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 ON-OFF 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

This manual provides operating and service information for the Oxford Instruments VT Controller model VTC4.

The Variable Temperature Controller (VTC) is intended for use in conjunction with a Varian NMR spectrometer. It is designed to control the sample temperature within the NMR probe. Heating of the sample is by means of a nitrogen gas stream which is warmed by a heater within the probe. The heater is supplied with 0-40v DC from the VTC. For operation below room temperature the gas stream is precooled by passing it through a heat exchanger immersed in liquid nitrogen.

The sample temperature is sensed by two thermocouples mounted in the gas stream between the heater and the sample. These are connected in parallel via a potentiometer which allows the ratio of their contributions to be adjusted.

An additional platinum resistance safety sensor is mounted directly on the heater assembly. This enables the heater power to be shut down in the event of a failure of the gas flow. Additional safety features are incorporated to protect the VT probe against operator errors and system faults.

The VTC employs a 4 digit display of temperature covering the range -150.0 to +200.0 degrees C. In addition a Status Lamp allows an operator to observe the current VT status. All control of the VTC is by serial data sent from the spectrometer computer via an RS232C data link. This link also allows the computer to interrogate the VTC. The same link may be used, connected either to a computer or to a standard 9600 baud terminal, to effect a full calibration of the VTC.

The following error conditions may be detected and produce an status message to the computer.

o/c Thermocouple
o/c Safety Sensor
s/c Safety Sensor
Over-temp at safety sensor
s/c Output transistor
Software/uProcessor failure

Over-temperature at the safety sensor initially turns the heater off. If this fails to correct the condition within 5 seconds, it is assumed that either the gas flow has been interrupted, or that an output transistor failure has occurred. In this case a protective relay operates, isolating the heater from the control electronics. Sensor failure on any of the sensors also results in this relay operating.

Once the protective relay has operated the output will remain off. A power down, or an "N" or "C" instruction from the computer is required to release the relay.

An auxillary output port is available on the VTC for control of a gas solenoid of other external devices.

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, the main sensor (Copper/Constantan Thermocouple) and the safety sensor (Platinum Resistance Thermometer) are by means of a 9 way D-socket on the rear panel. Pin connections are:

1 Thermocouple +ve
2 0v
3 Thermocouple -ve
4 n/c
5 n/c
6 Heater Output +ve
7 Heater Output -ve
8 Platinum Resistance Thermometer -ve
9 Platinum Resistance Thermometer +ve

SAME AT PROBE 6 WAY CONNECTOR

The Heater Output connections are electrically isolated from the controller ground and from the power supply ground within the temperature controller.

The Input connections and the 0v connection on the 9 pin socket, share a common ground with the temperature controller electronics and are linked to the RS232 socket signal ground within the temperature controller. Both are isolated from power supply ground within the controller, though signal and power grounds may be linked within the computer.

It is important to note that the the room temperature compensating sensor for the main sensor thermocouple is mounted at the rear panel of the VTC. 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 probe to the VTC must use thermocouple compensating cable for the main sensor leads. If the rear panel in the region of the connector is likely to be exposed to temperature fluctions, it will be an advantage if a draught shield is placed around the plug, and the RT sensor, positioned immediately to its right.

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 VTC is powered up
7	Signal Ground
8	+5V when VTC 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

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 Auxilliary Port Connections

The auxilliary port is provided primarily for the control of a gas solenoid. However it has up to 8 independant output lines and 4 input lines available. 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). These may be used to drive solenoids etc.

directly. The solenoids should be supplied from an external supply of 25 volts maximum and the maximum current per line should not exceed 500mA. The solenoid supply ground should be linked directly to the 0v pin of the Auxilliary socket.

Inductive loads such as solenoids must be protected by diodes to prevent the driver transistors being damaged by inductive spikes. This may either be achieved by individual diodes directly across the loads, or alternatively the +ve solenoid supply may be linked directly to pin 15 of the auxillary socket, in which case the protection diodes within the VTC will operate.

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

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

Pin connections at this socket are:

1	Output Bit 0
9	Output Bit 1
2	Output Bit 2
10	Output Bit 3
3	Output Bit 4
11	Output Bit 5
4	Output Bit 6
12	Output Bit 7
5	Input K4
13	Input K5
6	Input K6
14	Input K7
7	+5v
15	Driver Protection / +11v unregulated.
8	0v

4 OPERATION

4.1 First Time Operation

For first time operation it will be probably simplest to connect the VTC directly to a data terminal. Any terminal capable of operating at 9600 baud should be suitable.
Once familiar with the operation of the various commands and responses, software may be written for the computer to perform the required functions.

With the terminal connected to the VTC the latter may be switched on using the POWER switch on the front panel. This switch should illuminate. If it fails to do so, check the power connection and the fuses.
At switch on, the VTC first performs a self test of its internal memory and its back-up battery. If all is well the display shows the message "PASS" for 2 seconds. If hardware errors are detected the message "Err" followed by a number is displayed for 10 seconds. If the back-up battery is aging the message "batt" is displayed for 10 seconds. (See below for the significance of this message).

On completion of the self test the display is blanked whilst the analogue circuits are given time to stabilise and the sensors are checked for error conditions.

If the sensors are within range the output safety relay is closed and the VTC enters its Stand-By state. In this state the STATUS indicator is unlit and the the heater and gas-control solenoid are un-energised.

If a sensor error condition is encountered the relay is not closed and the status indicator flashes at a fast rate (2Hz).

In either case the display illuminates and indicates the measured probe temperature.

If the display blinks on then immediately goes out for another 1-2 seconds and continues to cycle on and off, check that the supply voltage is adequate. (The VTC automatically senses low supply volts and performs a reset function, to protect the data stored in memory). If necessary operate the instrument on a lower voltage setting.

Once the display is lit, the VTC should be fully operational. To test the serial link, type a "V" at the terminal (must be upper-case letters). The VTC should respond by sending two lines of text, describing the software and its version number. Provided this message is correctly printed the communication link is fully operational. The other commands given below may then by tried to gain familiarity with the system operation.

In the Stand-By state, manual control of the heater and gas solenoid is possible by means of the "O" and "G" commands. To leave the Stand-By state and commence Automatic Control, the "A" command may be used. To provide full system operation, it will be necessary to have a VT probe connected with gas flowing. However most of the commands may be tested by placing a s/c across the thermocouple input terminals and a 100 ohm resistor across the safety sensor terminals.

Note that if an error condition is detected on the sensor assembly the safety relay may operate making it impossible to obtain any output. After clearing the problem the the "N" command may be used to reset the safety relay.

4.2 Communication Protocols

All dialogue with the computer is in 9600 baud serial form.

Data is sent as a start bit, 8 data bits plus two stop bits.

All normal user commands to the VTC and responses received, are sent as strings of ASCII characters. Where numeric values are required, these are also sent as ASCII strings representing the number in normal, decimal format. Numbers are preceeded where appropriate by a "+" or "-" sign. To simplify interfacing, the VTC is fairly flexible in the format of numbers it will accept from the computer. Characters sent by the VTC have the MSB (parity bit) set to "0". If parity is sent by the computer it is ignored.

None of the Modem control lines of the RS232C interface are used. The VT controller will accept serial data at all times. In its default state it will only send data to the computer in response to a specific command. If however the computer is able to accept serial data at all times, the VT controller can be instructed to send a status message spontaneously whenever the status changes. This is done by means of the "Q" command, see below. The same command may also be used to control the sequence of characters returned by the VTC in response to a command. These may consist of any combination of:

Single Letter Echo
<CR> . Prompt String
EOM character (ctrl-C)
<LF> after all <CR>

If the computer used does not have adequate buffering it may be possible for messages from the controller to over-run this. To overcome this problem, the data rate from the controller may be slowed down to any chosen speed by means of the W command. This introduces a delay, before each character is sent. With this feature it is possible to accomodate computers with no input buffering.

4.3 Commands and Responses

Commands to the controller consist of a single upper case letter A-Z, optionally followed by a parameter sent as an ASCII decimal string. Where a parameter is required, it must be terminated by an ASCII <RETURN> character. <LINE FEED> characters, if sent are ignored. Commands not requiring a parameter, need no terminator. Only the single command letter is required. Again if a terminator is sent it will be echoed, but otherwise ignored.

The VTC may respond to a command to indicate that it has been correctly received. In some cases the response is to return a requested value. In cases where no other specific response is required, the controller may be instructed to remain silent, to echo the command letter or to issue a prompt string. In addition, if required the VTC may issue an EOM character after a command letter to indicate that its parameter may be sent. (It is however not necessary for the computer to await the EOM, the VTC will accept the parameter immediately after the command letter). merely echos the command letter.

Any commands which are not understood or cannot be obeyed in the current state of the instrument result in a "?" being echoed, followed by the command string as received. The "?" will always be the first character returned to simplify error handling by the computer. Again an EOM may optionally be sent following an error message.

Apart from responses to specific commands, the VTC will not normally issue messages. However another option in the Q command allows the VTC to send a status message spontaneously whenever the status changes.

Section 5 gives a list of the available commands and details of each.

5 COMMAND LIST

A list of all the currently active commands is given below, followed by a more detailed description of each of these,

In the list which follows the symbol n is used to indicate a decimal digit in the range 0-9.

1. COMMANDS NOT REQUIRING A PARAMETER

A	COMMENCE AUTOMATIC CONTROL
M	RETURN TO MANUAL CONTROL
B	RETURN TO STANDBY STATE
R	SEND READING (MEASURED TEMPERATURE)
E	SEND ERROR (BETWEEN MEASURED AND SET TEMPERATURES)
H	SEND HEATER OUTPUT (Range 0-100%)
S	SEND STATUS
V	SEND VERSION NUMBER FOR SOFTWARE
C	INITIATE CALIBRATION DIALOGUE
N	RESTORE NORMAL OPERATION

2. COMMANDS REQUIRING A PARAMETER & TERMINATOR

Tnnnnn	SET TEMPERATURE (See note 1)
Pn	SET PROPORTIONAL BAND (See note 2)
In	SET INTEGRAL ACTION TIME (See note 2)
Dn	SET DERIVATIVE ACTION TIME (See note 2)
Onnnnn	SET OUTPUT VOLTAGE (In MANUAL mode only)
Gnnn	SET GAS SOLENOID (In MANUAL mode only)
Qn	SET "QUIET" STATUS (See Note 3)
Fnn	SET FRONT PANEL DISPLAY
Wnnnn	SET WAIT INTERVAL BETWEEN OUTPUT CHARACTERS
Unnnn	UNLOCK MEMORY PROTECTION

3. CHARACTERISATION AND DIAGNOSTIC COMMANDS

L	LOAD LINEARISER DATA TABLE
X	LOAD PATCH MEMORY
Y	LOAD WHOLE MEMORY
Z	DUMP WHOLE MEMORY

6. COMMAND SYNTAX

A COMMAND

The AUTO command sets the VTC into automatic control. It should be followed by a "T" command to select a desired temperature. After power-up or a "B" command the assumed set temperature will be 0.0 degrees. Otherwise the set point will remain at the last value selected. Note that it is possible to give the "T" command whilst in standby, but in this case the facility to automatically set the gas solenoid on the basis of the temperature requested will be lost. (See "T" command below).

M COMMAND

The MANUAL command returns the VTC from automatic to manual control. A fully "bumpless" auto-manual transition is effected. i.e. at switch-over the heater output is maintained at its current value and the state of the gas solenoid is unchanged. Similarly the transition from manual back to auto is also made "bumpless", by precharging the integrator to the current manual output. Thus if the temperature is being manually controlled at the desired set-point, there will be no change in heater output when switching to auto. (If the temperature is not at the set point when the switch to auto is made, there will of course be a change in output as the VTC attemps to move towards the set point).

B COMMAND

The BEGIN command performs a complete power-up and initialisation sequence, and returns the controller to the stand-by state with heater and gas solenoid both off. It is exactly equivalent to switching the controller off and then on again.

R COMMAND

The READ command instructs the computer to send the measured temperature. This is sent in the form of a signed integer giving the temperature in tenths of a degree, followed by a <CR> character.

E COMMAND

The ERROR command sends the temperature difference between measured and set temperatures in the same format.

H COMMAND

The HEATER command sends the heater voltage as a percentage of full output. (Note that this value is only approximate, it is not a calibrated parameter.)

S COMMAND

The STATUS command instructs the controller to send its current status. This is sent as a response consisting of S followed by a signed, single decimal digit and a <CR> character. Positive values of status indicate normal operation whilst a negative value normally indicates that a fault has been detected. When a negative status occurs, the output safety relay operates, to isolate the heater and prevent any possible damage to the VT probe. This relay may be reset by means of the "N" command (or by performing a calibration).

The following status reports are currently defined.

S+0	Control in Stand-By or Manual Control
S+1	Temperature Stable at Set Point
S+2	Temperature Changing
S+3	Safety Sensor limiting output
S-1	Gas not flowing or o/p stage fault (turn up gas flow or check)
S-2	Main Sensor on Bottom Limit
S-3	Main Sensor on Top Limit (o/c Thermocouple)
S-4	s/c Safety Sensor
S-5	o/c Safety Sensor

V COMMAND

The VERSION command results in the Software title, and version being sent as two lines of ASCII text, each terminated by a <CR>.

C COMMAND

The CALIBRATE command initiates a calibration dialogue where the controller issues messages requesting various input conditions to be applied, on the basis of which the internal calibration constants are set up. Once set, these are retained in non-volatile memory. Recalibration will normally only be necessary if sensors are changed or servicing work is carried out on the analogue portions of the controller.

To reduce the possibility of inadvertant loss of calibration, a "U" command is required before the "C" command will be recognised. See section 7.

N COMMAND

The NORMAL command restores a normal operation of the controller. Specifically it resets the output safety relay. Before issuing this command the cause of the relay operating should be investigated, and a "S" command issued to ensure that the controller is in a normal state. The "N" command also resets the front panel display to show Measured Temperature (equivalent to "F0" command).

Tnnnn COMMAND

The TEMPERATURE command instructs the controller to set a specific target temperature. Temperatures may be set in the range -150C to +200C. (The indication range is made larger than this to allow for overshoot etc.)

The format of the parameter following the T command has been made flexible to cope with a variety of computer output formats. The parameter required is a signed integer, representing the temperature in tenths of a degree. A decimal point, a +ve sign or leading zeros are all optional and will be ignored. However a digit for the tenths of degrees must be included even if this is zero. Thus the following formats will be accepted for a set temperature of 38.0 degrees.

```
38.0
0038.0
+ 38.0
380
```

whilst

```
38
38.
```

will be accepted but will give rise to a set point of 3.8 degrees. Other characters within a number will give rise to an error message.

If the "T" command is issued whilst under automatic control, the state of the Gas Control solenoid will be selected automatically on the basis of the temperature requested. For temperatures of 25.0 Celcius and below, the solenoid will be energised, to provide cooling. Above this temperature it will be un-energised.

If non-standard control of the gas solenoid is required, an "M" command should be issued to select the manual state, before issuing separate "T" and "G" commands to set the target temperature and gas solenoid respectively. Automatic operation may then be resumed by means of an "A" command.

Pn,Inand Dn COMMANDS

This family of three commands set the PROPORTIONAL, INTEGRAL and DERIVATIVE control terms. The commands are followed by a single digit specifying the value required, as shown in the following table. At power up the P,I and D values are set to defaults of 4, 4 and 0 respectively.

VALUE of n	P COMMAND	I COMMAND	D COMMAND
0	100%	32 min	OFF
1	50%	16 min	8 sec
2	25%	8 min	16 sec
3	12%	4 min	32 sec
4	6%	2 min	1 min
5	3%	1 min	2 min
6	1.5%	32 sec	4 min
7	-	16 sec	8 min
8	-	8 sec	16 min
9	-	4 sec	32 min

Onnnnn COMMAND

The OUTPUT command allows the output voltage to be set directly when in manual mode. (Status S=0). The command is not recognised in auto mode. The parameter may take values of 0 to 32767. (Note that output voltage is not directly proportional to nnnnn. There will be a dead bands at the end for which changes of nnnnn will not produce output changes.

Gnnn COMMAND

The GAS control command allows the state of the auxillary output port to be set directly when in manual mode. (Status S=0). The command is not recognised in auto mode. The parameter may take values of 0-255, allowing each of the eight lines of the auxilliary output port to be controlled directly. Each line is represented as ont bit of an 8-bit binary number. Any line that is active (i.e. pulled low) is represented by a binary 1. Then the required parameter nnn is the decimal equivalent of this 8-bit binary number.

In normal use only the least significant line is used, to control the gas solenoid. Hence the only two options will be G0 for solenoid off and G1 for solenoid energised.

Qn COMMAND

The "QUIET" command controls the responses generated by the VTC. The parameter n may take any value in the range 0-255. With n=0 or omitted. The VTC is totally quiet, the only data transfered to the computer are the actual number strings in response to a measure command. Non-zero values for the parameter, result in a selection of any combination of 8 independant response options. Each is given a value (in a binary sequence) and the required Q parameter is obtained by adding together the values for each of the options required to be active. The list below shows the options available.

VALUE	OPTION
1	Echo Single Command letter on command-completed
2	Echo each character as received
4	Send "<CR>." prompt on command-completion or after STATUS sent automatically
8	Send <EOM> after initial command letter received
16	Send <EOM> after illegal-command error message
32	Send STATUS message whenever status changes
64	Send <EOM> after automatic status message
128	Send <LF> after every <CR>

At power-up the VTC is in the Q254 state, which is believed to be the state requested by Varian. ✓ (AS SEEN ON ACQ DIAG PORT)

Fn COMMAND

The FRONT PANEL command determines which of the internal variables is displayed on the front panel LED display. The parameter normally displayed is measured temperature. For diagnostic purposes it can be useful to have a display of various other parameters. The following may be displayed:

F0	MEASURED TEMPERATURE
F1	SET TEMPERATURE
F2	ERROR (SET TEMP. - MEASURED TEMP.)
F3	HEATER VOLTS (AS A PERCENTAGE OF FULL OUTPUT)
F4	SAFETY SENSOR RESISTANCE (OHMS)
F5	RT SENSOR VALUE (DEGREES)
F6	CH1 INPUT FREQ/4
F7	CH2 INPUT FREQ/4
F8	CH3 INPUT FREQ/4
F9	P PARAMETER
F10	I PARAMETER
F11	D PARAMETER

NOTES

1. F2 is currently on an expanded scale (x20 approx) for dignostic purposes.
2. The values for F3, F4 and F5 are approximate readings, intended for diagnostic purposes only.
3. F6, F7 and F8 provide a measure of the frequencies of the input V/F converters. Again these are intended for service diagnostic purposes only.
4. F9, F10 and F11 serve as a reminder of the current values of the P, I and D control parameters. Note that unlike the other values above, the displayed value is not continuously updated.

