Fundamentals of PID Controllers

USING ∘ SELLING ∘ SPECIFYING

Presenter

Joe Ryan
VP of Sales & Marketing

Joe brings more than 15 years of process industry experience in the design, support, manufacturing, marketing, and sales of process measurement and control devices. Joe has extensive field and support experience with process displays and controls, and a strong technical background including a bachelor's degree in Electromechanical Engineering and a master’s degree in Computer & Electrical Engineering.

Agenda and Takeaways

1. Learn what is a PID controller
2. Review common PID controller terms and features
3. Compare what *is* and *is not* a good application for PID controllers
4. Build your list of the “need to know” questions to buy or sell the right PID controller
5. Learn about the New SuperNova PD500 PID Process & Temperature Controllers

What is a PID Controller?

What is PID?

To Put It Simply…

PID control is a method of providing a control output for a system. It is a control algorithm that calculates a system output.

In the process industry, this could mean:

- Driving a solid-state relay to control a heater
- Sending a control signal to regulate a power controller
- Positioning a value
- Controlling a motor speed
- Maintaining the speed of a fan

There are many other possibilities, but the job of *PID* in a PID controller is always the same.

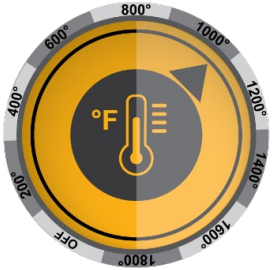
- Provide a system output that will be used to control a flow, level, temperature, pressure, or other measured process.

https://www.omega.com/en-us/resources/how-does-a-pid-controller-work

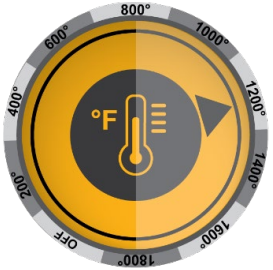
What is PID?

What Does the P, I, and D Stand For?

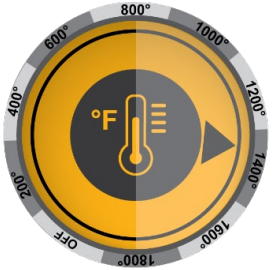
Proportional, Integral, and Derivative. In other words, they combine to make the math calculation that makes PID able to control more accurately that simple on/off control or alarms. PID math can result in any output from 0-100% necessary to meet the set value, not just 0 or 100%.



Proportional Tuning: Correcting a target proportional to the difference. Target value is never achieved because as the difference approaches zero, so too does the applied correction.



Integral Tuning: Attempts to reach the target value by effectively cumulating the error result from the "P" action to increase the correction factor.



Derivative Tuning: Attempts to minimize this overshoot by slowing the correction factor applied as the target is approached.

https://www.omega.com/en-us/resources/how-does-a-pid-controller-work

What is PID?

PID Control Algorithm

Process Variable (PV)

The PV is the measurement value of the temperature or process input *now.* It is the actual sensing input to the controller, typically a thermocouple, RTD, voltage, or current input (displayed as engineering units).

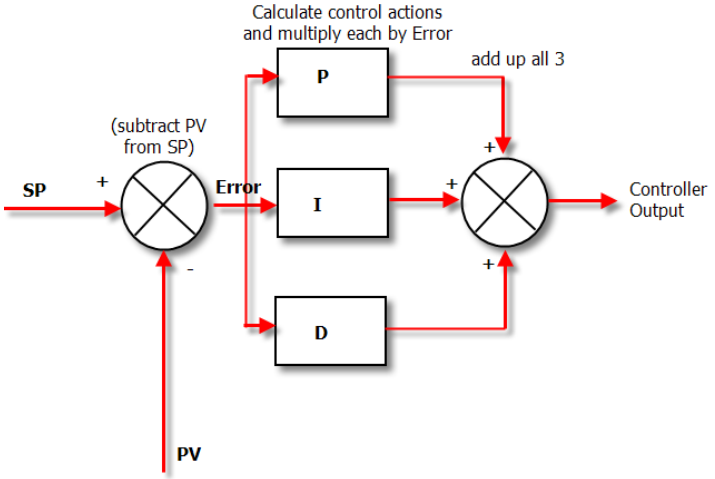
Set Value (SV)

The set value is the desired PV the controller will try to maintain. Also called the Set Point (SP).

