.

By increasing the GAIN of the controller the output can be made proportional to the error over part of the total range of the instrument. Outside this range the output is either fully on or completely off. The range over which the output is proportional to the input is the PROPORTIONAL BAND. This is normally expressed as a percentage of the total span of the instrument. Thus a Proportional band of 100% is equivalent to a gain of unity.

By reducing the proportional band, the accuracy of the controller may be improved since a smaller error will then be necessary to produce a given change in output.

This would seem to imply that, by sufficiently reducing the proportional band, any required accuracy could be obtained. Unfortunately as the proportional band is progressively reduced, there will come a point at which temperature oscillations reappear. (In the limit, a controller with a proportional band of 0% is an on-off controller, as described above).

The reduction in proportional band which can be achieved before the onset of oscillations, will depend largely on the design of the system being controlled. In some systems it may be possible to achieve the required control accuracy without oscillations but in most cases this will not be so.

14.5 Integral Action

To overcome this problem, INTEGRAL ACTION is introduced. Consider a system controlled by proportional action as described above, with the proportional band sufficiently large to prevent oscillation. The result will be stable control but with a residual error between the measured and desired temperatures. Suppose this error signal is fed to an integrator, the output of which is added to the existing controller output. The effect of this will be to vary the overall output until control is achieved with no residual error. At this point the input to the integrator will be zero and this will therefore maintain a constant output. Integral action has thus served to remove the residual error. Provided the contribution from the integrator is only allowed to vary slowly, proportional action will prevent the occurrence of oscillations. The response of the integrator is characterised by the INTEGRAL ACTION TIME. This is defined as the time taken for the output to vary from zero to full output, in the presence of a fixed error equal to the proportional band.

To ensure that the integrator itself does not give rise to oscillations, it is usual to employ an Integral Action Time of at least the response time constant of the system.

When a controller is responding to a large change in set point, the integrator will charge whilst the system is approaching the new set point. If left unchecked the integrator is likely to be fully charged by the time the temperature comes within the proportional band. This will inevitably result in a large overshoot. To overcome this it is usual to incorporate an INTEGRAL DESATURATOR whose function is to hold the integrator in its discharged state when the measured temperature is outside the proportional band. This can considerably reduce the amount of overshoot. In ITC4 a more sophisticated DESATURATION ALGORITHM is employed, which rather than discharging the integrator, deliberately pre-charges it in such a way as to further minimise overshoot.

14.6 Derivative Action

The combination of Proportional and Integral Action will suffice to ensure that accurate and stable control can be achieved at a fixed temeprature. However when the set point is changed many systems will tend to overshoot the required value. By means of Derivative Action this effect may be reduced or eliminated completely. Derivative Action monitors the rate at which the measured temperature is changing and modifies the control output such as to reduce this rate of change. (Derivative Action is exactly analogous to the use of velocity feedback in servo systems and serves the same function).

Like Integral Action, Derivative Action is characterised by an action time. If the measured temperature is changing at a rate of one proportional band per DERIVATIVE ACTION TIME, Derivative Action will contribute a signal sufficient to reduce a full output to zero or vice versa.

In ITC4, use of the integral desaturation algorithm referred to above, may be sufficient to limit overshoot in many systems. In this case no derivative action will be required.

14.7 North American Terminology

In North America, a different terminology exists for 3-term control.

PROPORTIONAL BAND is replaced by its reciprocal, GAIN. (e.g. A proportional band of 2% is equivalent to a gain of 50).

INTEGRAL ACTION is replaced by RESET. This may either be specified as a time (as for integral action) or as its reciprocal, "REPEATS PER MINUTE".

DERIVATIVE ACTION is replaced by RATE. Again this may be specified as a time or as repeats per minute.

15. SERVICING

15.1 Circuit Description

The majority of the circuitry involved in ITC4 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 5v supply for the logic. The raw 11 volts from which the 5v is obtained, is used on the main PCB to monitor mains volts. Should this fall below 8 volts, a RESET is performed, protecting the data in the Non-Volatile Memory. (If ITC4 is operated on very low mains volts, it may keep resetting. This may be identified by the "PASS" message reappearing during use.)

The main transformer also generates an 18v 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 +/-6.2v 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 convertor 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 USART 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.

The output stage accepts a high frequency time proportioned waveform from the microprocessor via the opto-isolator U201. This is converted to a 27 v p-p waveform at TP203.

A DC level is established from this by filtering and is used in a conventional analogue output stage. R217, R218 and Q203 provide Safe Operating Area protection for the output device Q204.

Q201 and Q202 provide protection to the heater in the event of a failure within the digital circuitry. Should this occur, the drive to the output stage would remain fixed in one or other state. If it is ON, the heater output is zero and no problem arises. If it is OFF, C201 will charge, switching on Q202 and taking the heater output to zero. In normal use the microprocessor ensures that the output drive is always pulsed on briefly, so switching on Q201 and preventing C201 charging.

The protection relay RL1 allows the microprocessor to switch off the heater under circumstances where failure of the output stage is suspected.

