SNAP PID MODULE USER'S GUIDE

Form 1263-030703—July, 2003

OPTO 22
43044 Business Park Drive • Temecula • CA 92590-3614
Phone: 800-321-OPTO (6786) or 951-695-3000
Fax: 800-832-OPTO (6786) or 951-695-2712
www.opto22.com

Product Support Services
800-TEK-OPTO (835-6786) or 951-695-3080
Fax: 951-695-3017
Email: support@opto22.com
Web: support.opto22.com

SNAP PID Module User's Guide
Form 1263-030703—July, 2003

The information in this manual has been checked carefully and is believed to be accurate; however, Opto 22 assumes no responsibility for possible inaccuracies or omissions. Specifications are subject to change without notice.

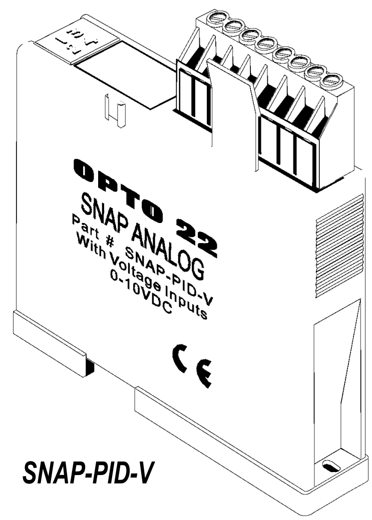
Opto 22 warrants all of its products to be free from defects in material or workmanship for 30 months from the manufacturing date code. This warranty is limited to the original cost of the unit only and does not cover installation, labor, or any other contingent costs. Opto 22 I/O modules and solid-state relays with date codes of 1/96 or later are guaranteed for life. This lifetime warranty excludes reed relay, SNAP serial communication modules, SNAP PID modules, and modules that contain mechanical contacts or switches. Opto 22 does not warrant any product, components, or parts not manufactured by Opto 22; for these items, the warranty from the original manufacturer applies. These products include, but are not limited to, OptoTerminal-G70, OptoTerminal-G75, and Sony Ericsson GT-48; see the product data sheet for specific warranty information. Refer to Opto 22 form number 1042 for complete warranty information.

Table of Contents

SNAP PID Module User's Guide

Introduction

The SNAP-PID-V module is designed for users of Opto 22 SNAP Ethernet I/O™ systems with the SNAP-B3000-ENET, SNAP-ENET-RTC, or SNAP-WLAN-FH-ADS brain. The SNAP-PID-V monitors input signals and adjusts output signals to control one proportional-integral-derivative (PID) loop, performing all necessary PID calculations in the module itself.



SNAP-PID-V

Before the introduction of the SNAP-PID-V module, using a PID loop with SNAP Ethernet I/O systems required an Opto 22 industrial controller running an OptoControl™ strategy or a remote computer running SCADA software. For non-Ethernet I/O units, the multifunction B3000 brain could be used. The SNAP-PID-V module makes this equipment unnecessary, since all PID calculations are made in the module independent of a controller or other processor.

SNAP-PID-V Applications

Typical applications for the SNAP-PID-V module include temperature, pressure-level, flow, and process control. The SNAP-PID-V is ideal for remote installations or other environments where communication links are subject to interruption. Since PID calculations run locally on the I/O module independent of a controller, brain, or other processor, PID loop control can continue even if the communication link to the I/O system is broken.

The SNAP PID module is also useful in applications where multiple PID loops must be controlled at one location. When multiple PID loop calculations run on a single industrial controller or computer, a performance degradation can occur. When additional SNAP-PID-V modules are added to a SNAP rack, however, all modules continue to perform PID loop calculations at a constant speed without system degradation, providing a highly scalable solution. Up to twelve SNAP-PID-V modules can be used on an Opto 22 16-module B-series mounting rack.

Inputs and Outputs

The SNAP-PID-V can use 0–10 VDC analog inputs for PID setpoint and process variables. Analog inputs share a common reference and are not isolated from each other. PID output, sharing a common negative terminal, provides 4–20 mA current and 0–10 VDC voltage outputs. (The PID output value is calculated by the module and then sent simultaneously to both 4–20 mA and 0–10 VDC outputs as a percent of output scale.) Additionally, PID output can be configured for analog or time-proportional-output (TPO) signals.

The standard SNAP removable top-mounted connector allows easy wiring of inputs and outputs. LED indicators, shown on page 28, are provided to show PID calculation mode status (manual or auto) and PID output signal status (analog or TPO).

Software Support

PID loop tuning and module configuration can be performed using OptoENET PID Module Tuner software, which is available free of charge on the Opto 22 Web site (www.opto22.com). This software plots PID values against time to provide visual feedback when tuning PID loops. Additionally, the SNAP-PID-V can be accessed using OptoControl, Opto 22's development tool for industrial automation programming that is part of the FactoryFloor suite of industrial automation software.

What's in this Guide?

This guide assumes that you have some familiarity with tuning PID loops. Many commercial resources are available for learning about this subject. To learn more about the SNAP Ethernet brain used with the SNAP PID module, see Opto 22 form 1112, the *SNAP Ethernet Brain User's Guide.* This document can be downloaded from the Opto 22 Web site at www.opto22.com.

This guide includes the following sections:

- Quick Start to get your PID module installed and connected quickly
- Instructions for setting PID parameters using ioManager utility software or OptoENET PID Module Tuner software
- Wiring diagrams
- Specifications.

For Help

If you have problems installing or using SNAP PID modules and cannot find the help you need in this guide or on our Web site, you can call, fax, or e-mail Opto 22 Product Support.

Phone:	800-TEK-OPTO (835-6786) 951-695-3080 (Hours are Monday through Friday, 7 a.m. to 5 p.m. Pacific Time)
Fax:	951-695-3017
Email:	support@opto22.com
Opto 22 Web site:	support.opto22.com

NOTE: Email messages and phone calls to Opto 22 Product Support are grouped together and answered in the order received.

When calling for technical support, be prepared to provide the following information about your system to the Product Support engineer:

- Software and version being used
- Ethernet brain firmware version
- PC configuration
- A complete description of your hardware, including:
  - jumper configuration
  - IP addresses and net masks for devices on the system
  - accessories installed (such as expansion cards)
  - type of power supply (brand and model)
  - types of I/O units installed
  - third-party devices installed (for example, barcode readers)
- Specific error messages seen.

Quick Start

Check Brain Compatibility

The SNAP-PID-V module can be used with the SNAP-B3000-ENET, SNAP-ENET-RTC, or SNAP-WLAN-FH-ADS Ethernet brain. Firmware version 3.0.2.0 or higher must be installed on the Ethernet brain, which must be located on the same rack as the PID module(s).

NOTE: If you have an older SNAP Ethernet brain that uses firmware prior to version 3.0.2.0, contact Opto 22 Product Support for assistance with firmware requirements for PID module support.

Follow these steps to check the firmware version installed on a SNAP Ethernet brain. You will need to know the brain's IP address.

Determining Firmware Version

1. On the PC, choose Start➞Programs➞Opto 22➞SNAP Ultimate I/O➞ioManager➞ioManager.

   The ioManager window opens.

2. Select Inspect from the Mode menu.

   The Inspect window opens

3. Type the IP address of the brain in the field at the upper-left corner of the window and then click the Status Read button.

4. Click Status Read in the Ethernet I/O Menu.

5. Scroll down until you see Kernel Version.

   The kernel should be version 3.0.2.0 or higher.

Install the Module

SNAP-PID-V modules can be installed in any position on an Opto 22 B-series mounting rack. Do not install more than twelve SNAP-PID-V modules on the same rack.

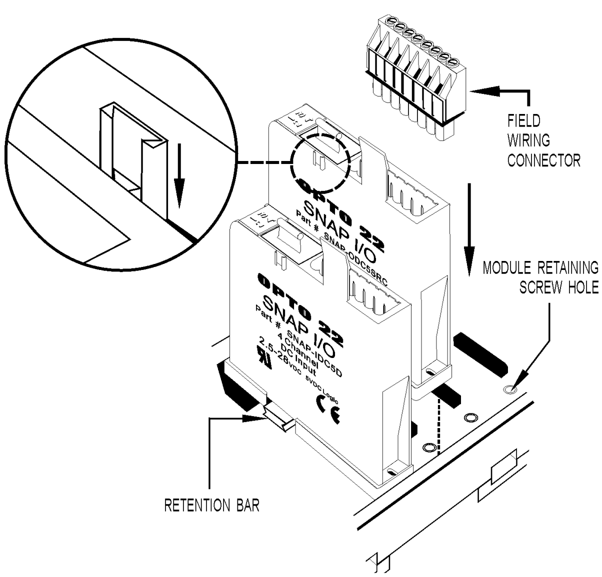
NOTE: SNAP PID modules draw considerably more power than a standard SNAP analog or digital module. A SNAP-B16M, SNAP-B16MC, or SNAP-B16MC-P rack can handle a maximum of twelve SNAP PID modules, plus the Ethernet brain and up to four other digital or analog modules. For detailed power requirements, see the SNAP-PID-V module specifications on page 26. Make sure you have sufficient power for the brain and all modules on the rack.

1. Remove the module from its packaging.

2. Position the module over the connector on the rack, aligning the small slot at the base of the module with the retention bar on the rack. If it is next to another module, make sure the male and female module keys are aligned, as shown at right.

3. Push straight down on the module to snap it into position.

   If you need to remove the module, see page 16.



Attach Input and Output Wiring

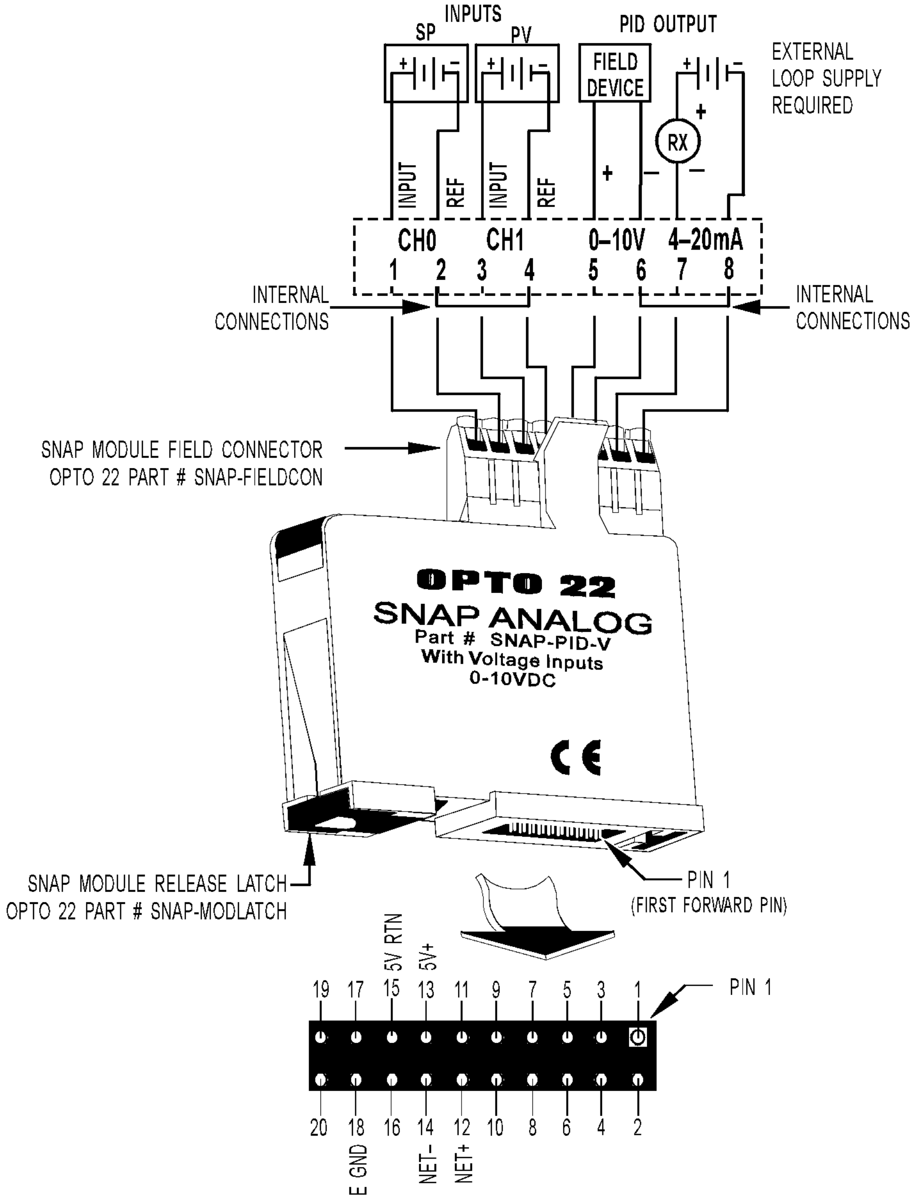
1. (Optional) If you want to use PID setpoint and process variable analog inputs from external sources with the SNAP PID module, follow the wiring diagram shown on page 6 to connect PID setpoint inputs to Channel 0 and process variable inputs to Channel 1.

   Analog inputs share a common reference and are not isolated from each other.

2. Connect PID output wiring to the module as shown in the diagram on the following page.

   PID output can be 4–20 mA current and 0–10 VDC voltage outputs, both of which share a common negative terminal. PID output is calculated by the module and then sent simultaneously to both current and voltage outputs as a percent of output scale. This PID output can be analog or TPO signals (if TPO is selected, both current and voltage outputs are switched from 0% to 100%).

See the following wiring diagram for connection details.



SNAP-PID-V MODULE BASE CONTROL CONNECTOR (BOTTOM VIEW)

Apply Power to the Rack

When you apply power to the rack, the top two LEDs on the SNAP-PID-V blink once. See "LED Indicators" on page 28 for more information on LED functions.

Configure the SNAP PID Module

Choose one of two ways to enter PID values and set parameters for a SNAP-PID-V module:

- If you have previously calculated PID values and parameters, use ioManager. See "Using ioManager Utility Software" on page 7 for instructions.
- If you want to iteratively tune a PID loop, use OptoENET PID Module Tuner. This software includes graphing features and is available free-of-charge from the Opto 22 Web site. See "Using OptoENET PID Module Tuner Software" on page 8 for instructions.

IMPORTANT: *PID module settings are* **not** *saved when you cycle power to the SNAP Ethernet brain and the PID module. PID module settings cannot be saved to the brain's flash memory. If you turn off power to these components, you will need to re-enter PID module settings using either ioManager or the OptoENET PID Module Tuner software.*

Using ioManager Utility Software

ioManager does not provide visual feedback of changes to PID values. You must first calculate optimal PID values for your application using the PID velocity algorithm described on page 17 and the PID variable formulas on page 20. After calculating these values, enter them in the appropriate fields on the PID Module screen.

ioManager utility software was installed on your computer when the SNAP Ethernet brain was installed and configured. See the *SNAP Ethernet Brain User's Guide* for more information.

Entering PID Values

These instructions describe how to enter and modify PID values using ioManager's Inspect mode. You can also enter values as part of configuring and saving an I/O unit configuration file.

1. On the PC, choose Start→Programs→Opto 22→SNAP Ultimate I/O→ioManager→ioManager.

   The ioManager window opens.

2. Select Inspect from the Mode menu.

   The Inspect window opens

3. Type the IP address of the brain in the field at the upper-left corner of the window.

4. Click the PID button and from the submenu select Module.

5. From the PID Module Number drop-down menu, select the number matching the position of the SNAP-PID-V module on the SNAP rack.

6. For each parameter in the Description column to be modified, enter a value in the corresponding field in the Value column. Unless indicated, all parameters are entered in raw counts.

   For parameter descriptions, see "SNAP PID Module Reference" on page 17.

7. Click Apply.

Using OptoENET PID Module Tuner Software

OptoENET PID Module Tuner is an Opto 22 software application for Microsoft Windows that works with the SNAP Ethernet brain to set PID values and other parameters for a SNAP-PID-V module. The primary use of this software is to graph PID values against time, providing visual feedback for tuning the PID loop that the module controls. OptoENET PID Module Tuner is available free of charge from the Software downloads section of the Opto 22 Web site at www.opto22.com/support.

You should be aware that OptoENET PID Module Tuner has the following restrictions:

- **No automatic tuning**—The application does not automatically tune PID loops or otherwise automatically set PID parameters. You must enter PID values and other settings manually.
- **Works with one PID module at a time**—A SNAP-PID-V module can control a single PID loop, and OptoENET PID Module Tuner software works with only one SNAP PID module at a time. Up to twelve SNAP-PID-V modules can be used on a 16-module SNAP rack, however, and you can use OptoENET PID Module Tuner with different individual SNAP PID modules by simply selecting a new module on the SNAP rack.

System Requirements

Here's what you need to install and run OptoENET PID Module Tuner:

- 90 MHz or higher personal computer (200 MHz Pentium II or better recommended)
- Microsoft Windows 95, Windows 98, Windows NT 4.0 (with latest Microsoft service pack installed), or newer operating system
- Microsoft Internet Explorer 5 or newer
- At least 16 MB RAM for Windows 95 or Windows 98, or 32 MB RAM for Windows NT (64 MB or more recommended)
- At least 8 MB of available hard disk space
- VGA or higher resolution monitor (Super VGA recommended)
- Mouse or other pointing device.

Installing the Software

After downloading the OptoENET PID Module Tuner installer from the Opto 22 Web site, double-click the installer's icon and follow the instructions that appear. By default, OptoENET PID Module Tuner is installed with other Opto 22 Ethernet I/O software in the Opto22\OptoENET-IO directory on your computer's C: drive.

Tuning a PID Loop

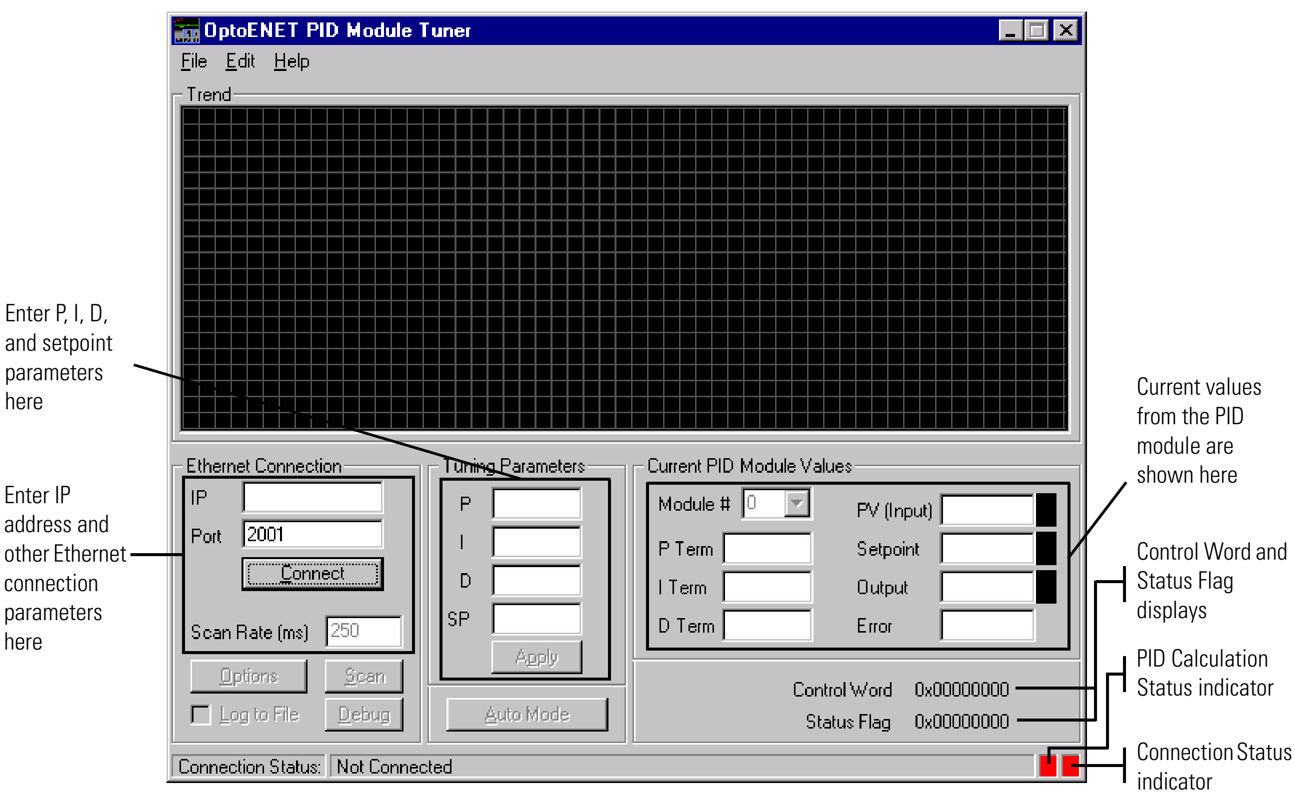
The following steps outline how to use OptoENET PID Module Tuner software to tune a PID loop controlled by a SNAP PID module. Each step is described in more detail in the following sections. For complete descriptions of SNAP-PID-V module variables and other parameters shown in OptoENET PID Module Tuner, see "SNAP PID Module Reference" on page 17.

These instructions assume you have already gone through the Quick Start procedure earlier in this guide.

Step 1—Connect to the SNAP Ethernet Brain

1. To start OptoENET PID Module Tuner, from the Microsoft Windows Start Menu select Programs➞Opto22➞OptoENET-IO➞OptoENET PID Module Tuner.

   The OptoENET PID Module Tuner main window appears:



2. In the Ethernet Connection group, enter the SNAP Ethernet brain's IP address in the IP field.

3. Leave the default Port number of 2001, unless you have changed the default Command Processor port number for the SNAP Ethernet Brain. If this is the case, enter this port number in the Port field.

4. Click Connect to establish a link to the SNAP Ethernet brain.

5. From the "Module #" drop-down menu in the Current PID Module Values section, select the position of the SNAP-PID-V module on the SNAP rack.

   Values associated with the module you selected should appear, and the connection status indicator in the lower right-hand corner of the window turns green. If a SNAP-PID-V module is not installed in the rack position you select, the value fields will display zero values.

6. Enter a scan rate for communicating with the SNAP Ethernet brain.

   This rate determines how often OptoENET PID Module Tuner communicates with the SNAP Ethernet brain. The default scan rate of 250 ms should be suitable for most 10/100 Mbps Ethernet connections.

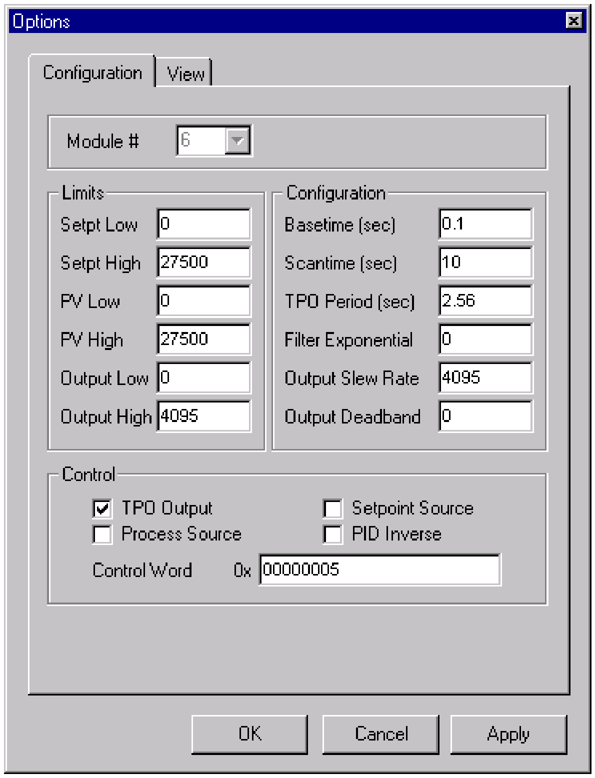
   IMPORTANT: *The Ethernet scan rate is **not** the same as the PID loop scan time. See "SNAP PID Module Reference" on page 17 for more information on PID loop scan times.*

Step 2—Configure PID Parameters

The PID parameters you enter will depend on your particular control application. OptoENET PID Module Tuner default settings, however, usually provide a good starting point. For complete descriptions of SNAP-PID-V module variables and other parameters shown in OptoENET PID Module Tuner, see "SNAP PID Module Reference" on page 17.

1. Click the Options button in the Ethernet Connection section (lower left part of the window).

The OptoENET PID Module Tuner Options window appears:



2. In the Limits section, enter setpoint, process variable, and output limit values.

3. In the Configuration section, enter PID loop base time and scan time values.

   If needed for your PID control application, also enter values for TPO period, filter exponential, output slew, and output deadband.

4. In the Control section, do the following:

   a. To use an internal setpoint value, select the Setpoint Source checkbox. Deselect the checkbox to use an external analog input for the setpoint.

   b. To use an internal process variable, select the Process Source checkbox. Deselect the checkbox to use an external analog input for the process variable.

   c. To have PID output use a time-proportional (TPO) signal, select the TPO Output checkbox. Deselect the checkbox to use a regular analog signal.

      If TPO output is used, you should confirm that the TPO Period value in the Configuration section is correct for your application.

   d. To use the inverse of the PID output value, select the PID Inverse checkbox. Deselect the checkbox to use a regular noninverted signal.

   If Setpoint Source or Process Source is selected (that is, an internal setpoint or process variable is used), values are displayed in raw counts. If Setpoint Source or Process Source is not selected (that is, an internal setpoint or process variable is not used), values are from 0 to 10, corresponding to the 0–10 VDC analog input signal.

Note that the hexadecimal control word in the Options window changes to reflect the changes you make to control settings.

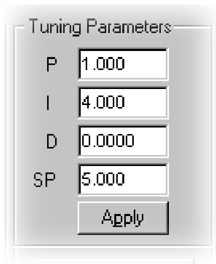
5. (Optional) To hide or display graphed values on the trend chart, click the View tab and in the Pens section select or deselect the PV (Input), Setpoint, and Output checkboxes.

   All values are graphed by default.

6. (Optional) To change the colors used for graphed values, click the View tab and click the color box next to each value, select a color, and click OK.

7. Click OK to close the Options window.

8. In the OptoENET PID Module Tuner main window, enter values for the following terms in the corresponding fields:



   - **P**—Gain (proportional)
   - **I**—Integral
   - **D**—Derivative
   - **SP**—Setpoint

   If you need to calculate starting P, I, D, and SP values, use the PID velocity algorithm shown on page 17. You can also start PID calculations using the default P, I, D, and SP values that appear in these fields and then adjust the terms as you tune the PID loop.

9. Click Apply.

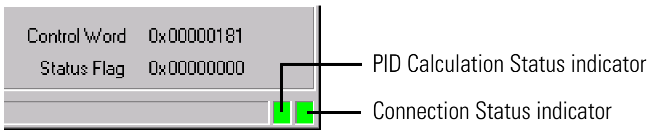
Step 3—Run PID Calculations

1. In the Ethernet Connection section of the main window, click Scan to start receiving PID module values from the SNAP Ethernet brain.

   The Connection Status indicator in the lower right-hand corner of the window turns green, and the Trend chart starts graphing process variable, setpoint, and output values.

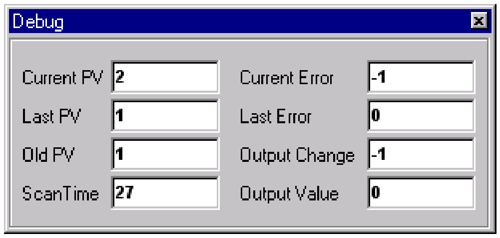
2. Click Auto Mode to start running PID calculations on the SNAP-PID-V module.

   The PID calculation status indicator in the lower right-hand corner of the window turns green.



3. To view calculated PID values that are not shown in the main window, click Debug.

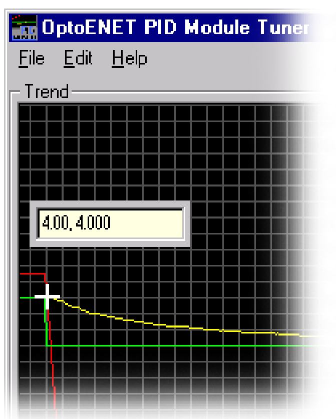
The Debug window appears.



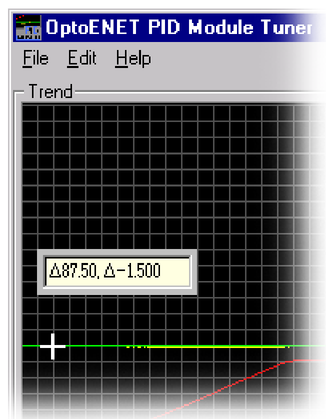
Step 4—Optimize PID Loop

1. Observe the graphed process variable (input), setpoint, and output values on the chart.
2. To see the coordinate values for a point on the graph, just click on that point.

   Coordinate values appear near the cursor. To measure distances between two points, click on the graph and then drag the mouse. Measurements will appear near the cursor. Examples of viewing coordinate values and measuring distances appear below.



Coordinate values



Distance measurement

3. Enter new P, I, D, and SP values in the Tuning Parameters section if necessary, and then click Apply.
4. Continue to observe the graphed values and change PID values until the PID loop is optimized.
5. If you need to adjust PID loop scan time, base time, or the limit values you set earlier, do the following:
   - **a.** Click Manual Mode to stop PID calculations.
   - **b.** Click Options.
   - **c.** Change values in the Limits and Configuration sections as needed.
   - **d.** Click OK.
   - **e.** Click Auto Mode to start PID calculations again.

6. When the PID loop is correctly optimized, click Disconnect to close the link to the Ethernet brain, and then select File→Exit to close OptoENET PID Module Tuner.

   IMPORTANT: *Do not click Manual Mode before disconnecting the Ethernet link and closing OptoENET PID Module Tuner. This will stop the PID calculations that are running on the SNAP-PID-V module, and your PID loop will no longer be controlled by the PID module.*

Saving PID Values to a Log File

You can use OptoENET PID Module Tuner to create a log file that contains process variable, setpoint, output, and other PID values. To create the log file, do the following:

1. Select the Log File checkbox in the OptoENET PID Module Tuner main window.

2. In the file dialog box that appears, enter a name for the file, choose the location where you want to save it, and then click Save.

   Whenever PID values are graphed in the main window, OptoENET PID Module Tuner will record the data listed below in an ASCII text file that you can open using a spreadsheet, word processor, or other software application.

   – PID calculation date and time
   – Setpoint
   – Gain
   – Integral
   – Derivative
   – Current process variable
   – Last process variable
   – Oldest process variable
   – Current error
   – Last error
   – Output change
   – Output value
   – Time remaining to next scan/PID calculation

Using the SNAP PID Module with OptoControl

The SNAP-PID-V module can be used as an analog input module with Opto 22's OptoControl industrial automation software. OptoControl R3.1d or newer is required to use the SNAP-PID-V with OptoControl. Contact Opto 22 Product Support for additional information. Contact information appears on page 2.

Using Analog Inputs

In OptoControl you can configure two types of analog input points with the SNAP-PID-V. Both types of input points can range from 0 to 100 percent; one type is scalable and the other is not.

Accessing PID Variables

PID variables from the SNAP-PID-V are stored in the SNAP-B3000-ENET's memory map, and can be accessed from OptoControl using the commands listed below. See Opto 22 form 725, the *OptoControl Command Reference*, for more information about these commands.

- Read Numeric Variable from I/O Memory Map
- Write Numeric Variable to I/O Memory Map
- Read Numeric Table from I/O Memory Map
- Write Numeric Table to I/O Memory Map

Finding a PID Module Memory Map Address

To determine the hexadecimal memory map address for a particular PID module variable:

1. Open ioManager and select the SNAP Ethernet brain on the same rack as the PID module.
2. Click the PID button and select Module from the submenu.
3. At the top of the PID Module window select the PID module that will be used with OptoControl.

   The memory map address appears to the right of the variable's description.

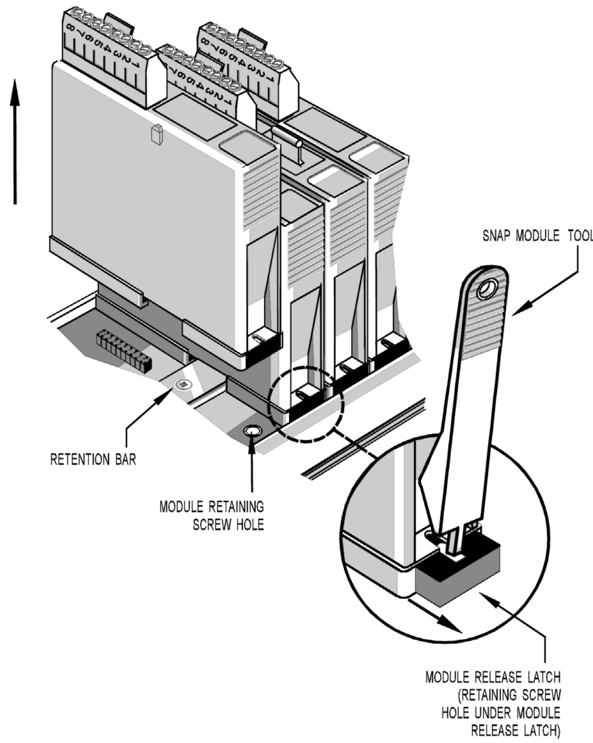
Removing a SNAP PID Module

To remove a SNAP PID module, use the SNAP module tool that came with the module.

1. Holding the SNAP module tool as shown in the illustration at right, insert it into the notch at the base of the module.

   NOTE: If you are facing the rack with the brain on the left side, the notch is on the back of the module.

2. Squeeze the module tool against the module to open the release latch, and pull straight up on the module to remove it.



Troubleshooting

If you encounter problems using the SNAP-PID-V, please review the information below for solutions to common problems. If this information does not solve your problem, contact Opto 22 Product Support. Contact information is found on page 2 of this guide.

Ethernet Brain Communications

If you are having trouble establishing an Ethernet network connection with the SNAP Ethernet brain, refer to the Troubleshooting section in Opto 22 form # 1112, the *SNAP Ethernet Brain User's Guide.* If Ethernet communications problems continue after you have tried the solutions in that guide, contact Opto 22 Product Support for assistance.

SNAP PID Module Access

Check the following items if there are problems accessing the PID module on the SNAP rack:

- Check that the correct kernel version is installed on the SNAP Ethernet brain. See "Check Brain Compatibility" on page 3 for instructions on how to check the Ethernet brain's kernel version.

- Confirm that the module is plugged firmly into the mounting rack. For applications where vibration or thermal expansion and contraction may be a consideration, it may be beneficial to use screws to attach the PID and other SNAP modules to the SNAP mounting rack.
- If PID information doesn't appear in the ioManager PID Module screen or when using OptoENET PID Module Tuner, do the following:
  - Check that the correct module location on the mounting rack is selected in ioManager's PID Module screen.
  - Confirm that signal input and output wiring is correctly connected to the module's screw terminal connector. See "Attach Input and Output Wiring" on page 5 for wiring information.

SNAP PID Module Reference

PID Velocity Algorithm

The SNAP-PID-V module uses the following PID velocity algorithm:

Change in output = Gain $\times$ (A + B – C)

where A = (Error at t_0) – (Error at t_1)

B = ((Error at t_0) / Integral ratio)

C = (Derivative ratio $\times$ (PV input at t_0) – (2 $\times$ PV input at t_1) + (PV input at t_2))

and Error = Setpoint – PV

t = Scan time (the time between setpoint and process variable readings)

t_0 = Time when the scan timer reaches zero. This is when PID is calculated.

t_1 = The last time the scan timer reached zero, or (t_0 – t).

t_2 = The second-to-last time the scan timer reached zero, or (t_0 – (2 $\times$ t)).

PV = Process Variable (the input signal)

Integral ratio = Integral / Scan time

Derivative ratio = Derivative / Scan time

Setpoint and process variable readings are taken when the scan timer reaches zero and the PID calculation is made.

PID Control Word

The SNAP-PID-V module's control settings are configured by modifying a single hexadecimal *control word.* When using ioManager software you need to use the control word to configure the PID module. When using OptoENET PID Module Tuner, it isn't necessary to enter a control word since control settings are made using the software's user interface.

Defining a PID Control Word

To determine a hexadecimal control word for a particular combination of control settings, do the following:

1. In the table "Control Word Bits" on page 18, identify the bits that correspond to the parameters you want to set.

2. For each bit you select, choose the binary value that corresponds to the control setting you want.

3. Convert the binary values to hexadecimal to determine the PID control word.

   For example, read the table below from top to bottom and right to left to see how you might figure out a control word that sets the PID mode to Auto (that is, by setting bit 7 to 1).

Control word bits:	7 6 5 4	3 2 1	0	7 6 5 4	3 2 1 0
Binary data for each bit:	(bits 1–7 are not used)			1 0 0 0	0 0 0 0
Hexadecimal value:				8	0
Enter this control word:				8 0	

Note that the leading zeros do not need to be entered; in this example, entering "80" in the Control Word field is sufficient. See "Binary/Hexadecimal Conversion Chart" on page 25 for a table of 4-bit binary data and equivalent hexadecimal values.

Control Word Bits

Bit	Bit Name and Description	Default	To Modify, Use Mode...
0	(not used)	n/a	n/a
1	(not used)	n/a	n/a
2	**TPO Output** Sets PID output to use analog or TPO signals. 0 = Analog PID output. The analog output value is set to the Low Output Limit. 1 = TPO PID output. The TPO output is set to the High Output Limit.	0 (analog output)	Manual
3	**Process Variable Source** Sets an internal or external source for the process variable value. 0 = Process variable obtained from external analog source connected to SNAP-PID-V channel 1. 1 = Process variable obtained from internal value.	0 (external source)	Manual

Bit	Bit Name and Description	Default	To Modify, Use Mode...
4	**PID Inverse** Sets PID output to use an inverted or non-inverted signal. 0 = PID output is not inverted. 1 = PID output is inverted. Inversion occurs only after the PID calculation has occurred. For the PID module, output limits and outputs made in Manual mode are absolute values and are not inverted.	0 (not inverted)	Manual
5	(not used)	n/a	n/a
6	(not used)	n/a	n/a
7	**PID Mode** Sets SNAP-PID-V module's calculation mode (Auto/On or Manual/Off). 0 = Manual mode (Off). The PID scan timer is stopped and reset. Any current PID calculations are cancelled, and all PID variables are reinitialized. PID output value is sent to either current or voltage outputs. Changes to all PID variables and control bits are allowed, as well as direct writes to PID output. *Note:* If the Process Quality status flag bit is set, Auto mode cannot be used until the flag is cleared. 1= Auto mode (On). The PID scan timer is active, and PID values are calculated and executed. PID output value is sent simultaneously to both current and voltage outputs as a percent of the output scale. Changes to scantime variables are ignored, and will result in an error. Changes to control bits are allowed except where noted. Direct writes to PID output is not allowed. *Note:* If the Process Quality status flag bit is set, PID output stops and PID mode is forced to Manual.	0 (Manual/ Off)	n/a
0*	**Setpoint Source** Sets an internal or external source for the setpoint value. 0 = Setpoint obtained from external analog source connected to SNAP-PID-V channel 0. 1 = Setpoint obtained from internal value.	0 (external source)	Manual or Auto
1*	(not used)	n/a	n/a
2*	(not used)	n/a	n/a
3*	(not used)	n/a	n/a
4*	(not used)	n/a	n/a
5*	(not used)	n/a	n/a
6*	(not used)	n/a	n/a
7*	(not used)	n/a	n/a

* Second 8-bit byte in control word

PID Variables

PID variables are used to hold the parameters that you enter using ioManager software, and also to hold values calculated by the PID module. Unless otherwise indicated, all variables are entered in raw counts.

Variables Requiring Calculation

If you use ioManager software to enter PID values and other settings for the SNAP-PID-V, you must calculate in advance the variables listed in the following table. When using OptoENET PID Module Tuner software, these calculations are done automatically.

Variable	Description	Default	To Modify, Use Mode...
Scantime Base (also called *Scantime Resolution*)	This variable is used to calculate the PID loop basetime using the following formula: ***Basetime (sec.) = .01 x (1 + Scantime Base)*** Enter the basetime value you want to use for your PID loop in the formula and then solve for Scantime Base using the following equation: ***Scantime Base = (Basetime / .01) – 1*** Enter the result in the Scantime Base field in ioManager's PID Module window. **Range:** 0–255 (10 ms to 2.6 sec.)	100 ms	Manual
Scantime Mult (also called *Scantime Multiplier*)	This variable is used to calculate the PID loop scantime using the following formula: ***Scantime (sec.) = Basetime x (Scantime Mult + 1)*** Enter the scantime value you want to use for your PID loop in the formula and then solve for Scantime Mult using the following equation: ***Scantime Mult = (Scantime / Basetime) – 1*** Enter the result in the Scantime Mult field in ioManager's PID Module window. **Range:** 0–65535 (10 ms to 1.8 hr.)	10 sec.	Manual
TPO Period Mult (also called *TPO Period Multiplier*)	This variable sets the period of the PID module's TPO output using the following formula: ***TPO Period = (1 + TPO Period Mult) x 256*** Enter the TPO period value you want to use for your PID loop in the formula and then solve for TPO Period Mult using the following equation: ***TPO Period Mult = (TPO Period / 256) – 1*** Enter the result in the TPO Period Mult field in ioManager's PID Module window. **Range:** 0–255 (2.56 sec. to 10.92 min.)	2.56 sec.	Manual

Variable	Description	Default	To Modify, Use Mode...
Tune, IntegRatio (also called the *Integral Ratio*)	(IntegRatio) This variable sets the integral value used for the PID module's PID calculations using the following formula: ***IntegRatio = Integral / Scantime*** Enter the integral and scantime values you want to use for your PID loop and then solve for IntegRatio. Enter the result in the Tune, IntegRatio field in ioManager's PID Module window. **Range:** 0.000 to 255.996	4.000	Manual or Auto
Tune, DerivRatio (also called the *Derivative Ratio*)	(DerivRatio) This variable sets the derivative value used for the PID module's PID loop calculations using the following formula: ***DerivRatio = Derivative / Scantime*** Enter the derivative and scantime values you want to use for your PID loop and then solve for DerivRatio. Enter the result in the Tune, DerivRatio field in ioManager's PID Module window. **Range:** 0.000 to 0.9992	0.000	Manual or Auto
Filter Exponential	This variable sets the filter exponential used for the Process filtering or Setpoint filtering equation using the following formula: $y^{(t-0)} = (b \times y^{(t-1)} + (1-b) \times y(t-0))$ where: $y^{(t-0)}$ = raw input data $y^{(t-0)}$ = current filtered answer $y^{(t-1)}$ = last filtered answer b = filter exponential		
	For **Process filtering,** the input to the filter is the raw Process Variable. The output of this filter is used for the Process Variable in the PID calculation. **Range:** 0–255	0 (no filter)	Manual or Auto
	For **Setpoint filtering,** the input to the filter is the raw Setpoint value. The output of this filter is used for the Setpoint value in the PID calculation. **Range:** 0–255	0 (no filter)	Manual or Auto

Variables Not Requiring Calculation

Values for the PID variables listed in the following table can be entered directly into ioManager software. It is not necessary to calculate these values in advance.

Variable	Description	Default	To Modify, Use Mode...
Output	PID output value for analog or TPO outputs. For **analog output,** this variable is the PID output value written to the analog outputs, subject to the applicable output limits. **Range:** 0–4095 (0–10 VDC or 4–20 mA) For **TPO output,** this variable is the TPO duty cycle. **Range:** 0 to 100%	0 0%	Manual Manual
Tune, Proportional (also called *Proportional Term, P term,* or *Gain*)	This is one of the four key values for PID loop tuning (Gain, Integral, Derivative, and Setpoint). **Range:** 0.000 to 255.996	1.000	Manual or Auto
Setpoint (also called *SP*)	The Setpoint value used in the PID calculation. You can specify a setpoint value or select an external source for the value using OptoENET PID Module Tuner software or ioManager's PID Module window. See "Control Word Bits" on page 18 for more information on PID module control settings. **Range:** 0 to 25000 (in raw counts)	0	Manual or Auto
Process Variable (also called *P*)	The Process Variable value used in the PID calculation. You can specify a process variable value or select an external source for the value using OptoENET PID Module Tuner software or ioManager's PID Module window. See "Control Word Bits" on page 18 for more information on PID module control settings. **Range:** 0 to 25000 (in raw counts)	0	Manual or Auto
Setpoint Lo (also called *Setpt Low*)	Sets the Setpoint Lo limit. If the Setpoint input is less than the Setpoint Lo limit, it is clamped to this limit. If this condition occurs, the Setpoint Lo status flag will also be set. The Setpoint Lo limit must be less than or equal to the Setpoint Hi limit, or an error will occur. **Range:** 0 to 25000 (in raw counts)	0	Manual or Auto
Setpoint Hi (also called *Setpt High*)	Sets the Setpoint Hi limit. If the Setpoint input is greater than the Setpoint Hi limit, it is clamped to this limit. If this condition occurs, the Setpoint Hi status flag will also be set. The Setpoint Hi limit must be greater than or equal to the Setpoint Lo limit, or an error will occur. **Range:** 0 to 25000 (in raw counts)	27500	Manual or Auto
Process Lo (also called *PV Low*)	Sets the Process Lo alarm. If the Process Variable input is less than the Process Lo alarm, the Process Lo and Process Quality flags are set. This occurs when the PID is calculated. The Process Lo alarm must be less than or equal to the Process Hi alarm. **Range:** 0 to 25000 (in raw counts)	0	Manual or Auto

Variable	Description	Default	To Modify, Use Mode...
Process Hi (also called *PV High*)	Sets the Process Hi alarm. If the Process Variable input is greater than the Process Hi alarm, the Process Hi and Process Quality flags are set. This occurs when the PID is calculated. The Process Hi alarm must be greater than or equal to the Process Lo alarm. **Range:** 0 to 25000 (in raw counts)	27500	Manual or Auto
Output Lo (also called *Output Low*)	Sets the Output Lo limit. If a PID output is calculated that is below the Output Lo limit, the output is clamped to the limit and the Output Lo flag is set. The Output Lo limit must be less than or equal to the Output Hi limit. **Range:** 0 to 4095	0	Manual or Auto
Output Hi (also called *Output High*)	Sets the Output Hi limit. If a PID output is calculated that is above the Output Hi limit, the output is clamped to the limit and the Output Hi flag is set. The Output Hi limit must be greater than or equal to the Output Lo limit. **Range:** 0 to 4095	4095	Manual or Auto
Output Slew Rate	Limits the maximum change in peak output that occurs each time the PID is calculated. This variable can be used to minimize PID overshoot when there is a large change in a setpoint step. Changes to this limit take effect the next time the PID is calculated. **Range:** 0 to 4095	4095	Manual or Auto
Output Limit (also called *Output Limit Deadband*)	This variable sets the minimum number of PID output raw counts needed to cause the output to change. PID changes that are less than or equal to the Output Limit are ignored. This variable can be used to minimize wear on control linkages. Changes to this limit take effect the next time the PID is calculated. **Range:** 0 to 4095	0	Manual or Auto

Read-Only Variables

The following PID variables contain values that cannot be modified.

Variable	Description
Status Flag	Hexadecimal word that indicates the state of PID module status flags. See "Status Flag Word" on page 24 for bit descriptions.
Current PID	Process Variable used for the most recent PID calculation.
Last PID	Process Variable used for the second most recent PID calculation.
Oldest PID	Process Variable used for the third most recent PID calculation.
Current PID Error	Calculated PID error (Setpoint – PV) used for the most recent PID calculation.
Last PID Error	Calculated PID error (Setpoint – PV) used for the second most recent PID calculation.
Output Change	Calculated change in PID output between most recent PID calculation and the second most recent PID calculation in raw counts.

Variable	Description
Output Value	Most recently calculated PID output value in raw counts.
Scantime Countdown	Time remaining until the next PID calculation is performed.

Status Flag Word

A status flag *word* indicates the state of certain PID module parameters. A status flag word is a single hexadecimal word, similar to a PID control word, that displays the state of status flag bits. These bits are read-only and cannot be modified. Status flag bits are primarily used with ioManager's PID Module window, since OptoENET PID Module Tuner software displays this status information in the user interface.

Reading a Status Flag

To read a hexadecimal status flag word, do the following:

1. Break the 8-bit word into its two separate hexadecimal values.
2. Convert each hexadecimal value into its corresponding binary data.
3. Match the positions of each "1" in the binary data to a status flag bit.

The table below illustrates an example of these steps. Read the table from right to left to see how you might interpret a status flag word.

Status flag word:	0 0 0 0 0 0 50	
Hexadecimal value:	5	0
Binary data:	0 1 0 1	0 0 0 0
Status flag bits:	7 6 5 4	3 2 1 0

This status flag word shows that bit 4, the Output Lo flag, and bit 6, the TPO Status flag, are set. See "Binary/Hexadecimal Conversion Chart" on page 25 for a table of binary data and equivalent hexadecimal values.

Status Flag Bits

Bit	Flag Name and Description
0	**Setpoint Lo** 1 = Setpoint input is below the Setpoint Lo limit, and is clamped to that value for calculating PID output. In Auto Mode, this flag is checked when PID output is calculated. If setpoint input re-enters the normal range, the flag will clear at the next scan time.

Bit	Flag Name and Description
1	**Setpoint Hi** 1 = Setpoint input is above the Setpoint Hi limit and is clamped to that value for calculating PID output. In Auto Mode, this flag is checked when PID output is calculated. If setpoint input re-enters the normal range, the flag will clear at the next scan time.
2	**Process Lo** 1 = Process input is below the Process Lo limit and is not suitable for calculating PID output. In Auto Mode, this flag is checked when PID output is calculated. When this flag is set, the Process Quality flag is also set and the module is forced to Manual mode. The output will not change. After the condition is fixed, you must change back to Auto Mode. The flag will clear when the PID output is calculated.
3	**Process Hi** 1 = Process input is above the Process Hi limit and is not suitable for calculating PID output. In Auto Mode, this flag is checked when PID output is calculated. When this flag is set, the Process Quality flag is also set and the module is forced to Manual mode. The output will not change. After the condition is fixed, you must change back to Auto Mode. The flag will clear when the PID output is calculated.
4	**Output Lo** 1 = Output is clamped to the Output Lo clamp value. In Auto Mode, this flag is checked when PID output is calculated. This flag is for indication only and will clear when the output is above the clamp value.
5	**Output Hi** 1 = Output is clamped to the Output Hi clamp value. In Auto Mode, this flag is checked when PID output is calculated. This flag is for indication only and will clear when the output is below the clamp value.
6	**TPO Status** 1 = TPO is in the “On” portion of the TPO period. 0 = TPO is in the “Off” portion of the TPO period.
7	**Process Quality** 1 = Process input was not suitable for the PID calculation as it was calculated using the Hi/Lo process limits. In Auto Mode, this flag is checked when PID output is calculated. If the flag is set, the mode is forced to Manual. After the condition is fixed, you must change back to Auto Mode. The flag will clear when the PID output is calculated. If this flag is set after an initial powerup or reset command, the PID module failed to load variables from its flash memory, and all configuration parameters and variables are at factory default settings.

Binary/Hexadecimal Conversion Chart

For using PID module control words and reading status flags, use the following chart to convert binary data to and from hexadecimal (or “hex”) values:

Binary Data	Corresponding Hex Value
0000	0
0001	1
0010	2
0011	3

Binary Data	Corresponding Hex Value
1000	8
1001	9
1010	A
1011	B

Binary Data	Corresponding Hex Value
0100	4
0101	5
0110	6
0111	7

Binary Data	Corresponding Hex Value
1100	C
1101	D
1110	E
1111	F

Specifications

PID

Scan time range (programmable)	100 ms to 1.8 hrs. (default = 10 sec.)
Proportional range (gain)	0.000 to 255.996 (default = 1.000)
Integral range	0.000 to 255.996 (default = 4.000)
Derivative range	0.0000 to 0.9999 (default = 0.000)
PID output Resolution Deadband range High/Low limits	 12 bits 0 to 100% (default = 0%) Low = 0 VDC or 4 mA (default = 0%) High = 10 VDC or 20 mA (default = 100%)
Max. PID output step change	0 to 100% (default = 100%)
Analog PID outputs	0 to 10 VDC, 4 to 20 mA
TPO PID output Resolution Period range On/Off levels	 8 bits 2.56 sec. to 10.92 min. 0/10 VDC, 4/20 mA

Voltage Output

Range	0 to 10 VDC
Span	10 VDC
Resolution	2.44 mV
Response time (% of span / ΔV / Δtime)	99.9% / 19.98 V / 3 ms
Load current	±5 mA min.
Short circuit output (current)	40 mA

Accuracy	0.1% of span
Gain temperature coefficient	50 ppm / ° C
Offset temperature coefficient	20 ppm / ° C

Current Output

Range	4 to 20 mA
Span	16 mA
Resolution	3.9 µA
Output at powerup	4 mA (before initialization)
Response time (% of span / ΔmA / Δtime)	99.9% / 15.98 mA / 3 ms
Accuracy	0.1% of span
Gain temperature coefficient	50 ppm / ° C
Offset temperature coefficient	20 ppm / ° C
Loop voltage (with 250 Ω loop resistance)	8 VDC min. to 32 VDC max.
Formula for max. loop resistance	Loop resistance = (loop voltage – 3) / .02
Max. loop resistance vs. loop supply	250 Ω @ 8 VDC min. 450 Ω @ 12 VDC 600 Ω @ 15 VDC 1050 Ω @ 24 VDC 1450 Ω @ 32 VDC max.

Setpoint/Process Variable Inputs

Range	0 to 10.000 VDC
Overrange	0 to 11 VDC
Resolution	400 µV
Data freshness (max.)	126.2 ms (63.1 ms per channel)
DSP notch filter	10 Hz (–3 dB = 32 Hz)
Input filtering (analog front end)	T.C. = 2.5 ms –3 dB @ 64 Hz
DC common mode rejection	> –120 dB
AC common mode rejection	> –120 dB @ 60 Hz
Max. survivable input	220 VAC/VDC
Max. operating common mode voltage (field terminal to logic connector)	250 VAC/VDC

Accuracy (% full scale)	0.05%
Drift Gain temperature coefficient Offset temperature coefficient	 30 ppm / ° C 15 ppm / ° C
Input resistance (single-ended)	1 M Ω (each channel) (Both inputs share the same reference point.)

Module and Power Requirements

Isolation (inputs to analog outputs)	250 V_{rms}
Logic supply voltage	5.0 VDC
Logic supply current	250 mA DC
Max. number of modules per rack	12
Brain compatibility	SNAP-B3000-ENET
Operating temperature Storage temperature	0° to 70° C –30° to 85° C

LED Indicators

LED 1 on the SNAP-PID-V indicates PID calculation mode. When lit, the PID module is in Auto Mode and is calculating PID values. When not lit, the PID module is in Manual Mode and is not running PID calculations.

LED 3 on the PID module indicates TPO signal status. The SNAP-PID-V supports both analog and time-proportional output (TPO) PID output signals. When LED 3 is lit, TPO PID output is being used. When not lit, analog PID output is being used.

SNAP-PID-V Top View