Thus after a P command it will be necessary to repeat the F9 command if the new value of P is to be displayed.

Wn COMMAND

The WAIT command is provided to simplify interfacing to slow computers, with no input buffering. For example a computer running a simple logging program in basic, may take several milliseconds between issuing an R command and being ready to accept the resulting response. The W command introduces a fixed delay before every character sent. The value of nnnnn specifies the delay in milliseconds. (Leading zero's may be omitted). Delays may extend from zero to 1 minute. (Though the latter is not recommended!).

Unnnn COMMAND

The VTC holds a number of key parameters in non-volatile memory. These can however be overwritten by specific sequences of commands, in order to reconfigure the instrument. To prevent erroneous commands causing such a corruption, a lock is built into the software. As supplied, the L, X and Y commands will not be recognised and produce an error message. To Unlock these commands the command Unnnn must be issued, where nnnn is the correct key-value.

To prevent inadvertant operator error a second lower level of locking is incorporated. This is used for example on the "C" command. At power up the command is locked but it can be unlocked by a U1 command. Almost any non-zero U parameter will open this lock. It is not necessary to know the full four digit key-value.

L COMMAND

The L command allows data to be sent to load the lineariser data table. The data is sent as a series of 257 decimal values in the range 0 to 65535. These represent the start and end points for the 256 segments into which the working range of the controller is divided. A relatively simple program written in Basic, is available from Oxford Instruments to transfer a data table from a computer to the VTC. To avoid the data table becoming corrupted by an inadvertant L command, this command is normally "locked" (see above).

X,Y & Z COMMANDS

This family of commands are provided purely for software diagnostic purposes. They transfer pure binary data (ie non-ASCII) between the controller and a computer. The X and Y commands overwrite areas of the non-volatile memory and could therefore have a serious effect if misused. For this reason they are "locked". The Z command performs a binary RAM dump. It will produce confusing output at a terminal but can do no harm to the controller and is therefore left unlocked.

7. CALIBRATION

All linearisation data and calibration constants are held in NONVOL RAM (Mostek 480-Z-02, internal dual Lithium Battery with retention life >10 years). New linearisation tables can be loaded from the computer and all other calibration is handled by an interactive dialogue with the computer.

Minimal equipment required for a full calibration is:

Millivolt Calibration Source
Resistance box (to simulate safety sensor)
Thermometer (to measure Room Temperature)
9600 Baud Terminal (or the spectrometer computer)

To reduce the chances of a calibration sequence being started inadvertantly, the calibration command is "locked" at switch-on. Before calibration can take place a "U1" command must be given. (Almost any non-zero parameter will suffice, it is not necessary to know the unique key required for the "X" and "Y" commands).

Following the "U1" command, calibration is initiated by sending a "C" command. The VTC then conducts a dialogue in which it requests that various input conditions are applied in sequence. Once the specified condition has been applied the operator responds by pressing <RETURN>. After a pause to ensure that conditions have settled, the parameter is measured and the appropriate calibration constant is stored in non-volatile memory.

The calibration sequence is split into 3 sections covering the safety sensor, the main sensor and the room temperature sensor. Any section may be omitted by entering a <SPACE> rather than a <RETURN> for the first step of its sequence. However once a calibration sequence has been started for a sensor it must be completed. If any errors are made, the sequence for that sensor should be completed and then the calibration routine restarted to correct the error.

When calibration is complete, the "C" command may be relocked by means of a "U0" command. The "C" command automatically becomes locked if the instrument is switched off or if a "B" command is issued.

The following is an example of the calibration dialogue conducted in response to a C command. The operators responses are underlined and the symbol <RET> is used to denote a carriage return entered by the operator.

U1
C
CALIBRATION SEQUENCE

Apply Input Condition specified, then press RETURN. To skip any step, press SPACE.

Safety Sensor = 20 ohms<RET>,wait
Safety Sensor = 210 ohms<RET>,wait
Safety Sensor = 199 ohms<RET>,wait
RT sensor TP = 0.35 volts<RET>,wait
RT sensor TP = 1.55 volts<RET>,wait
Isolate RT sensor TP<RET>,wait
Enter Room Temp in form XX.X 24.3<RET>
Main sensor = -5.603 mV<RET>,wait
Main sensor = +9.827 mV<RET>,wait
CALIBRATION COMPLETE
U0

8. CALIBRATION CONSTANTS AND NOTES

ROOM TEMP SENSOR TEST POINTS

Voltages are applied between TP1 (+ve) and TP0 (-ve) on the input board. (The smaller board at the left-hand side of the instrument. Positions of the test points are shown on the PCB silk-screen.

MAIN SENSOR INPUT VOLTAGES

(Apply these voltages direct to 9 way D socket. The calibration logic takes care of any RT corrections required.)

The values given calibrate the instrument for a range from -200C to +210C. In general it will not be possible to obtain readings down to -200C with the reference junction at room temperatures. The input amplifier will normally limit at around -190C. Calibration down to at least -150C is guaranteed with ambient temperatures up to 40C at the rear panel.

RESTORATION OF ORIGINAL CALIBRATION

If calibration has been lost for any reason and a suitable voltage source is not available, it may be expedient to restore the original calibration settings determined when the equipment was initially tested. To this end, a copy of the original calibration data is contained within the program memory EPROM U2. Use of this facility is described in section 10.3.

In instruments prior to serial number 07/006 this calibration data was supplied in a separate EPROM.

9. THEORY OF CONTROL

9.1 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 the VTC4.

9.2 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 hman 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 the VTC in its MANUAL mode.

9.3 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).

9.4 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.

9.5 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 contant 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 twice the response time constant of the system.

9.6 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 charcterised 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.

10 THE NON-VOLATILE MEMORY

All the sensor linearisation tables, calibration data and long-term parameters such as the prompt string are held in a non-volatile memory, so that they are retained when power is removed. This memory is contained in the integrated circuit U3 on the main circuit board.

Retention of the memory in the absence of power is achieved by means of a small lithium battery built into the memory package. Thus data is retained even when the integrated circuit is removed from its socket. The battery has sufficient capacity to retain the memory contents for at least 10 years.

Under exceptional circumstances, it is possible that some or all of the contents of the non volatile memory may be lost. Indications that this has occurred are a sudden change in calibration or a string of random characters, returned in place of the normal "." prompt, after every response.

Should this occur, follow the procedure given in section 10.3 below, to restore the calibration. If the fault re-appears after the instrument has been switched off, the non-volatile memory chip has failed and should be replaced.

10.1 "batt" warning message

Every time power is applied to the controller, internal circuitry within the memory tests the state of the battery. If this is starting to fail the normal "PASS" message obtained at power-up is replaced by a "batt" message. The letters are rather stylised and appear as:-

This message is held for 10 seconds instead of the normal 2 seconds. If this message is obtained, it is an indication that the memory chip needs replacing. There is a large voltage margin between the point at which the low battery warning is obtained and the point at which data is lost. Thus it will normally be possible to obtain and fit a replacement memory chip before data has been lost from the old one.

10.2 Memory Replication

If calibration data is not to be lost it is obviously necessary that the contents of the old memory chip must be copied into the new one. This may be done automatically by the VTC itself. The procedure to be followed is:

1. Disconnect the instrument from the mains supply and remove the top cover. (Once the four screws have been removed, the cover may be slid towards one corner, and the opposite corner lifted clear of the frame.)

2. Mark the old and new memory chips to avoid confusing them.

3. Carefully remove the program memory chip U2 from its socket and put it somewhere safe.

4. Carefully remove the old data memory chip U3 from its socket and install it in the U2 socket. Make sure it is the same way round. There will be a mark in one corner, or a notch at one end, which should be towards the front of the VTC. The data memory chip is a 24 pin device, whereas in later instruments the program memory chip is a 28 pin device. In this case the data memory chip should be mounted at the rear of the U2 socket, with the unused four positions towards the front of the instrument.

5. Install the new memory chip in the U3 socket. Again make sure it is the right way round.

6. Now reconnect the mains and switch the instrument on for 5 seconds, then switch it off again and disconnect from the mains once more. (Provided fingers are kept clear it is not necessary to replace the cover for this operation.). Apart from the mains indicator lighting, there will be no indication that anything is happening. The displays will not light. However a special piece of code contained within the memory chip will have copied its entire contents into the new chip.

7. Finally remove the old memory chip from the U2 socket and replace the original program memory chip in the socket. Replace the top cover and test the instrument. It should now operate normally and will still be fully calibrated.