15.2 Test Mode

ITC4 performs a basic self test of the microprocessor and memory at switch on, before displaying the "PASS" message. A more detailed hardware test mode is accessed by pressing the internal RED button SW1 on the main circuit board.

One application of this has already been described in section 11.5. Other test routines which may be of use to the user are described below. Selecting a given test involves using RAISE and LOWER to display the test number required, then pressing LOC/REM to activate the test.

** WARNING **

Never press any other button whilst the internal RED button is depressed. To do so could result in erasure of the NON-VOLATILE memory content with the loss of any installed custom ranges.

Test 01 lights each LED or display segment in turn, then pulls each of the auxiliary output lines low in turn. When the test is complete, ITC4 re-enters the test mode.

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

Test 04 allows the front panel display to be set to indicate one of the internal parameters rather than the normal measured temperature. This produces the same effect as the "Fn" command described in section 10, without the need to connect a computer. When test 4 is selected, the display will show:

F 00

RAISE and LOWER may be used to select an option in the range 0 to 15 for front panel display. The options are as given in the list for the "R" command in section 10. When the required option has been selected, pressing LOC/REM will implement it. ITC4 will return to normal operation but with the selected parameter on display. To restore a normal display, the display SENSOR button may be used.

Test 07 provides sensor configuration as described in section 11.5.

Test 03 and **Tests 05 & 06** are currently unused.

16. IN CASE OF DIFFICULTY

This section indicates some of the more common pitfalls and operator errors.

Display always shows "Hot 0"
Cryostat safety sensor faulty or disconnected.

Display always shows "Hot 1", "Hot 2" or "Hot 3"
Sensor not connected, or faulty.
Sensor limit inadvertantly set to zero (see section 5.2). In this case it will be necessary to reset the limit, but since the display will always show the "Hot" message, this must be done "flying-blind". The procedure shown below should be used. This is the same procedure normally used to change a limit, but the absence of a display can be disconcerting! If more than one limit is wrongly set it may be necessary to reset each in turn.

1 Switch on POWER
2 Use DISPLAY SENSOR to select the sensor shown in the "Hot" message.
3 Press LIMIT and hold in.
4 Press SENSOR and release.
5 Still holding LIMIT, press RAISE and hold for 1 second.
6 Release LIMIT, switch off POWER and switch on again. All should now be well, with the LIMIT set to maximum.

No Heater Output
The heater limit has been set close to zero. (See section 5.1).

Heater Output Voltage Varies with Set Temperature
This is intentional when the heater limit is set to zero. (See section 5.1).

RAISE and LOWER appear not to work
Controller is set to REMOTE

HEATER SENSOR appears not to change sensor
Controller is in REMOTE or AUTO

ITC4 appears to control with a large offset
INT time has been set to a very large value.

ITC4 only moves very slowly towards set point
DERIV time has been set to a very large value.

When SWEEP used, LED's light but the temperature does not change
Not switched to AUTO.

Set Point changes without pressing SET
SWEEP RUN/PROG pressed.
HEATER SENSOR changed (see section 4.3).

"PASS" message appears during operation
Low mains voltage. ITC4 is resetting. It will switch to MAN with

output at zero. Check mains voltage setting is correct.

Calibration changes when RAISE/LOWER pressed
CAL button stuck in.