Manipulated Value (MV)

This is the output value, in %, of the PID function. It is the % of the output level being generated. For example, at a 50% MV, a 4-20 mA output would be transmitting 12 mA.

The P, I, and D fed by the current system error, combine to generate the controller output.



This is a very simple explanation. A more in-depth on how a PID control system functions is not appropriate for this fundamentals presentation. It can get complicated!

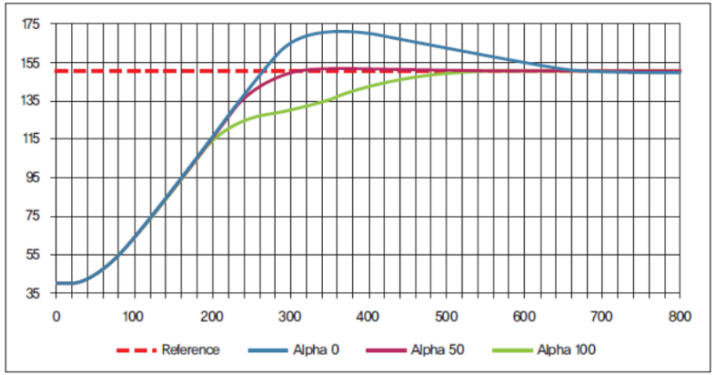
https://www.csimn.com/CSI_pages/PIDforDummies.html

What is PID?

Other Terms to Know

Gain/Alpha:

The ALPHA parameter is used to adjust the response characteristics to the set value (SV) changes.



Response Adjustment with Alpha

Auto-Tuning:

The auto-tuning function automatically measures, computes the control system characteristics, and sets the optimum proportional band (P), integral time (I), and derivative time (D) constants.

Manual Tuning:

Manual tuning is the art of entering or editing P, I, and D values manually. Not common anymore thanks to auto-tuning.

Unless you consider yourself a PID expert (and then, why are you here?) I always recommend performing an auto-tune, and then using the Alpha (aka: Gain) parameter for adjustment.

May be necessary for very long processes where auto-tuning may take over 24 hours.

What is PID?

What is NOT PID?

On/Off Control

On/Off control is when a system output has just on (100%) and off (0%) states.

A good example of this is a very simple heating systems – like your home thermostat & heater.

- Heating system is on or off only, and cycles around an SV you set.
- On/Off cycle based only on achieving the set value, and a deadband.
- Time is not a function of the system in any way.

PID Controllers are often used for On/Off control.

Alarms

Alarms on instrumentation are often used for simple control, in addition to indication or alert.

An alarm is often just another form of on/off control.

Control functions like pump alternation or lead-lag control are also not PID control.

PID controllers often use alarms as well, and include relays specifically for alarms.

What are PID Controllers?

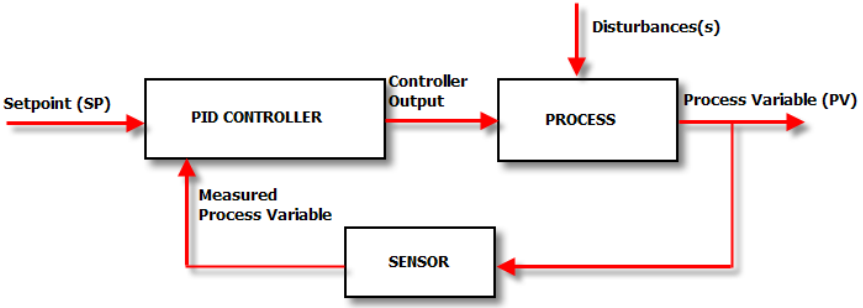
- Instruments that use PID algorithms are PID controllers
- PID controllers are the most accurate and stable
- Designed to make PID control easy
- Come in a variety of shapes, sizes, and appearances

What are PID Controllers?