10.3 Restoration of Original Memory Content

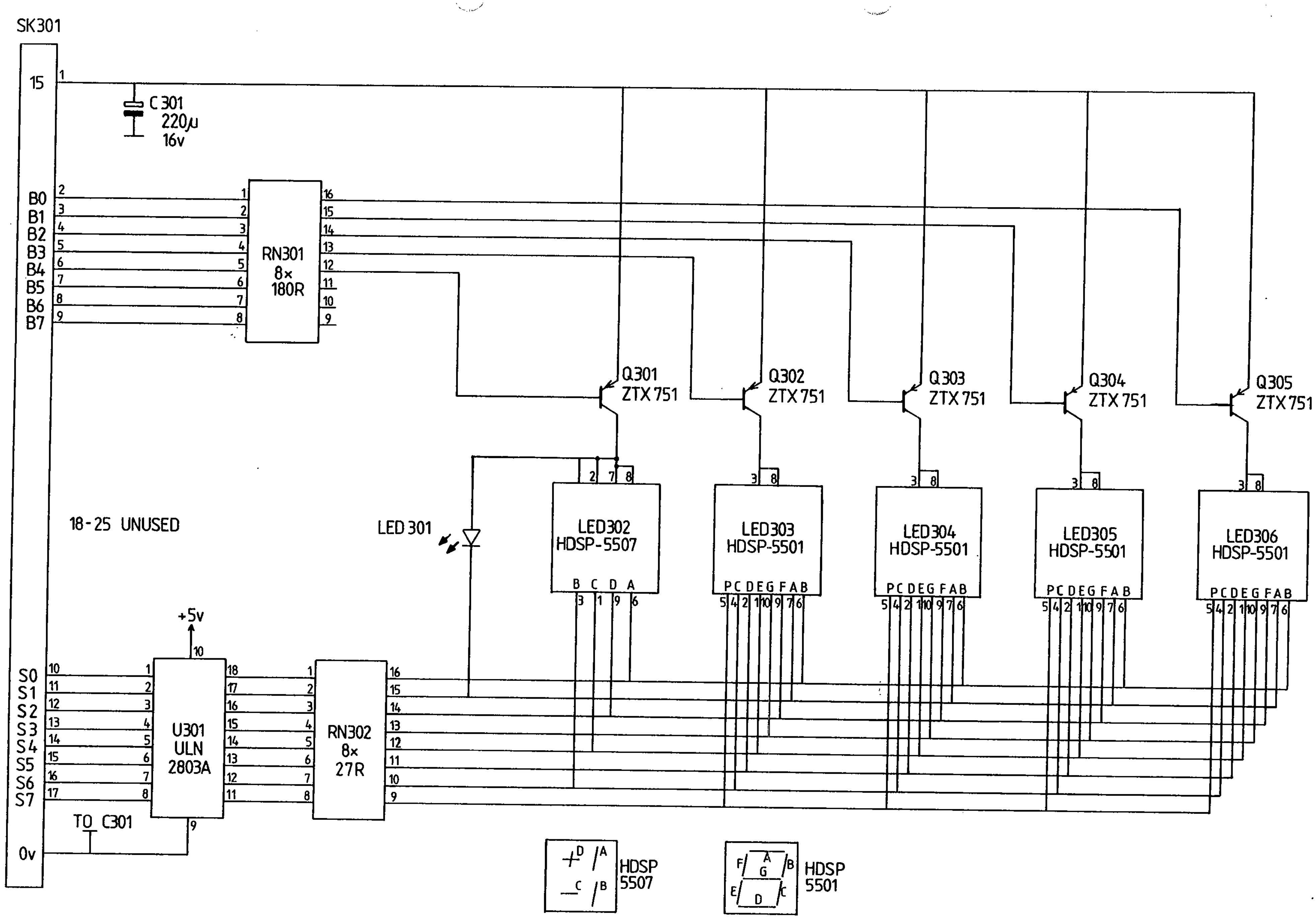
If the calibration of an instrument has been lost for any reason, it is possible to restore the original calibration parameters determined during manufacture. On units from serial number 07/006 onwards, having software version 5.01 or later, this calibration data is incorporated in the program memory EPROM U2, which is a 28 pin device type 2764.

To restore the original calibration, the red button SW1 on the main PCB should be pressed, whilst the unit is switched on. Data from U2 will automatically be copied into U3.

On instruments prior to serial number 07/006, with software version 4.xx, U2 is a 24 pin device type 2732. In this case the calibration data is written in a separate calibration EPROM supplied with the instrument.

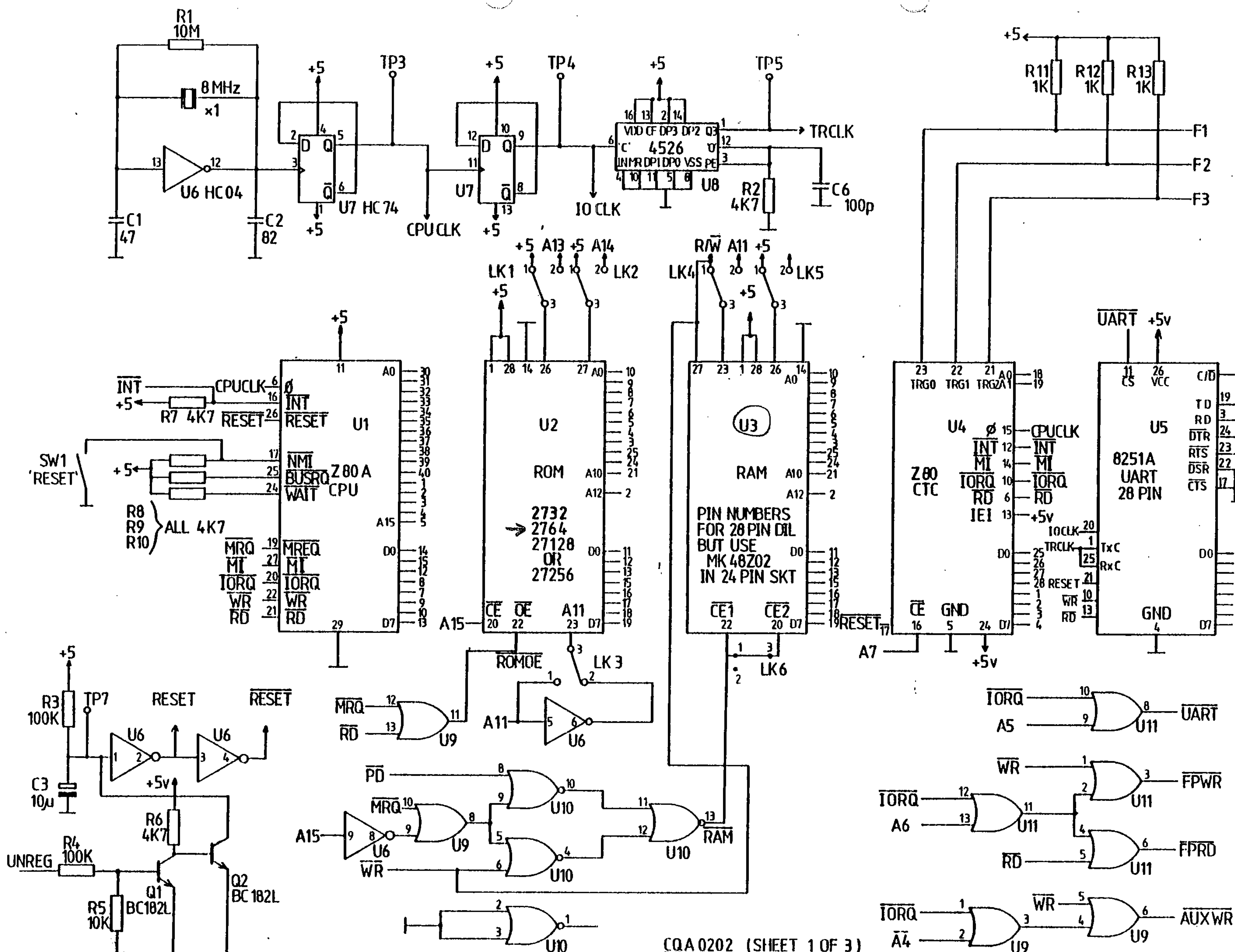
To use this EPROM, follow the procedure given in section 10.2 but use the calibration EPROM in U2 socket rather than the old memory chip.

In either case it is important to use the correct calibration data for a specific instrument. Check that the label on the EPROM containing the calibration matches the serial number of the instrument it is to be used with.



