PID Control Technical Notes

General

PID (Proportional-Integral-Derivative) control action allow the process control to accurately maintain setpoint by adjusting the control outputs. In this technical note we have attempted to explain what PID is in practical terms. We have available further technical references for our customers.

SKY-HIGH TECHNOLOGY.Co.,Ltd. has a complete line of PID controls suitable for virtually an application. We also have numerous tools (such as software, data loggers and recorders) to help to optimize any control application. Our application engineers have extensive practical knowledge in the tuning of PID controls to all types of applications.

While controls can be used for many different process variables for clarity we have chosen to use temperature as the process variable throughout these notes. Other processes can utilize these control concepts and the effects will be the same.

PROPORTIONAL & PID CONTROL ACTION

Proportioning control continuously adjusts the output dependent on the relative positions of the process temperature and the setpoint. PID (Proportioning/Integral/Derivative) are control functions commonly used together in today's controls. These functions when used properly allow for the precise control of difficult processes.

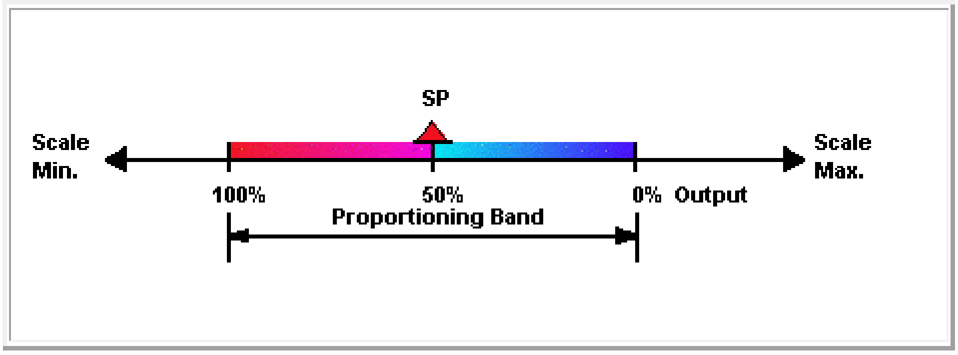
General:

1) Allows for the output to be a value other than 100% or 0%.

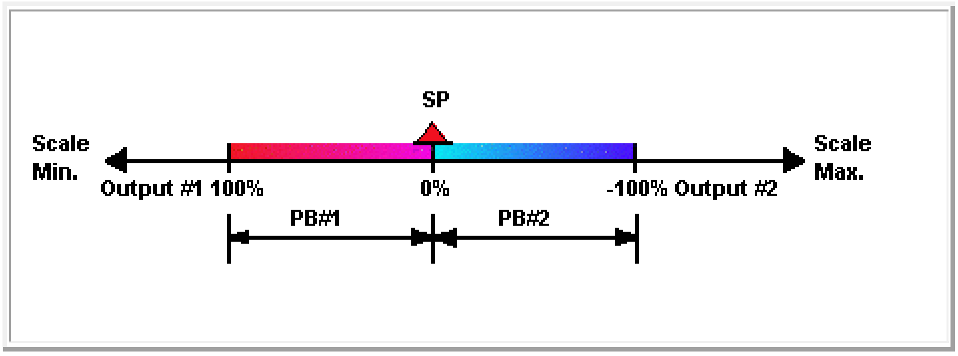
2) Temperature can be controlled without oscillations around the setpoint.

Definitions:

1) **Proportioning Band:** is the area around the setpoint where the controller is actually controlling the process; The output is at some level other than 100% or 0%. The band is generally centered around the setpoint (on single output controls) causing the output to be at 50% when the setpoint and the temperature are equal.



On (2) two output controls (i.e.: heat/cool) there are two proportioning bands. One is for heating and one is for cooling. In this case the bands generally end at the setpoint as shown below.



Proportioning bands are normally expressed in one of three ways:

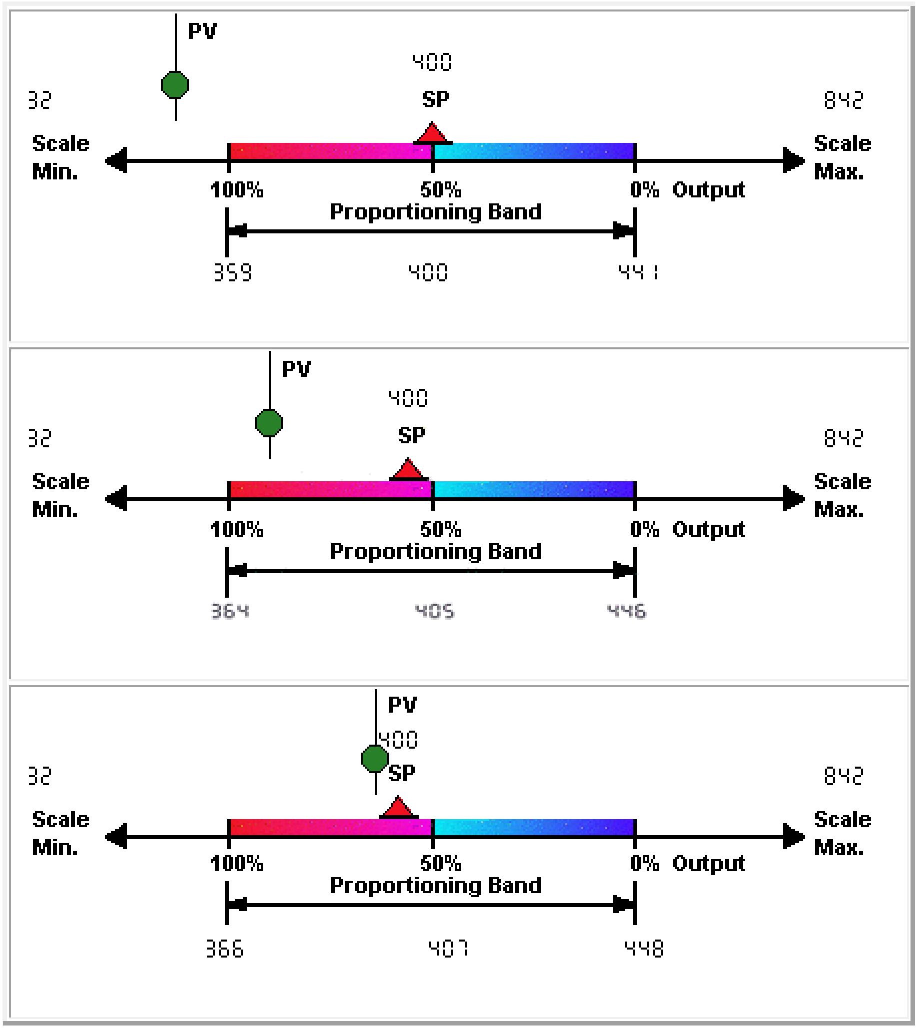
- As a percentage of full scale
- As a number of degrees (or other process variable units)
- Gain which equals 100%/proportioning band% (example PB% = 5; Gain = 20)

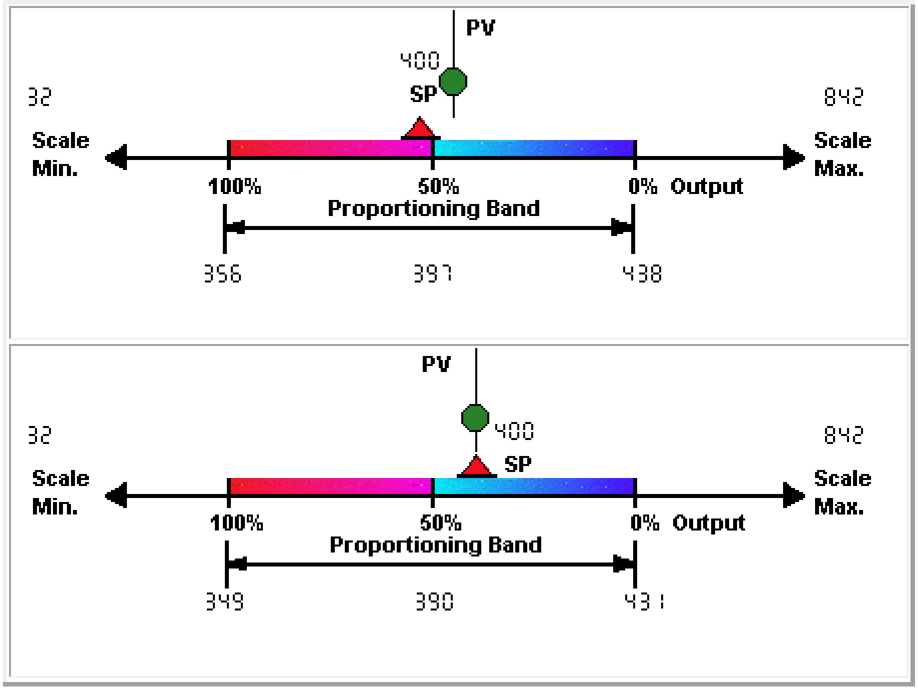
If the proportioning band is to narrow an oscillation around the setpoint will result. If the proportioning band is to wide the control will respond in a sluggish manner, could take a long time to settle out at set point and may not respond adequately to upsets.

Manual Reset: Virtually no process requires precisely 50% output on single output controls or 0% output on two output controls. Because of this many older control designs incorporated an adjustment called manual reset (also called offset on some controls). This adjustment allows the user to redefine the output requirement at the setpoint. A proportioning control without manual or automatic reset (defined below) will settle out somewhere within the proportioning band but likely not on the setpoint. Some newer controls are using manual reset (as a digital user programmable value) in conjunction with automatic reset. This allows the user to preprogram the approximate output requirement at the setpoint to allow for quicker settling at setpoint.

Automatic Reset (Integral): Corrects for any offset (between setpoint and process variable) automatically over time by shifting the proportioning band. Reset redefines the output requirements at the setpoint until the process variable (temperature) and the setpoint are equal. Most current controls allow the user to adjust how fast reset attempts to correct for the temperature offset. Control manufacturers display the reset value as minutes, minutes/repeat (m/r) or repeats per minute (r/m). This difference is extremely important to note for repeats/ minute is the inverse of minutes or minutes/ repeat). The reset time constant must be greater (slower larger number m/r smaller number r/m) than the process responds. If the reset value (in minutes/repeat) is to small a continuous oscillation will result (reset will over respond to any offset causing this oscillation). If the reset value is too long (in minutes/ repeat) the process will take to long to settle out at setpoint. Automatic reset is disabled any time the temperature is outside the proportioning band to prevent problems during startup.

Below is an example of a single output (heat only temperature control) with a 10% proportioning band and a setpoint of 400. Note how reset shifts the proportioning band when the temperature (PV) enters the proportioning band.





Reset stops moving the proportioning band as soon as the setpoint and PV are equal. In the above example reset determined approximately 38% output is required to maintain setpoint. Stable control is achieved and the temperature matches the setpoint of 400.

Rate (Derivative): Shifts the proportioning band on a slope change of the process variable. Rate in effect applies the "brakes" in an attempt to prevent overshoot (or undershoot) on process upsets or startup. Unlike reset rate operates anywhere within the range of the instrument. Rate usually has an adjustable time constant and should be set much shorter than reset. The larger the time constant the more effect rate will have. Too large of a rate time constant will cause the process to heat too slowly. Too short and the control will be slow to respond to upsets. The time constant is the amount of time any effects caused by rate will be in effect when rate is activated due to a slope change.

Self Tuning / Adaptive Tuning / Pre-Tuning

Many control manufactures provide various facilities in their controls that allow the user to more easily tune (adjust) the PID parameters to their process. Below is a description of same.

Tuning On Demand with Upset: This facility typically determines the PID parameters by inducing an upset in the process. The controls proportioning is shut off (on-off mode) and the control is allowed to oscillate around a setpoint. This allows the control to measure the response of the process when heat is applied and removed (or cooling is applied). From this data the control can calculate and load appropriate PID parameters. Some manufactures perform this procedure at setpoint while others perform it at other values. Caution must be excersized for substantial swings in the process variable values will likely occur while the control is in this mode.

Adaptive Tuning: This mode tunes the PID parameters without introducing any upsets. When a control is utilizing this function it is constantly monitoring the process variable for any oscillation around the setpoint. If there is an oscillation the control adjusts the PID parameters in an attempt to eliminate them. This type of tuning is ideal for processes where load characteristics change drastically while the process is running. It cannot be used effectively if the process has externally induced upsets for which the control could not possibly tune out. For example: A press where a cold mold is inserted at some cyclic rate could cause the PID parameters to be adjusted to the point where control would be totally unacceptable.

Some manufactures call Tuning on demand Self Tune, Auto Tune or Pre-Tune. Adaptive tuning is sometimes called Self Tune, Auto Tune or Adaptive Tune. Since there is no standardization in the naming of these features questions must be asked to determine how they operate.

General Control Types

ON-OFF CONTROL ACTION

On-Off control is the most basic form of temperature control.

1) Changes output only after temperature crosses the setpoint.

2.) Should only used on non-critical applications, The process temperature never stabilizes at the setpoint due to process inertia.

3.) Also used in alarms and safety circuits.

4.) Most PID controls operate in this mode if the proportioning band is set to "0".

Time Proportioning Controls

1.) Vary the output by cycling a relay, SSR or logic voltage on and off.

2.) Proportions by varying the On Time versus Off Time.

3.) Usually include a parameter such as Cycle Time which is the total of the On Time and the Off Time. Example of its operation is as follows: With a Cycle Time of 10 seconds if the control decides it wants 42% heat applied to the process the output would be On for 4.2 seconds and Off for 5.8 seconds giving an effective output of 42%.

Linear Output Controls

1.) Provides a DC voltage or current output related to the required output demand. For example: If the control has an output range of 4-20 mA and decides it wants 50% power to the process the control would output 12.0 mA

2.) Normally connected to an SCR Power control or other solid state device. The power handling device then converts this signal to a relative power output.

Closed Loop Valve Motor Controls

1.) These controls are used in conjunction with motor actuators in gas heating applications. The control has (2) outputs (typically relays) one for clockwise rotation and one for counter clockwise rotation.

2.) Feedback as to motor position is provided by a potentiometer attached to the motor.

Open Loop Valve Motor Controls

1.) These controls are used in conjunction with motor actuators in gas heating applications. The control has (2) outputs (typically relays) one for clockwise rotation and one for counter clockwise rotation.

2.) No feedback as to motor position is provided. The user enters a value for motor travel time in the control. This allows the control to determine how long to operate the motor in either direction.

High & Low Limit Controls

1.) Usually used as safety devices upon the failure of the primary control device or some other failure in the system.

2.) Once the process variable goes through the limit setpoint the controllers output switches. The output will not revert back to normal until the process variable returns to a safe value and a reset button is pressed.

3.) Most insurance companies require FM approved limit devices on certain applications particularly on gas fired and on applications that are left unattended.

4.) For complete safety a separate sensor and contactor is required. On electric applications utilizing SCR power controls a contactor connected to the incoming power of the SCR should be used to protect against SCR failure.