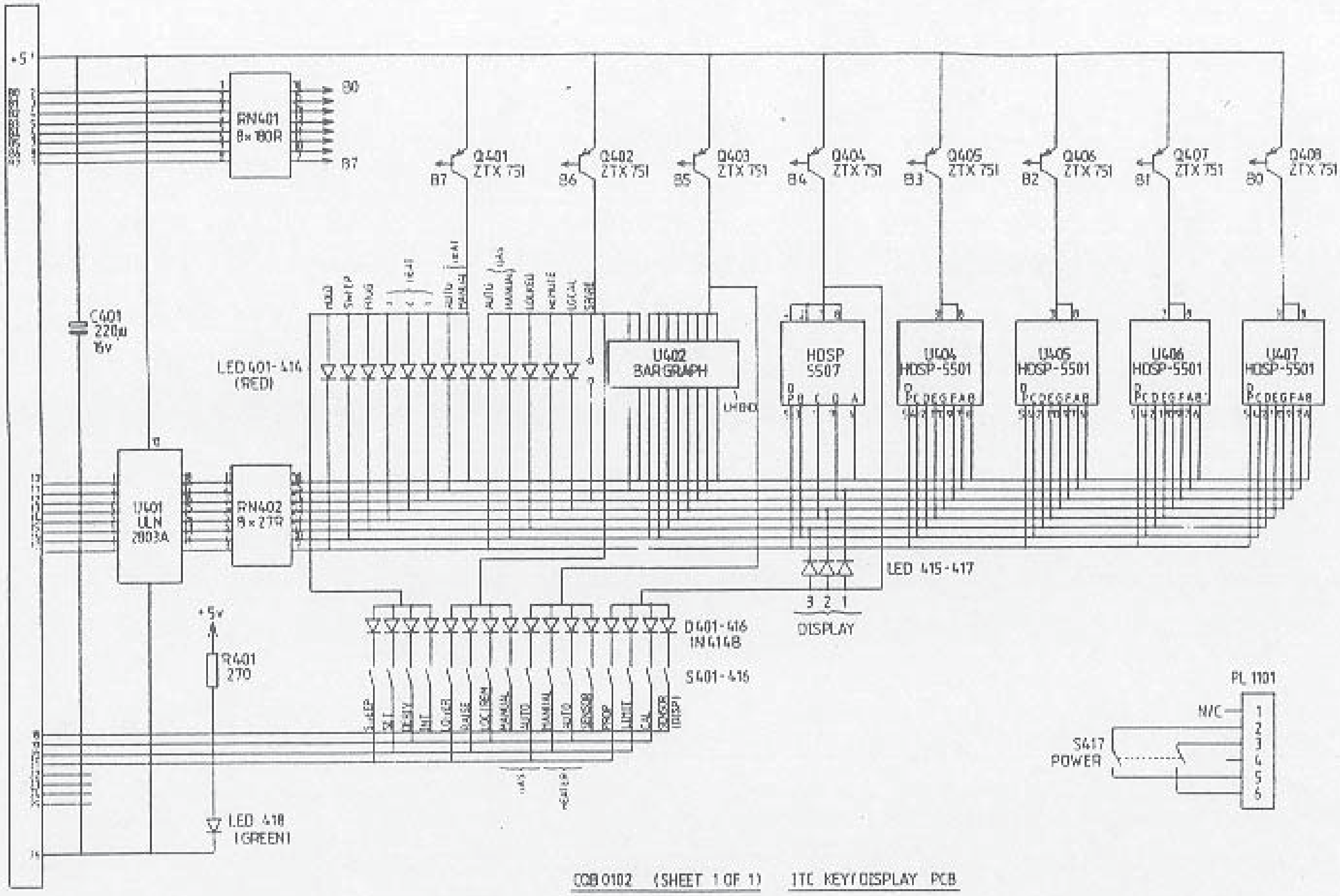
Cannot get SPAN & ZERO calibration correct together
The calibration points chosen are not sufficiently near the ends of the range, so ITC4 is adjusting the same constant, (e.g. the ZERO) at both points (see section 7.1).
The span DIP switches (SW1/1 to SW1/5) are wrongly set so that the voltage at TP3 stops a long way short of 5 volts (see section 12.5).

Measured Display will not Reach Full Range
Either the span or zero switches (SW1/1 to SW1/10) are wrongly set so that the voltage at TP3 goes below zero or above 5.75 volts at the extremes of the range (see section 12.5).