SEGMENT ALLOCATION

CQA0102 (SHEET 1 OF 1) VTC DISPLAY PCB

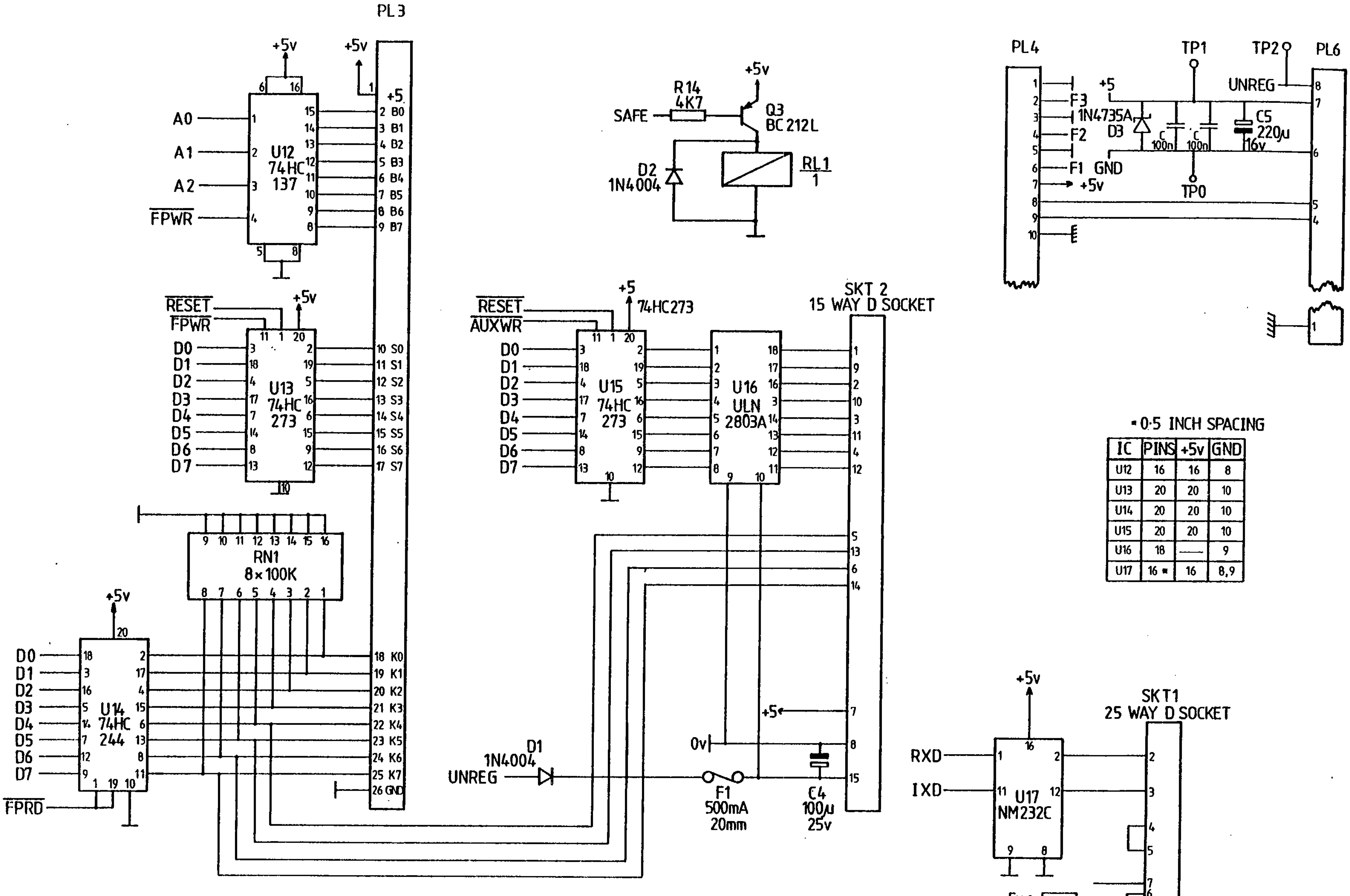


IC	PINS	+5v	GND
U1	40	11	29
U2	28	28 LK1	14
U3	28	28 LK5	14
U4	28	24	5
U5	28	26	4
U6	14	14	7
U7	14	14	7
U8	16	16	8
U9	14	14	7
U10	14	14	7
U11	14	14	7

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

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

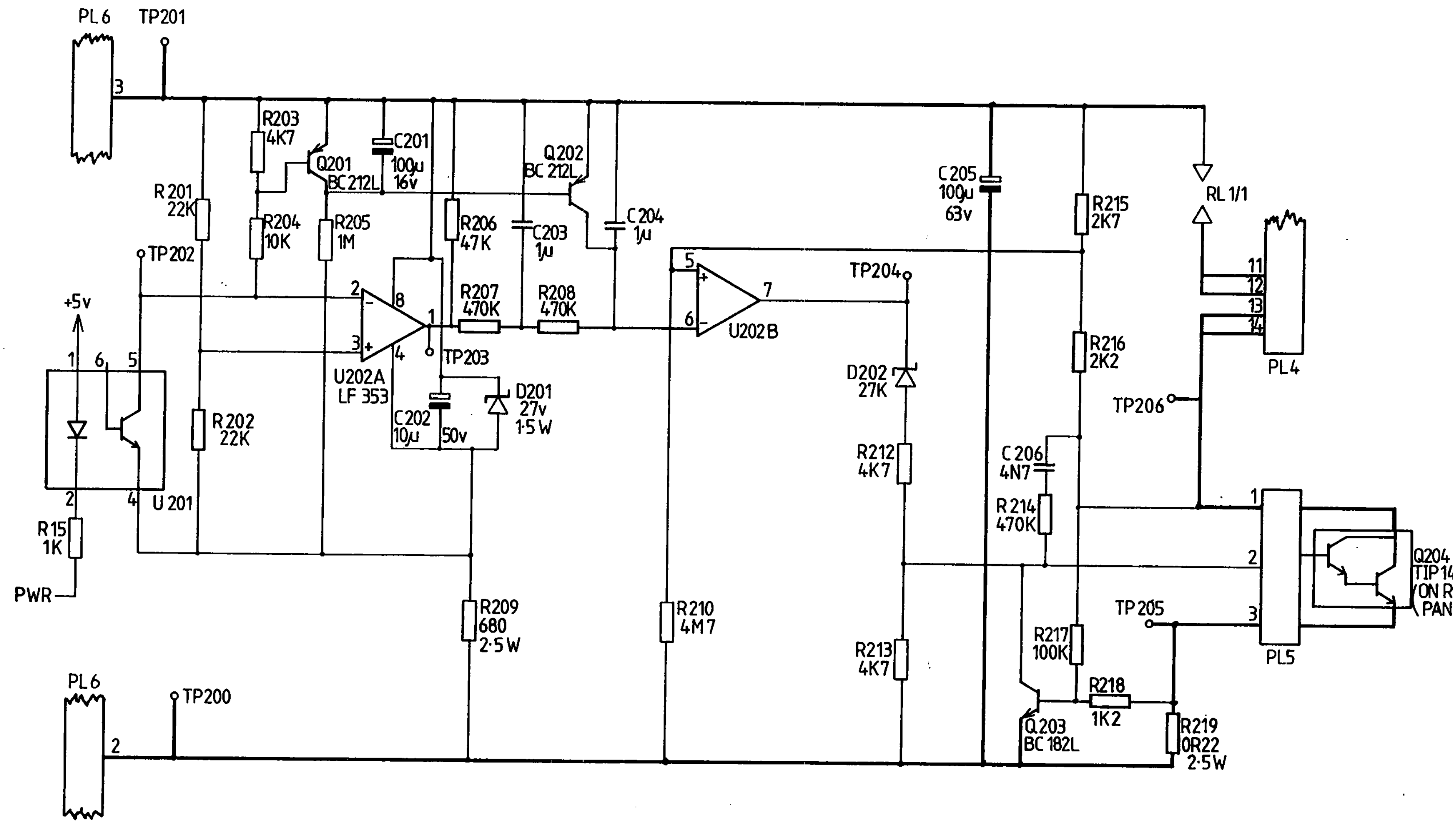
U3 RAM
- sensor linearisation tables
- calibration [illegible]
- long term paramet[illegible]



