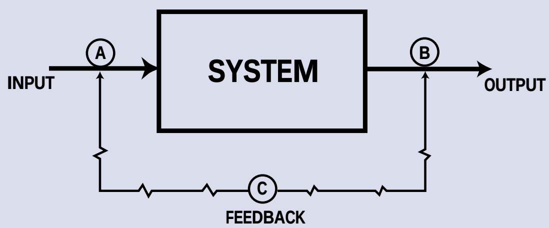
Engineer's Notebook

PID Control

PID Control

PID Control

The long-term operation of any system, large or small, requires that there be a mass/energy balance between input and output. If a process is operated at equilibrium at all times, control would be simple. Since change does exist, the critical parameter in process control is TIME, i.e. how long it takes for a change in any input to appear in the output. System time



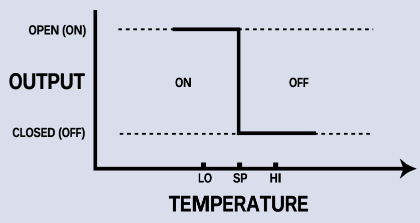
constants can vary from fractions of a second to many hours.

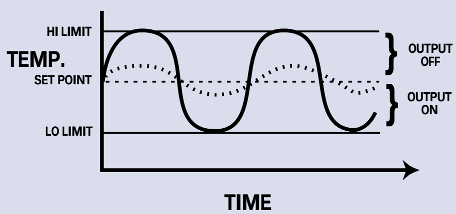
The PID controller is the most widely used type of process controller. It is the ability to tune its control action to specific process time constants and therefore to deal with process changes over time that has earned the PID controller its wide-spread acceptance.

To measure output or deviation form, what is desired is to measure difference (error). The most common way of measuring and reducing any error is through FEEDBACK, a technique of measuring the output and feeding it back to the controller. The function of the process controller is to adjust a process variable input to eliminate that error. The PID controller is most often the type of controller chosen to do this.

ON/OFF Control

The simplest control action is ON/OFF. This type of control is inexpensive, but not accurate enough in most process and machine control applications. ON/OFF control almost always means overshoot and resultant system cycling. A deadband is usually required around the setpoint to prevent relay chatter at setpoint. ON/OFF control has no provision for adjusting to the time constants of a particular system.

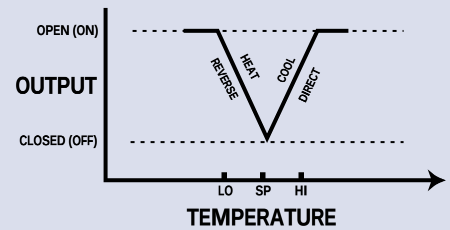


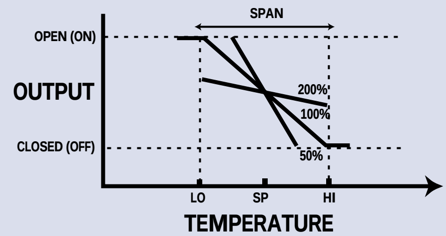


IMPORTANT NOTE: Temperature is used in this discussion since temperature is the most commonly controlled parameter, but the parameter could as easily be pressure, flow, level or any other and the PID discussion would be the same.

Proportional Control

Proportional control offers smoother response to process changes that ON/OFF control. A proportional controller adjusts its control action in proportion to the need of the process system. Proportional control can be HEAT (reverse) or COOL (direct) acting in temperature systems. For other applications either reverse or direct acting control may be appropriate.

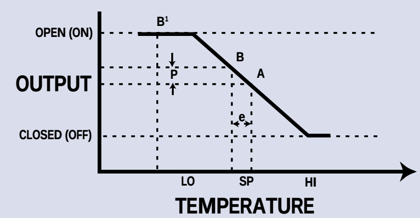


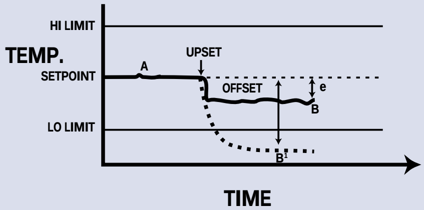


Proportional controllers are tuneable. Their response to process changes can be adjusted to suit the time constants of the specific process system (see figure). In theory, a proportional controller should be all that is needed for process control. Any change in system output is corrected for by an appropriate change in controller output. Unfortunately, the operation of a proportional controller leads to process deviation known as OFFSET or DROOP.

Proportional Control Action

Assume process equilibrium at point "A". The proportional controller output is constrained once a proportional band is selected to always operate as defined by the proportional band plot. Any change in the process, such as a change in flow rate, will result in a new equilibrium point B or even point B1. The proportional controller has done its job. It has established a new equilibrium at point B in this example. However, the equilibrium is at a new PV value offset from the desired value. Proportional control action "P" took place correctly, but now error "e" exists.