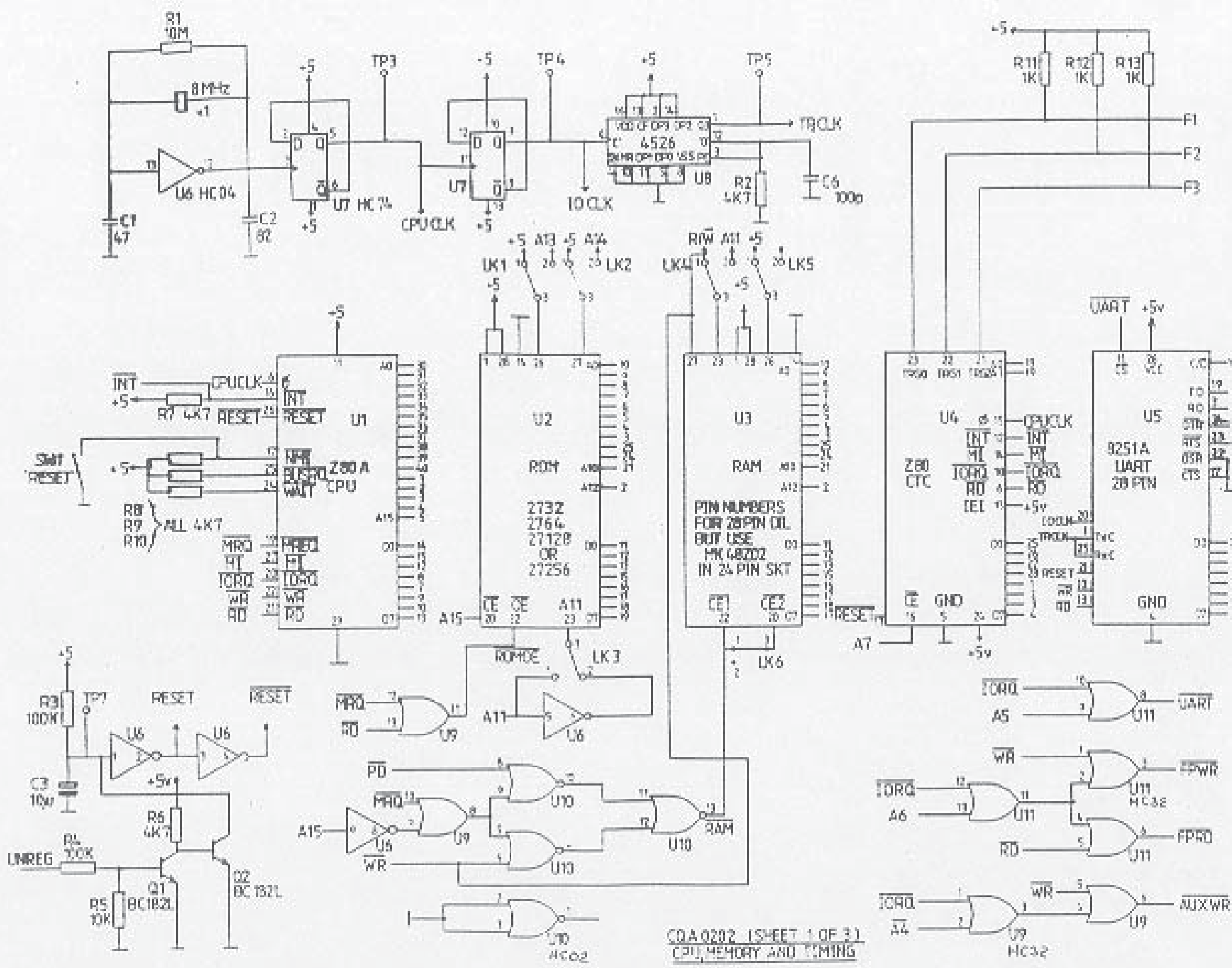
No Display or Abnormal Display (e.g. Multiple Decimal Points)
This probably indicates a hardware defect but can occasionally be due to corruption of the non-volatile RAM content. There are two **reset** procedures which may assist in diagnosing the problem. A **two-button reset** is carried out by holding the RAISE button pressed, whilst pressing and releasing the internal RED test button SW1 on the main PCB (See section 11). This partially resets the RAM content and will always restore a "PASS" message and a normal display if no other faults are present. A **three-button reset** should be used with extreme caution. It completely resets the entire memory, wiping out all calibration information and any custom linearisation curves which have been installed. It should only be used when the RAM content is known to be beyond recovery (e.g. after replacement of the RAM chip). It is carried out by holding both RAISE and LOWER pressed whilst pressing and releasing SW1 on the main PCB. After a three-button reset, any custom ranges must be re-installed, the range configuration described in Section 11.5 must be carried out and finally the Zero and Span calibration described in Section 7 must be carried out.

17. SPECIFICATION

INPUT CHANNELS	1 standard, 3 optional
INPUT RANGE	5mV TO 2V FSD
INPUT OFFSET	-2v to +2v
CURRENT SOURCE	10uA, 100uA, 1mA (+/-10%)
SENSOR TYPES	
Voltage Input	5mV to 2V FSD
Resistance Input	4-wire, 5 Ohm to 200 K Ohm FSD
Thermocouple	See List. (RT comp. on Celcius ranges)
Pt, RhFe Resistor	4-wire resistance measurement
Ge, Carbon Resistor	4-wire conductance measurement
Si, GaAs Diode	Volts sense at constant current
HEATER OUTPUT	0-40v DC
HEATER RESISTANCE	20 ohms min
OUTPUT POWER	80W max into 20 ohms
AUXILIARY I/O	For gas controller
CHART RECORDER o/p	Time Prop Signal on AUX Socket. (Requires external passive filter)
DISPLAY TYPE	0.56 inch RED LED
DISPLAY RANGE	-19999 TO +19999
CONTROL METHOD	Digital 3-Term (P,I,D)
SAMPLE RATE	4 Hz
INPUT RESOLUTION	16 Bit
OUTPUT RESOLUTION	16 Bit
INTERNAL ARITHMETIC	16 Bit for P & D Terms 32 Bit for I Term
RS232 INTERFACE	Configured as DCE
HANDSHAKE	None Required
BAUD RATE	9600 Baud
IEEE-488 INTERFACE	Option, via external convertor.
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	100-240V 50/60Hz
POWER CONSUMPTION	120VA approx
CASE STYLE	Freestanding Metal Case Optional Rack Mount Ears
DIMENSIONS	
FREESTANDING	446mm x 106mm x 298mm
RACK MOUNT	19 inch x 2U x 298mm
WEIGHT	6.5kg