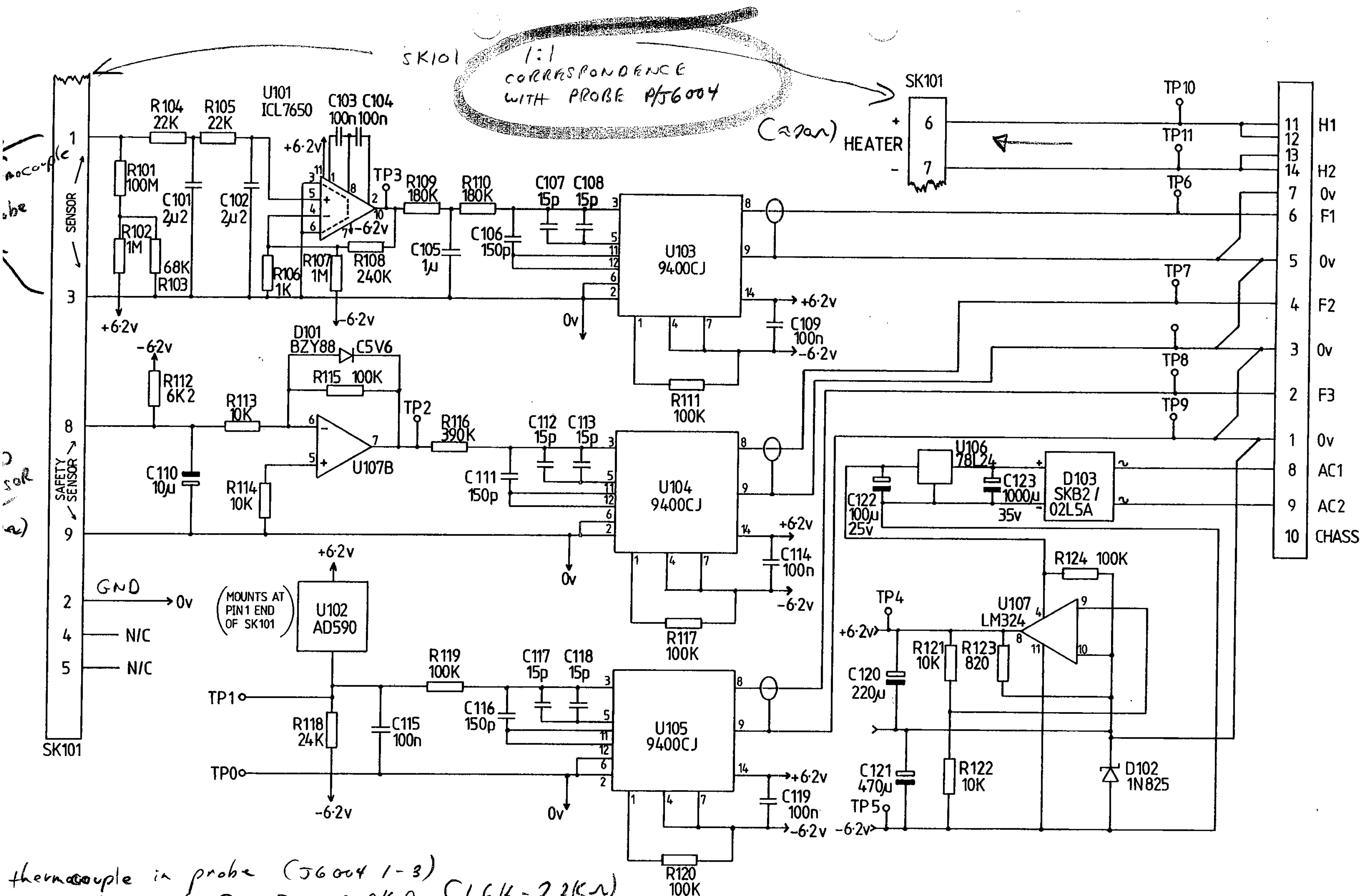
* 0·5 INCH SPACING

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



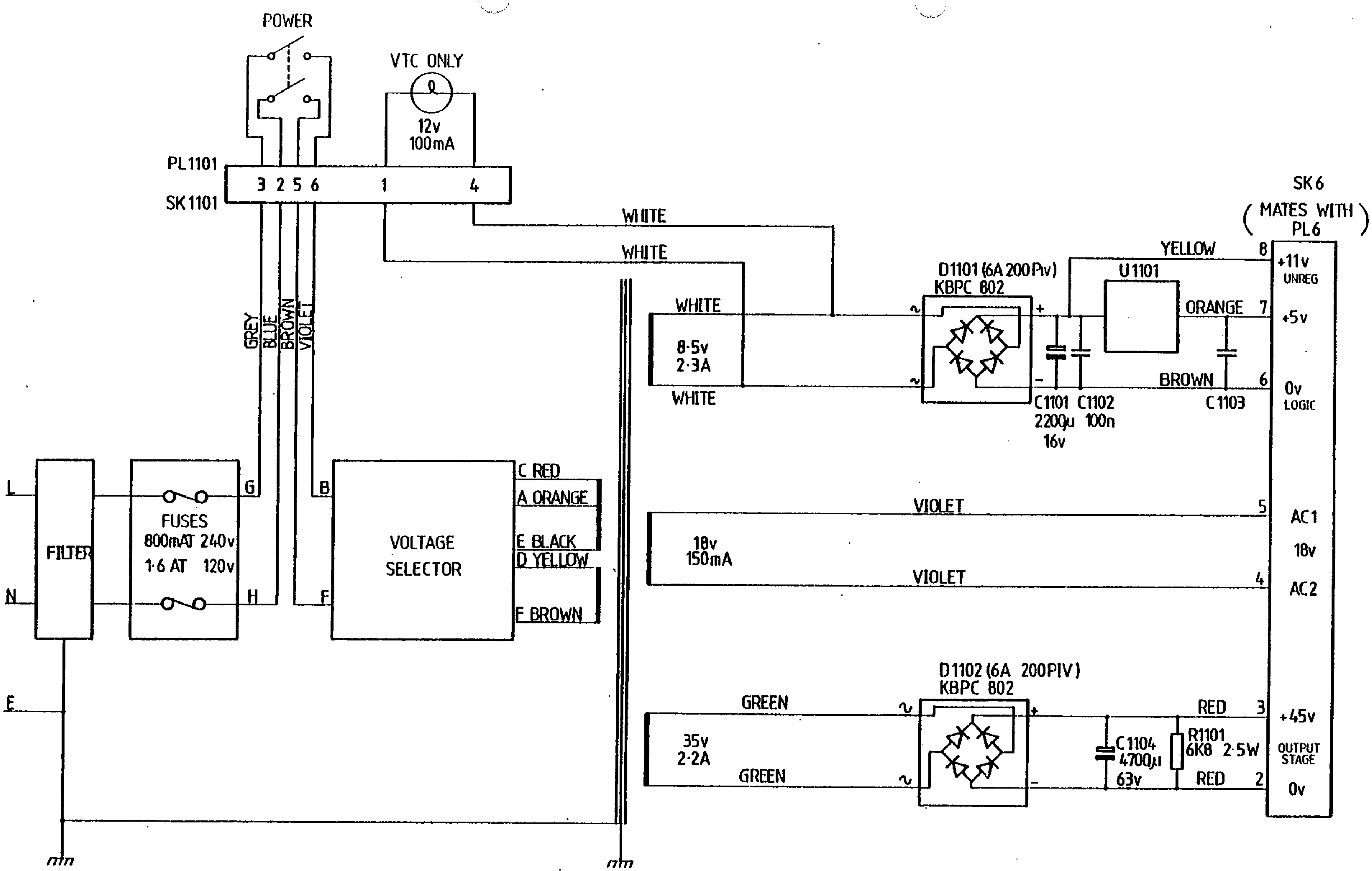
CQ.A 0202 (SHEET 3 OF 3) OUTPUT STAGE



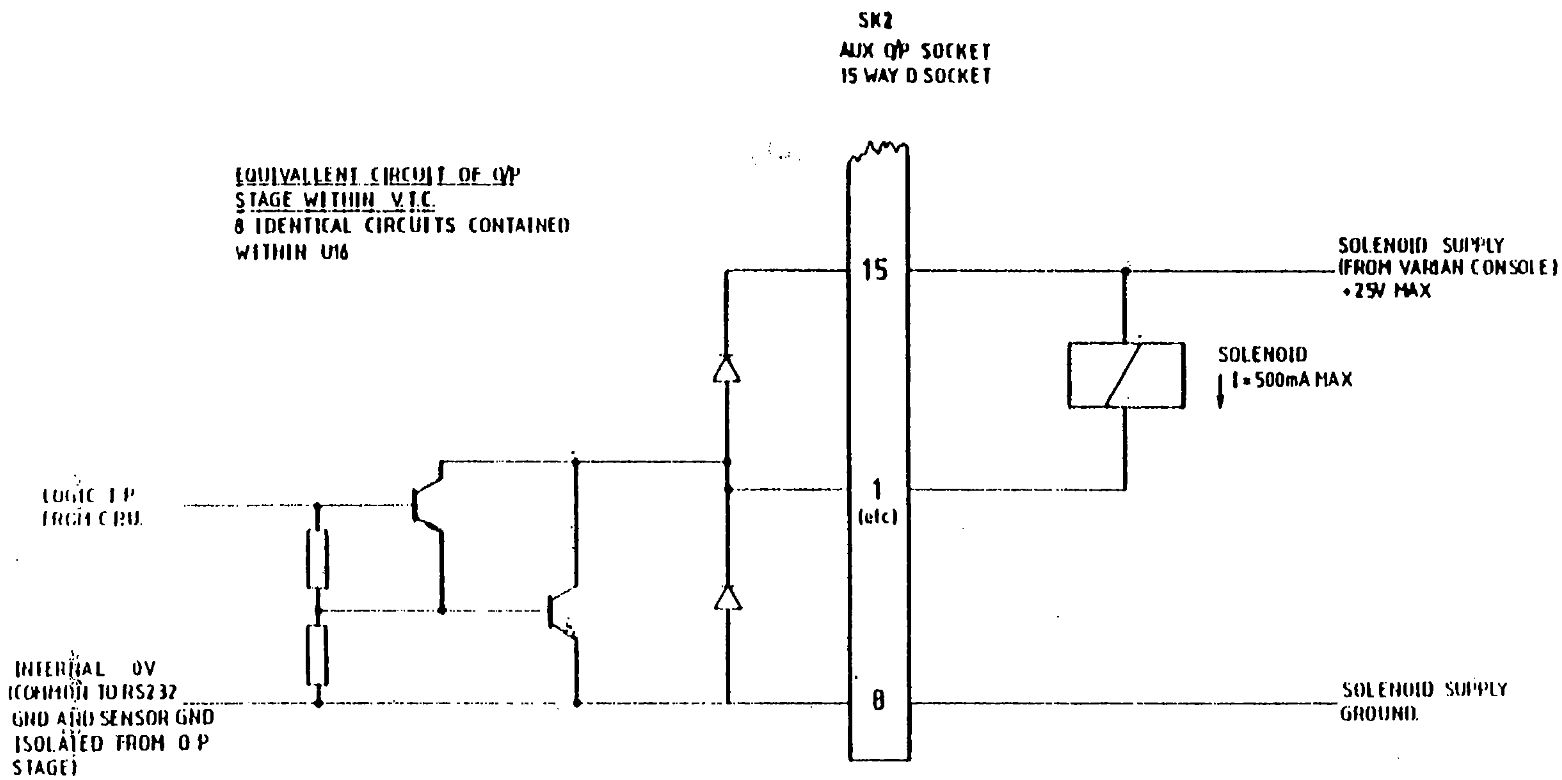
thermocouple in probe (J6004 1-3)
Gen III + early Gen IV ≈ 2KΩ (1.6K - 2.2KΩ)

CQA 0302 (SHEET 1 OF 1) VTC INPUT PCB

new Gen IV 1-3 ≤ 100Ω (typ. 28Ω)



CQA 1102 (SHEET 1 OF 1) POWER SUPPLY


SK2
AUX O/P SOCKET
15 WAY D SOCKET
EQUIVALLENT CIRCUIT OF O/P
STAGE WITHIN V.T.C.
8 IDENTICAL CIRCUITS CONTAINED
WITHIN U16
15
1
(etc)
8
SOLENOID SUPPLY
(FROM VARIAN CONSOLE)
+25V MAX
SOLENOID
I = 500mA MAX
LOGIC I P
FROM C P.U.
INTERNAL 0V
(COMMON TO RS232
GND AND SENSOR GND
ISOLATED FROM O P
STAGE)
SOLENOID SUPPLY
GROUND.

