Principles of PID Control and Tuning

If you need help in choosing the controller most suitable for your application, don't hesitate to contact our technical help desk on: 01903 695777.

Eurotherm controllers will automatically control process variables such as temperature, humidity, pressure, flow rate, level or Ph - in fact, almost any physical variable that can be represented as an analogue signal.

The example below assumes that the variable is temperature, which is the most common, but the principles are equally applicable to all analogue variables.

The automatic control loop

The diagram below shows an automatic temperature control 'loop'. It consists of a sensor to measure the temperature, a controller and a power regulator.

The controller compares the measured temperature with the desired temperature, called the 'setpoint', and regulates the output power to make them the same.

The measured temperature is referred to as the Process Value, or 'PV' for short.

The difference between the setpoint and the measured value is called the 'error signal'.

Input sensors

An automatic controller requires some means of measuring the process value.

Eurotherm controllers will accept an input from almost any type of sensor. Linearisation of the measured value, if necessary, will be performed within the controller.

In temperature applications, either a thermocouple or resistance thermometer is typically used. The type will depend on the temperature range and the environment in which it has to operate.

Please refer to the sensor section in this catalogue for details of thermocouples and resistance thermometers.

In applications where it is difficult to attach a fixed temperature sensor, non-contact temperature measurement can be made using infra-red or optical pyrometers. Eurotherm controllers support inputs from a wide range of pyrometers.

Eurotherm controllers will accept direct inputs from strain gauges and pressure, flow, or Ph transducers.

In large process control applications, signal conditioners are normally used to convert the sensor measurement into a 4 to 20mA or 0 to 10Vdc signal for transmission to the controller. In Eurotherm controllers it is a simple matter to scale these inputs to the desired display range.

Controller outputs

An automatic controller requires some means of varying the heating power, or flow rate, or pressure, to the process under control.
The main output types are:

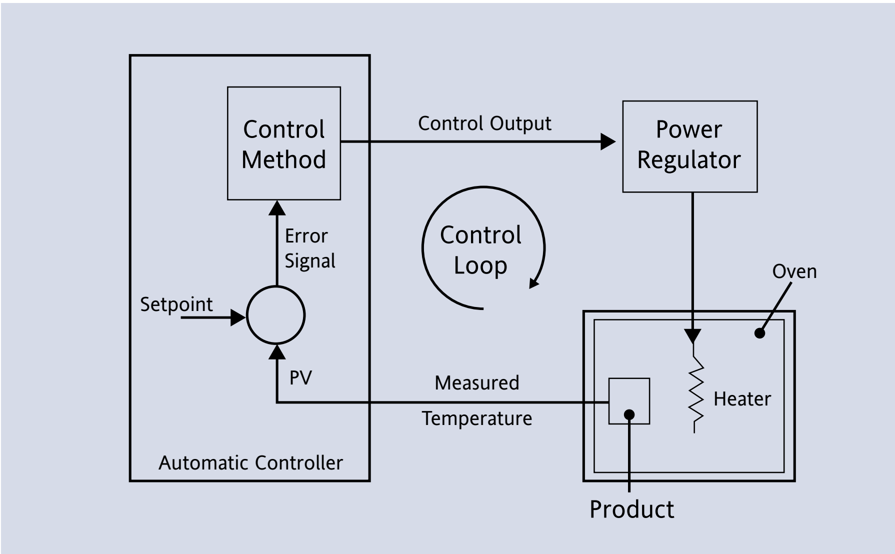
Relay, which is used to operate a contactor or solenoid valve in heating and cooling applications.

Logic, which is used to switch a solid state relay. The benefits are: long life, no maintenance and the ability to rapidly switch heaters which have a small thermal mass.

Triac, Triacs are solid state switches primarily used to operate solenoid valves. They are also ideal for the positioning of motorised gas burner valves.

DC milliamps or volts, used for positioning control valves and to drive analogue input thyristors (used in phase angle and three phase heating applications).

Automatic control loop



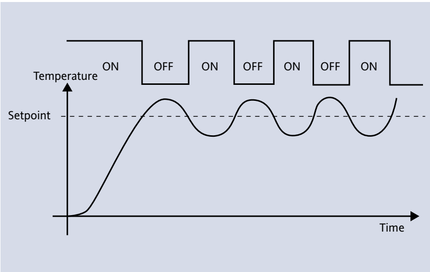
Types of control

There are three main types of control:

- On/Off control
- PID control
- Motorised Valve Positioning

On/Off Control

On/Off control action is shown in the graph below. The heating power is either fully On when the temperature is below setpoint or fully Off when it is above. As a result the temperature oscillates about the setpoint.

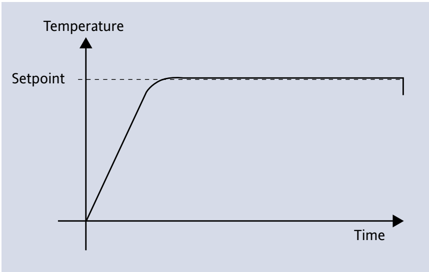


The amplitude and time period of the oscillation is a function of the thermal lag between the heating source and the temperature sensor.