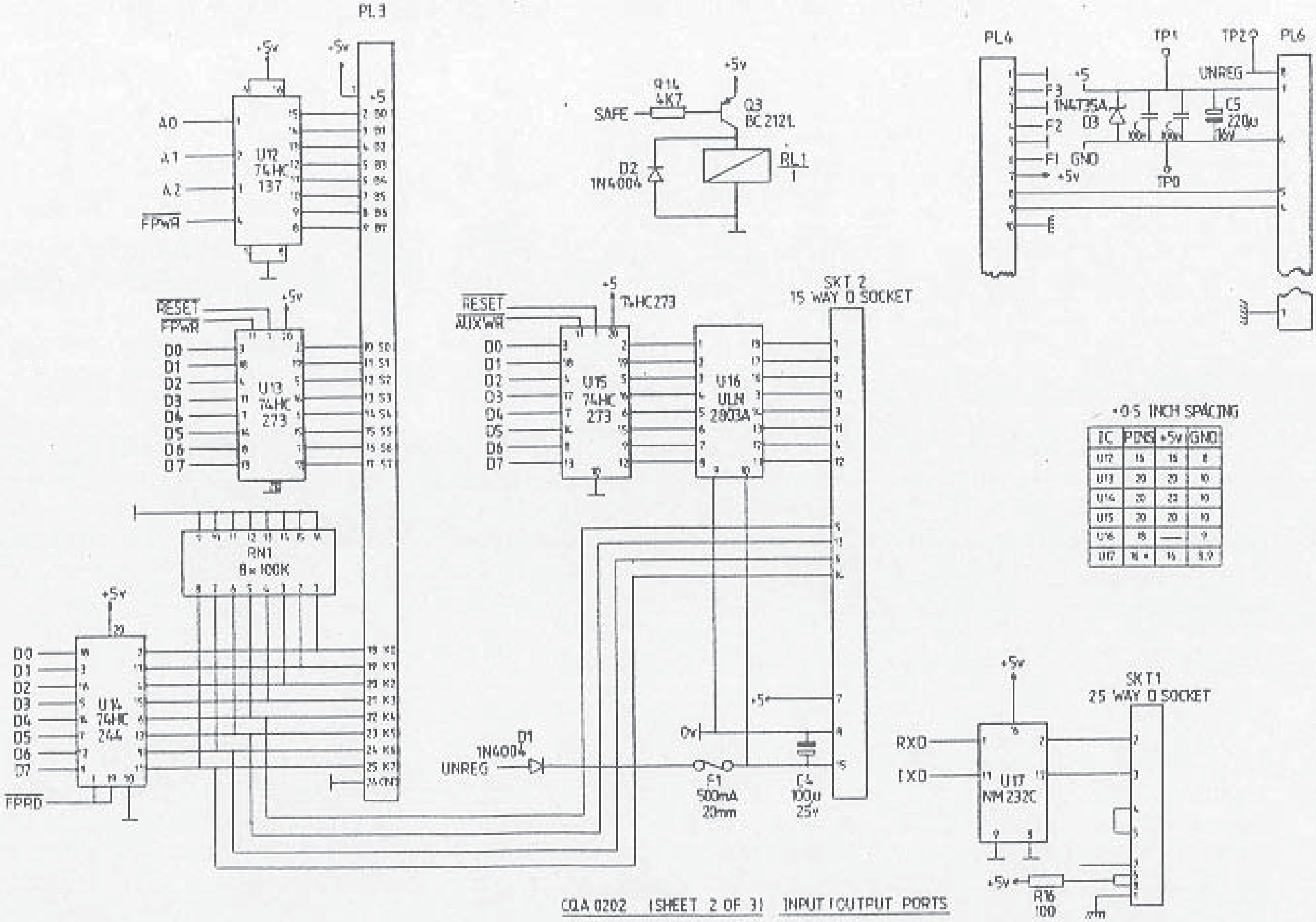
CQB 0102 (SHEET 1 OF 1) 1TC KEY/DISPLAY PCB



CDA 0202 (SHEET 1 OF 3)
CPU, MEMORY AND TIMING

IC	PINS	+5V	GND
U1	40	11	29
U2	28	28/LK1	14
U3	28	28/LK5	14
U4	28	24	5
U5	28	26	4
U6	14	14	7
U7	14	14	7
U8	16	16	8
U9	14	14	7
U10	14	14	7
U11	14	14	7

