PID Temperature Controller

RS Stock No. 340-083

Instruction Manual

RS stock no. 340-083 Temperature Controller Instruction Manual

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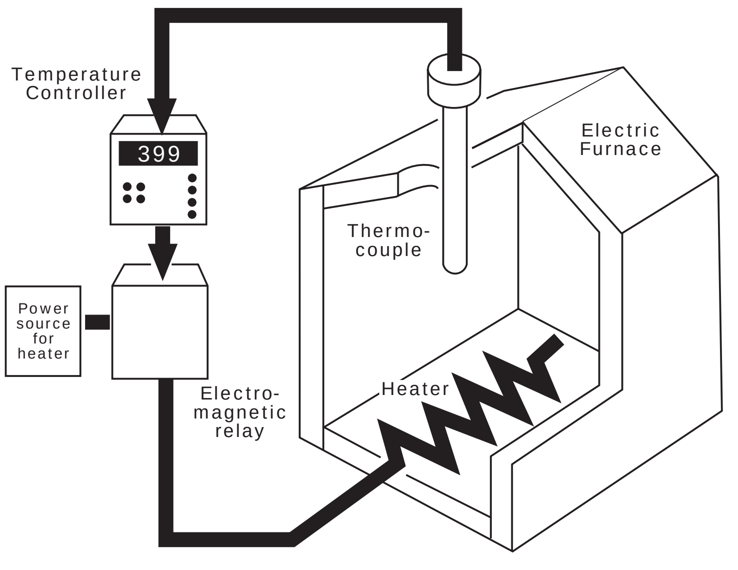
1. Introduction

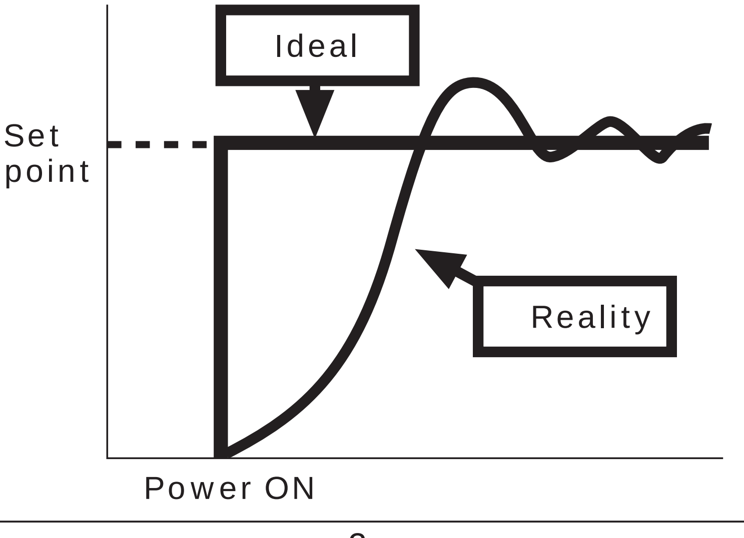
1.1 Introduction To Temperature Control

The temperature of a process can be controlled by sensing the actual temperature, calculating its deviation from the desired process temperature and applying a stimulus to the process of the correct magnitude to achieve the desired temperature. This form of control is known as feedback control and is equally applicable to the control of pressure, flow or any measurable and controllable process parameter. A typical example of a temperature control application is shown below.



In the above example the controller opens or closes the relay according to whether the temperature measured by the thermocouple is above or below the setpoint programmed into the controller.

There are many factors which influence the design of a process control system. Firstly, we need to be able to measure the process temperature or characteristic which we want to control. The choice of sensor type is determined by the temperature at which it has to work and the environment in which it will be working. Secondly, we must be able to control the process. This must be achievable using a relay directly or controlling another device such as a contactor, or with an analogue voltage or current. Thirdly, the controller must be set up to apply the optimum amount of control to the process.

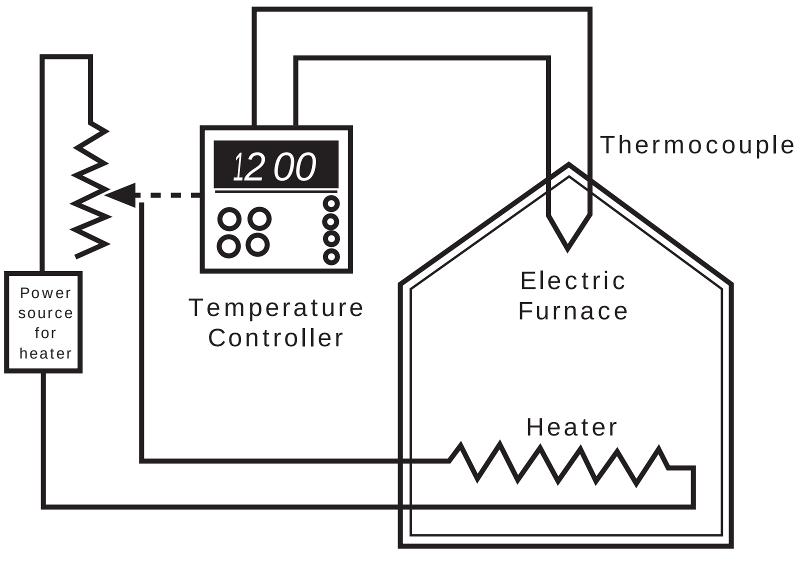


In the curve on the previous diagram we can see the ideal response of the process to the controller output. In reality the response is more likely to look like one of the other curves. In curve A the process overshoots the setpoint and thus the controller applies less power to return the temperature to setpoint. The temperature then undershoots and the controller responds. If the controller is set up with too much gain the process could end up oscillating. In curve B we can see that the opposite is the case. The controller gain is not set high enough and so the controller applies power too slowly to the process and the response is sluggish. Controller setup usually involves trading off these two curves to obtain a smooth response to changes in setpoint or disturbances to the process while giving the best response time.

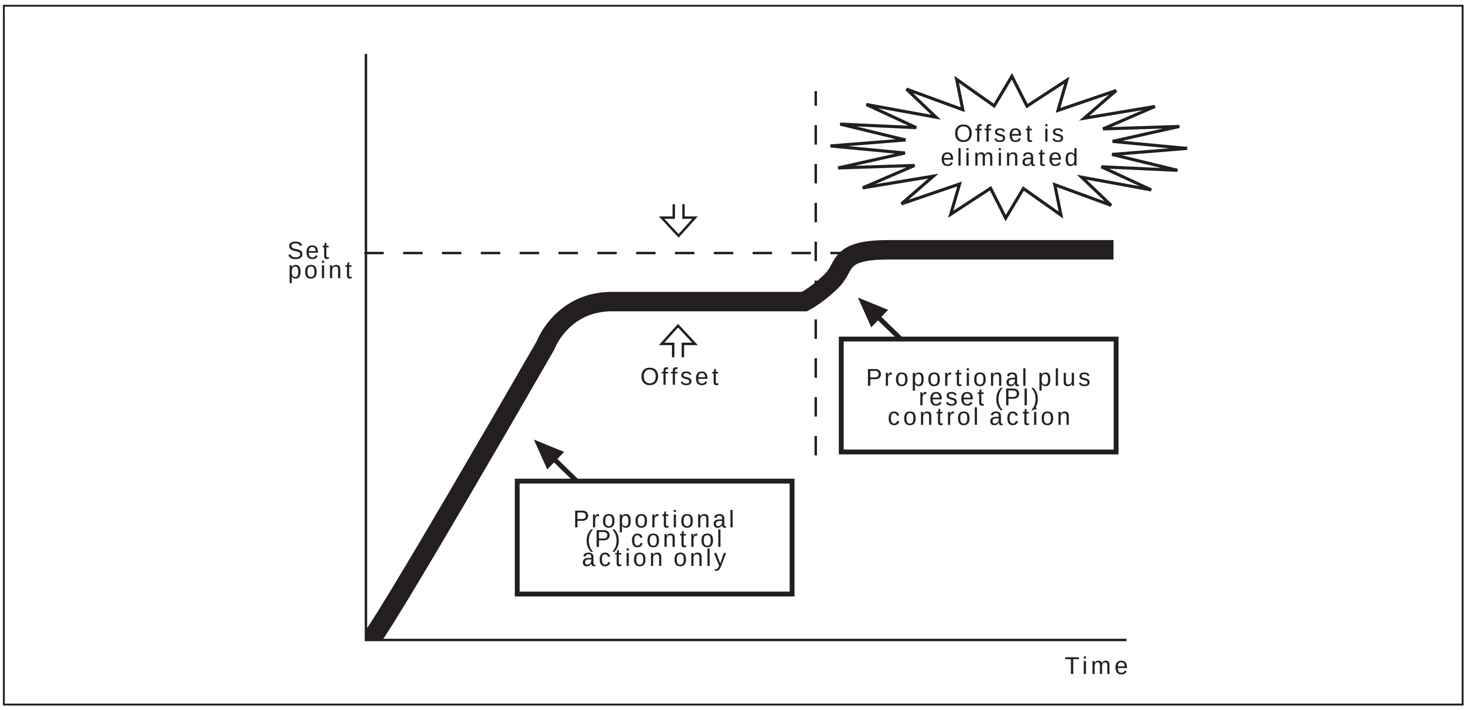
1.2 Types Of Control

ON/OFF control. This is the simplest form of control. When the process temperature is below setpoint the controller applies full heat and when it is above setpoint the controller applies no heat or full cooling. In many systems this produces a perfectly acceptable response, but in many others it will cause a response similar to curve A in the previous diagram.

Proportional (P) control. It is possible for the controller to apply a variable amount of power to a process. This is achieved by cycling the relay output on and off for a variable percentage of a fixed cycle time. Therefore, if the relay is closed all the time, 100% power is being applied, and if the relay is only closed for 10% of the cycle time then 10% power is being applied. Proportional control produces an output power proportional to the process temperatures deviation from setpoint and is usually expressed as a Proportional Band (PB), as defined below.