CQA0200 VT CONTROLLER MAIN PCB ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA0010	VTC PCB MOUNTING BLOCK	
CQA0201	VTC MAIN PCB MAN. DETAILS	
ECC0147	CAP 47p CER N150 2% 63V	C1
ECC0182	CAP 82p CER N150 2% 63V	C2
ECC0210	CAP 100p CER N150 2% 63V	C6
ECC0347	CAP 4n7 CER MED-K 10% 63V	C206
ECD0510	CAP 100n MONOCER -20+80% 50V	C10-14, C16-20.
ECP0610	CAP 1u0 POLYESTER 10% 100V	C203,204
ECR0710	CAP 10u LOWLEAK ELEC 20% 50V	C3,C202
ECS0810	CAP 100u ELEC -10+50% 25V	C4,C201
ECS0812	CAP 100u ELEC -10+50% 63v	C205
ECS0822	CAP 220u ELEC -10+50% 16V	C5
EDA4004	DIODE 1N4004 400V 1A	D1&D2
EDR6127	ZENER 1N4750A BZX61 27V 1.3W	D201 D202
EFF2205	FUSE 20mm GLASS QUICK 500mA	F1
EFH2300	FUSEHOLDER 20mm PCB MTG	
EHH0300	FULL NUT B/Zn M3	
EHP4300	FEMALE SCREWLOCK (D TYPE)	
EHS0207	SCREW PAN-POZI B/Zn M2.5x6mm	
EHS0310	M3x10mm PAN-POZI B/Zn SCREW	
EHW3300	WASHER FIBRE M3.	
EHW4201	WASHER WAVY B/Zn M2.5	
EHW4300	WASHER WAVY B/Zn M3	
EHZ0000	SELF ADHESIVE FOAM 25x12mm 0.8	UNDER CRYSTAL
EIA0353	IC LF353 DUAL J FET AMP 8 DIL	U202
EIG0526	IC HC14526 COUNTER 16 DIL	U8
EIH0002	IC 74HC02N 14 DIL	U10
EIH0004	IC 74HC04N 14 DIL	U6
EIH0032	IC 74HC32N 14 DIL	U9&U11
EIH0074	IC 74HC74N 14 DIL	U7
EIH0137	IC 74HC137N 16 DIL	U12
EIH0244	IC 74HC244N 20 DIL	U14
EIH0273	IC 74HC273N 20 DIL	U13&U15
EIM2732	IC 2732 EPROM 450nS 24 DIL	U2
EIM4802	IC NOVRAM 2K X8 MK48Z02B	U3
EIQ0035	IC OPTO-ISOLATOR 4N35 6 DIL	U201
EIU8251	IC 8251A USART 28 DIL	U5
EIU8400	IC Z80A CPU 40 DIL	U1
EIU8430	IC Z80A CTC 28 DIL	U4
EIZ0232	IC MM232C TTL/RS232 C'INTFACE	U17
EIZ2803	IC OPTO DRLGTON DRIVER ARRY 5V	U16
EPA0000	TEST POINT (SPACE INVADER)	TP'S
EPI0025	SOCKET IC TURNED PIN 24 DIL	
EPI0028	SOCKET IC TURNED PIN 28 DIL	
EPI0040	SOCKET IC TURNED PIN 40 DIL	
EPM0303	PLG AMP .100 PCB 3P S	PL5
EPM0308	PLG AMP .100" PCB 8P S	PL6
EPM1615	SKT D TYPE PCB PLASTIC 15P 90	SK2
EPM1625	SKT D TYPE PCB PLASTIC 25P 90	SK1
EPR0314	PLG IDC PCB LOCKING 14P S	PL4
EPR0326	PLG IDC/PCB LOCKING 26P S	PL3
EQA0080	QUARTZ CRYSTAL 8MHz HC18U WRES	X1
ERB0210	RES MF 100R 1% 0.25W 50PPM	R16
ERB0247	RES MF 470R 1% 0.25W 50PPM	R214
ERB0310	RES MF 1K0 1% 0.25W 50PPM	R11,12,13, R15
ERB0312	RES MF 1K2 1% 0.25W 50PPM	R218
ERB0322	RES MF 2K2 1% 0.25W 50PPM	R216
ERB0339	RES MF 3K9 1% 0.25W 50PPM	R215
ERB0347	RES MF 4K7 1% 0.25W 50PPM	R2,R6-10, R14,R203 R212,213
ERB0410	RES MF 10K 1% 0.25W 50PPM	R5,R204
ERB0422	RES MF 22K 1% 0.25W 50PPM	R201,202
ERB0447	RES MF 47K 1% 0.25W 50PPM	R206
ERB0510	RES MF 100K 1% 0.25W 50PPM	R3,4,R217
ERB0547	RES MF 470K 1% 0.25W 50PPM	R207,208
ERB0610	RES MF 1M0 1% 0.25W 50PPM	R205
ERC0647	RES MF 4M7 5% 0.25W 100PPM	R210
ERC0710	RES MF 10M 5% 0.25W 100PPM	R1
ERM2522	RES WW 0R22 2.5W 10%	R219
ERN8510	RES NETWORK 8x100K D.I.L.	RN1
ERP2268	RES WW 680R 2.5W 5%	R209
ESR1106	RELAY MINI 3A 6V SPC/O 100R	RL1
ESZ0102	SWITCH SPST MINI .100 PCB RED	SW1
ETB0182	TR BC182L NPN 300mW TO92	Q1,2,203
ETB0212	TR BC212L PNP 300mW TO92	Q3,201,202
EZB0001	CERAMIC BEAD SDP1	FOR ITEMS 17 & 23

CQA0300 VT CONTROLLER INPUT PCB ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA0010	VTC PCB MOUNTING BLOCK	
CQA0301	VTC INPUT PCB MAN. DETAILS	
ECC0115	CAP 15p CER NPO 2% 63V	C107,108 C112,113 C117,118
ECC0215	CAP 150p CER N150 2% 63V	C106,111 C116
ECD0510	CAP 100n MONOCER -20+80% 50V	C109,114 C119
ECP0510	CAP 100n POLYESTER 10% 100V	C103,104 C115
ECP0610	CAP 1u0 POLYESTER 10% 100V	C105
ECP0622	CAP 2u2 POLYESTER 10% 100V	C101,102
ECR0710	CAP 10u LOWLEAK ELEC 20% 50V	C110
ECS0810	CAP 100u ELEC -10+50% 25V	C122
ECS0822	CAP 220u ELEC -10+50% 16V	C120
ECS0847	CAP 470u ELEC -10+50% 16V	C121
ECS0912	CAP 1m0 ELEC -10+50% 40V	C123
EDB0220	DIODE BRIDGE 1.6A 200v	D103
EDR0825	DIODE REF. 1N825 6.2V 20ppm	D102
EDR8805	ZENER BZY88 C5V6 500mW	D101
EHH0300	FULL NUT B/Zn M3	
EHP4300	FEMALE SCREWLOCK (D TYPE)	
EHS0207	SCREW PAN-POZI B/Zn M2.5x6mm	
EHS0310	M3x10mm PAN-POZI B/Zn SCREW	
EHW3300	WASHER FIBRE M3.	
EHW4201	WASHER WAVY B/Zn M2.5	
EHW4300	WASHER WAVY B/Zn M3	
EIA0324	IC QUAD OP-AMP LM324 LOW POWER	U107
EIA7650	IC OP-AMP ICL 7650 U-LOW DRIFT	U101
EID9400	IC 9400CJ V/F CONV. 14 DIL	U103,104 U105
EIV7825	IC VOLT REG. 78L24 24V 100mA	U106
EPA0000	TEST POINT (SPACE INVADER)	
EPM1609	SKT D TYPE PCB (PLASTIC) 9P 90	SK102
EPR0314	PLG IDC PCB LOCKING 14P S	SK101
EQT0590	THERM SENSR AD590JH -55to+150C	U102 POSITION AS DRAWN
ERB0282	RES MF 820R 1% 0.25W 50PPM	R123
ERB0310	RES MF 1K0 1% 0.25W 50PPM	R106
ERB0362	RES MF 6K2 1% 0.25W 50PPM	R112
ERB0410	RES MF 10K 1% 0.25W 50PPM	R113,114 R121,122
ERB0422	RES MF 22K 1% 0.25W 50PPM	R104,105
ERB0424	RES MF 24K 1% 0.25W 50PPM	R118
ERB0468	RES MF 68K 1% 0.25W 50PPM	R103
ERB0510	RES MF 100K 1% 0.25W 50PPM	R111,117 R119,120 R124
ERB0516	RES MF 160K 1% 0.25W 50PPM	R115
ERB0518	RES MF 180K 1% 0.25W 50PPM	R109,110
ERB0524	RES MF 240K 1% 0.25W 50PPM	R108
ERB0539	RES MF 390K 1% 0.25W 50PPM	R116
ERB0610	RES MF 1M0 1% 0.25W 50PPM	R107
ERC0710	RES MF 10M 5% 0.25W 100PPM	R102
ERC0810	RES CA 100M 5% .5W	R101