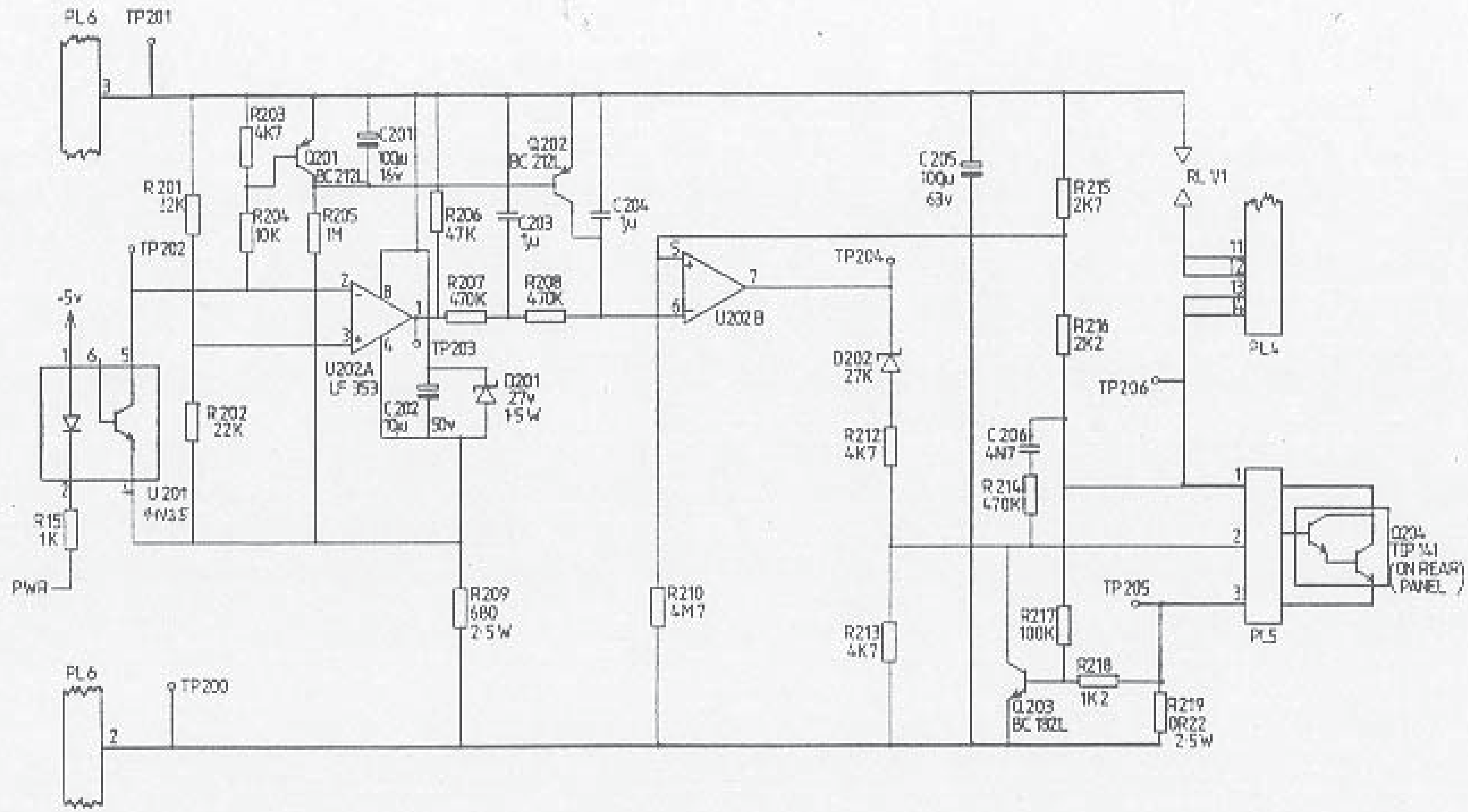
ROM	LK1	LK2
2732	1	1
2764	1	1
27128	2	1
27256	2	2



•0.5 INCH SPACING

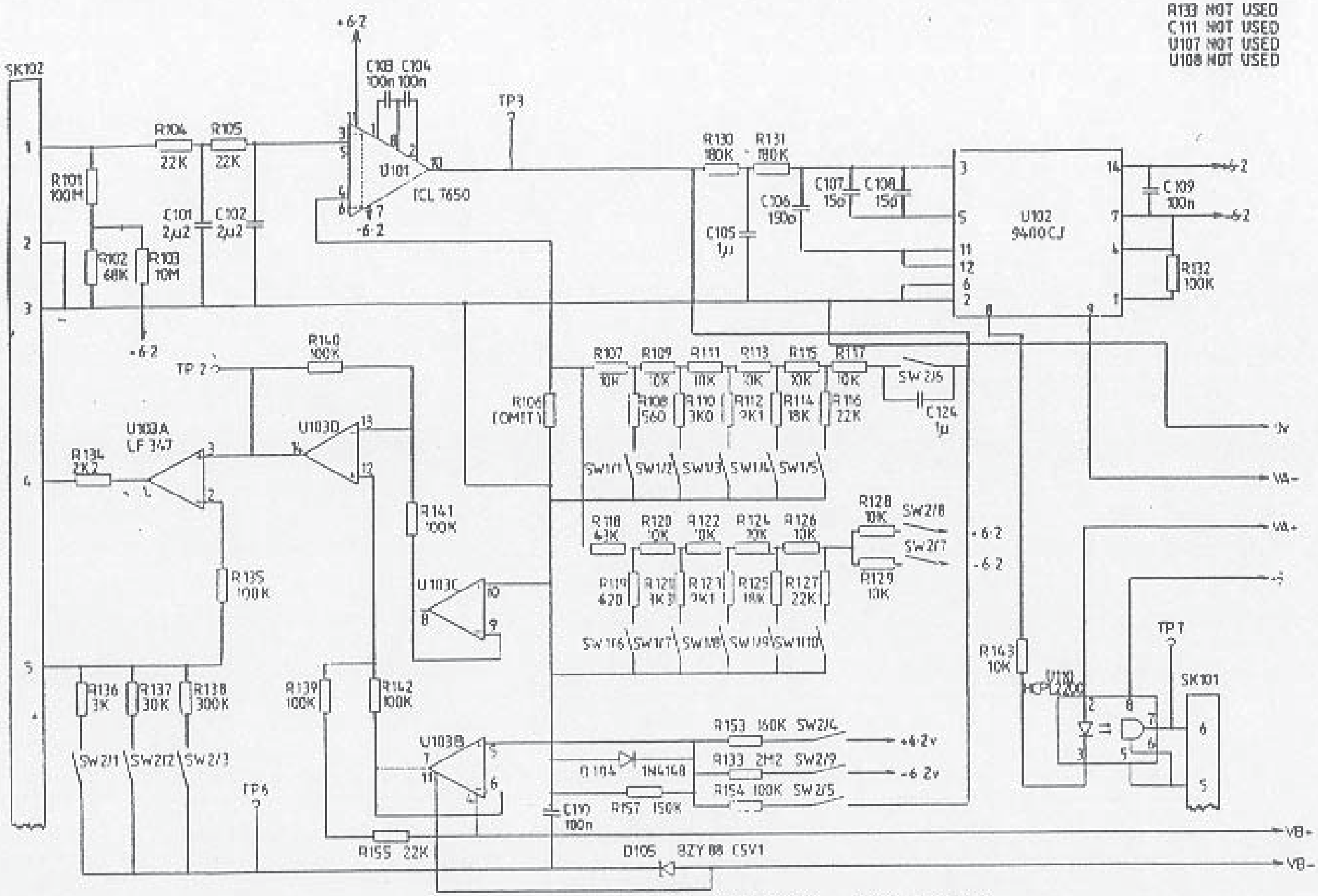
IC	PINS	+5v	GND
U12	16	16	8
U13	20	20	10
U14	20	20	10
U15	20	20	10
U16	18	—	9
U17	16 •	16	8,9