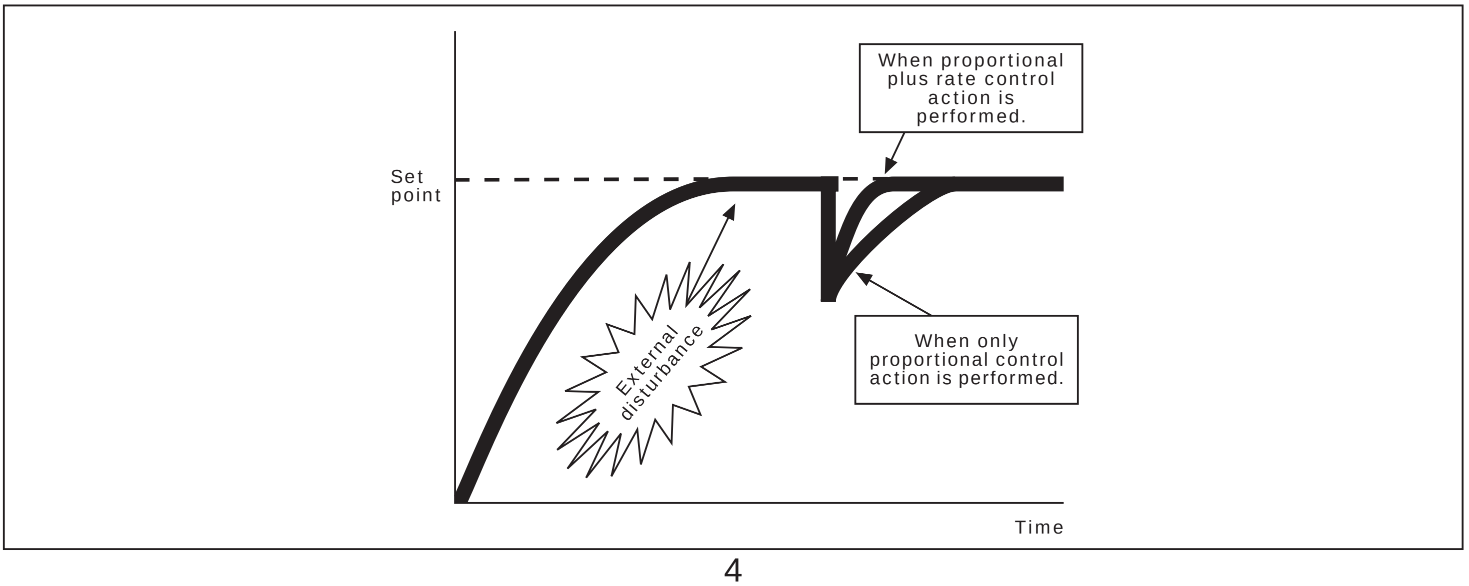


Reset (I) control. Reset control overcomes a problem encountered when using proportional control. In any real system there are energy losses to or from the environment surrounding the process. The problem with proportional control is that it will always achieve a state of balance with these losses before the setpoint is reached and thus will need an offset (traditionally referred to as a reset) to counteract the system losses. On older controllers a reset potentiometer was usually supplied to adjust the balance point. With the advent of microprocessor based controllers such as the **RS** stock no. 340-083 series it is possible to perform a mathematical function called integration (I) which automatically applies just the right amount of control action necessary to correct for the losses. The curve overleaf shows the response curve with proportional control only up to time t1. At time t1 the integral term is turned on and the controller applies progressively more power until the process reaches setpoint.

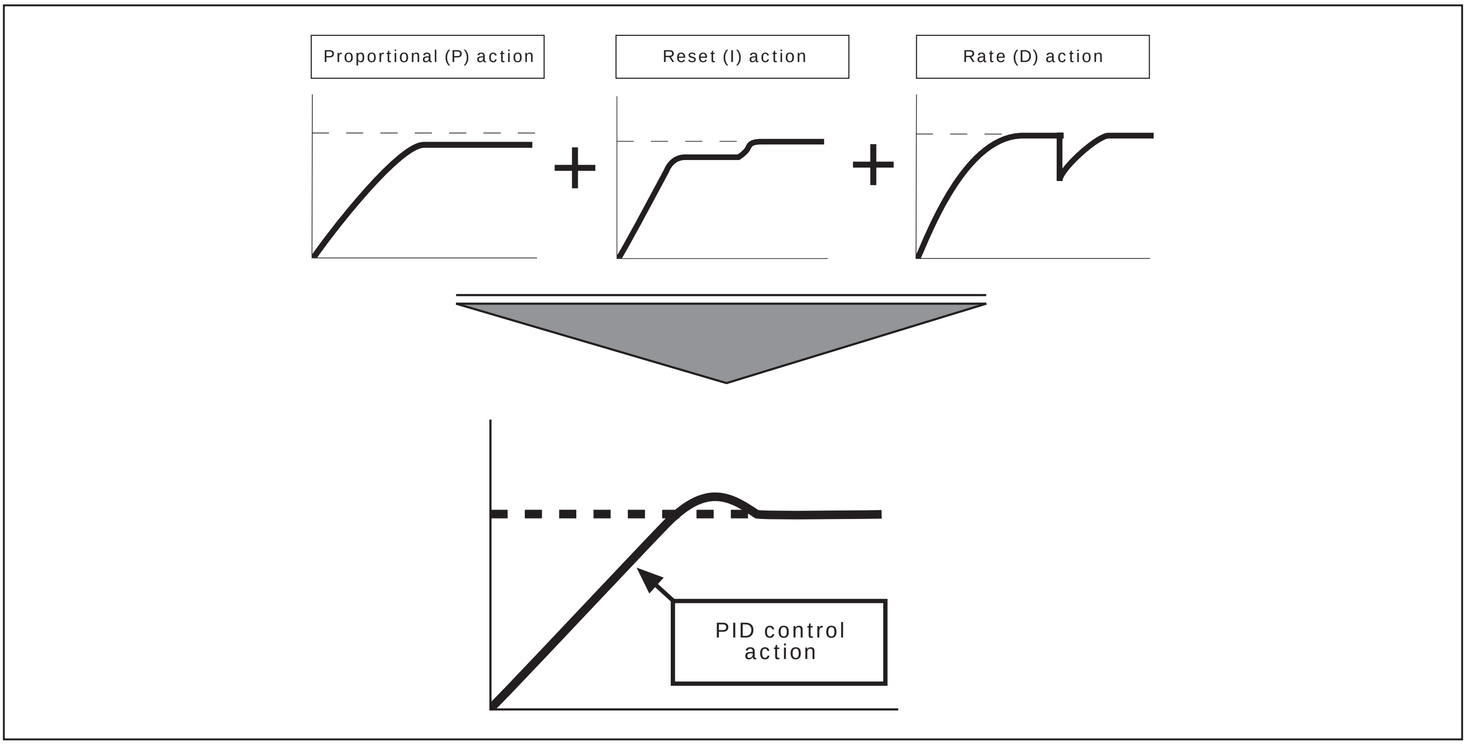


The way the integral term works is as follows. The deviation from setpoint (e) is continuously added to an accumulator. If the process temperature goes above setpoint then the value of e is negative, and so this works to return the process to setpoint. The accumulator then has a gain applied to it called the integral action time (IT). The larger the integral action time, the smaller the contribution of the error accumulator to the output power, and so the longer it takes to have effect. The gain of the proportional term is also applied to the integral term. In this way, the PB acts on the overall gain of the controller, not just the proportional term.

Rate (D) control. One of the problems with reset action is that it takes time to integrate the error and is thus slow to respond to process disturbances. The solution to this is to apply rate action. Rate action continuously monitors the process value and calculates the rate at which it changes. Mathematically, this is called the derivative (D) term. Thus, if the process suddenly changes temperature (for example, a cool object is introduced into the heating zone) the derivative term calculates a large positive increase in the deviation from setpoint and produces a large increase in output power to counteract it. A gain is applied to the derivative term called the derivative action time (DT). The larger the derivative action time, the larger the effect, and so the longer it is effective. Once again the proportional band gain is applied to the derivative term to provide an overall gain to the controller. The curve below shows the effect of the derivative term to produce a faster response to disturbances than proportional only control.



Full PID control. By applying proportional integral and derivative control actions at the same time, the optimum control can be achieved. As shown in the next figure, this will produce a process which responds as fast as possible to disturbances with as little overshoot as possible and as accurate a control of process temperature as possible.



Unfortunately, there is a snag. If the integral action time, the derivative action time, and the proportional band are not set correctly, the system response can be worse than if ON/OFF control was used. There are established procedures (see section 8 on the Ziegler-Nichols method) for calculating the correct values of PB, IT and DT, but these do not always work well with non-linear systems or systems with large time delays relative to the action times. Also the process needs to be exercised to find out how much it overshoots and its period of oscillation. For some processes this may not be feasible of safe.

1.3 Controller Capabilities

The **RS** stock no. 340-083 temperature controller can provide ON/OFF, P, PI, PD or full PID control with very flexible control over the associated parameters via a menu operated from the front panel display and pushbuttons. Most types of thermocouples can be connected as sensors. Alternatively the unit can accept input from Pt100 type resistance temperature detectors (RTDs). The units can also accept input from voltage or current sources and the display can be scaled to suit the application. Output is by means of a mechanical or solid state relay. There are various alarm relay configurations possible with the range. A security switch is provided within the unit to prevent unauthorised tampering with the setup parameters or to restrict the menu to changing the setpoint within defined high and low limits. The unit can accept power from 120 to 240 Volts a.c. supplies and automatically detects whether 50 or 60Hz supply is in operation to minimize the effects of supply noise on measurements.