PID Controllers are Part of a Control System

The PID controller is one part of a complete control system:

- Sensor
  - Thermocouple, RTD, transmitter
- PID Controller
- Process
  - Controlled device such as valve, power controller, heater, pump, or fan.
  - The rest of the system such as tanks, pipes, and the application hardware.
  - Elements that cause disturbances such as the ambient temperature, or process waste heat.



Example of a Process Under PID Control

https://www.csimn.com/CSI_pages/PIDforDummies.html

Panel Mount PID Controllers: Common DIN Sizes

SuperNova PD510

1/16 DIN

SuperNova PD520

1/8 V DIN

SuperNova PD530

1/4 DIN

Trident PD765

1/8 DIN

Other, non-panel mount options exist as well. PID controllers can be DIN rail mounted, or even be an aspect of PLCs, multichannel controllers, or the control room software suite.

Panel Mount PID Controllers: Other Common Design Elements

IP65 Front

NEMA 4X Enclosure

- Plastic NEMA 4X
- Externally mounted through hinged cover
- Cover has stainless steel hinge & latch

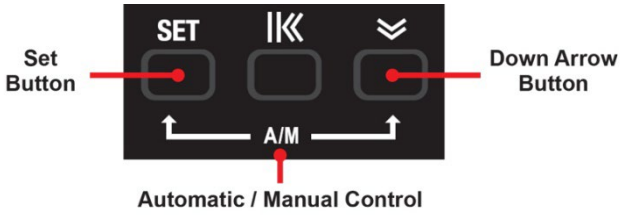
Panel Mount PID Controllers: Other Common Design Elements

Set Value and PV on Display

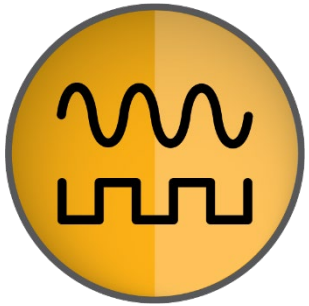
- PV line displays process variable
- SV line displays set value

Auto/Manual Control Switching

- Easily switch to automatic or manual control by pushing two buttons simultaneously!
- A graphic on the front panel labeled A/M points to the buttons to push

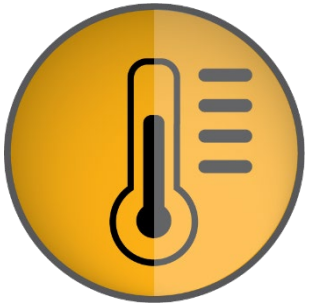


Common Inputs



Process Inputs

- 1-5 V (4-20 mA)
- 0-5 V
- 0-10 V
- 0-50 mV
- 0-100 mV
- External 250 Ω resistor required to read 4-20 mA



Temperature Inputs

- Thermocouple Type:
  K, J, E, T, R, B, S, L, N, U, W, PLII
- RTD Type:
  JPT100, PT100

Control Outputs

Control Output Varieties

4-20 mA (SCR)

- Stands for “Silicon Controlled Rectifier”
  - Specific type of power controller
- Also used to control valves, motor controllers, pump controllers, and many other process devices
- Commonly driven by less than 24 VDC, so, watch voltage needs

Voltage Pulse (SSR)

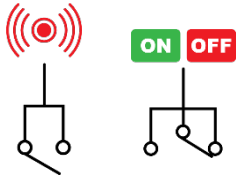
- Stands for “Solid-State Relay”
  - Used to drive a solid-state relay on/off quickly
- Time-proportional on/off cycles, where a cycle, or period is short, such 1 second.
- Used with power controllers, heaters, and other quick on/off devices.
- Also used with solid-state relays as an alternative to electromechanical relays (see below) for On/Off control.

Relay Control

- This is just On/Off control. Does *not* use PID capabilities.
- Often chosen due to ease of PV/SV interface and the ease of using a PID controller as an operator interface for control.

Alarm Outputs

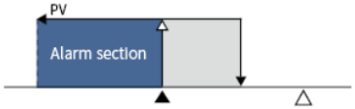
Alarm Outputs (SUB)



Alarm Output Basics

- Relays (SPST vs SPDT)
- Used alarms, or sometimes On/Off control
- May be exclusive, or programmable for alarming or control
- Specifications may vary from control relay outputs

Deviation Alarm Example

4	Low deviation		Deviation	
(10)	Low deviation with standby sequence			Yes

▲: AL-n Alarm value. This is the specific PV value, or for deviation alarms the deviation amount from the SV, when the alarm activates.

