Calculation guide

ThermoFisher
S C I E N T I F I C

.... Exploration

.... Production

.... Custody transfer

.... Storage

.... Refining

.... Distribution

UPSTREAM

MIDSTREAM

DOWNSTREAM

PID

AutoSERIES of Thermo Scientific Flow Computers

Designed for greater control where you need it most.

thermo scientific

Contents

Revision History

Revision	Date
01	02-01-2023

1. PID (Table #33)

A PID (proportional-integral-derivative) loop is commonly used in process control applications. PID loops may be configured to maintain a certain pressure, temperature, or flow rate. The function works by comparing the process variable (the current flow rate for example) to the setpoint (the desired flow rate) and making adjustments to the output value as necessary, such as opening or closing valves, to reach and maintain the setpoint.

Prior to configuring a PID, determine whether it will run on 1–5 V or 4–20 mA output. If you are using 1–5 V, a 12-V power source going to the analog output board is required. If using 4–20 mA, a 24-V power source going to the analog output is required.

Figure 1. Table 33 PID Calc#1

1.1 Parameter Definitions

Calculation: Default=Disabled Enable/disable PID calculation.

Descriptor: Enter a text string that identifies the device or function associated with the calculation.

ID: The PID calculation table ID.

Mode: Default=Manual. Select **Auto** if you want the instrument to control output based on process input. Select Manual if you want a user/technician to control the output directly. Allows user to directly edit the "Output Value".
   Caution: Caution must be taken as ramp rates, setpoints, etc. are no longer applicable when in "Manual Mode".

Failure Status: This indicates operational status of PID, Normal or Failed based on selection of any "Fail Mask" criteria.
   Note: If no Fail Mask is selected, Status will always remain Normal.

Output Value: The actual calculated output value in percentage (0% to 100%). Note: User will connect either Analog output or High/Low Selection to this field. This field is a calculated output unless in Manual Mode which then allows user to enter output value between 0-100%.

Output Mode: Select whether the end device will be connected to an analog or discrete output.

Open / Close Discrete Out: (Default=Off) If the PID is using two discrete outputs to control a stepper motor for a valve (as opposed to using an analog output), these two discrete outputs represent the points that activate the opening and closing of the valve.

Open /Close Limit Discrete In: (Default = Off) These discrete inputs function as limit switches to the PID calculation. The PID will stop trying to open or close the outputs if the corresponding input limit is active.

Process Variable block: The live values of the process outputs. For example, Process Variable #1 could be the hourly flow rate of DP run #1. If more than one Process Variable is to be used, the Output Value will be based on the Total sum of all process variables.

Control Mode: (Default=Local) Specify whether a local or remote setpoint is to be used. The remote setpoint is selected for remote setpoint download from a host system, while the local setpoint is used by the local technician. This option allows a local technician to place the loop in local control during maintenance.

L. (Local) Setpoint: When the Control Mode parameter is set to Local, specify the local setpoint value in this field. When in local control mode, this value will be immediately copied to the Operating Setpoint field.

R. (Remote) Setpoint: (Default=Disabled) When the Control Mode parameter is set to Remote, specify the remote setpoint value in this field. When in remote control mode, this value will be immediately copied to the Op. Setpoint field if the "Remote Load Required" field is set to Disabled or after the "R. Setpoint Load" field is set Enabled if "Remote Load Required" field is set to Enabled.

R. (Remote) Setpoint Load: Use this field to load the remote setpoint value into the Operating Setpoint field when R. Setpoint Load is set to Enabled.

Remote Load Required: (Default=Disabled) Specify whether a two-step process (load the remote setpoint value and set the remote setpoint load discrete to Load SP) is required to load the remote setpoint value into the operating setpoint. This feature is designed to facilitate "readback before execution" functionality, meaning a remote operator will download the desired setpoint value, wait for readback to verify that the setpoint was successfully downloaded, and then issue a Remote Setpoint Load.

Op. (Operating) Setpoint: The actual operating setpoint being calculated by the algorithm and used by the program.

Note: This is a calculated and read only value.

Max. Setpoint: Specify the maximum allowable setpoint value that will be accepted (applies to both local and remote setpoints). If a setpoint (remote or local) is entered that is greater than the maximum setpoint, the setpoint will be set to the maximum value. For example, if the maximum setpoint is 1000 and the local setpoint is set to 1050, the local setpoint will be set to 1000 (the maximum) automatically. Setting the parameter to 0.0 disables this feature.

Ramp Setpoint: The ramp setpoint is the actual setpoint value being used in the current PID loop. If the Ramp Rate parameter is set to a non-zero value, the ramp setpoint will ramp to the value of the operating setpoint at the rate specified in the Ramp Rate field (process variable EU/second).

Note: This is a calculated and read only value.