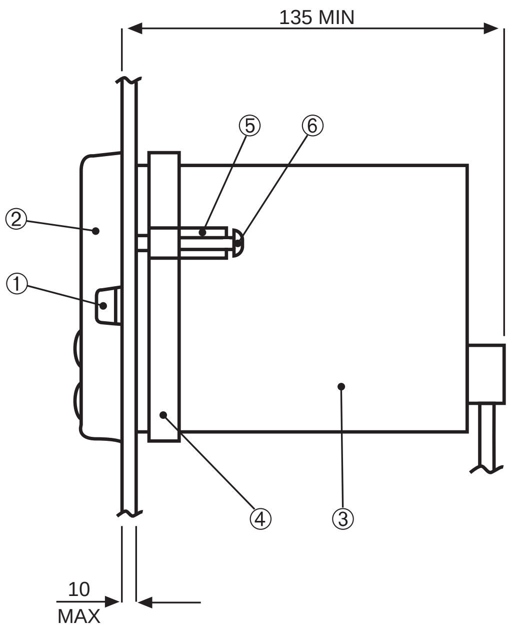
2. Installation

2.1 Unpacking

The controller is supplied with all necessary fittings. Unpack the carton and check that the panel mounting ring and screws are present.

2.2 Mounting

The controller is designed for mounting in a panel up to 10mm thick into a square cutout 92mm by 92mm (tolerancing +0.8/-0mm) or 3.62 inches by 3.62 inches (tolerancing +0.03/-0 in). A space of at least 135mm must be available behind the panel. Controllers may be mounted in a continuous line vertically, but at least 11mm must be allowed between mounting holes with controllers mounted in a horizontal line.



To mount the controller, the instrument should first be removed from the case by squeezing the catches (1) on either side of the fascia (2), and at the same time firmly pulling it out of the case (3). The mounting ring (4) can be removed from the case by lifting both latching arms (5) and sliding back. The controller case should be inserted into the mounting hole from the front, and the mounting ring slid onto the rear of the case and pushed forward until it touches the back face of the mounting panel, and the latches ave engaged firmly in the case. The two screws (6) should then be GENTLY tightened to pull the case onto the panel. Do not overtighten the screws or the mounting ring may be damaged.

To remove the case from the panel, loosen both screws (6), disengage both latching arms using a screw driver, and slide the ring back off the case. The case may then be removed from the front of the panel.

Once the case has been secured to the panel, the instrument assembly may be inserted into it by carefully aligning first the top, then the bottom PCBs with the case slots and then gently pushing the instrument into the case until both catches engage.

2.3 Removing Instrument From Case

The instrument can be removed from its case by squeezing the catches on either side of the fascia and at the same time firmly pulling the instrument out of its case. Do not force the instrument out of its case.

2.4 Factory Set Configuration

When you receive the TC9600 controller from your supplier it will be set up to a default configuration. This is unlikely to be exactly correct for your application. Read this manual fully and familiarise yourself with the menu system and the modes of operation of the controller. Keep a written copy of the configuration details in a safe place for reference in the event of damage to the controller or unauthorised access to the menu.

In order to prevent the controller from doing any damage during installation, it is supplied in manual mode with the power set to 0%. However, in this mode the alarms will still operate. To get the controller operating familiarise yourself with the menu and set the controller into auto mode. Please refer to section 7.1 for more details about manual mode and section 6 for details about the menu.

3. RS Stock No. 340-083 Series Model Descriptions

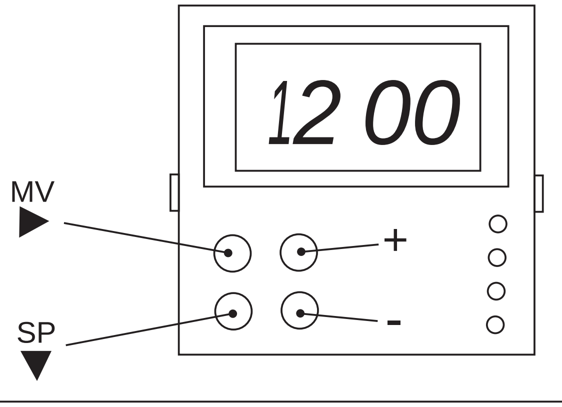
Note: On early versions of the **RS** stock no. 340-083 controller the relay actions were referred to as forward and reverse in the manuals and the menu. This caused confusion with the control actions traditionally referred to as direct and reverse. By definition a reverse acting controller applies less power as the measured process value (normally temperature) increases whereas a direct acting controller applies more power as the process value increases. For example in a typical heating application a reverse acting controller would be used, whereas in a refrigeration plant a direct acting controller would be needed. To avoid confusion the **RS** stock no. 340-083 controller now refers to the relay actions as normally open (n-o) instead of forward (Frd) and normally closed (n-c) instead of reverse (rEv).

The **RS** stock no. 340-083 is a triple output controller with a measurement accuracy of 0.25%. The first and second outputs can be used as heat and cool, whilst the third output is an extra alarm which can be used as a versatile absolute or deviation alarm. The absolute and deviation alarm settings can be active at the same time to allow maximum flexibility of operation. All outputs are single pole normally open relays whose action is selectable. The **RS** stock no. 340-083 also has the ability to accept a d.c. input voltage or current and has a definable display range.

4. RS Stock No. 340-083 Series Front Panel

4.1 Display

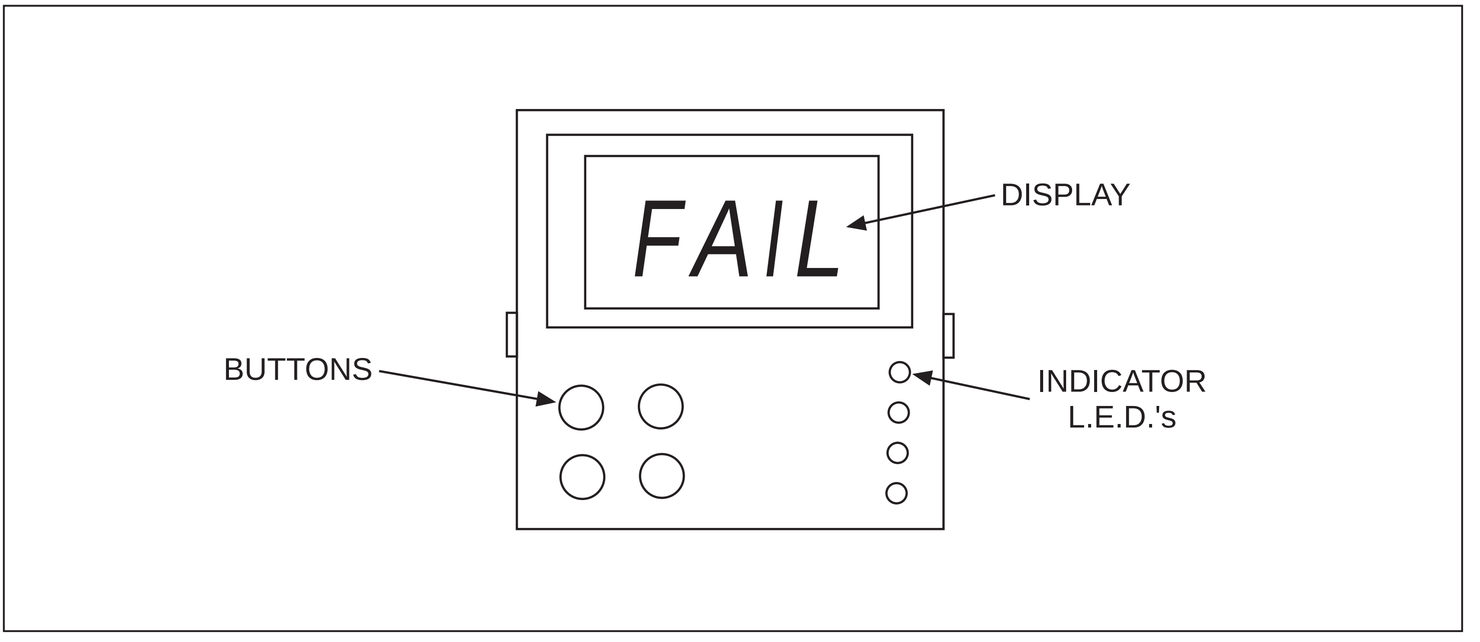
The controller front panel features a high contrast ratio, four digit, seven segment, liquid crystal display (LCD).



The LCD is used to display the process temperature in the selected units of °C or °F. If a d.c. input type is used then the display is in the range set by the IPHI, IPLO, TOP and BOT parameters in the setup menu.

The LCD is also used to display the menu messages and parameters. The messages have been carefully designed to be readable on a seven segment display.

During the first few seconds after power is turned on, the controller goes through a series of self tests during which every digit of the display is turned on so that they can be seen to be working. If the controller detects any faults during self test the message below is displayed and the unit must be returned for repair. The controller will not work once a fail has been detected.



When the measurement input of the controller goes out of range or when a break occurs in the lead of a thermocouple, RTD or d.c. voltage type input sensor the display shows the following message:
See section 5.5 for a description of the control state when a lead break is detected.

4.2 Buttons
The four front panel buttons are used to gain access to the controllers setup parameters using the built in menu. The menu is organised as a table of parameters and is described in section 6. At the top left corner of the table is the measured value. In the column underneath the measured value are the operating parameters:- Setpoint, the setpoint adjustment limits, auto manual mode selection and the output power. To the right of the measured value are the column headings, under which are grouped related subheadings.

