Using Quadrature Counters

Introduction

Incremental encoders are often used to track movement in applications from cranes and conveyors to motion control and robotics, where control depends upon knowing a precise position. speed, or direction.

- *Single-channel encoders* are generally used in systems that rotate in just one direction, where simple position information is all that's required.
- *Quadrature encoders* (also called two-phase incremental encoders) provide bi-directional information, because they have two channels (A and B), electrically phased 90 degrees apart. The direction of rotation can be inferred from these two output signals by detecting the leading or lagging signal of the two.

This technical note shows you how to use quadrature encoders with Opto 22 SNAP products to determine the positional information you need for your application. You'll learn how to wire the encoder to a SNAP-IDC5Q quadrature counter module, configure points, and read the quadrature counters.

The information in this technical note will be useful to you:

- If you are using an Opto 22 controller and control programming software (PAC Control™ or legacy ioControl/OptoControl) with SNAP I/O units
- If you are using SNAP I/O™ as remote I/O for an Allen-Bradley® PLC system
- If you are using SNAP I/O without an Opto 22 controller and writing your own control program, using the OptoMMP protocol, for PC-based control

This technical note assumes that you are already familiar with quadrature encoders, counters, and the programming method you are using.

For Help

If you need help using SNAP quadrature counters and cannot find the answers in this document or the related documents (see page 2), contact Opto 22 Product Support. Product support is free.

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

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

Email: support@opto22.com

Opto 22 website: www.opto22.com

Related Documents

See the following documents for additional information, depending on the programming tool you are using:

For this information	See this document	Form #
Wiring and specifications for SNAP quadrature module (SNAP-IDC5Q)	*SNAP Two-Axis Quadrature Input Module Data Sheet*	1053
Configuring I/O points and system functions	*PAC Manager User's Guide*	1704
Designing flowchart-based control programs for an Opto 22 SNAP PAC controller	*PAC Control User's Guide*	1700
	PAC Control Command Reference	1701
Communicating with Allen-Bradley PLC systems using EtherNet/IP	*EtherNet/IP for SNAP PAC Protocol Guide*	1770
Programming your own applications using the OptoMMP Communication Toolkit or the OptoMMP protocol	*OptoMMP Protocol Guide*	1465

All forms are available on our website (www.opto22.com). The easiest way to find one is to search on the form number.

Opto 22 SNAP Quadrature Counting

Quadrature Input Module

In systems using Opto 22 SNAP products, the quadrature encoder is wired to a SNAP quadrature input module, part number SNAP-IDC5Q. Two encoders can be wired to one SNAP-IDC5Q module. An I/O processor on the same mounting rack as the module handles the counting. See the *SNAP Two-Axis Quadrature Input Module Data Sheet* (form #1053) for specifications and processor compatibility.

NOTE: If you are having problems with an older SNAP-IDC5Q, you may have a compatibility issue. See our OptoKnowledgeBase article (KB49667) for more information.

Quadrature Encoder Support

The SNAP-IDC5Q supports quadrature encoders with the following output types:

- Open collector
- Open collector with pull-up resistors
- CMOS
- TTL
- LSTTL
- HC
- HCT

In addition, the following encoder output types may be compatible, depending on the wiring requirements and signal levels of the encoder:

- Line driver
- Differential
- Push-pull

Wiring

Two encoders can be wired to each SNAP-IDC5Q module. Each encoder must provide a signal of at least 4 VDC (maximum 24 VDC) for the ON state, and less than 1 VDC for the OFF state.

Wiring diagrams are shown on the following page; use the diagram that applies to your encoder type.

Notice that each axis on the module is represented by two input points—one for Phase A and one for Phase B—like this:

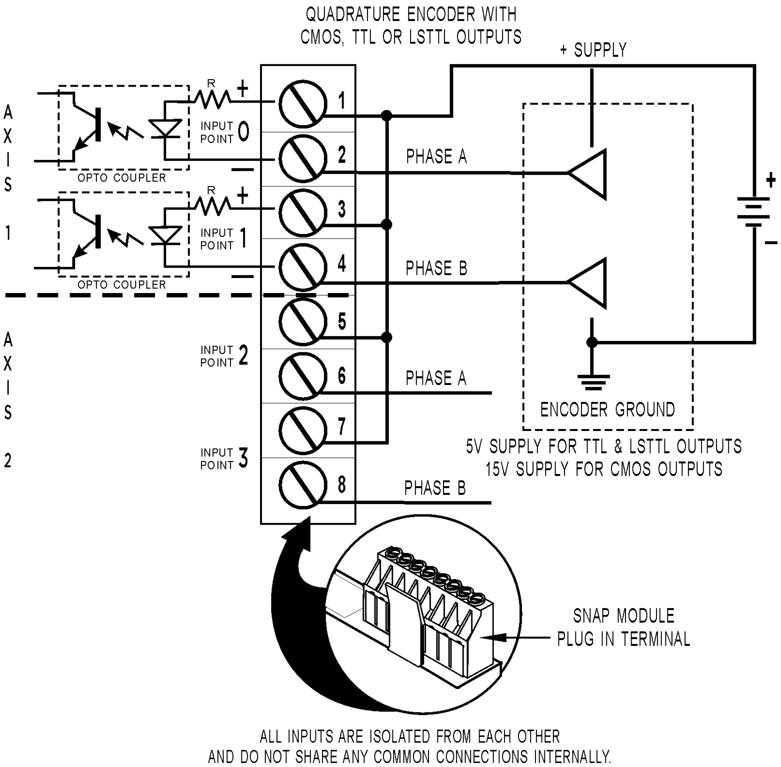
Axis 1	Phase A	=	Point 0	Terminals 1 and 2
	Phase B	=	Point 1	Terminals 3 and 4
Axis 2	Phase A	=	Point 2	Terminals 5 and 6
	Phase B	=	Point 3	Terminals 7 and 8

When wiring the encoder to the SNAP-IDC5Q, observe signal polarity. The odd terminals of the module are positive, and the even terminals are negative.

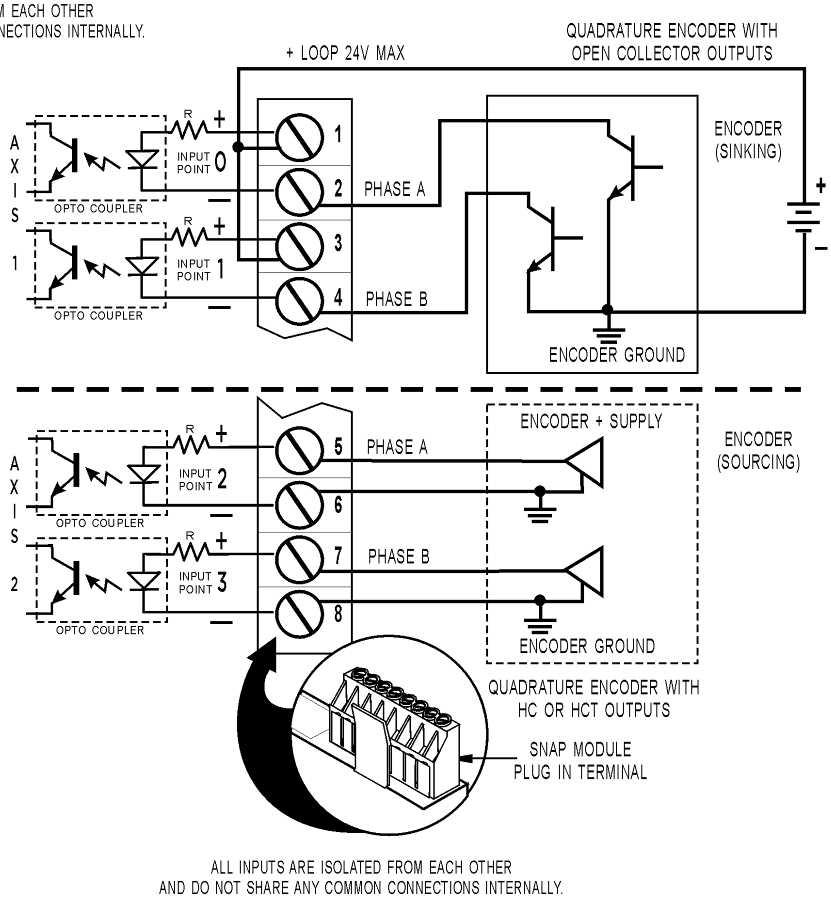
Input channels are isolated from each other by optocouplers, as shown in the simplified schematic in the wiring diagram.

SNAP-IDC5Q Wiring Diagrams

Use the diagram at left for quadrature encoders with **CMOS**, **TTL**, or **LSTTL** outputs, and also for encoders with a **pull-up option** (internal pull-up resistors).



Use the diagram below for quadrature encoders with **open collector** outputs (top half) or **HC** or **HCT** outputs (bottom half).



SNAP-IDC5Q
digital input module

How Counting Works

The module sends a pulse to the processor upon each change in quadrature state. The processor counts the pulses and keeps track of the direction and rotation.

The counter counts up if Phase A leads Phase B; it counts down if Phase A lags behind Phase B. Each axis can have counts from –2,147,483,648 to +2,147,483,647.

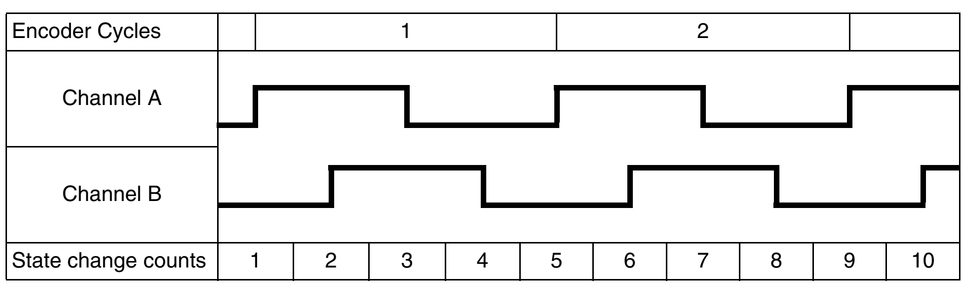
Note: The maximum allowable input frequency for the SNAP-ICD5Q varies, depending on the I/O processor you use with the module. The module itself is capable of 25 kHz, and SNAP PAC I/O processors with high-speed digital functions support that rate. Legacy processors, however, have much more limited quadrature counting capability. See the SNAP-IDC5Q's data sheet (form #1053) for details.

Resolution

Resolution refers to an incremental encoder's cycles per revolution (CPR). An incremental encoder generates a specific number of cycles for each full 360-degree shaft revolution. A 60 CPR encoder, for example, generates 60 pulses on each output channel for each shaft revolution.

Since each encoder channel produces two state changes per cycle, and a quadrature encoder has two output channels, four state changes occur per cycle. So a 60 CPR quadrature encoder, for example, generates 240 state changes per revolution.

Because the SNAP-IDC5Q sends one count to the I/O processor for each state change, the module acts as a pulse multiplier. The following simplified diagram shows the relationship between encoder cycles, state changes, and the resulting counts.



Index Points (Optional)

If your encoder has an index feature, you can use an additional digital input point for the index pulse. This pulse (called an index, marker, or reference) occurs once per revolution at the same mechanical point of the encoder's shaft, and it automatically resets the count. The index is often used to provide a known mechanical reference for positioning in motion control applications. You can read the processor's registers for total count, count when the index has occurred, and count since the last index pulse.

The index pulse is on a separate output channel and is wired to a separate input point. The point used for the index must be on the same mounting rack but *cannot* be on the quadrature module nor on a high-density digital (HDD) module. Use a four-channel digital input module that is suited to your index inputs.

Processors and Tools Used for Quadrature Counting

Several I/O processors work with the SNAP-IDC5Q module, including current SNAP PAC brains and rack-mounted controllers with high-speed digital functions, plus older legacy brains and controllers as well.

The software tool you use to configure counting depends on which processor you're using, whether it's used with a controller, and whether you use indexes.

The table on the following page lists processors that support the quadrature module and shows the tool you should use to configure the modules. Legacy products are shown in shaded cells; these products should not be used for new development.

Once you determine the tool to use, follow instructions beginning on page 8 to configure the quadrature counting feature.

Processors and Software Tools for Configuring Quadrature Counting with the SNAP-IDC5Q

Processor	Used with a Controller						Used without a Controller	
	SNAP PAC		Allen-Bradley PLC		mistic (Legacy)			
	Simple Counter	Index Counter	Simple Counter	Index Counter	Simple Counter	Index Counter	Simple Counter	Index Counter
SNAP-PAC-R1 SNAP-PAC-R1-FM SNAP-PAC-R1-W	PAC Control	PAC Manager	EtherNet/IP Configurator	PAC Manager	--n/a--	--n/a--	PAC Manager or custom program	PAC Manager or custom program
SNAP-PAC-EB1 SNAP-PAC-EB1-FM SNAP-PAC-EB1-W	PAC Control	PAC Manager	EtherNet/IP Configurator	PAC Manager	--n/a--	--n/a--	PAC Manager or custom program	PAC Manager or custom program
SNAP-PAC-SB1	PAC Control	PAC Manager	--n/a--	--n/a--	--n/a--	--n/a--	PAC Manager or custom program	PAC Manager or custom program
SNAP-B3000-ENET (legacy)	PAC Control	PAC Manager	--n/a--	--n/a--	OptoControl	--n/a--	PAC Manager or custom program	PAC Manager or custom program
SNAP-UP1-ADS (legacy)	PAC Control	PAC Manager	--n/a--	--n/a--	OptoControl	--n/a--	PAC Manager or custom program	PAC Manager or custom program
B3000 B3000-B	PAC Control[1]	PAC Manager[1]	--n/a--	--n/a--	OptoControl	--n/a--	Custom program[2]	--n/a--
B3000-HA	--n/a--	--n/a--	--n/a--	--n/a--	OptoControl	--n/a--	Custom program[2]	--n/a--

1 Requires a SNAP PAC S-series controller
2 For mistic I/O and Optomux, using OptoDriver Toolkit (not covered in this document)

Instructions for Simple Counter:

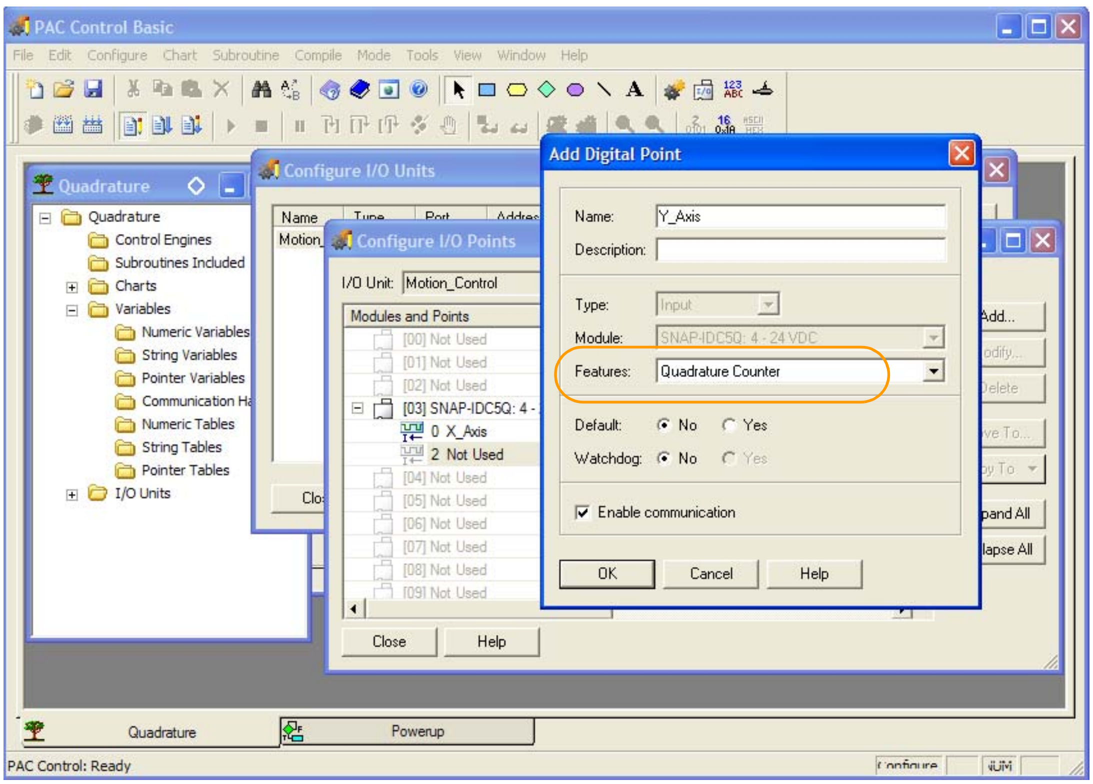
- PAC Control—page 8
- PAC Manager—page 9
- EtherNet/IP Configurator—page 10
- Custom Program—page 10
- OptoControl—page 11

Instructions for Index Counter—page 11

Using a Simple Quadrature Counter (No Index)

PAC Control—Simple Quadrature Counter

Configuration—When you configure the SNAP-IDC5Q module's points in PAC Control, you see one point per encoder (point 0 or 2). Because you've already chosen the SNAP-IDC5Q, the Quadrature Counter feature is automatically inserted for you. No other configuration is necessary.



Control—After configuration, use these Digital Point commands in your control strategy:

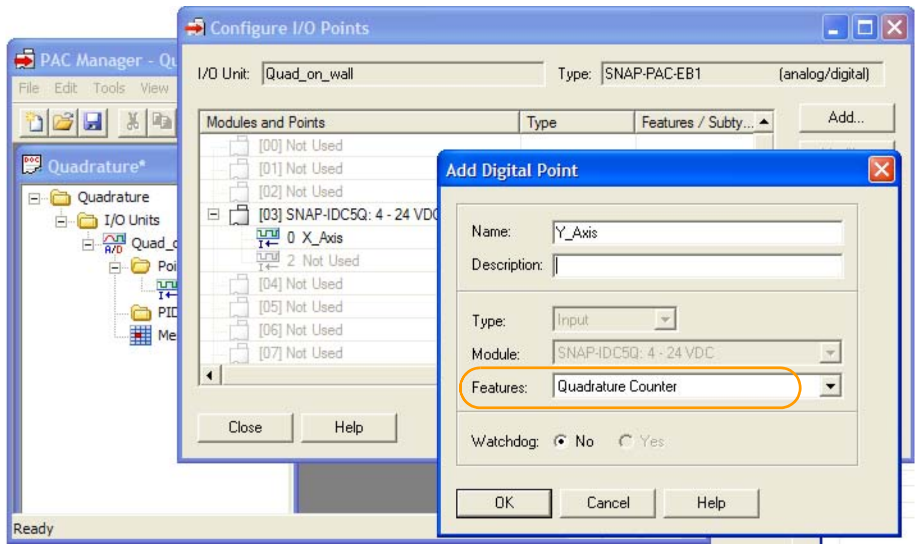
Clear Counter	Start Counter
Get & Clear Counter	Stop Counter
Get Counter	

See command details in the *PAC Control Command Reference*, form #1701.

PAC Manager—Simple Quadrature Counter

Configuration—Use a configuration file to configure a simple quadrature counter in PAC Manager.

For a simple quadrature counter, you see just one point per encoder (point 0 or 2). When you choose the SNAP-IDC5Q, the Quadrature Counter feature is automatically inserted for you. No other configuration is necessary.

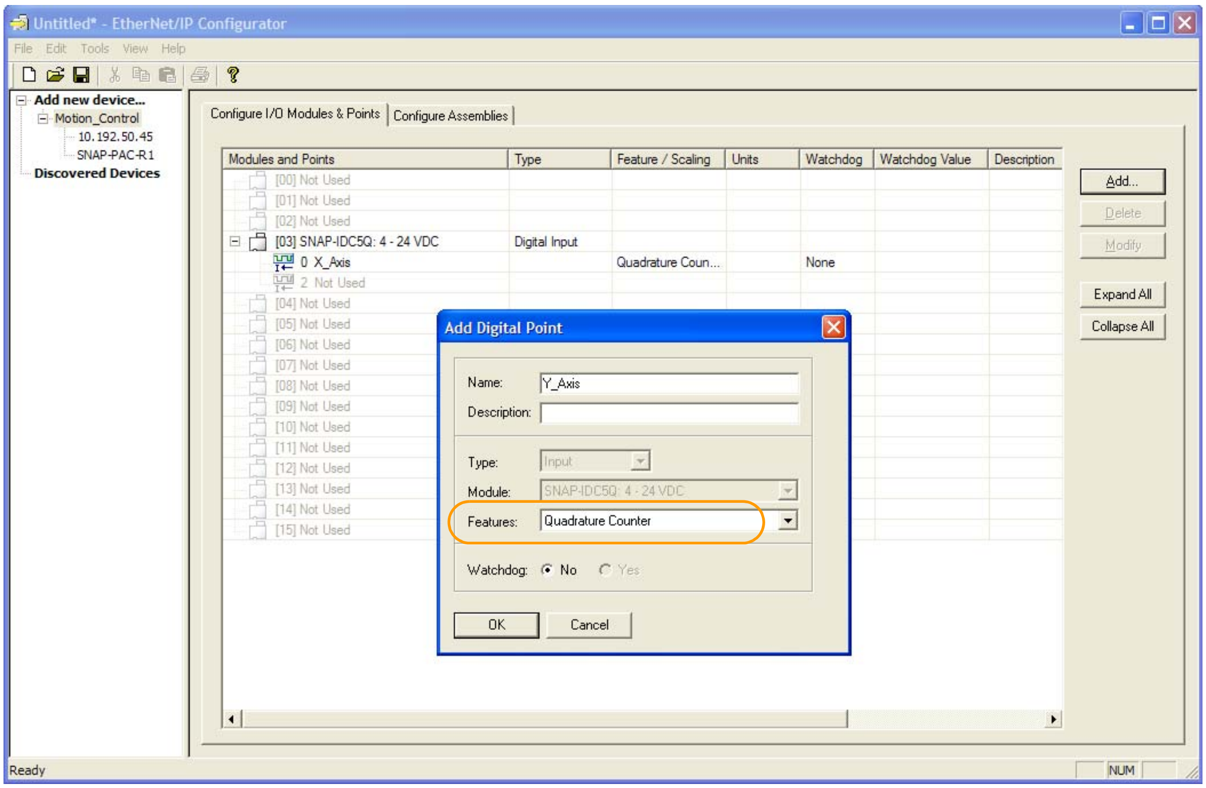


Control—Read and control counters in PAC Control or your custom program.

EtherNet/IP Configurator—Simple Quadrature Counter

Configuration—If you are using intelligent remote SNAP I/O with an Allen-Bradley PLC system, you can configure a simple quadrature counter in the EtherNet/IP Configurator software utility.

Follow steps in form #1770, the *EtherNet/IP for SNAP PAC Protocol Guide*, to add the SNAP-IDC5Q module. When you add the module's points, the Quadrature Counter feature is automatically chosen for you.



Custom Program—Simple Quadrature Counter

Configuration—If you're using the OptoMMP Protocol to build a custom control program, see the (Expanded) Analog and Digital Point Configuration section of the Memory Map Appendix in form #1465 (*OptoMMP Protocol Guide*).

Locate the addresses for Point Feature for points 0 and 2 at the module's position. (These are the Phase A points on the module.) Write `0x00000004` to these two addresses.

Control—Use the Digital Point Read and the (Expanded) Digital Point Read & Clear areas of the memory map to read and clear counter data. Again, read or write to the address for point 0 or 2 at the module's position.

OptoControl—Simple Quadrature Counter

NOTE: Opto Control is a legacy product and not recommended for new development.

Configuration—In OptoControl, when you configure the SNAP-IDC5Q module's points, the Quadrature Counter feature is automatically chosen for you. No other configuration is necessary.

Control—Use standard counter commands to control simple quadrature counters.

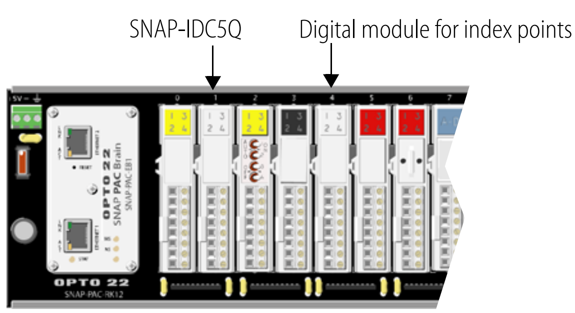
Using a Quadrature Counter with an Index

If your encoder has an index feature, you can use an index. Because PAC Control, the EtherNet/IP Configurator, and OptoControl assume no index, you'll need to use either PAC Manager or a custom program based on the OptoMMP protocol to configure the point feature.

As explained earlier, each encoder (each axis) is represented by two input points on the module—one for Phase A and one for Phase B:

Axis 1	Phase A	=	Point 0
	Phase B	=	Point 1
Axis 2	Phase A	=	Point 2
	Phase B	=	Point 3

An index requires one additional digital point per encoder. Index points cannot be on the SNAP-IDC5Q and they cannot be on a high-density digital module. They must be located on a suitable 4-channel digital input module on the same rack. For example, on this rack a SNAP-IDC5-FAST has been used for index points:

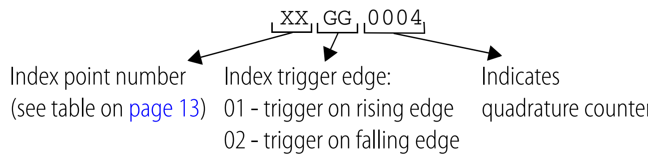


To see how to configure the point feature, we'll first look at some basic information that applies to configuration in both PAC Manager and in a custom program. Then you'll see a step-by-step example, with details for both PAC Manager and the OptoMMP protocol.

Basic Configuration Information (Counter with Index)

For each axis, you will configure the point feature for *either* the Phase A point (0 or 2) or the Phase B point (1 or 3). You don't need to configure both points.

The point feature value you'll enter will be in hex. Its format is: `XXGG0004`



Once you have configured the Phase A or Phase B point, the other phase and the index point are *automatically* configured for you. If you look at the index point, you'll see its point feature in the following format (again in hex): `QQGG0041`

In this format, QQ is the Phase A or B point number, GG is the index edge, and 0041 is the point feature value for an index point. The point number for the Phase A or B point is a hex value representing its position on the rack. The "Point Numbers Table" on page 13 explains this value.

Here's a summary of how to configure the three points for each axis and how each point behaves in use:

	Phase A Point	Phase B Point	Index Point
Point feature format:	XXGG0004 • XX = index point • GG = index edge (01 = rising edge, 02 = falling edge)	Same as A; configure A or B	QQGG0041 (automatically configured): • QQ = Phase A or B point • GG = index edge (01 = rising edge, 02 = falling edge)
Possible point numbers (see table on page 13):	Even point numbers 0–62 (see table)	Odd point numbers 1–63 (see table)	Any point on a *different* 4-ch digital input module (not a high-density module)
Counter data shows:	Current quadrature count	Quadrature count since index was triggered	Quadrature count when index was triggered
Counter data resets upon:	Read & Clear	• Read & Clear • Index edge	Read & Clear

Point Numbers Table

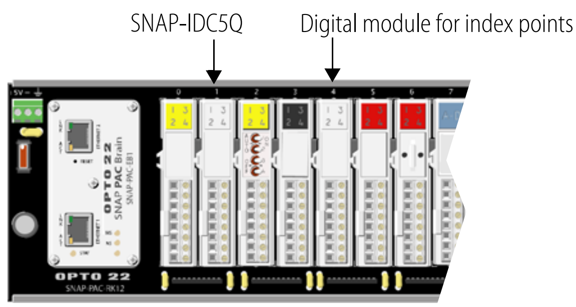
Because the quadrature module and the module with the index points are both four-channel modules, the hex point values used for configuration are based on a 16-module rack filled with 4-point modules—a total of 64 possible points on the largest rack.

Use the following table to convert the module position and point number to the hex point value needed for configuration.

Module position	Point #	Use Hex Point #	Module position	Point #	Use Hex Point #	Module position	Point #	Use Hex Point #	Module position	Point #	Use Hex Point #
0	0	0	4	0	10	8	0	20	12	0	30
	1	1		1	11		1	21		1	31
	2	2		2	12		2	22		2	32
	3	3		3	13		3	23		3	33
1	0	4	5	0	14	9	0	24	13	0	34
	1	5		1	15		1	25		1	35
	2	6		2	16		2	26		2	36
	3	7		3	17		3	27		3	37
2	0	8	6	0	18	10	0	28	14	0	38
	1	9		1	19		1	29		1	39
	2	A		2	1A		2	2A		2	3A
	3	B		3	1B		3	2B		3	3B
3	0	C	7	0	1C	11	0	2C	15	0	3C
	1	D		1	1D		1	2D		1	3D
	2	E		2	1E		2	2E		2	3E
	3	F		3	1F		3	2F		3	3F

Configuration Example (Counter with Index)

In this example, two encoders will be connected to a SNAP-IDC5Q located in position 1 on the rack (remember that module and point numbers start at zero). The index points are on the module in position 4.



Axis	Function	Mod.	Pt.
1	Phase A	1	0
	Phase B		1
	Index	4	2
2	Phase A	1	2
	Phase B		3
	Index	4	3

In this example we'll configure the Phase A points, points 0 and 2 (remember, you only need to configure Phase A or Phase B, not both).

You use the table on page 13 to look up the index points for both axes. The index for Axis 1 is on module 4, point 2; you see from the table that its hex value is 12. The index for Axis 2 is on module 4, point 3; from the table, its hex value is 13.

You want the index to trigger on the falling edge.

Here's what you do:

- Configure module 1, point 0 with a point feature value of: `12020004`
  `12` = Axis 1 index point (module 4, point 2) from table on page 13
  `02` = trigger on falling edge (value from page 12)
  `0004` = quadrature counter
- Configure module 1, point 2 with a point feature value of: `13020004`
  `13` = Axis 2 index point (module 4, point 3) from table on page 13
  `02` = trigger on falling edge (value from page 12)
  `0004` = quadrature counter

If you now look at the index points, you'll see they have been automatically configured as follows:

- