+ 2000 Series NUFLO Scanner Flow Computer

PID Control Manual

Introduction to PID Control

Industry has been using PID controllers for automatic process control since the early 1940s because unlike on-off controllers, PID controllers can consistently produce more stabilized control, which improves application results.

The PID controller compares a user defined setpoint (SP) to the current process value (PV) and adjusts the 4-20 mA analog output in an attempt to make the PV equal the SP. The 4-20mA output is used to position a final control element which is usually a valve coupled to a current-to-pneumatic (I/P) converter.

The controller acts on the difference between the PV and the SP based on the combined settings for three tuning factors:

+ a proportional constant which is the controller gain (K_p)
+ an integral constant (K_I)
+ a derivative constant (K_d)
+ Proportional Constant (K_p) or "Gain"

The proportional control action (or "proportional band") is referred to as gain in the ModWorX™ Pro software interface. Gain is fundamental to a PID controller and the controller cannot operate without it. To determine the output value, the controller multiplies the error by the gain factor.

The Scanner scales or "normalizes" the process variable operating range to a range of 0 to 1, so the gain values used with the Scanner PID controller may be significantly smaller than those used with a controller that is not normalized. Both a gain and an integral value must be entered if the process variable is to achieve the user-specified setpoint. In some cases, the use of a gain alone can result in an offset between the setpoint and process variable that cannot be resolved without an integral adjustment.

INTEGRAL CONSTANT (K_I)

The integral setting eliminates the offset between the setpoint and the process variable. While the gain acts only on the current error, the integral value acts on the sum of the current error and the previous error (the error that existed at the previous execution period). The controller will read the error between SP and PV each execution period, sum the existing error and the previous error, and multiply the sum by the integral value to determine the integral action on the output.

The integral value is typically very small, well below 1, and should be used in combination with a proportional constant.

DERIVATIVE CONSTANT (K_D)

The derivative action of a controller reacts to the rate at which the process variable is approaching setpoint or the rate of change in the error and adjusts the output accordingly. A derivative component is used only in slow-responding processes like temperature control where a significant amount of time is required for a fluid to heat or cool. It should not be used in applications where noise is likely to effect the process variable measurement. When a derivative adjustment is not required, the derivative value should be set to zero (default).

UNDERSTANDING GAIN: A SAMPLE CALCULATION

For the sake of simple calculations, we assume a gain value of 1 in this example. Actual gain values used with the Scanner® 2000 or Scanner® 2200 PID controller will be much smaller, due to normalization of the process variable operating range.

+ Setpoint = 50%
+ Process Variable = 60%
+ Gain = 1.0

To determine the output value, the controller multiplies the error by the gain factor.

If the gain were set to 1.0, the control-ler will adjust the output by 10%.

+ 60 - 50 = 10 (% variable error)
+ 10 x 1 (gain) = 10 (% output change)

If the gain were 2.0, the controller would respond with a 20% output change to 10% variable error. The direction of change in the output (increase or decrease) varies, depending on the action setting selected for the controller. See page 6 for information on direct and reverse controller action.

Scanner Solution

The integrated PID control of the Scanner® 2000 and Scanner® 2200 and the configuration and tuning controls built into the Mod- WorX™ Pro software provide a powerful solution for a variety of control applications. The control valve position is regulated via a 4-20 mA output, as shown in the illustration below. The analog output is standard on the Scanner® 2200, and is available on an optional expansion board for the Scanner® 2000.

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When purchased with the PID control option, the Scanner can be used to control parameters such as

+ static pressure (from integrated MVT or external analog input)
+ differential pressure (from integrated MVT or external analog input)
+ temperature (from integrated RTD or external analog input)
+ flow rate (mass, volume or energy) based on a DP or turbine input

The tuning values selected for the controller will determine if the process control is effective and stable.

All installations must be tuned and this task is nearly impossible by observing numeric values alone. Competitive products often require that the user observe the mechanical movement of the control valve indicator in response to an upset condition to validate the tuning process. In many installations, this is a twoperson job. Without a partner to validate the valve's movement, an operator's tuning success may be marginal.

The tuning tools within ModWorX™ Pro eliminate the need for a partner to monitor the valve indicator. The software plots the process variable, setpoint and valve position in an easy-to-read, scaleable graph and updates the output in realtime so a single operator can monitor the impact of every tuning change and determine when an optimum response is achieved.