△: Set value. For deviation alarms only, indicates the alarm operation as high, low, or both in relation to the SV.

Specific PID Controller Alarm Features

- Deviation Alarms
  - Alarm based on the difference of PV to Set Value
- Standby Mode
  - Ignores alarm condition due to SV changes, alarm mode changes, power-on, etc.
- Latching Alarms Common
- Loop Break Alarm
  - Indicates a failure of the PV to change over time when the MV is 100%.

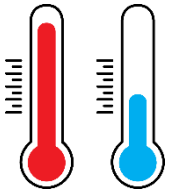
Heating and Cooling Control Outputs

“Heating and Cooling”

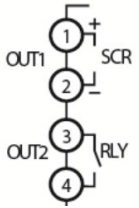
- Used for more than just temperature applications.
- Bi-directional control, driving PV both up and down.
- Not as common as one-directional “heating *or* cooling” control.
- One control output for “heating” or increasing the PV
- One control output for “cooling” or decreasing the PV
- Heating and cooling side outputs never run in opposition.

H&C on the PD500 Specifically…

- Heating and Cooling abilities standard.
- Cooling, when using heating and cooling, is *always* a relay output.
- Functions normally as a heating *or* cooling controller unless Out 2 relay set to On/Off.
- This dramatically reduces user confusion, and covers most process applications.



Heating & Cooling is Standard on PD500



Relays on SuperNova PD500 Process & Temperature Controller

Other Common / Useful IO

Other Common I/O Features

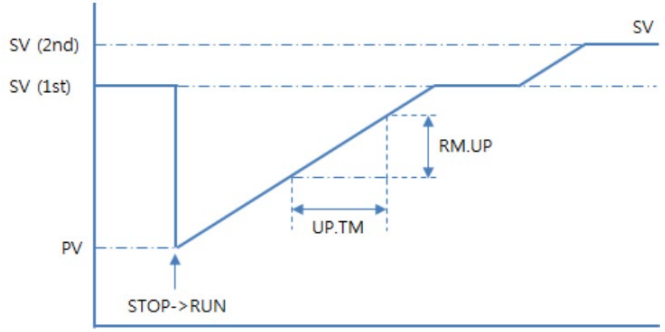
- Modbus and RS-485
  - Modbus slave/server
  - Useful for SCADA access
  - Used for live field monitoring software
- USB for programming
  - SuperNova has front-accessible USB connection for easy programming with FREE software
- Ethernet
  - Grants remote access via the internet.
  - Not present on the SuperNova

- Remote Set Value Input
  - 4-20 mA input to control the SV remotely.
  - Useful to control the SV from a set point generator or a PLC.

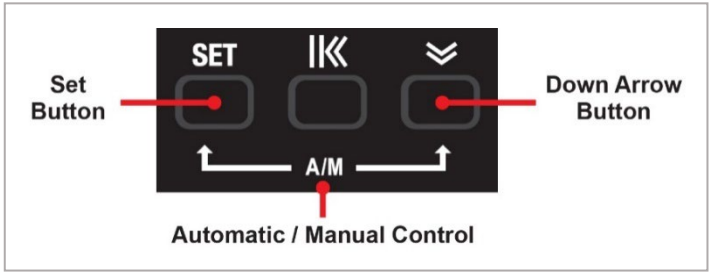
Set Point Generators

Other Common PID Controller Features Not Found on Panel Meters

- PV, SV, and MV Displays
- Auto/Manual switching
- Ramp up/down
- Ramp & soak programming (not on SuperNova)
- Remote set value inputs
- Cascade Control (not on SuperNova)
- Common Programming Style using “Group” based programming
- Input power often only high voltage AC
- UL Recognized vs Listed vs Nothing



Set Value Ramp Up



Easy Two-Button Auto to Manual Control

“Need-to-Know” Questions to Buy or Sell the Right PID Controller

“Need-to-Know” Questions to Buy or Sell the Right PID Controller

ASK QUESTIONS!