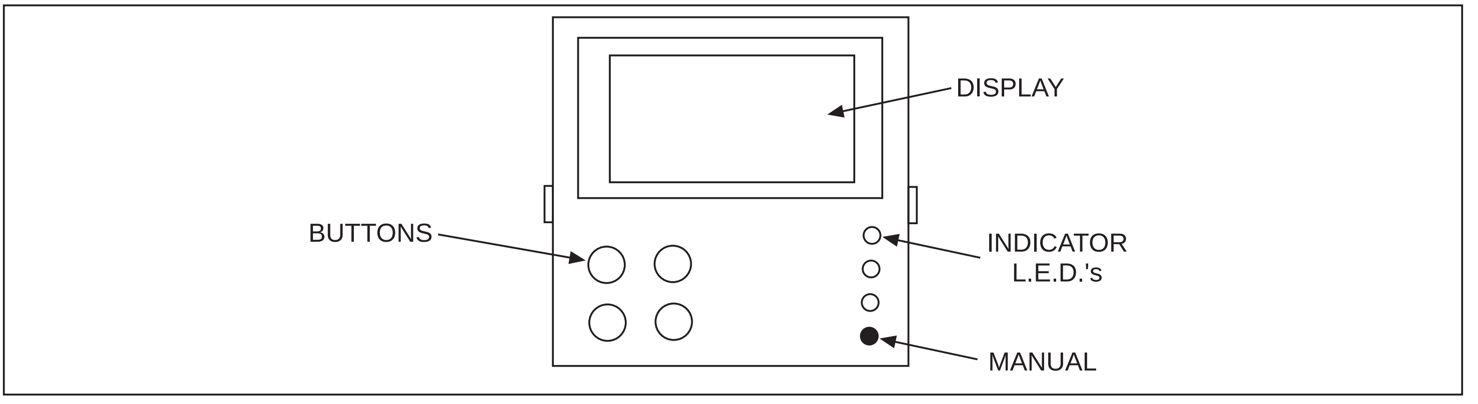
Adjusted parameters take effect immediately although they are only updated in the non-volatile memory when the button is pressed or the fifteen second timeout occurs.

The ▶ button has the following functions. From any heading a single press will move the menu to the next heading on the right. If the menu is at a subheading then a single press will return the menu to the heading, saving any adjusted parameter in memory. If the button is held for more than one second then the menu returns to displaying the measured value, saving any parameter that was being adjusted. This last function also happens if no button is pressed for more than 15 seconds.

The ▼ button has the following functions. From a heading, a single press will send the menu down to the next subheading and display its name. If the button is held down the menu will step through all of the subheadings in that column. Once the desired subheading has been reached the menu will display the name of the subheading alternating with the current value, once a second. If no key is pressed for 15 seconds a timeout sends the menu back to the measured value. Also, when a numeric parameter is being adjusted the v button will increase the range of the adjustment by a factor of ten. The adjustment range is indicated by the appropriate digit of the number flashing while no buttons are pressed. This allows faster setting of large changes to a parameter.

The **+** and **-** buttons are used to adjust parameters. The ▶ and v buttons are used to select the heading and subheading to be adjusted and then a single press of the **+** or **-** buttons displays the value to be adjusted. If it is a numeric parameter then the right hand digit will be flashing. Further presses of + or - will adjust the parameter up or down. If the keys are held down the number will continuously adjust. Pressing the ▶ button or pressing no keys for 15 seconds will store the parameter in non-volatile memory. The contents of this memory are saved when power is removed from the controller.

4.3 Lamps
There are four front panel lamps on the **RS** stock no. 340-083 temperature controller.

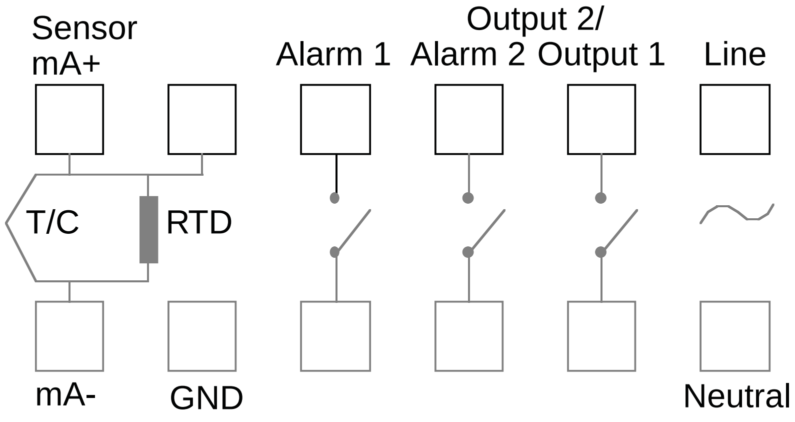


The bottom lamp shows whether the controller is in auto or manual mode. In manual mode the controller alarms, if configured, still operate but the control output power is supplied from a parameter on the menu. This enables the engineer to test the system to find out its response to different levels of power or to take control in an emergency. The lamp is lit when the controller is in manual mode and unlit under normal automatic control. The controller is switched from auto to manual mode using the Auto parameter under the measured value heading, and the power is set in manual mode using the PR parameter under the measured value heading. In auto mode the PR parameter just displays the current output power.

The other lamps show the status of the output and alarm relays. If the lamp is LIT then the relay is closed.

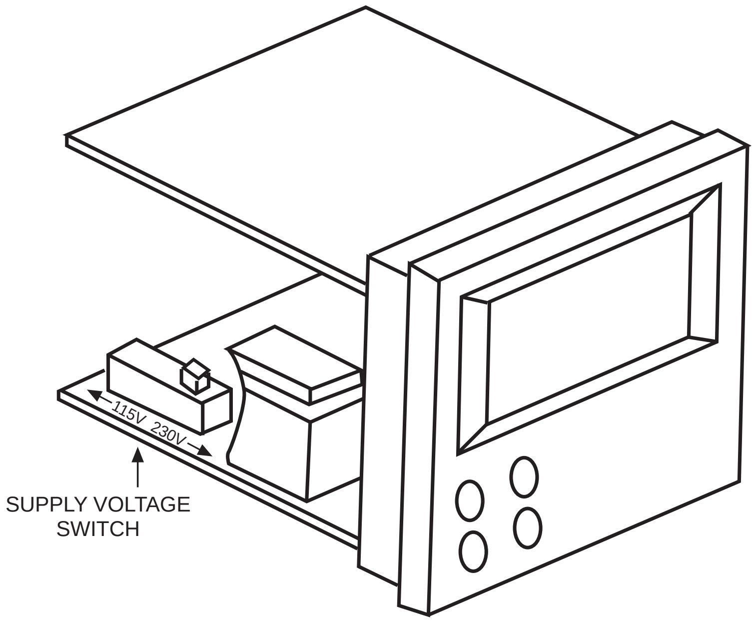
5. RS Stock No. 340-083 Back Panel
5.1 Connections And Wiring
To prevent inadvertent damage, it is recommended that connections are made after installing the case, but with the instrument removed from the case.

Twelve screw terminal connections are provided at the rear of the case. A clear plastic cover normally protects the terminals from fingers. This should be removed by gently pulling backwards to gain access to the screws.



5.2 Power Supply

The controller will operate on a supply of either 115V a.c. or 230V a.c., +10%/-15%, 47-63Hz. The supply voltage must be selected by a slide switch on the lower instrument PCB as shown in the next figure. Check the local supply before installing the instrument as damage will be caused if the wrong voltage is selected. The supply should be connected with the LIVE connected to terminal 7B and the NEUTRAL connected to terminal 7A.



5.3 Grounding Considerations And Safety

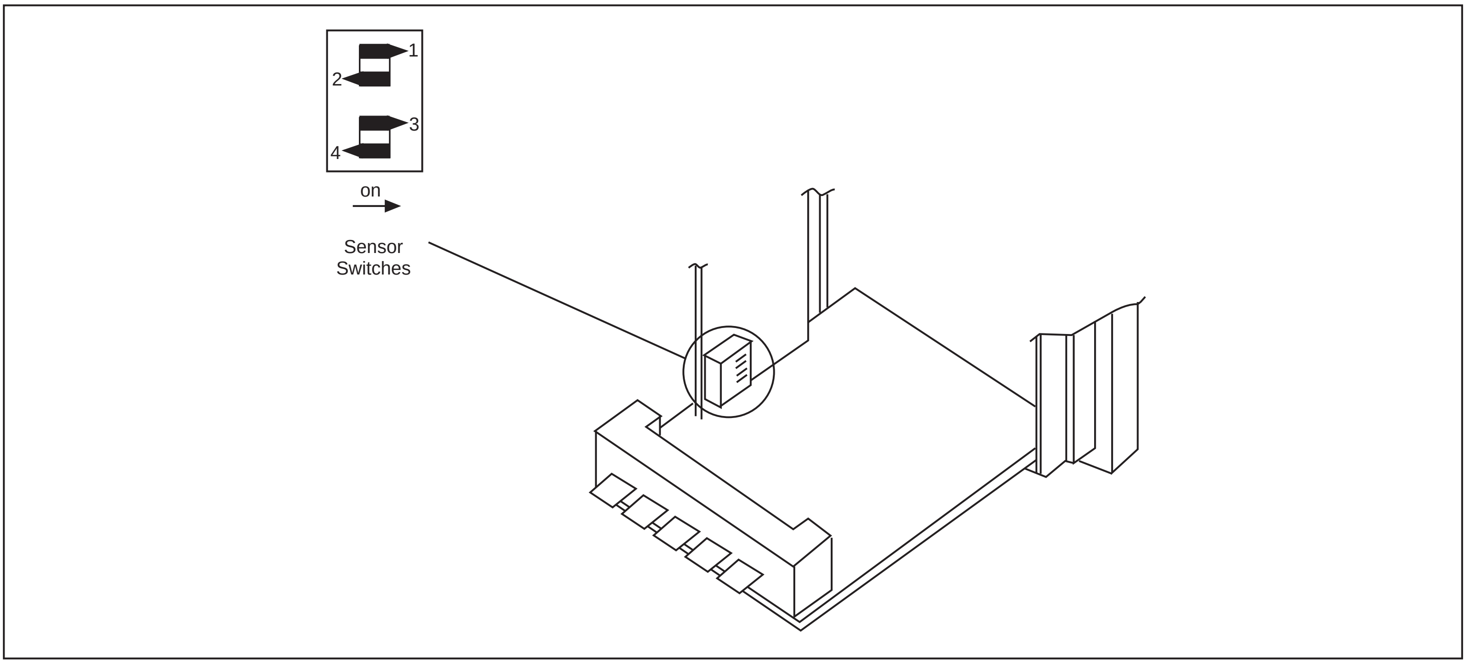
The unit has been designed as a class I device and has a safety earth terminal provided, which is connected to the case. This must always be connected to the local earth in accordance with local wiring regulations.