CQA 0202 (SHEET 2 OF 3) INPUT/OUTPUT PORTS

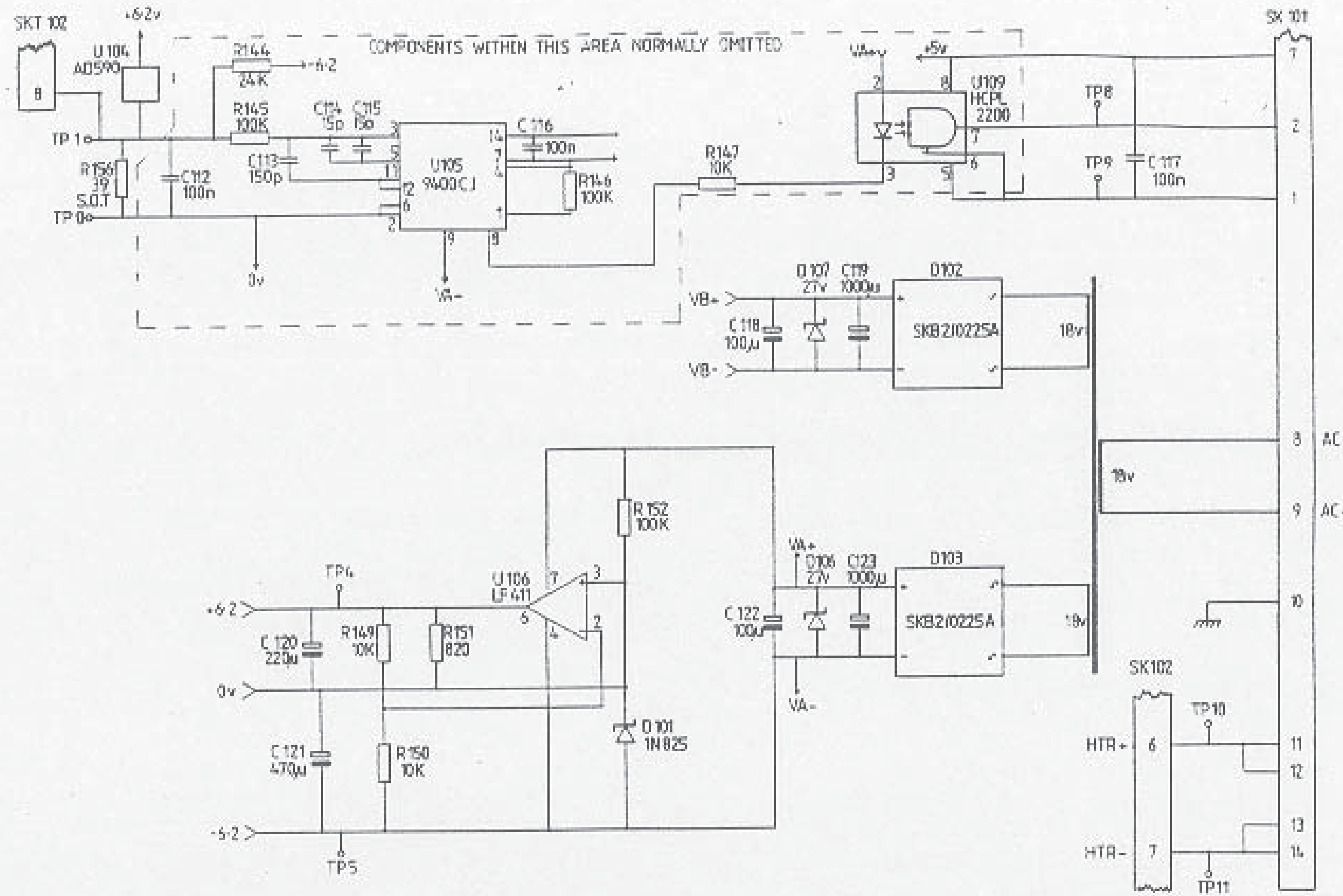


COLA 0202 (SHEET 3 OF 3) OUTPUT STAGE

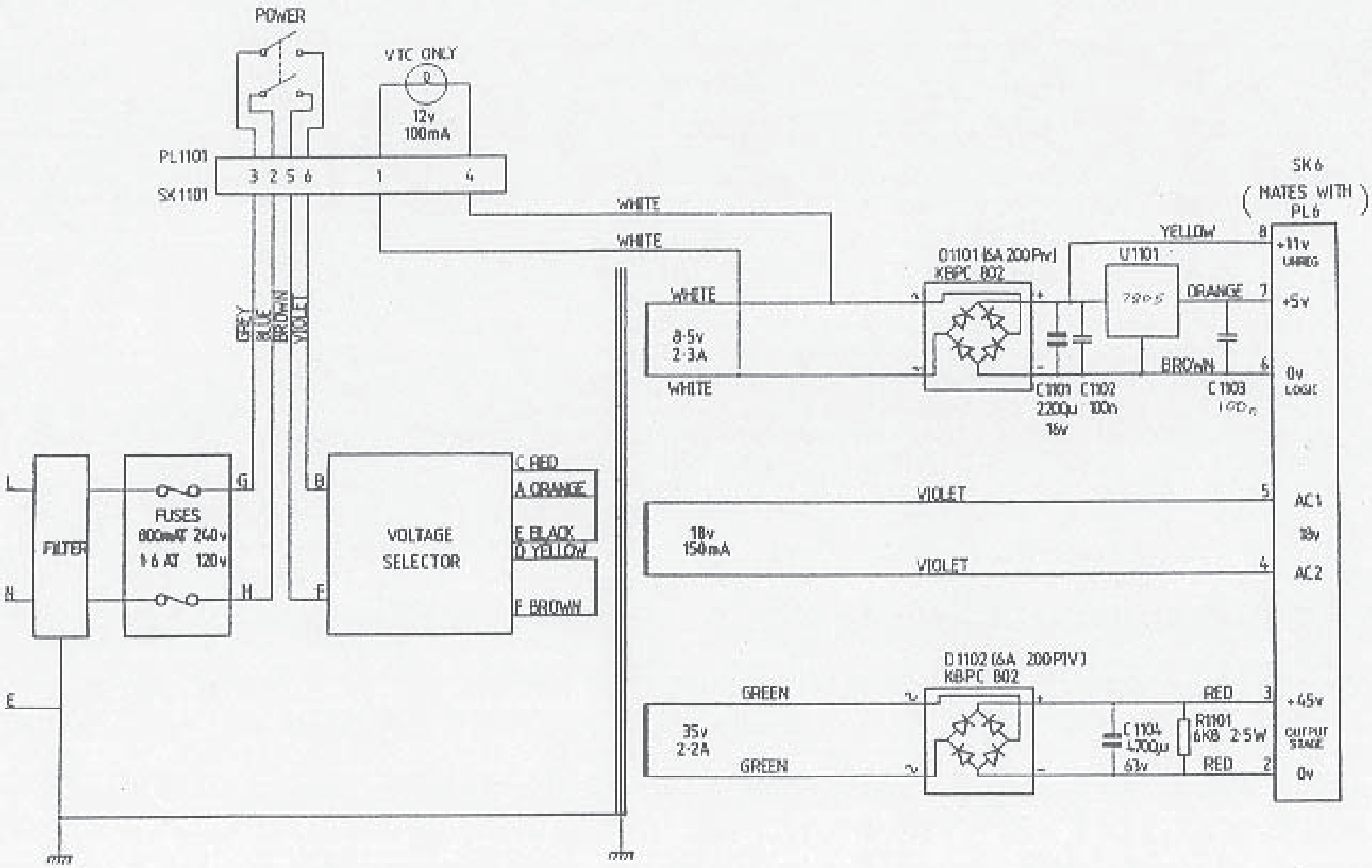
R133 NOT USED
C111 NOT USED
U107 NOT USED
U108 NOT USED



COB 0302 (SHEET 1 OF 2) INPUT AMPLIFIER



CDB0302 (SHEET 2 OF 2) ITC INPUT PSU



CQA 1102 (SHEET 1 OF 1) POWER SUPPLY