You need to fully understand the application!

1. What type of control is being done? PID? On/Off? Alarms?
2. What is the main PV input from, and what is the signal?
3. How is the PV being controlled?
4. What type of control output signal(s) are needed?
5. Is this one-direction or heating & cooling control?
6. Do they want more than just control outputs, such as alarms?
7. What size or format best works for the customer?
8. What *other* I/O, software, communication is needed?
9. How will they power the controller or other equipment like transmitters?
10. Ask them how they want it to operate? Watch for Ramp/Soak, SP ramps, etc?

SuperNova PID Controllers

SuperNova PID Controllers: Overview

SUPERNOVA

PID Process & Temperature Controllers

PD530 PD520 PD510

Features

- Auto-Tuning PID Process & Temperature Controllers
- Reverse Polarity Three-Color LCD: -1999 to 9999
- Thermocouple and RTD Inputs
- DC Voltage & Current Inputs (1-5 V, 0-5 V, 0-10 V, 0-50 mV, 0-100 mV; 4-20 mA with Resistor)
- Primary Control Output Options: 4-20 mA (SCR), Voltage Pulse (SSR), or Relay
- Secondary Control Output Relay Standard
- Easily Switch Between Auto and Manual Control
- Up to 2 Alarm Relays & 4-20 mA Retransmit Outputs
- Remote Set Value 1-5 V Input Option (4-20 mA with External Resistor)
- FREE Programming and Monitoring Software

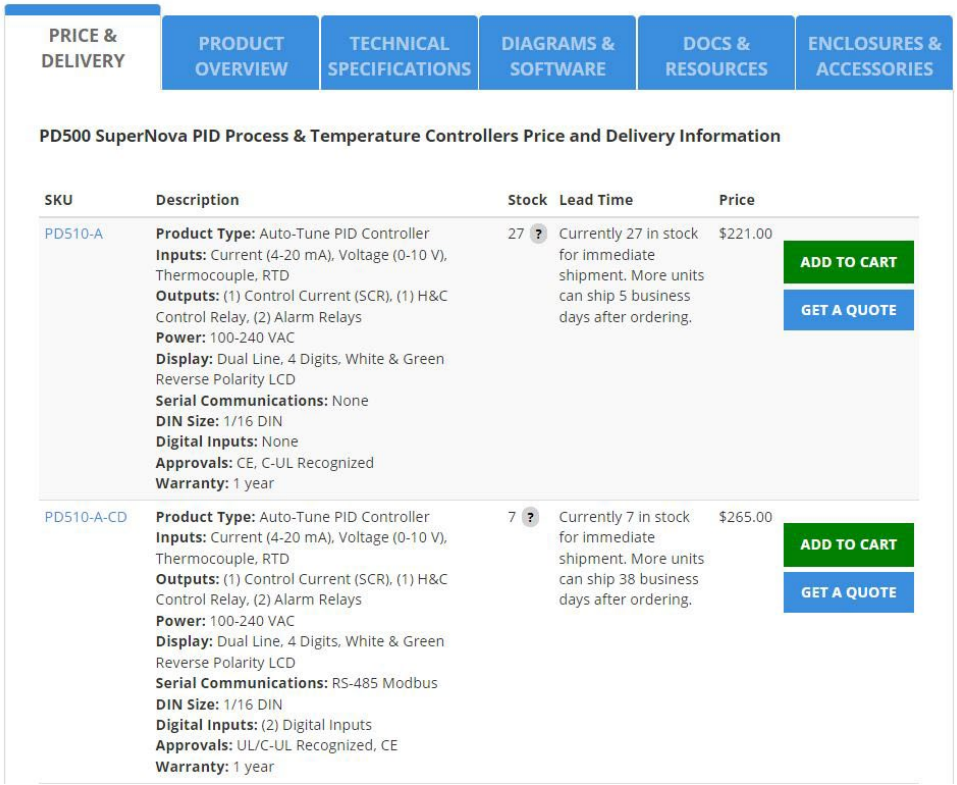
SuperNova PID Controllers: Ordering Guide Example