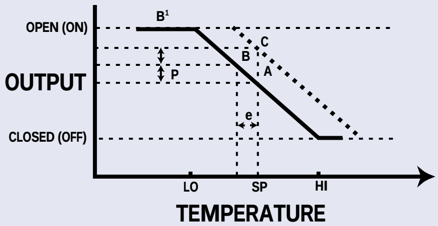
PID Control

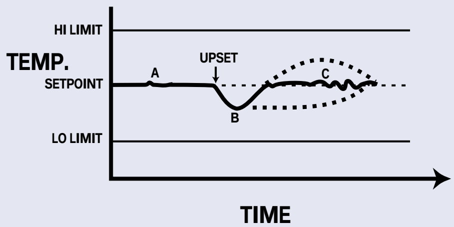
Engineer's Notebook

(Continued)

Reset (Integral) Control Action (I)

To eliminate "e" the controller needs to change its output until the PV error is zero. RESET (Integral) control action changes the controller output by some amount "I" to drive the PV back to the setpoint value. The new equilibrium point after RESET action is at point "C" in the example.

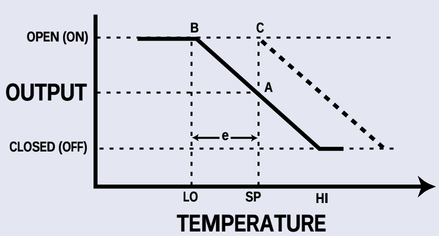


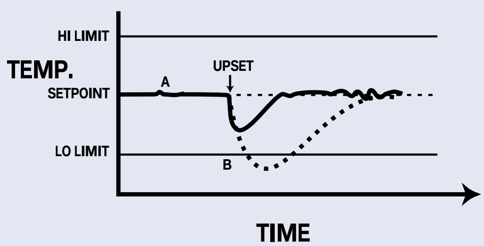


Since the proportional controller is constrained to always operate on its proportional band, the proportional band must be shifted to include the new point "C". A controller with RESET does this automatically.

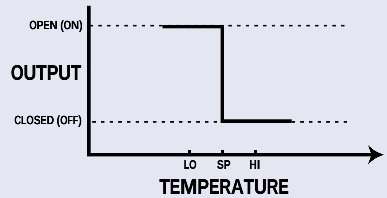
Rate (Derivative) Control Action (D)

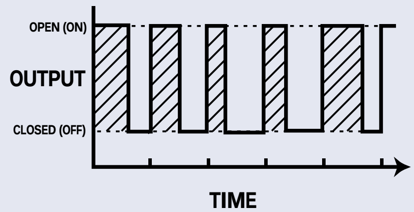
Rate action acts on error just like reset does except rate action is a function of the rate of change, rather than the magnitude of error. Rate action is applied as a change in output for a selectable time interval usually stated in MINUTES. Rate induced change in controller output is calculated from the DERIVATIVE of the change in input. Input change rather than proportional control error change is used to improve response.





Rate action quickly positions the output where proportional action alone would eventually position the output. In effect, rate action puts the brakes on any offset or error by quickly shifting the proportional band.





Anti-Reset Windup

The anti-reset windup shuts off reset action any time the measurement is outside of the proportional band to prevent the reset circuit from overloading. Reset action begins again when the measurement returns to within the proportional band. Anti-reset windup is standard in just about all quality PID controllers.

Time Proportional Control (TPR)

PID control can also be applied in an ON/OFF control system by the addition of a time base within the controller. For each preset time interval (CYCLE TIME) the controller will proportion the ON and OFF time depending on the magnitude of effort and the tuning values selected. This control action, called TIME PROPORTIONAL, provides better control than pure ON/OFF, while still taking advantage of the simplicity and lower costs usually associated with ON/OFF control devices.

PID Tuning

Each operator manual contains detailed instructions within the TUNING section on how to tune a PID controller. It is the responsibility of the user to tune the controller, but it is useful to be at least familiar with the tuning process.

In general, tuning is started by determining the correct proportional band. In most applications, a proportional band is desired that will bring the system to setpoint quickly without cycling or overshoot. Small changes in PB are not usually effective. It is not unusual when tuning a controller to make PB changes by a factor of 2 while zeroing in on the optimum PB. Setting the Reset action requires following the instructions in the manual.

Rate action is often misunderstood and difficult to set. For this reason most PID controllers are normally used at PI only. Our instructions show how to tune Rate. A general rule of thumb is that Rate should be numerically one-quarter the value of Reset. Do not use Rate in systems with fast changing inputs or on noisy input signals such as flow measurements.