Important: Operators must configure and tune PID control settings to operate in accordance with their specific application. As with any automated control system, operators are advised to take safety precautions to guard against control changes that could cause personal injury or property damage.
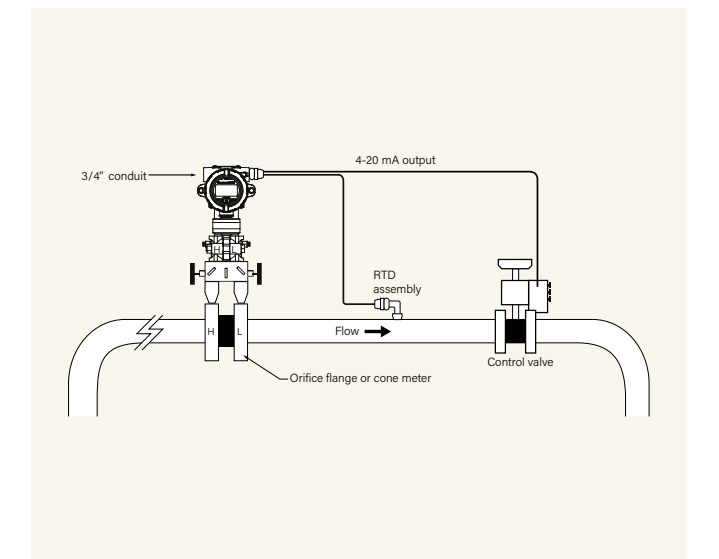
ModWorX™ Pro

ModWorX™ Pro, the software interface for the Scanner® 2000 and Scanner® 2200, allows the user to configure, tune and maintain a PID controller.

When ModWorX™ Pro is used to connect to a PIDenabled Scanner, the Configuration menu will include a "PID Control" button in the Outputs section of the screen. This button opens a dialog that guides a user through the configuration of the PID controller.

A "Manage PID" button also appears at the top of the main screen. This button opens a maintenance dialog which allows the user to change the control mode and control setpoint only. All other configuration settings are protected, if security settings are enabled.

To configure a controller, the user selects the control method to be used, mode of operation, the process parameter to control, and the range of operation required for the control parameter.

Then, using the tuning dialog, the user can change the tuning parameters and observe the system response. The user can switch between manual and automatic operating modes and observe the system's response to changes in valve position and the controller's response to changes in tuning values. A user can even view the progression of the controller response in a time-scale graph and pause the graph as necessary to make tuning adjustments.

TWO CONTROL METHODS

From the Configuration menu, users can choose either of two control methods:

+ simple single-variable PID control
+ PID control (for flow) with secondary pressure control

When configured with the second method, the Scanner can provide flow rate control and maintain static pressure below a user-configured setpoint. This is essential for industrial applications that require monitoring of two process variables and the flexibility to switch from one to the other as the primary control parameter.

For example, when a new gas well or zone is introduced in a field of old wells, the new well often produces at a higher pressure and delivers a higher volume of gas than the old wells. If the new well is tied into an existing production facility, it will dominate and prevent the old wells from flowing into the production system. The new well may also have a shut-in pressure that exceeds the older production system. To limit the flow and the pressure, a single control valve is installed.
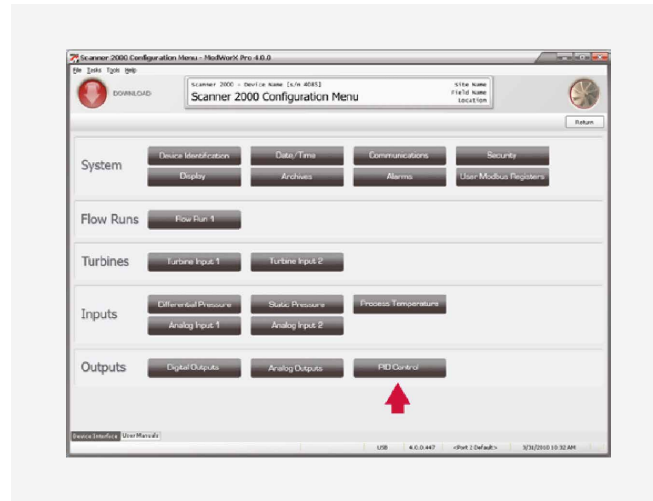

In this example, the user would configure the Scanner for PID with secondary pressure control. The user would enter two setpoints, one for the flow rate desired and one for the maximum pressure desired. The Scanner would control the valve in accordance with the flow rate setpoint until the pressure reached its limit, at which time the controller would throttle the valve to quickly bring the pressure back to the acceptable range. Once the pressure is in check, the controller would transition back to flow control.

Unlike the primary controller that is used to control flow in accordance with a fixed setpoint, the secondary pressure controller does not require a balance of gain and integral values. Because the secondary controller is concerned only with reducing pressure quickly, gain is the only tuning value required.

Configuring the Controller

SIMPLE PID CONTROLLER

1. From the Configure PID Control screen, change the controller type to Simple PID Controller.

2. Select the type of controller action desired (direct or reverse).

3. From the Process Variable section, select the parameter that you want to control. If the parameter you wish to control is based on an analog input, you must configure the input before configuring the PID Controller. See the ModWorX™ Pro manual for details. The execution period of the controller is automatically set to match the sampling and/or calculation period of the process variable being controlled.

4. Enter the Range Low and Range High values for the process variable you will control (for example, 0 to 200 In. H_2O, as shown).

5. Enter the desired setpoint.

6. In the Control Loop section, you may enter tuning values, if known. Otherwise, use the tuning dialog (step 8) to discover the appropriate values.

7. Click Apply to save the settings. The 4 to 20 mA output will automatically be configured for PID control.

8. Click on the Tune button in the Control Loop section of the screen. See Tuning the Controller, page 7, for tuning instructions.
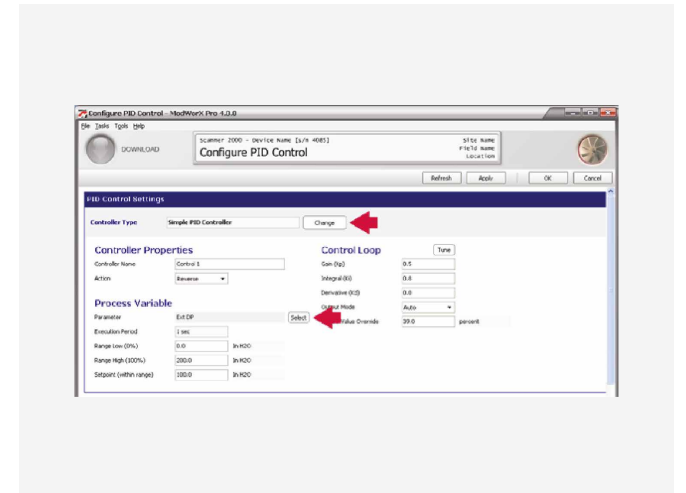
FLOW CONTROLLER WITH PRESSURE OVERRIDE

When configured for this type of control, the Scanner can provide flow rate control and maintain static pressure below a user-configured setpoint.

1. From the Configure PID Control screen, change the controller type to Flow Controller with Pressure Override.

2. Enter the settings described above in steps 2 through 6.

3. In the Pressure Override section, select the static pressure source. (When the pressure source is the integral MVT, the setting will be Integrated Static Pressure).

4. Enter the Range Low and Range High values to establish the range of the pressure source.

5. Enter the setpoint for the pressure override in the Max. Pressure Test Value field. Should the pressure exceed this value, the controller will actuate the valve to reduce the pressure.

6. Enter a value for Gain to control how quickly the valve responds to a pressure override.

7. Click Apply to save the settings.
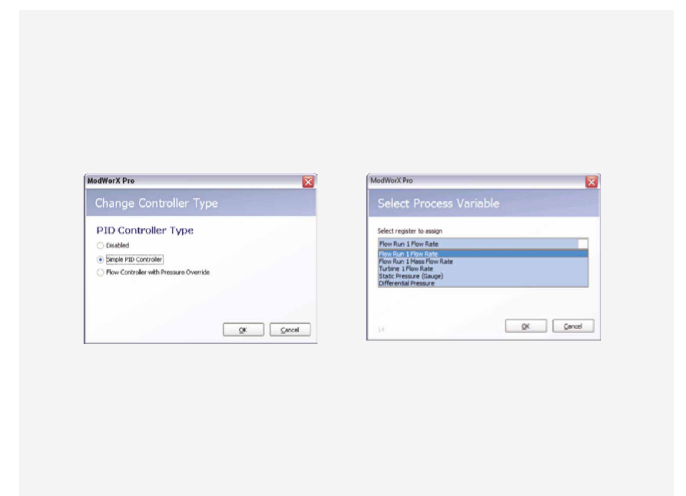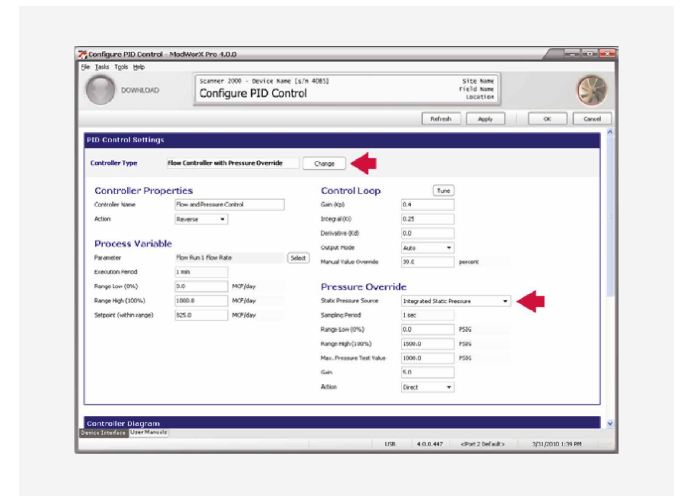
CONTROLLER ACTION: DIRECT OR REVERSE?

To configure the PID controller, the user must define the type of controller action desired. The action setting answers the question "what type of change in the controller output (increase or decrease) is required to bring the process variable in line with the control setpoint?". If an improper action setting is selected, the controller will respond in a manner opposite the intended response (increasing temperature, rather than decreasing it, for example).

Direct action causes the output value to change in the same direction as the change in PV (increase in PV ► increase in controller output).

Reverse action causes the output value to change in the opposite direction as the change in PV (increase in PV ► decrease in controller output).

CONTROLLER OUTPUT: INCREASED OR DECREASED?

How do you know if an increased or decreased controller output is needed for a particular application? The answer depends heavily on two variables:

+ the configuration of the valve (air-operated valves are referred to as "fail open" or "fail close")

+ how a change in valve position will affect the process variable (in some installations, opening a valve will increase the process value; in others, opening a valve will decrease the process value)

The following examples show how valve configuration can affect the action setting. In both cases, the process is designed such that when the valve opens, the process value will decrease. In the first example, an increased output is required to actuate a "fail close" valve. In the second example, a decreased output is required to actuate a "fail open" valve. With the proper action setting, either valve configuration can be used to achieve the desired result.

DIRECT ACTING

The control valve will fail in the closed position. An increased controller output opens the valve, and decreases the process value.

In this example, the error is initially positive (PV - SP>0). The positive error is counteracted by an increased controller output; therefore, this controller is direct-acting.

REVERSE ACTING

The control valve will fail in the open position. A decreased controller output opens the valve and decreases the process value.

In this example, the error is initially positive (PV - SP>0). The positive error is counteracted by a decreased controller output; therefore, this controller is reverse-acting.

INDEPENDENT CONTROLS FOR FLOW AND PRESSURE

When configuring a Scanner for PID with secondary pressure control, the user must choose two controller action settings—one for the primary flow controller and one for the secondary pressure controller. The controllers operate independently to control the position of a single control valve. A single application may require increased controller output to control flow, and decreased output to relieve pressure on the system. With dual controller action settings, each controller is configured to do the job it is designed to do.

Tuning the Controller
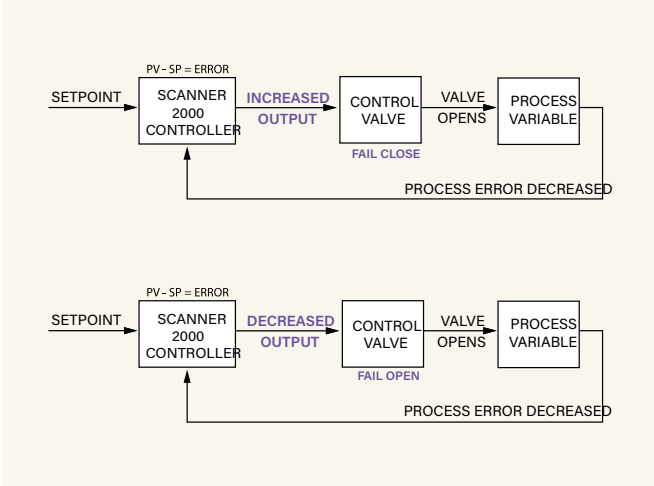
Press the Tune button on the Configure PID Control screen to open the Tune PID Control dialog. From this screen, an operator can observe the system's response to changes in tuning values, valve position and setpoint. When the process variable tracks to the setpoint in a stable trend, the controller is properly tuned.

Because control parameters are unique to each application, the tuning values for achieving an optimum response vary widely.

The Scanner controller has been normalized to a range of zero to 1. Therefore, tuning values may be significantly lower than those used with a system that is not normalized.

CONFIGURING THE DISPLAY

Main Graph
The graph display allows the user to monitor the system's response to changes in valve position, setpoint and tuning values. The x axis displays time, the left y axis displays valve position in percentage, and the right y axis displays the range of the controller in the engineering units associated with the process variable being controlled. The progression of the graph can be paused for observation while data continues to be gathered, and then unpaused to display the accumulated data.

Strip Graph
The small graph at the top of the screen scales the viewing area of the main graph. By moving the slider bar left and right, the user controls how much of the data collected is visible on the screen.

Setpoint Control
The setpoint can be changed two ways: by moving the slider bar or by entering a value in the field below the bar. The setpoint can be entered in engineering units or a percentage; to change the format, click on the Setpoint Scale field and change the selection in the dropdown menu. To plot the setpoint on the graph, make sure the Plot checkbox beneath the slider bar is checked. Changes will not become effective until you press Apply.

Valve Position
The valve position is displayed as a percentage. In automatic mode, the controller sets the valve position via the 4 to 20 mA output; in manual mode, the user can change the valve position by moving the slider bar or entering a value in the field below the slider bar. To plot the setpoint on the graph, make sure the Plot checkbox beneath the slider bar is checked. Changes will not become effective until you press Apply.
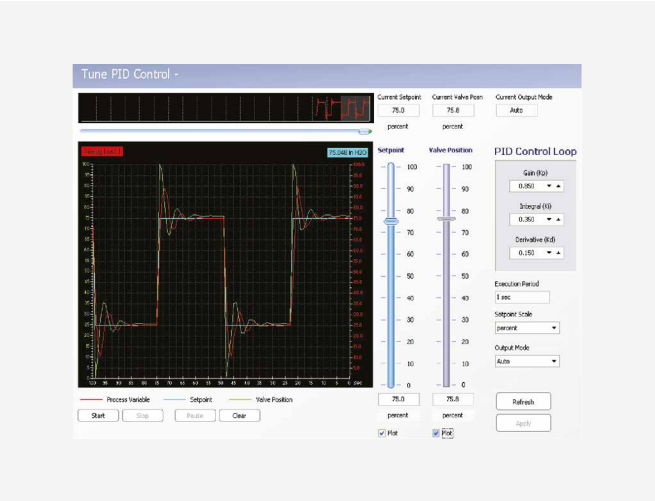
PID Control Loop
The control constants (K_p, K_i and K_d) can be changed using the arrows or by selecting the existing value with the mouse and re-entering a new value. Changes will not become effective until you press Apply.

In manual mode, the user can adjust the valve position and observe the system's response.

1. To place the controller in Manual mode, click on Output Mode and select Manual from the dropdown menu.

2. Change the valve position (type value or move slider bar).

3. Observe the response in the trend graph. With this information, tuning algorithms (such as Ziegler-Nichols) can be used to estimate appropriate tuning values.

In auto mode, the user can adjust the setpoint and observe the system's response.

1. To place the controller in Auto mode, click on Output Mode and select Auto from the dropdown menu.

2. Enter a new setpoint (type value or move slider bar).

3. Observe the response on the graph. With this information, tuning algorithms (such as Ziegler-Nichols) can be used to estimate appropriate tuning values.

Maintaining the Controller

The field operator can modify the setpoint and override the valve position setting from the Manage PID Controller screen without affecting the controller's configuration, which remains secure and inaccessible to those without security access.

To access the Manage PID Controller screen, click Manage PID from the menu buttons at the top of the ModWorX™ Pro main screen.

From the Manage PID Controller screen, the user can:

+ change the setpoint
+ change the mode of operation (auto or manual)
+ change the units for displaying the setpoint
+ change the valve position (manual mode only)

The setpoint and valve position can be changed two ways: by moving the slider bar or by entering a value in the field below the bar. Changes will not become effective until you press Apply.

Configuring the Valve Control Signal

The analog output provides the control signal for opening and closing the valve. An analog output is standard on the Scanner® 2200 EFM, and is easily added to the Scanner® 2000 with an optional expansion board.

When a PID controller is configured, the analog ouput is automatically configured for tracking the PID controller.

To view the analog output setting, navigate to the Scanner Configuration Menu, and click the Analog Outputs button.

The Configure Analog Outputs screen is displayed.

The Change button near the Output Mode field near the top of the screen allows users to configure the analog output for other uses.

To test or calibrate the analog output signal, see Analog Output Testing, page 10.

Testing the Analog Output

ModWorX™ Pro gives users quick and easy tools for calibrating and testing the 4 to 20 mA output signal, which can be a timesaver in troubleshooting operating issues.

Before calibrating and testing the output, ensure that the following tasks have been completed:

+ A current meter must be connected to the Scanner.

+ The Scanner must be powered by an external power supply. Wiring diagrams are provided in the applicable Scanner hardware manuals, in the Scanner® 2000 Expansion Board Quick Start Guide, and in the Scanner® 2200 Quick Start Guide.

Caution: Before performing a 4-20 mA calibration or test, verify that the position of the automated valve or control is as desired for continued operations and disable the controlled device if necessary. Calibrating and testing the 4-20 mA output with peripheral equipment in operation may change the position of the valve, causing false alarms or unexpected changes in operations.

4-TO-20 MA CALIBRATION
To calibrate the analog output, navigate to the Configure Analog Output screen perform the following steps:

1. Under New Output Calibration, click on the 4 mA Setting button to send a 4 mA signal to the receiving device.

2. Enter the output value as read by the receiving device, in the Zero Adjustment screen and click OK. The adjustment will appear in the Active Output Calibration section. Click Apply.

3. Repeat the steps for the 20 mA setting.

4-TO-20 MA TESTING
To test the analog output following adjustments, click the Test Output button at the bottom of the Configure Analog Output screen. A Test Analog Output dialog box will appear.

Enter the output value (in milliamps) you wish to apply and click Apply. The Scanner will send the signal to the receiving device. If everything in the loop is properly connected and calibrated, the readout of the receiving device should match the test value entered in the Test Analog Output screen.

Frequently Asked Questions

Does the Scanner PID controller "bump" when you switch from "auto" to "manual" mode?
In some process control systems, the switch from manual to automatic mode can result in a sudden change in the output, which then settles back to the setpoint. The Scanner PID controller eliminates this "bump" in the output by implementing what is commonly called "bumpless transfer" between manual and automatic modes.

Does the PID controller handle problems with integral windup?
When a controller receives an error signal, the integral term of the controller will increase with each execution period. Normally, this integral action will result in a change in the output. However, when the valve has reached an absolute limit (fully open or fully closed), the integral action can no longer change the valve position, and the integral term continues to act on the unresolved error. This is referred to as "integral windup."

Integral windup can also occur when a system override is applied, such as the secondary pressure control in the Scanner. When the secondary controller takes control of the system, the original controller is not switched off, so it still receives an error signal, which over time "winds-up" the integral term.

Integral windup can cause oscillation and numeric overflow and result in significant control inefficiencies. The Scanner PID controller is designed to prevent problems associated with integral windup.

My controller is running in auto mode, but it appears to be stuck in the 100% (or 0%) valve position. Why?

This response may be caused by an improper controller action setting (for example, a setting which may be telling a fully closed valve to close). Verify that the controller is configured for the correct action (direct or reverse). See page 6 for more information.

I am controlling the flow rate and the update in the controller output seems very slow. Why?

The execution period for the PID controller is the same as the calculation period for the flow run. The default setting for flow run calculation is 60 seconds. At this default value, the system response may be too slow for optimal control. The flow run calculation period (execution period) can be changed on the ModWorX Pro Flow Run Configuration screen. To avoid computational delay entirely, consider using the raw differential pressure or pulse meter measurement for control rather than the computed flow run values.

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