5.4 Connecting A Sensor

The controller must be configured for the chosen type of sensor using the switches mounted internally on the small instrument PCB. The switches need to be set to the following positions:-

Thermocouple/mV:	**2 &4**
RTD:	**1 & 4**
mA:	**2 & 3**

The menu also needs to be setup for the sensor type using the IP subheading of the Etc heading. If a d.c. input type is selected (mV or mA according to switch setting) the input top and bottom of scale and the display top and bottom of scale need to be set.



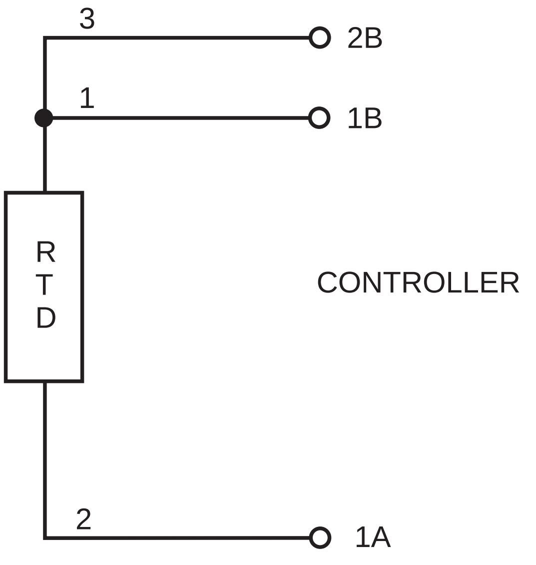
Thermocouples should be connected with the positive lead to terminal 1B, and negative to 1A (see table 1 for lead colours). If the thermocouple lead needs extending, the correct type of compensating cable and matching connectors must be used to prevent errors, taking care to ensure correct polarity, avoiding unnecessary joints, and keeping separate from cables carrying other than low level signals. If shielded cable is used it should only be grounded at one point, preferably terminal 1A.

Thermocouple Type	**To BS1843 +ve**	**-ve**	**To ANSI/MC96.1 +ve**	**-ve**	**To DIN 43714 +ve**	**-ve**
J - Fe/NiCu	yellow	blue	white	red	red	blue
K - NiCr/NiAl	brown	blue	yellow	red	red	green
N - NiCrSi/NiSi			no standard colours			
R - PT13%Rh/Pt	white	blue	black	red	-	-
S - Pt10%Rh/Pt	white	blue	black	red	red	white
T - Cu/CuNi	white	blue	blue	red	red	brown

Table 1 - Standard Thermocouple Cable Core Colours

Resistance Temperature Detectors may use either a two or three wire connection. Where short cables are possible, two wire connection may be used. For best accuracy or where long leads are necessary, the three wire connection is recommended.

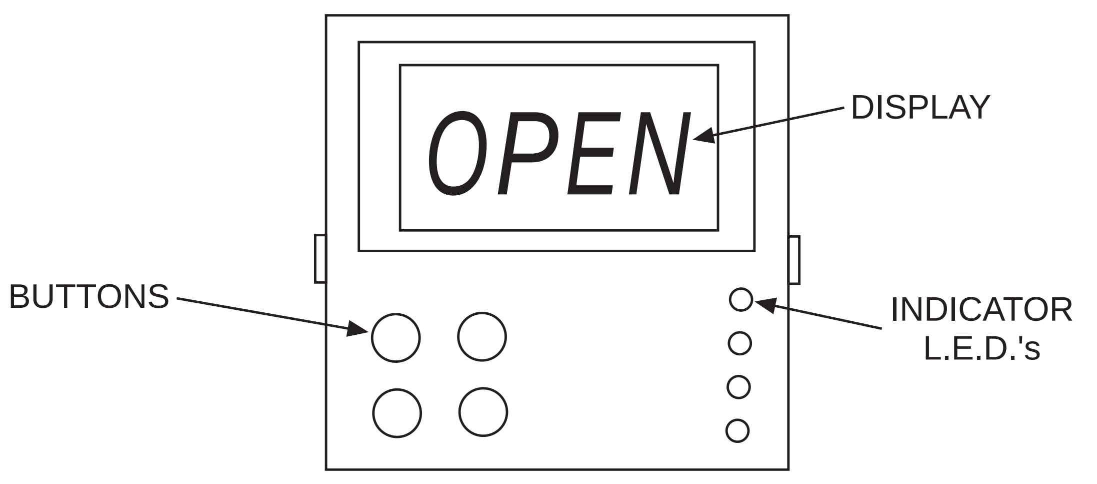
Two wire RTDs should be connected between terminals 1A and 1B, and terminals 1B and 2B must be linked. Three wire RTDs should be connected as shown below, and care should be taken to ensure that each lead is of the same length, and uses the same type of wire (i.e. exhibits the same resistance). Each wire should have a resistance of less than 10 ohms; three core 3 to 10 Amp mains cable (heat resisting if required) should be adequate for many applications.



Linear mA and mV inputs should be connected with the positive to terminal 1B, the negative to 1A. The circuitry for mA inputs employs a 100 ohm sensing resistor, so the full scale voltage drop will be 2.0V.

5.5 Sensor Lead Break And Burnout Detection

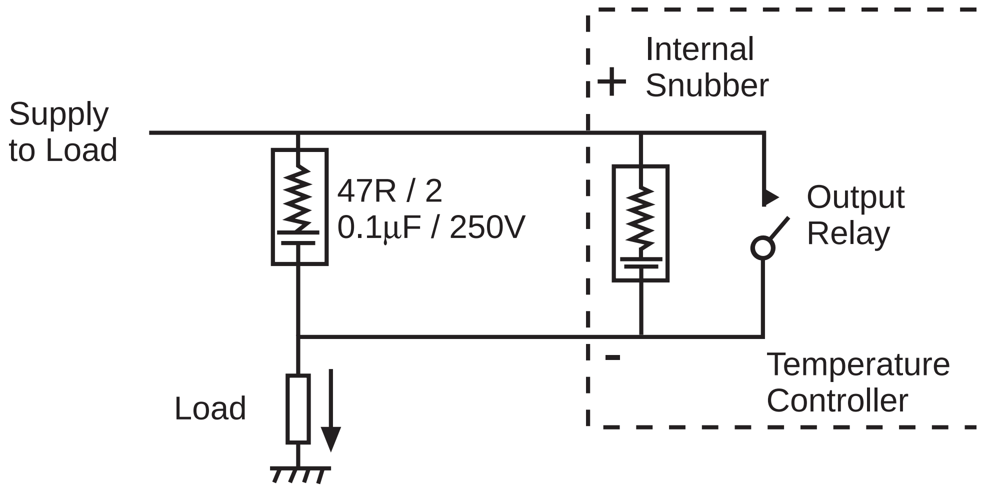
The controller contains circuitry to detect a lead break or sensor burnout. In effect the measured value ramps up or down scale until it hits the end of span. The direction of ramp is set by the output 1 action, n-o ramps up, n-c ramps down. mA inputs go to 0mA with a lead break. RTD inputs can ramp in either direction depending upon which lead breaks but will always hit an end of span. When the measured value hits end of span or when it exceeds the selected range, the following message is displayed and the control outputs are sent to their selected off state (closed for n-c, open for n-o). The alarms will be on.



5.6 Output Connections

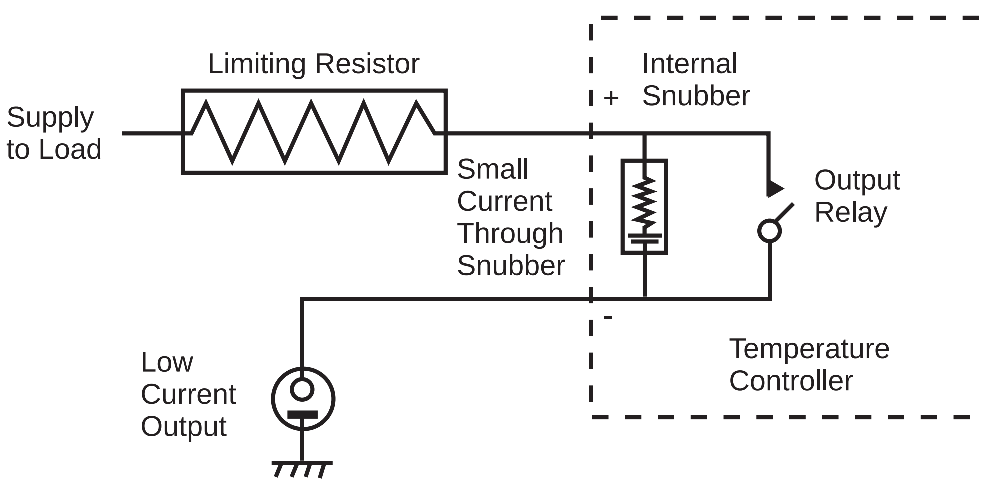
The **RS** stock no. 340-083 controller uses relays as the output and alarm drivers. These are configured on the menu to be normally open or normally closed during operation, although the actual relay is normally open and will open on removal of power. Each relay has an LED indicator on the front panel, as shown in section 4.3, which is lit when the relay is closed. Each relay is also fitted with a snubber network (22nF in series with 100R) across its contacts to increase the contact life and reduce emitted interference when switching heavy current or inductive loads. The relays are rated at 5A/240Va.c.(resistive). For loads in excess of 100mA, it is recommended that additional external network(s) of 0.1µF/250Va.c. in series with 47R/2W be fitted across the contacts.

Snubber Network



Where low current loads such as neon lamps are used, the current passed by the snubber when the relay is open may be sufficient to energise the load. An external current limiting resistor, such as 22K ohm 5 Watt, in series with the relay contacts should restore operation. The precise value should be chosen to ensure reliable operation of the load. Adequate ventilation should be

Limiting Resistor

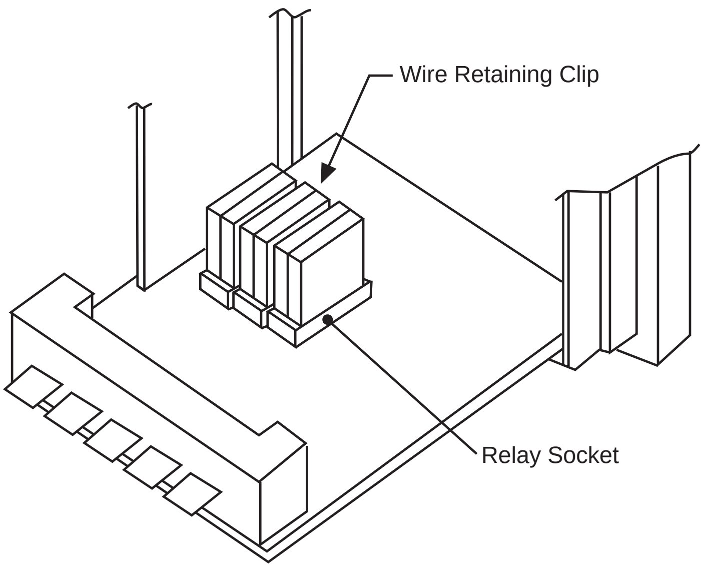


provided to prevent overheating the resistor.
Care should be taken to ensure that the leakage current through the snubber and external limiting resistor (if fitted) is less than the hold in current of the load. For example, the current at which a neon turns off is much lower than the current at which it turns on.

5.7 Solid State Relay Drive Option

The **RS** stock no. 340-083 can have an optional solid state relay drive module fitted in place of each relay.

To fit the drive module, the instrument should first be removed from its case. The output relays



are mounted in sockets with wire retaining clips on the lower PCB.
Looking from the rear of the instrument, the relays are arranged (left to right) as follows:-

ALARM 1 OUTPUT 1/ALARM 2 OUTPUT 1

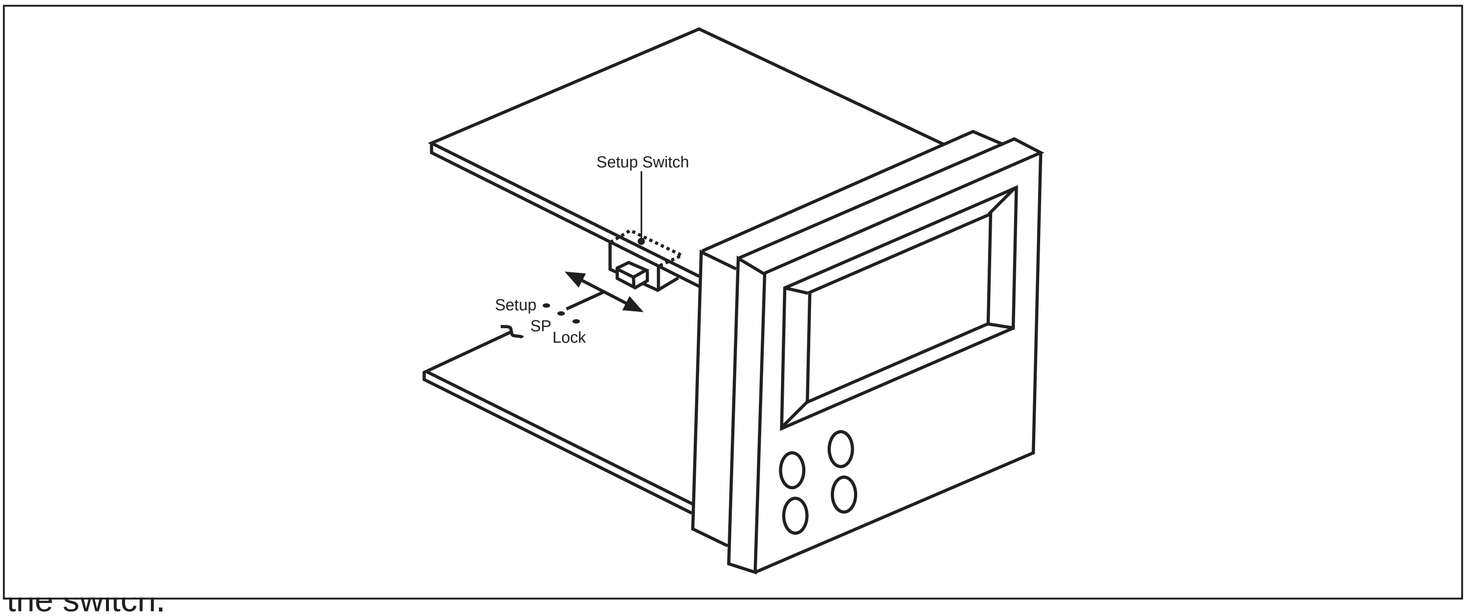
Gently prise the wire clip retaining the relevant relay to one side, and ease the relay out of its socket. Remove the wire clip from the socket, and insert the solid state drive module into the socket with the two level pins nearest the front of the instrument. Ensure that the module is fully pushed home.

Each solid state drive module should be connected directly to the external solid state relay without making any other connection. The drive module supplies 15Vd.c. maximum via a resistor to limit the current to 20mA maximum, which is adequate for all normal d.c. input solid state relays.

6. RS Stock No. 340-083 Setup Menu

6.1 Selecting Setup Mode

The controller incorporates a slide switch to prevent unauthorised alteration of the setup parameters. It may be found by removing the instrument from the case. The switch is located on the left side of the upper PCB. In order to examine or modify any of the controller parameters the switch must be set to the SETUP position. When all parameters have been entered the switch can be set to either the LOCK position to lock all parameters, or SP which allows the setpoint to be adjusted between the limits set in SPHI or SPLo. The figure overleaf shows the location of



the switch.

6.2 Detailed Parameter Description

The first part of this section gives a detailed description of all the menu parameters for all of the models. The menu chart to be found later in this section shows the complete menu.

The controller has been designed to meet the majority of applications and so requires several setup parameters to configure it. However, once the unit is configured it is normally only necessary to adjust the setpoint or PID parameters and these have been grouped near the measured value in the menu to minimise the amount of button pushing required. It is worth familiarising yourself with the menu operation. If you do get lost, remember that the menu will timeout back to the measured value after fifteen seconds or by pressing and holding the MV button for 1 second.

Measured value. This heading is the normal display and shows the current measured value or its deviation from setpoint. The units and type of display are determined by parameters in the Etc column of the menu.

SP°C, SP°F or SP. This subheading contains the desired process setpoint in the units selected for the measured value.

SPhI. The setpoint cannot be adjusted above the value in this subheading. SPhI can be adjusted from the top of the selected measurement range down to the value of SPLo. SPhI is displayed in the units selected for the measured value.

SPLo. The setpoint cannot be adjusted below this value. SPLo can be adjusted from the bottom of the selected measurement range up to the value in SPhI. SPLo is displayed in the units selected for the measurement range.

Auto. This subheading selects whether the controller is in automatic control mode or manual control mode. In automatic control mode the PID parameters are used by the controller to calculate the output power to apply to output 1, and/or output 2. In manual control mode the output power is user settable using the Pr subheading described next.

Pr. In automatic mode this subheading displays the current output power. With the controller configured for a single output the power is always positive. For dual output configuration, positive power is output 1 and negative power is output 2. In manual mode this subheading is used to set

the output power. The power is settable from 0 to +/-100.0% in 0.1% steps.
PID. This column of the menu contains the PID parameters, which determine the way the controller responds to changes in setpoint and measured value. These must be correctly set up to match the process characteristics so as to provide the optimum level of control. This process is called tuning and is described in more detail in section 8.

Pb. This is the proportional band as described in section 1.1 and is settable from 0.1% to 100.0% in 0.1% steps. If set to 0.0% then the message OFF is displayed, and On/Off control with hysteresis of 0.2% of measurement span operates.

It. The integral action time is adjustable between 0.1 and 99.9 minutes in units of 0.1 minutes (6 seconds). If set to 100.0 minutes, OFF is displayed and no integral action occurs. The integral term may be reset to power up condition by momentarily entering manual mode (see Auto above). The integral term is not reset by mains interruptions of less than 60 milliseconds duration.

dt. The derivative action time is adjustable between 0.1 and 100.0 minutes in units of 0.1 minutes (6 seconds). If set to 0.0 minutes, OFF is displayed and no derivative action occurs. The derivative term may be reset to power up condition by momentarily entering manual mode (see Auto on the previous page). The derivative term is not reset by mains interruptions of less than 60 milliseconds duration.

OP1. This column of the menu configures output 1.

CYCL. This is the relay output cycle time settable from 1 to 1000 seconds in units of 1 second. If 0 is selected, OFF is displayed and the output is held off. The relay state will be determined by the action parameter described later. The cycle time should be set as large as is practicable to prolong the relay life. Shorter times are practical if the solid state relay drive module is fitted as it is not subject to mechanical wear. The cycle time should also take into account process variables such as boiler ignition costs, refrigeration compressor lifetime and so on.

PL. This is the output 1 power limit. The output power cannot go above this limit which is settable from 0.1% to 100.0% in units 0.1%. When set to 0.0%, OFF is displayed and the output is held off as described above for a cycle time of 0. The power limit is useful to protect sensitive processes where too much power would cause damage but a high gain is required to achieve the desired response.

Act. This is the relay off state and can be set to n-o for normally open or n-c for normally closed, i.e. when OP1 is off and Act is n-o the relay contacts are open and when set to n-c they are closed. This parameter should not be confused with the controller action as described at the start of section 3.

OP2. This column of the menu configures output 2. It will only appear on the menu if the OP2 subheading in the Etc. column of the menu is set to OP, otherwise output 2 is an alarm and has a different set of parameters for configuration which are described later.

CYCL. This subheading contains the relay output cycle time settable from 1 to 1000 seconds in units of 1 second. If 0 is selected, OFF will be displayed and the output is held off. The relay state will be determined by the Act parameter in this column.

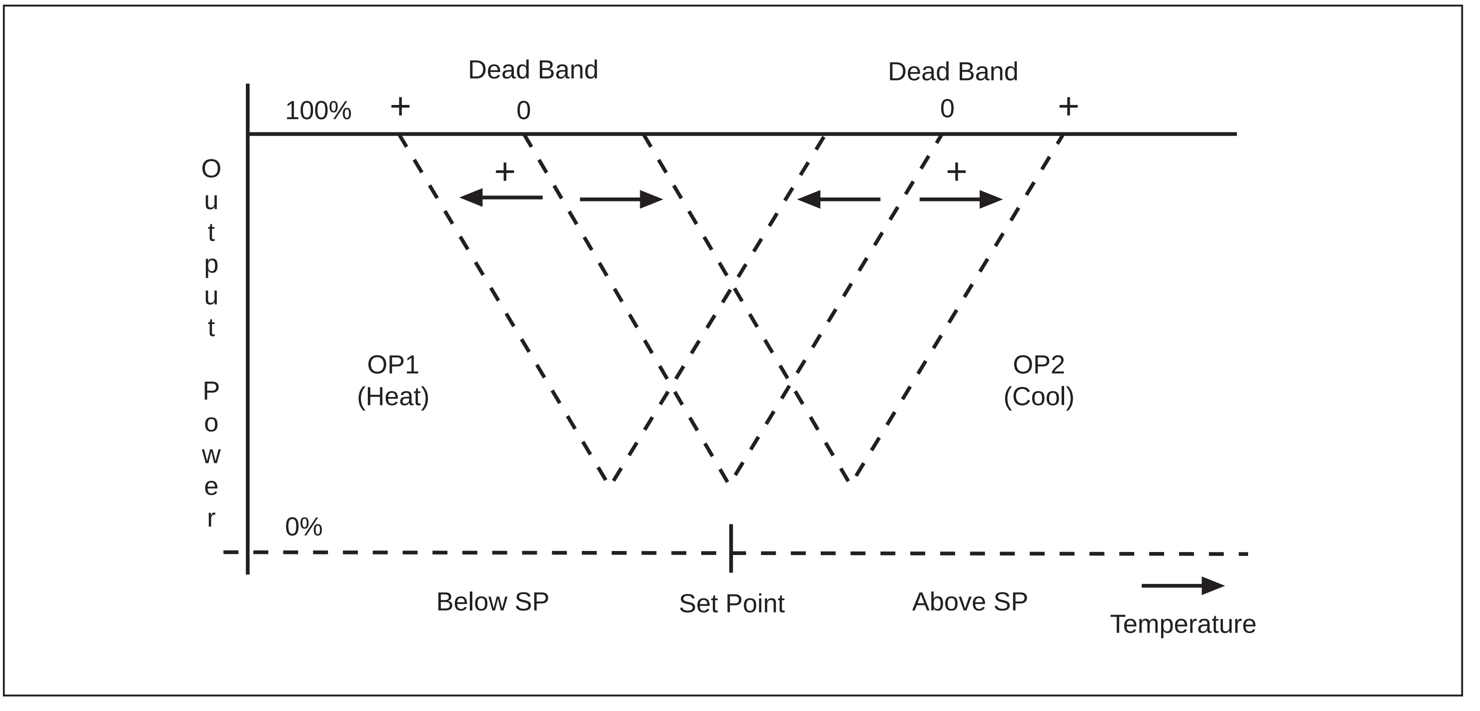
PL. This is the output 2 power limit and has the same effect and setting range as the output 1

power limit.
Act. This subheading contains the output 2 relay off state and is settable to n-o or n-c.

Pb2. Output 2 proportional band settable from 1% to 1000% in units of 1%. If set to 0%, OP2 acts as an on-off output with 0.2% hysteresis. Many processes require different gains for heating and cooling. Pb2 is a relative gain applied to the output of the PID equations which has no effect on output 1. The actual power output from OP2 is defined below:-

$$\text{Actual power} = \text{PID output power} \star 100 / \text{Pb2}$$

dbnd. This subheading contains the output deadband settable from 0.0% to +/-100.0% in 0.1% units. The value in the deadband parameter is subtracted from the output 1 and output 2 power before the power limits are applied. Thus a positive dbnd causes a deadband where no power is output and a negative dbnd causes an overlap where both outputs are on. The diagram below



illustrates the effect of dbnd.
AL2. This column configures alarm 2 and appears in place of the OP2 column if OP2 is set to AL in the Etc. column. AL2 does not have hi and Lo parameters.

AL1. This column configures alarm 1.

hi, Lo. These subheadings of the AL1 column are absolute value high and low alarm limits displayed in the units of the measured value and adjustable over the full measurement span to the same resolution as the measured value. hi cannot be set below Lo and Lo cannot be set above hi. If the measured value goes above hi or below Lo the alarm relay will turn on.

dehi, deLo. These subheadings are deviation high and low alarm limits. They are settable to +/- measurement span and are settable to the resolution of the measured value. dEhi cannot be set below dELo and dELo cannot be set above dEhi. Positive deviation is defined as when the temperature exceeds setpoint. When the measured value deviates from setpoint by more than dEhi or less than dELo the alarm relay turns on.

Act. This is the relay off state. n-o (normally open) means that when the alarm is off the contacts are open, and n-c (normally closed) means that when the alarm is off the contacts are closed.

Etc. This column of the menu contains parameters which relate to the overall operation of the controller.

IP. This subheading selects the input sensor type. Before a particular type of sensor is used the switches inside the controller must be set as shown in section 5.3. The following table shows the range of sensors and their measurement spans.

Display	Sensor/Range		
J30	J type T/C	0 to 300°C	32 to 572°F
J80	J type T/C	0 to 800°C	32 to 1472°F
H40	K type T/C	0 to 400°C	32 to 752°F
H12	K type T/C	0 to 1200°C	32 to 2192°F
n50	N type T/C	0 to 500°C	32 to 932°F
n13	N type T/C	0 to 1300°C	32 to 2372°F
t35	T type T/C	-250 to 350°C	-418 to 662°F
r16	R type T/C	0 to 1600°C	32 to 2912°F
S18	S type T/C	0 to 1800°C	32 to 3272°F

d.c. mA/mV input, span set by toP, bot, IPhI and IPLo.
rtd. RTD sensor, -200 to 250°C, -328 to 482°F.

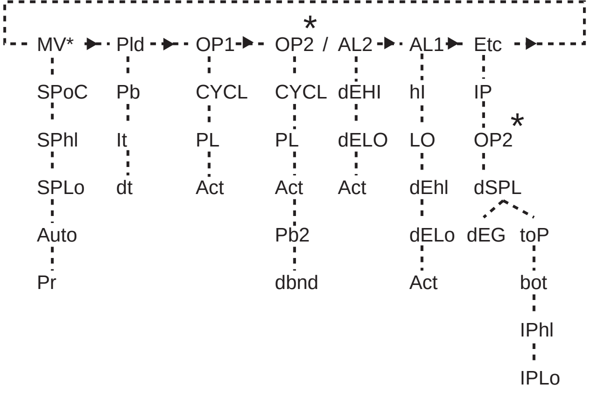
OP2. This subheading configures output 2 to be an alarm (AL), or a control (OP), output and changes the menu to show the AL2 or OP2 columns accordingly.

dSPL. This subheading changes the measured value from displaying the absolute value (AbS) or the deviation from setpoint (dEv).

dEg. Sets the measured value display between Fahrenheit (°F) or Centigrade (°C). This subheading does not appear if the d.c. input sensor type is selected, in which case it is replaced by the following four parameters. Setpoints and alarms are automatically scaled to the appropriate units and do not need to be re-entered.

toP, bot. These subheadings set the top and bottom of the measured value display for d.c. input sensors used in conjunction with IPhI and IPLo below, any d.c. input may be converted to any indicated measured value in the range +/-999. For instance 4 to 20 mA could display as -123 to 456. toP cannot be set less than or equal to bot. Setpoints and alarms will need to be re-entered if the top, bot, IPhI or IPLo parameters change.

IPhI, IPLo. These subheadings define the input voltage or current at top and bottom of range and may lie in the range +/-100.0%, (i.e. 20 mA = 100.0%, 4 mA = 20.0%). If IPhI has a value less than IPLo then the input sense becomes inverted, i.e. 4 mA to 20 mA will display as 456 to -123. The controller will not function correctly if IPhI is equal to IPLo.



* OP2 / AL2 Parameter heading depends on OP2 setting in ETC.

6.3. Menu Chart for RS Stock No. 340-083

7. RS Stock No. 340-083 Modes of Operation

7.1 Manual And Automatic Mode

When the Auto subheading is used to select automatic control the PID algorithm used by the controller to calculate the output power is reset by clearing the integral and derivative terms. When Manual mode is selected the current output power produced by the PID algorithm is stored in the Pr subheading. This value is then used as the output power instead of the PID calculated value, i.e. it is frozen at the time of transfer into manual mode. Thus a bumpless transfer is effected between auto and manual mode. The transfer from manual to auto mode, however, is not bumpless. The reason for this is that the value in the integral term after a period of time in manual mode may not represent a valid control action and so it is safer to reset the PID control and let the integral and derivative terms take control instantly.

When the controller is in automatic mode, the output power sometimes hits 100%, particularly when the gain is high. The PID algorithm cannot provide any more output in this situation and so the integral and derivative terms are frozen until the PID output power comes below 100%. This prevents the accumulators in the algorithms from overflowing. In a hardware based controller this would be analogous to a capacitor saturating when it reaches the power supply rails, but the recovery is much quicker and safer when it is done in software.

Another common problem has been solved in the design of the TC9600 controllers PID algorithm. Because the derivative term produces an output relative to the rate of change of the measured value deviation from setpoint, it is particularly sensitive to noise on the measured signal and to changes in the setpoint. The second problem is cured by making the P and I terms work from the measured value deviation from setpoint, and making the D term work from the measured value so that changes in the setpoint do not cause a step input to the D term. The first problem is cured by putting a filter into the D term whose time constant tracks with the derivative action time so that it is short enough to have an insignificant effect on the PID performance but large enough to reject noise. The TC9600 controllers have been designed to conform with the criteria set out in BS5558. This standard describes a series of tests to perform on PID controllers.

7.2. Setting the Action of the Controller

The action of a controller causes a great deal of confusion. However, because the TC9600 controllers are so flexible, they can be used as direct OR reverse action controllers.

In practice it is far easier to think of relay outputs as being either ON or OFF and setting the Act parameters to n-o or n-c for the OFF state.

For single relay outputs think of the relay as being a heat output. If a cool output is required then change the Act parameter.

For dual relay outputs think of OP1 as the heat output and OP2 as the cool output. The control action is then irrelevant. For the TC9612 think of OP1 as the heat output in reverse mode and as the cool output in direct mode and set the OP2 relay action to n-o or n-c for the required relay off state.

7.3 Sensor Type Selection

Thermocouples are made of two different metals welded together at one point. This junction creates a small voltage related to the temperature of the junction relative to the ends of the two wires. Thermocouples have the following advantages:-

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- Provides robust measurement point with low thermal mass.
- Works over wide temperature ranges, -200 to 1700°C.
- Good accuracy, typically 0.5 to 5°C.
- Cost effective.

Their disadvantages are:-
- The cold junction reference temperature must be measured.
- Compensating cable must be used for long wiring runs.

The thermocouple junction may consist of just the welded junction at the end of a length of cable, or it may be built into a protected probe assembly. Care should be taken if using a bare junction as they can become contaminated in certain environments. Care must also be taken to prevent shorts occurring in the leads to the junction, as these will give a false reading of the temperature. All junctions between different metals in the cable contribute to an error to the reading, so proper compensating cables and connectors should be used to extend the thermocouple cable. Cable length is only limited by the TC9600 requirement to keep the cable resistance below 1000 Ohms. It may take up to 30 minutes from power up for the cold junction temperature to settle. Keep draughts away from the rear of the TC9600 controller as these will affect the stability of the cold junction reference.

The table below lists some typical characteristics of thermocouples.

TC Type	Name	Material	Range	Comments
J	Iron/Constantan	Fe/CuNi	-180 to 750	Common in plastics industry, used in reducing atmospheres, but rusts at temperature extremes.
K	Chromel/Alumel	NiCr/NiAl	-180 to 1350	Most common UK type, wide range.
N	Nicrosil	NiCrSi/NiSi	-270 to 1300	New type, more stable than K type.
R	Pt13%Rh/Pt		-50 to 1700	High temp applications with good oxidation/corrosion properties, but requires protection.
S	Pt10%Rh/Pt		-50 to 1700	As R type, more common in UK
T	Cu/CuNi		-250 to 400	Good at low temperatures, suitable for unprotected use in mild oxidising/reducing atmospheres.

Resistance temperature detectors, or RTDs, consist of a length of thin wire (or thin film) wound on a ceramic or glass former. The electrical resistance of the material varies with temperature and so provides a direct measure of temperature.

Advantages:-

- Excellent accuracy, typically 0.1 to 1°C
- No special connecting wire required
- No cold junction compensation required

Disadvantages:-

- Narrow temperature range, -200 to 600°C
- Sensing area larger so slower to respond
- Less robust
- More expensive

The most common material is platinum as it can be made very pure to give good repeatability, and exhibits a stable non-linear characteristic over a wide temperature range. The most common type is the Pt100 detector which has a resistance of 100 Ohms at 0°C. This is the type the **RS** stock no. 340-083 accepts.

The RTD is available in a wide variety of tabular or plate shapes. These may be fitted into suitable protection tubes. The sensor is wired using ordinary copper cable. As cable resistance contributes to sensor errors, the **RS** stock no. 340-083 supports a three wire connection scheme to compensate for this. The third wire measures the error in the other two. The three cores should, however, all have the same resistance, 10 Ohms maximum, and should all be of the same type and gauge of wire. As it happens three core mains cable is ideal for the wiring of RTDs.

Both RTDs and thermocouples exhibit a non-linear characteristic but the **RS** stock no. 340-083 controller automatically compensates for this in software, which is much more accurate than older hardware methods.

7.4 Configuration Of Alarms And Outputs

The use and action of the outputs have been covered in previous sections. Do not forget that alarms can be used to control equipment as well as ringing bells! Typical applications include turning on boost heating or cooling when the temperature goes outside of a certain range, turning on a conveyor belt when the temperature reaches setpoint, triggering a process timer such as the Temperatron UDT or as an input to a process controller.

8. Achieving Optimum Control

8.1 Introduction

What is optimum control? That depends upon the factors we are trying to optimise. Usually we would try to achieve the setpoint temperature in the fastest time with the minimum of overshoot. However, in some systems the lowest cost may not be achieved by such a response and we can sacrifice speed of response for cost or some other factor. For the purpose of our discussion we will assume the fast response curve with minimum overshoot is optimum.

8.2 Ziegler Nichols Technique

Two engineers in the USA wrote a famous bulletin for the Taylor Instrument Company in the 1940's describing various methods of tuning PID controllers to their optimum values. The technique became known as the Ziegler-Nichols method after the engineers, J. G. Ziegler and N. B. Nichols. A summary of this technique is presented here, modified to suit the TC9600 controllers.

The aim of the technique is to characterise the system in such a way that the PID parameters can be simply calculated. To do this the controller needs to make the system oscillate about setpoint, which may be undesirable. Most processes do not change their characteristics appreciably either side of the setpoint and so it should be possible to perform the technique at a lower temperature, to calculate the values and then feed in the correct setpoint.

If the process is too expensive to run, or is so slow that the characterisation would take too long, then the values for the PID constants will have to be estimated and fine tuned later on. See section 8.3 for a rough guide to PID tuning.

The Ziegler-Nichols technique works as follows. Turn off both the derivative and integral terms and control the process with proportional band only. Use the menu to set up the setpoint and let the controller control the process. The proportional band can now be decreased (increasing the gain) until the process just begins to oscillate. It may take some time to establish the point at which the process just oscillates. Record the process response and note down the period of the oscillation. The period is the time taken between maxima of the process temperature. Also note down the value of the proportional band. We now have a measure of gain of the system and its time constant. Calculate the gains K_U and period T_U as follows:-

$$K_U = {}^{100}/\text{proportional band}$$

$$T_U = \text{Period of oscillation}$$

The Ziegler-Nichols method employs some empirical rules to calculate the PID parameters as follows.

1) For proportional only control (P) set PB = $^{200}/_{ku}$.
2) For proportional plus integral control (PI) set Pb = $^{100}/_{(0.45*ku)}$ and It = $0.83*t_U$.
3) For full PID control set Pb equal to 100 divided by between $0.6*K_U$ and $1*K_U$, It = $0.5*T_U$, and dt = $0.125*T_U$. Adjust Pb to obtain the best response.

8.3 Rough Guide To PID Parameters

First, estimate the time constant of the process. Set the Pb to 10.0% and set It = dt = time constant. This will control the process but will need fairly drastic tuning. If the process measured value oscillates with these settings increase the Pb and decrease the dt.

9. RS Stock No. 340-083 Detailed Specification

(Unless otherwise stated, Tambient = 20°C, V supply = 240Va.c., parameters measured more than 10 minutes after energisation).

Input: Thermocouple, RTD (Pt100), or mV/mA d.c., set by internal switch. Thermocouple type and mV/mA range operator set via front pushbuttons.

Thermocouples to BS4937, DIN43710:

Input impedance:	10 Mohm nominal.
Lead impedance:	1000 ohms total maximum.
Up/down scale break set by Output 1 action.	
Common mode rejection:	260Va.c. causes no change.
Series mode rejection:	50mVa.c. causes no change.
Series mode withstand:	24Va.c. maximum for 1 minimum without damage.

Type	Range Minimum	Range Maximum
J - Fe/CuNi	0.0°C	+300.0°C
	32.0°F	+572.0°F
J - Fe/CuNi	0°C	+800°C
	32°F	+1472°F
K - NiCr/NiAl	0.0°C	+400.0°C
	32.0°F	+752°C
K - NiCr/NiAl	0°C	+1200°C
	32.0°F	+2192°C
N - NiCrSi/NiSi	0.0°C	+500.0°C
	32.0°F	+932.0°F
N - NiCrSi/NiSi	0°C	+1300°C
	32°F	+2372°F
T - Cu/CuNi	-250.0°C	+350.0°C
	-418.0°F	+662.0°F
R - Pt13%Rh/Pt	0°C	+1600°C
	32°F	+2912°F
S - Pt10%Rh/Pt	0°C	+1800°C
	32°F	+3272°F

RTD (Pt100) to BS1904, DIN43760:

3 wire connection, automatic lead resistance compensation, 20 ohms maximum per equal lead. Up/down scale break set by Output 1 action.

Range: -200.0 to 250.0°C,
-328.0 to 482.0°F.

Input overvoltage: 250Va.c. maximum for 1 minute without damage.

D.C. linear inputs:

Input impedance: 100 ohms nominal (mA)
10 megohms nominal (mV)

Range: -20 to +20mA (2V drop at 20mA)
-50 to +50mV

Scale minimum: -999 to 999 for 0 input

Scale maximum: -999 to 999 for FS input

Output(s): N/O relays in sockets, contact rated 5A at 30Vd.c./240Va.c. resistive. Contacts fitted with 22nF/100R snubber network. Electrical life 500,000 operations at rated load. Any relay may be substituted for plug in adaptor to give 15Vd.c./10mA maximum (15V via 1kohm) non-isolated solid state relay (SSR) drive.

Setup options: See menu chart for details.

Isolation: 250Va.c., Class I BS4743, BS3456. Will withstand 3.0kVa.c. for 1 minute. Outputs, inputs and supply isolated from each other.

Supply: 115 or 240Va.c. internally switched, +10% -15%, 47-63Hz, 6VA maximum.

Environment:	Operating temperature:	0 to 50°C
	Storage temperature:	-20 to 80°C.

Calibration: Less than +/- 0.25% of display range at 20°C.

Stability: Less than 0.01% of span/°C ambient.

Cold junction: +/- 3.0°C absolute, linearity 0.05°C per °C ambient.

Linearity: Less than 0.15% of input span.

A/D Conversion: 14 bit dual slope auto-zero 5 samples per second.

Data retention: 5 years minimum.

Dimensions: 96 x 96 x 140mm.