Example:

The Local or Remote setpoint and ramp setpoint are both currently at 0.0. The Local or Remote setpoint is changed to 500 and the ramp rate is set to 10.0. The ramp setpoint will ramp up to the new setpoint value in steps of 10/second (0, 10, 20, 30, 40, etc.) until it reaches 500. The ramping of the setpoint value allows the PID to be tuned with more responsiveness since the maximum rate of change of the setpoint is known. If the ramp rate is set to 0.0, then the ramp setpoint will have the same value as the operating setpoint.

Ramp Rate: Specify the desired rate of change of the ramp setpoint. A value of 0.0 disables setpoint ramping. A non-zero value enables setpoint ramping.

Max Output: This parameter limits the amount of change that can be applied to the control output value during one calculation cycle (1 second). This prevents large output changes in response to process upsets and allows the control loop to be tuned for tighter control response. Entering a value of 0.0 disables this feature. A non-zero value enables the feature and sets the output change limit. For example, if this parameter is set to 1.0% and the calculated output change for one calculation cycle is 2.5%, the actual change in the Control Output Value field will be limited to 1.0%.

Pro. (Proportional) Term: The element of the PID that is proportional to the difference between the current and desired process output.

Integral and Derivative Terms: These values are used to control how fast the valve opens or closes. Fine tuning a valve is a matter of trial and error. Thus, we suggest using the default settings first and then making adjustments as necessary. The integral value is usually set at less than 1/10 of the PID gain to avoid overshooting the setpoint value. The derivative constant is

used to slow the changes of the process variable. For most gas control applications, leave the derivative value at 0.0 to reduce stability problems. A common practice when Derivative is necessary, is to not increment more than 1; suggested would be 0.01.

Error Deadband: Use this parameter to specify when the control loop should be considered to be on setpoint (no adjustments to the control output value will occur). If the difference between the setpoint and process variable value is less than or equal to the error deadband value, no change in the control loop's output value will be made. The purpose of this parameter is to prevent undue wear and tear on the control valve by preventing minute adjustments to the position when the process variable is "close enough" to the setpoint. For example, if controlling pressure with a setpoint of 500 and an error deadband of 10, no change will be made to the control output for that loop value if the pressure is between 490 and 510.

PID Action: (Default=Forward) Use this parameter to configure how the control output value should react to control the control valves correctly. Forward indicates that the output value should increase to open the valve (0% = valve fully closed, 100% = valve fully open). Reverse indicates that the output value should decrease to open the valve (100% = valve fully closed, 0% = valve fully open). If the valves are controlled using a 4–20 mA output and the valve positioners are configured so that the valve is fully open when a 20 mA signal is received, the control action should be set to **Forward**. If the valve positioners are configured so that the valve is closed when a 20 mA signal is received, the control action should be set to **Reverse**.

Maximum PV: Set this field to an estimate of the maximum PV value that is expected. For a pressure control loop, this could be set to the maximum span of the pressure transducer that is providing the pressure input. For a flow/energy control loop, this could be set to the estimated maximum rate that could be expected when the flow control valves are fully open. Recommended Max PV is maximum throughput of controlled process plus 5%. This value is an estimation and is used to calculate a normalized PID error term (roughly in the range -1 to +1) using the following equation:

(Setpoint – Process Variable) / Max PV.

Example: Pressure Control with a 500psi transducer with setpoint of 100psi starting at

50. Setpoint: 100

Process Variable: 50 (live value at any given point)

Max PV.: 505

(100 – 50)/505= 0.099

Copy Enable: (Default = Disabled) Specify whether the selected setpoint (local or remote) should be copied to the non-selected setpoint. When enabled, both the local and remote setpoints will always be equal to the selected setpoint value. Since this forces the local and remote setpoints to be equal, changes to the Control Mode (local/remote) will not cause a "bump" in the control outputs. When disabled, no copy is performed and the local and remote setpoints can contain different values.

Setpoint Track: (Default = Disabled) If this function is enabled and the PID is in manual mode, the algorithm will force the setpoint to the current process variable. If the PID is set to automatic, the setpoint is then equal to the input, resulting in a bumpless transfer.

CAUTION: When switching to Manual Mode and Setpoint Track is not enabled, it could result in the slamming of valve when placed back into Automatic mode.

Fail Mode: (Default=Fixed) Select what the end device should do in the event of a system failure. Options are listed below.

- Fail Fixed: Valve stops in exact position it is in at the time of the failure.
- Fail Open: Valve opens all the way in the event of a failure.
- Fail Closed: Valve closes all the way in the event of a failure.

Fail Mask section: Specify which conditions of the process variable are to be monitored for a failure condition. Any combination of conditions may be selected by checking the appropriate boxes. Failure will be indicated in the Failure Status field.
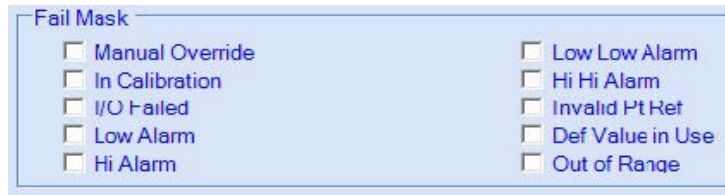
Figure 2. Fail Mask Selections

Figure 3. Failure Status

1.2 Example PID Graphs

1.2.1 Proportional Only

The graph below depicts a typical Proportional Only controller process response. Normally, this is all that is required to produce the desired process results. The process output typically overshoots the desired output and then settles into a steady-state output somewhat less than the desired output value. The process output settles to some value for which the proportional control output matches the control input needed to achieve a steady state. The integral element of the PID controller forces the process output to match the desired output by utilizing the total error signal.

Note: Proportional Only will never obtain setpoint without Integral term present. It is not recommended to perform a Proportional Only w/o Integral term.
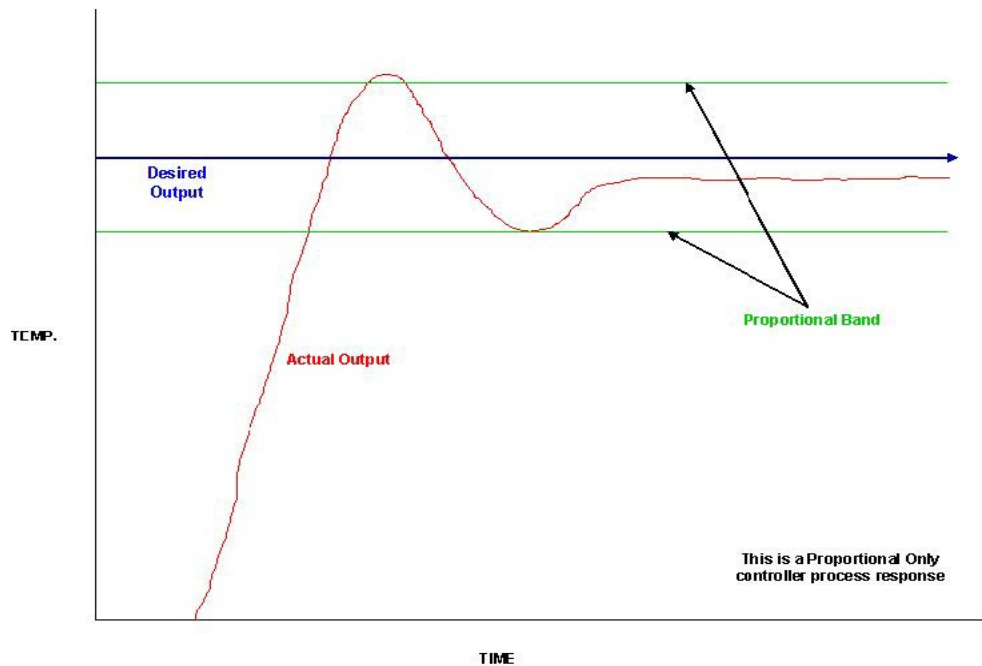

Figure 4. Proportional Only Graph

4

1.2.2 Proportional-Integral

This graph depicts a Proportional-Integral controller process response. It provides a control signal that is proportional to the total process output error over time. The initial overshoot and oscillations remain basically unchanged for the example below, and the steady-state process output gravitates more toward the desired output value.
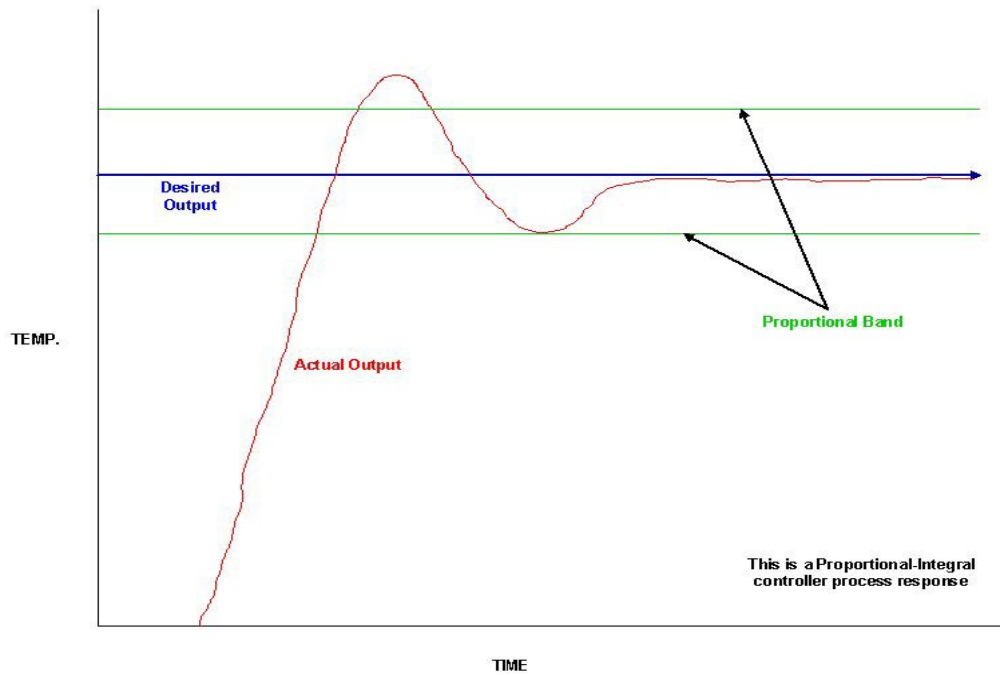

Figure 5. Proportional-Integral Graph

1.2.3 Proportional-Integral with Derivative

Below is an example of the derivative PID element. It provides a control signal that is proportional to the rate of change of the process output error signal. The derivative dampens the process overshoot and improves the system's response to change. The graph shows what happens when the derivative element is added to the proportional-integral controller. The initial process overshoot and oscillations are reduced, and the process output seeks the desired output value sooner than it does with P-I control alone.

Note: Using a Derivative, the actual output may not drive towards the set point at a steady rate as represented in the graph below resulting in a slower startup.
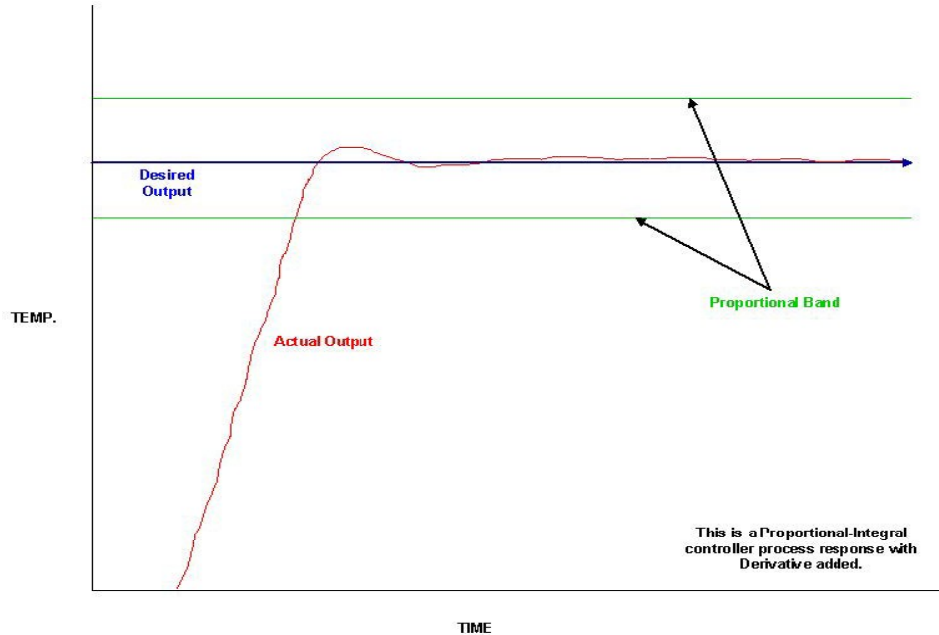

Figure 6. Proportional-Integral with Derivative Graph

1.2.4 Proportional Only with Gain Examples

Determining the PID gain constants that are necessary to control a given process can be difficult. However, understanding what each element contributes to the output may help make this task easier. The graph below contains four examples of the same process being controlled by a Proportional Only controller. Each line shows a different proportional gain. A smaller proportional band produces a response that is significantly closer to the desired output but has more overshoot and oscillations than a larger band.

The integral gain must be chosen so that it does not cause oscillations. The tendency is to use a large integral gain to reset the process output to the set point quickly. However, doing so can lead to process instability and uncontrollable oscillations. The integral element can be limited to operating when the process output is within the proportional band.
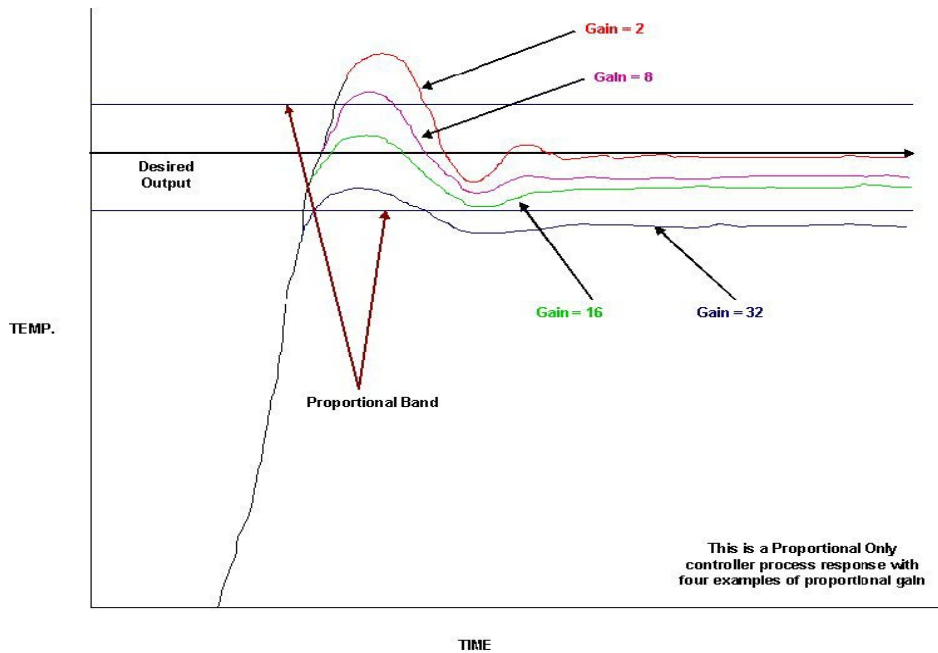

Figure 7. Proportional Only with Gain Graph

1.2.5 Proportional-Integral with Large Derivative

The derivative gain should be chosen to minimize overshoot on process start-up and process fluctuations in similar conditions. Too large of a derivative gain causes the derivative element to overpower the proportional element, resulting in a process start-up that is longer than necessary. This is demonstrated in the graph shown below. As with the integral element, the derivative may also be limited to operating whenever the process output is within the proportional band. This may be desirable because it allows a larger derivative gain to be used without lengthening the process start-up.
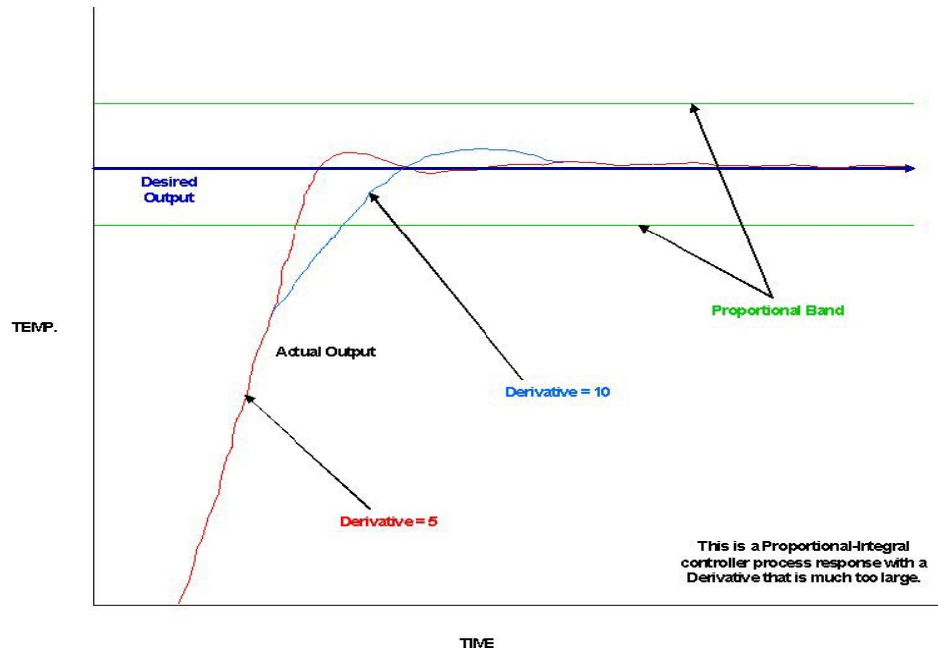

Figure 8. Proportional-Integral with Large Derivative Graph

Example: Flow Control Loop using PID with a Pressure Override

To help understand and utilize the PID capabilities that AutoCONFIG interface software offers, an example can be helpful. This example will demonstrate a commonly used method of setting up flow control with pressure override control loop.

Note: It should be mentioned that an alternative method of performing the same type of control (and more) can be accomplished in utilizing the "Station Control" calculation (Table #57).

This example will demonstrate how to do the following:

1. Connect the proper process variable(s) to the primary and secondary PID loops.

2. Connect the primary and secondary PID outputs to the High/Low select inputs.

3. Connect the High/Low select output to the analog output control.

A common valve control implementation in field installations is to control a meter's flow rate using a primary PID while also controlling with pressure "override" using a secondary PID. A High/Low selection function will be required to determine during operation which PID is in control. This is determined by the higher/lower percent output of the respective PID's.

If a user wishes to control a meter's flow rate but ensure that the pressure of that meter does not get too high, then the user would set the primary PID's setpoint to the desired flow rate, then set the override PID's setpoint to the desired maximum pressure setpoint, and finally set the High/Low option to "Low" select.

Under normal circumstances, the line pressure will be within normal operating range (below setpoint) and the primary PID (flow control) will be controlling the valve.

If pressure begins to rise to a point equal to or above the pressure override PID's setpoint then the pressure override PID's output will drop (close valve-assuming its forward acting), trying to limit the line pressure. Once the pressure override PID's output drops below the primary flow control output value then the override pressure PID will gain control until line pressure returns to normal operating range below the overrides setpoint. Once this occurs, the override PID's output value will raise to a level above the primary PID's output value at which point the primary PID will once again regain control of the valve.

Note: Please be sure that all default connections in the PID and High/Low functions have been cleared prior to setting up the example connections.

For this example, two PID loops (Table #33) and one High/Low Selection function (Table #35) will be used. The first PID loop will be used for the flow control utilizing DP Flow Calc#1 Hourly Flow Rate, and the second will be using DP Flow Calc#1 Static Pressure for pressure control. The High/Low Selection will be set to Low Select in this example.

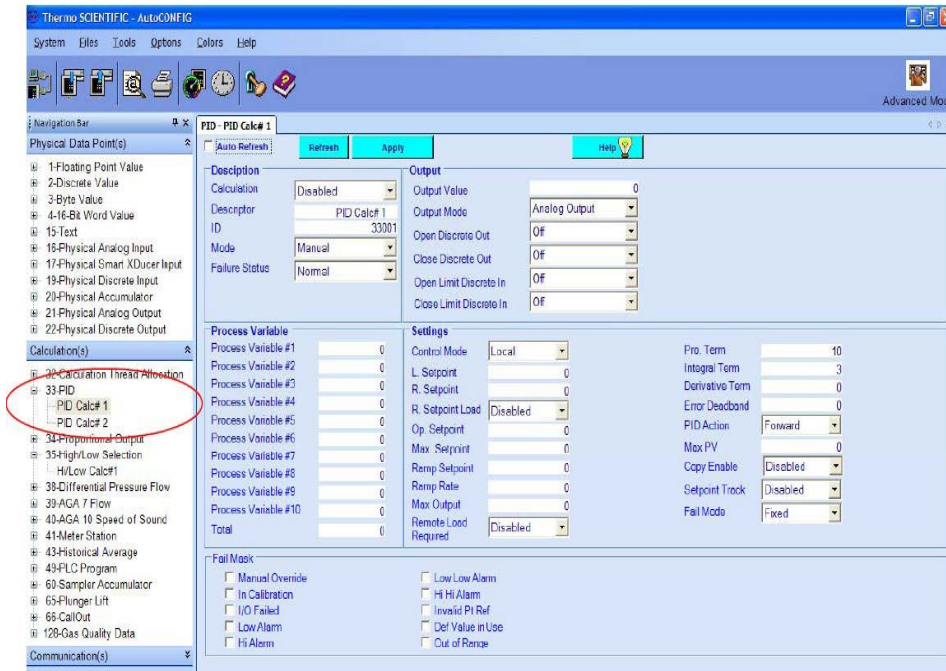1. In AutoCONFIG, go to **Calculations > 33-PID**. Double-click **PID Calc#1**.

Figure 9. Table 33 PID Calc#1

2. Go to the PID Calc#1 screen, and connect the hourly flow rate to the PID calc. With the exception of the first process variable, all remaining process variable connections may need to be cleared.

   a. Go to **Calculation(s) > 38-Differential Pressure Flow > DP Flow Calc#1 > Instantaneous tab** Right-click over **Hourly Flow Rate**, and select **Copy**. Go to **Calculations(s) > 33-PID > PID Calc#1**. Right-click over **Process Variable #1**, and select **Paste**. The Hourly Flow Rate for PID Calc #1 is now connected to the Process Variable #1.

3. Return to the PID selection list (33-PID) and double-click PID Calc#2. With the exception of the first process variable, all remaining process variable connections may need to be cleared.

   a. Go to **Calculation(s) > 38-Differential Pressure Flow > DP Flow Calc#1 > Instantaneous tab** Right-click over **Static Pressure**, and select **Copy**. Go to **Calculations(s) > 33-PID > PID Calc#2**. Right-click over **Process Variable #1**, and select **Paste**. The Static Pressure for PID Calc #1 is now connected to the Process Variable #1.

4. Go to the PID Calc#1 screen, and configure PID as desired (i.e. setpoint, proportional, integral, etc) making sure you change the Calculation field to **Enable** and click **Apply** as you make the changes.

5. Go to PID Calc#2, and configure the second PID loop as desired (i.e. setpoint, proportional, integral, etc).

6. Once both PID loops have been configured as desired, the next step is to connect to the High/Low Selection function. Connect PID Calc #1 Output Value to High/Low Selection Process Variable #1 and PID Calc#2 Output Value to High/Low Selection Process Variable #2.

a.   Go to **Calculation(s) > 33-PID > PID Calc#1**. Right-click over **Output Value**, and select **Copy**. Go to **Calculations(s) > 35-High/Low Selection > High/Low Calc#1**. Right-click over **Process Variable #1**, and select **Paste**. The output value for PID Calc #1 is now connected to the Process Variable #1 for the High/Low Selection function.

b.   Go to **Calculation(s) > 33-PID > PID Calc#2**. Right-click over **Output Value**, and select **Copy**. Go to **Calculations(s) > 35-High/Low Selection > High/Low Calc#1**. Right-click over **Process Variable #2**, and select **Paste**. The output value for PID Calc #2 is now connected to the Process Variable #2 for the High/Low Selection function.

7.   Go to **Physical Data Point(s) > 21-Physical Analog Output**. Copy the first analog output (Analog Out#1), and paste it into the **35-High/Low Selection > Hi/Low Calc#1 Output Value** field.

While still on the High/Low Selection table, configure as shown below.

a.   Calculation: Enabled
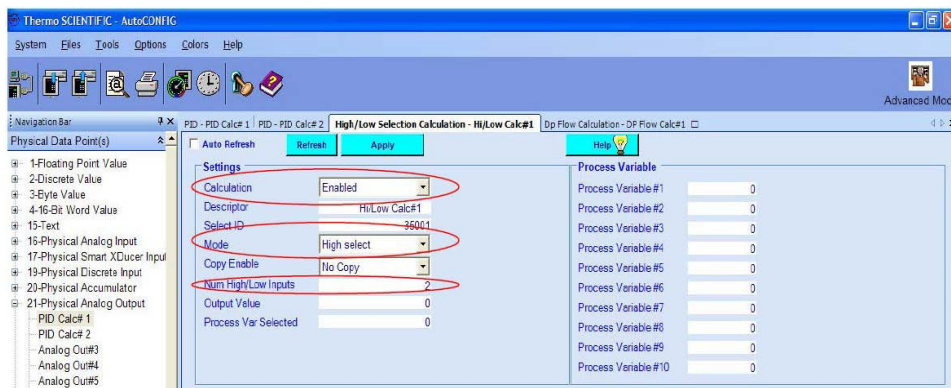
b.   Mode: Low Select

c.   Num High/Low Inputs: 2

Figure 10. Table 35 High/Low Selection

2. Proportional Output (#34)

Proportional control is used when an input range needs to be scaled higher or lower to obtain a desired output range. The proportional input is directly related to the output, whereas true PID is not. One analog output is required.

Prior to configuring the Proportional Output, determine whether it will run on 1–5 V or 4–20 mA. Typically, if you are using 1–5 V, a 12-V power source going to the analog output board is required. If using 4–20 mA, a 24-V power source going to the analog output is required. Additionally, adjusting the physical analog output (Table #21) may be required.

Figure 11. Table 34 Proportional Output Prop Calc#1

Figure 12. Table 21 Physical Analog Output-Analog Out #1

2.1 Parameter Definitions

Calculation: Enable/disable the calculation here.

Descriptor: Enter a text string that identifies the device or function associated with the calculation.

ID: The proportional output calculation table ID.

Value: The actual calculated output value in percentage (0% to 100%). The analog output would be pasted to this field.

Mode: Select Auto if you want the instrument to control output based on process input. Select Manual if you want to control the output directly.

Failure Status: This indicates operational status of proportional output, Normal or Failed based on selection of any "Fail Mask" criteria.

11

Note: If no Fail Mask is selected, Status will always remain Normal.

Note: Read Only field.

Minimum Scale: Set the minimum value that the percentage output is going to record as it ramps up toward the set point. This value is in engineering units.

Maximum Scale: Set the maximum value that the percentage output is going to record as it ramps beyond the set point. This value is in engineering units.

Action: (Default=Forward) Use this parameter to configure how the control output value should react to control the control valves correctly. Forward indicates that the output value should increase to open the valve (0% = valve fully closed, 100% = valve fully open). Reverse indicates that the output value should decrease to open the valve (100% = valve fully closed, 0% = valve fully open). If the valves are controlled using a 4–20mA output and the valve positioners are configured so that the valve is fully open when a 20mA signal is received, the control action should be set to **Forward**. If the valve positioners are configured so that the valve is closed when a 20mA signal is received, the control action should be set to **Reverse**.

Fail Mode: (Default=Fixed) Select what the output should do in the event of an input failure. Options are listed below.

• Fail Fixed: Output stops at the exact value at the time of the failure.

• Fail to Maximum Scale: Output goes to maximum scale in the event of a failure.

• Fail to Minimum Scale: Output goes to minimum scale in the event of a failure.

Process Variable block: The live values of the process outputs. For example, you could link Process Variable #1 to the hourly flow rate of DP run #1.

Fail Mask section: Specify which conditions of the process variable are to be monitored for a failure condition. Any combination of conditions may be selected by checking the appropriate boxes.

Example: Proportional Output using DP Hourly Flow Rate

To help understand and utilize the Proportional Output capabilities that the AutoCONFIG interface software offers, an example can be helpful. This example will demonstrate a commonly used method of setting up a proportional output utilizing DP Hourly Flow Rate.

This example will demonstrate how to do the following:

    i.   Connect the Hourly Flow rate to the Process Variable field.

    ii.   Connect the analog output to the Value field.

    iii.   Configure the remaining parameters (i.e. mode, min/max scale, action).

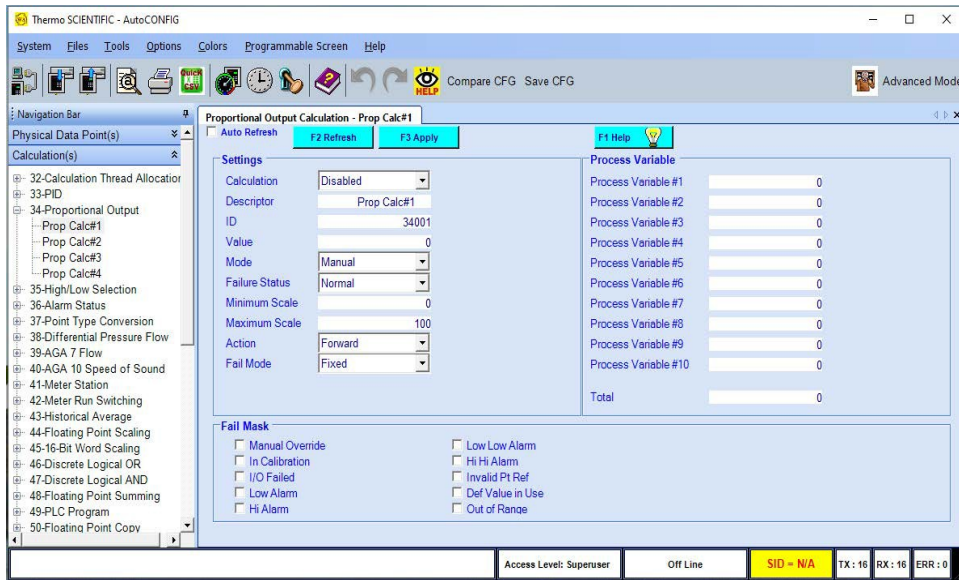In AutoCONFIG, go to Calculations > 34-Proportional Output. Double-click Prop Calc#1.

Figure 13. Table 34 Proportional Output

8. First, go to the Prop Calc#1 screen, and connect the hourly flow rate to the Process Variable #1. With the exception of the first process variable, all remaining process variable connections may need to be cleared.

   a. Go to **Calculation(s) > 38-Differential Pressure Flow > DP Flow Calc#1 > Instantaneous tab** Right-click over **Hourly Flow Rate** and select **Copy**. Go to **Calculations(s) > 34-Proportional Output > Prop Calc#1**. Right-click over **Process Variable #1**, and select **Paste**. The Hourly Flow Rate for Prop Calc #1 is now connected to the Process Variable #1.

Next connect the Current Value of Analog Output#1 to the Value field of the Prop Calc#1.

   b. Go to **Physical Data Point(s) > 21-Physical Analog Output > Analog Out#1.** Right-click over **Current Value**, and select **Copy**. Go to **Calculations(s) > 34-Proportional Output > Prop Calc#1**. Right-click over **Value**, and select **Paste.**

Next, Configure the parameters as indicated in picture below. In this example we are using a 0-100% scale.

Mode: (Default=Manual) switch to Automatic.

Note: Ensure calculation is "Disabled".

Minimum Scale: 0

Maximum Scale: 100

Action: Forward

Fail Mode: Fixed

Fail Mask: Select any appropriate Fail Mask criteria.

The final step would be to select Enabled in the Calculation field and select Apply. This will start the Proportional Output calculation.

USA
27 Forge Parkway
Franklin, MA 02038
Phone: 800-437-7979 • Toll free: (866) 282-0430
orders.process.us@thermofisher.com

Learn more at **thermofisher.com**