CQA1000 VT CONTROLLER FRONT PANEL ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA1300	VTC FRONT PANEL SUB ASSY	
EFB3210	INS BOOT 32mm FUSE (BLACK)	
EFL1014	BULB 14V HIGHLAND	
EPM3306	PLG TRI-DENT,CABLE,6WAY	
EPT0520	CONNECTOR PIN SIZE 20 BICC	
ESZ3240	SWITCH SERIES 31 H'LAND ROUND	
ESZ3242	LENS ROUND RED,FOR ESZ3240	
EWS0301	WIRE 3A 16/0.2 PVC BROWN	
EWS0306	WIRE 3A 16/0.2 PVC BLUE	
EWS0307	WIRE 3A 16/0.2 PVC VIOLET	
EWS0308	WIRE 3A 16/0.2 PVC GREY	

EWS0309	WIRE 3A 16/0.2 PVC WHITE	2 LENGTHS
EWT3095	CABLE TYRAP 2.5x95mm	

CQA1400 VT CONTROLLER REAR PANEL ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA1100	VTC TRANSFORMER MTG ASSY	
CQA1401	VTC REAR PANEL DETAILS	CQA1405
EHN0300	FULL NUT B/Zn M3	
EHS1310	SCREW CSK-POZI B/Zn M3x10mm	
EHW5300	WASHER STAR B/Zn M3	
EWZ2015	INS SLEEVE 20mmX1.5mm I/D BLK	
EZF3786	FILTER 240V AC FUSED FN378-6	

CQA1500 VTC INPUT/MAIN PC HARNESS

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
EPR2014	SKT.IDC 14W STRAIN RELIEF.	
EWR0114	RIBBON CABLE GREY 14 WAY	

CQA1600 HEATSINK/TRANSISTOR ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CHA0420	HEATSINK 3E-1 MACHINED 1.7c/W	
EHS0306	M3x6mm PAN-POZI B/Zn SCREW	
EPM0203	SKT AMP .100 PCB 3P S	
ETP0141	TR TIP141 DPN 125W 80V TO220	
EWS0151	WIRE 1.4A 7/0.2 PVC BROWN	
EWS0152	WIRE 1.4A 7/0.2 PVC RED	
EWS0153	WIRE 1.4A 7/0.2 PVC ORANGE	
EWT3095	CABLE TYRAP 2.5x95mm	
EWZ2015	INS SLEEVE 20mmX1.5mm I/D BLK	
EZS1032	INS.WASH MICA TO3P	
EZS1033	INS.BUSH NYLON TO3P	

CQA0000 V.T. CONTROLLER FINAL ASSY (EA)

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA0020	VTC MTG. EARS 2U	
CQA0099	VT CONTROLLER SPARES KIT	
CQA0100	VT CONTROLLER DISPLAY PCB ASSY	
CQA0200	VT CONTROLLER MAIN PCB ASSY	
CQA0300	VT CONTROLLER INPUT PCB ASSY	
CQA1000	VT CONTROLLER FRONT PANEL ASSY	
CQA1400	VT CONTROLLER REAR PANEL ASSY	
CQA1500	VTC INPUT/MAIN PC HARNESS	
CQA1600	HEATSINK/TRANSISTOR ASSY	
EEA0200	TAPPED STRIP BITE M2.5 (411mm)	
ELC2319	CASE HARMONIE 2Ux19"x261mm	
EHS0207	SCREW PAN-POZI B/Zn M2.5x6mm	
EHS0306	M3x6mm PAN-POZI B/Zn SCREW	
EHS0308	M3x8mm PAN-POZI B/Zn SCREW	
EHS1211	SCREW CSK-POZI B/Zn M2.5x10mm	
EHS8211	M2.5x10mm SCREW R'SED CSK BLCK	
EHW4201	WASHER WAVY B/Zn M2.5	
EHW5201	WASHER STAR B/Zn M2.5	
EHW5300	WASHER STAR B/Zn M3	

CQA0099 VT CONTROLLER SPARES KIT

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA0999	VTC4 MANUAL	
EFF2308	FUSE 20MM GLAS ANTISURGE800M/A	
EFF2316	FUSE 20MM GLASS ANTISURGE 1.6A	

CQA0100 VT CONTROLLER DISPLAY PCB ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA0010	VTC PCB MOUNTING BLOCK	
CQA0101	VTC DISPLAY PCB MAN. DETAILS	CQA0103
CQA1200	VTC DISP/MAIN PCB HARNESS	
ECS0822	CAP 220u ELEC -10+50% 16V	C301
EDL0002	LED GREEN STD .2"	LED301
EHS0207	SCREW PAN-POZI B/Zn M2.5x6mm	
EHW4201	WASHER WAVY B/Zn M2.5	
EIP5501	LED DIGIT 7 SEG .56 HE RED AN	LED303-306
EIP5507	LED SIGN DISPLAY .56 HE RED AN	LED302
EIZ2803	IC OPTO DRLGTON DRIVER ARRY 5V	U301
EPI0025	SOCKET IC TURNED PIN 24 DIL	
EPI0028	SOCKET IC TURNED PIN 28 DIL	
ERN0133	RES.NETWORK 8x33R D.I.L.	RN302
ERN8218	RES NETWORK 8X180R D.I.L.	RN301
ETB0751	TR ZTX 751 PNP BI-POLAR	Q301-305

CQA1100 VTC TRANSFORMER MTG ASSY

PART NUM	DESCRIPTION	REFERENCE DESIGNATOR
CQA1101	VTC TRANSFORMER MTG PLATE	
CQA1110	MTG. PLATE HARNESS SKT (VTC)	
ECD0510	CAP 100n MONOCER -20+80% 50V	C1102,1103
ECS0922	CAP 2m2 ELEC -10+50% 16V	C1101
ECS0947	CAP 4700uF ELEC -10+50% 63V	C1104
EDB0260	DIODE BRIDGE RECT. 6A 200V	D1101,1102
EHN0300	FULL NUT B/Zn M3	
EHS0205	SCREW PAN-POZI B/Zn M2.5x4mm	
EHS0304	M3x4mm PAN-POZI B/Zn SCREW	
EHS0312	M3x12mm PAN-POZI B/Zn SCREW	
EHS0405	SCREW PAN POZI B/Z M4x5mm	
EHW5300	WASHER STAR B/Zn M3	
EHW5400	WASHER STAR B/Zn M4	
EHZ0000	SELF ADHESIVE FOAM 25x12mm	PUT ON TOP OF ITEM 4
EHZ0005	CLAMP CAP (16mm DIA) BLACK	
EHZ0009	CLAMP CAP. 35mm DIA 30'	
EIV7805	IC VOLTAGE REG. 1A +5V	U1101
ELS0001	TRANSFORMER VT CONTROLLER	T1101
EPA0110	SOLDER TAG (EYELET) 4BA	
EPM0208	SKT AMP .100"PCB 8P S	SK6
EPM3206	SKT TRI-DENT,CABLE,6 WAY	SK1101
EPT0420	CONNECTOR SKT SIZE 20 BICC	
ERP0368	RES WW 6K8 2.5W 5%	R1101
EWS0150	WIRE 1.4A 7/0.2 PVC BLACK	
EWS0150	WIRE 1.4A 7/0.2 PVC BLACK	
EWS0151	WIRE 1.4A 7/0.2 PVC BROWN	
EWS0152	WIRE 1.4A 7/0.2 PVC RED	
EWS0152	WIRE 1.4A 7/0.2 PVC RED	
EWS0153	WIRE 1.4A 7/0.2 PVC ORANGE	
EWS0154	WIRE 1.4A 7/0.2 PVC YELLOW	
EWS0301	WIRE 3A 16/0.2 PVC BROWN	
EWS0306	WIRE 3A 16/0.2 PVC BLUE	
EWS0307	WIRE 3A 16/0.2 PVC VIOLET	
EWS0308	WIRE 3A 16/0.2 PVC GREY	
EWS0310	WIRE 3A 16/0.2 PVC GRN/YLLW	
EWT2101	'P'CLIP SIZE Nx1 BLACK	
EWT2102	'P'CLIP SIZE Nx2 BLACK	REAR
EWT3095	CABLE TYRAP 2.5x95mm	
EZS1220	INS.WASH MICA TO220AB	
EZS1221	INS.BUSH NYLON TO220AB	