To prevent the output 'chattering' as the measured temperature crosses the setpoint, the controller does not turn On and Off at precisely the same point. Instead a small differential known as the 'hysteresis' is applied. A typical value is 1°C On/Off control is satisfactory for non-critical heating applications where some oscillation in the temperature is permissible.

PID Control

Most industrial processes such as plastic extrusion, metals treatment or semiconductor processing require stable 'straight-line' control of the temperature as shown below. Eurotherm controllers employ advanced PID control algorithms to provide exactly that.



PID control is also referred to as "Three-term" control. The three terms are:

- **P** **for Proportional**
- **I** **for Integral**
- **D** **for Derivative**

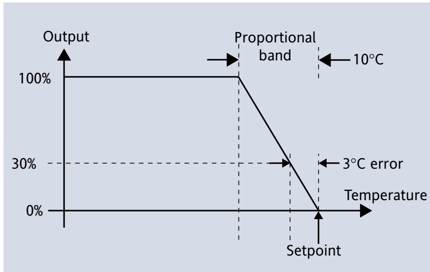
The output of the controller is the sum of the above three terms.

The combined output is a function of the magnitude and duration of the error signal, and the rate of change of the temperature or process value

Proportional term

The Proportional term delivers an output which is proportional to the size of the error signal. In the example below, the proportional band is 10°C and an error of 3°C will produce an output of 30%.

Proportional only controllers will not, in general, control precisely at setpoint, but with an offset corresponding to the point at which the output power equals the heat loss from the system.



Integral action

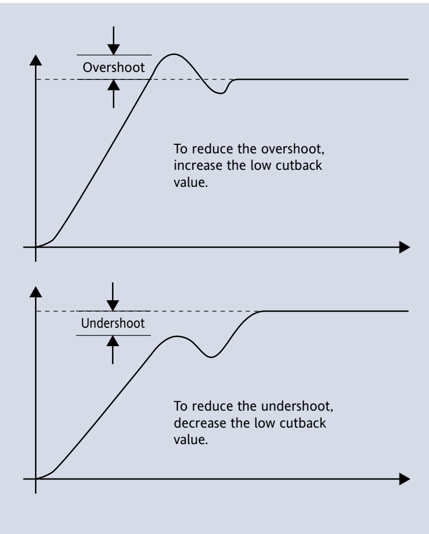
The Integral term removes steady state control offsets by ramping the output up or down in proportion to the amplitude and duration of the error signal. The ramp rate (Integral time constant) must be longer than the time constant of the process to avoid oscillations.

Derivative action

The Derivative term is proportional to the rate of change of the temperature or process value. It is used to prevent overshoot and undershoot of the setpoint and to restore the process value rapidly to the setpoint if there is a sudden change in demand, for example if an oven door is opened.

High and low cutback

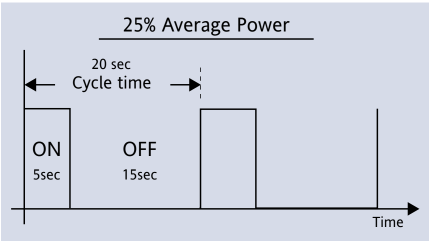
While the PID parameters are optimised for steady state control at or near the setpoint, high and low cutback parameters are used to reduce overshoot and undershoot for large step changes in temperature. They respectively set the number of degrees above and below setpoint at which the controller will start to increase or cutback the output power.



Time Proportioning action

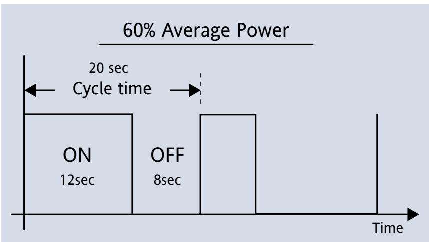
To obtain 'straight-line' temperature control, a PID controller requires some means of varying the power smoothly between 0 and 100%.

Time proportioning varies the % on time of relay, triac and logic outputs to deliver a variable output power between 0 and 100%. The graphs below illustrate the principle.



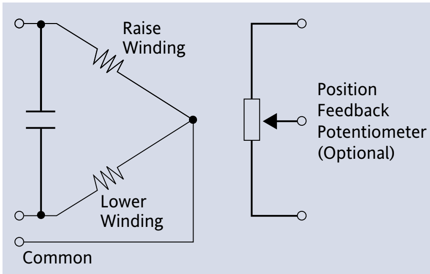
The cycle time must be short enough to allow the thermal mass of the load to smooth out the switching pulses. 20 seconds is typical. Systems with a small thermal mass will need shorter cycle times than can be provided with a relay. In these cases, a solid state relay is typically used with cycle times down to 0.2 seconds.

In practice Cycle Time may not be a constant, but vary with Power Demand, particularly at the extremes of the range 0-100%.



Motorised Valve Positioning

Motorised valves have two windings, one for opening the valve and the other for closing it. Control is achieved by sending raise or lower pulses to the appropriate winding. Some valves are fitted with a feedback potentiometer to indicate their position, while others are not.



Eurotherm controllers provide a control algorithm specifically designed for use with motorised valves. This algorithm works equally well with or without a position feedback potentiometer.