Model Number	DIN Size	Main Control Output	Additional Features	Price
PD530-A	1/4	4-20 mA (SCR)	Relay Control Output, 2 Alarm Relays	$265.00
PD530-A-CTD	1/4	4-20 mA (SCR)	Relay Control Output, 2 Alarm Relays, RS-485, 4-20 mA Retransmit, 2 Digital Inputs	$321.00
PD530-A-CTDR	1/4	4-20 mA (SCR)	Relay Control Output, 2 Alarm Relays, RS-485, 4-20 mA Retransmit, 2 Digital Inputs, 4-20 mA SV Input	$360.00
PD530-S	1/4	Voltage Pulse (SSR)	Relay Control Outputs, 2 Alarm Relays	$265.00
PD530-S-CTD	1/4	Voltage Pulse (SSR)	Relay Control Output, 2 Alarm Relays, RS-485, 4-20 mA Retransmit, 2 Digital Inputs	$321.00
PD530-S-CTDR	1/4	Voltage Pulse (SSR)	Relay Control Output, 2 Alarm Relays, RS-485, 4-20 mA Retransmit, 2 Digital Inputs, 4-20 mA SV Input	$360.00
PD530-R	1/4	Relay (On/Off)	Relay Control Output, 2 Alarm Relays	$265.00
PD530-R-CTD	1/4	Relay (On/Off)	Relay Control Output, 2 Alarm Relays, RS-485, 4-20 mA Retransmit, 2 Digital Inputs	$321.00
PD530-R-CTDR	1/4	Relay (On/Off)	Relay Control Output, 2 Alarm Relays, RS-485, 4-20 mA Retransmit, 2 Digital Inputs, 4-20 mA SV Input	$360.00

Ordering Information Example for the PD530 1/4 DIN Controllers

A special warning when doing part number cross-overs… GET THE COMPLETE STORY!

SuperNova PID Controllers: Website Stock, Price & Delivery



PRICE & DELIVERY | PRODUCT OVERVIEW | TECHNICAL SPECIFICATIONS | DIAGRAMS & SOFTWARE | DOCS & RESOURCES | ENCLOSURES & ACCESSORIES

PD500 SuperNova PID Process & Temperature Controllers Price and Delivery Information

SKU	Description	Stock	Lead Time	Price	
PD510-A	**Product Type:** Auto-Tune PID Controller **Inputs:** Current (4-20 mA), Voltage (0-10 V), Thermocouple, RTD **Outputs:** (1) Control Current (SCR), (1) H&C Control Relay, (2) Alarm Relays **Power:** 100-240 VAC **Display:** Dual Line, 4 Digits, White & Green Reverse Polarity LCD **Serial Communications:** None **DIN Size:** 1/16 DIN **Digital Inputs:** None **Approvals:** CE, C-UL Recognized **Warranty:** 1 year	27 ?	Currently 27 in stock for immediate shipment. More units can ship 5 business days after ordering.	$221.00	ADD TO CART GET A QUOTE
PD510-A-CD	**Product Type:** Auto-Tune PID Controller **Inputs:** Current (4-20 mA), Voltage (0-10 V), Thermocouple, RTD **Outputs:** (1) Control Current (SCR), (1) H&C Control Relay, (2) Alarm Relays **Power:** 100-240 VAC **Display:** Dual Line, 4 Digits, White & Green Reverse Polarity LCD **Serial Communications:** RS-485 Modbus **DIN Size:** 1/16 DIN **Digital Inputs:** (2) Digital Inputs **Approvals:** UL/C-UL Recognized, CE **Warranty:** 1 year	7 ?	Currently 7 in stock for immediate shipment. More units can ship 38 business days after ordering.	$265.00	ADD TO CART GET A QUOTE

Stock & Delivery at Predig.com

- SKU
- Description
- Stock
- Lead Time
- Price
- Add to Cart Button
- Get a Quote Button

Price & Delivery Webpage Example for the PD510 1/16 DIN Controllers on Predig.com Website

Questions?

If you have any questions, then reach out to us.

Joe Ryan
VP of Sales & Marketing

jryan@predig.com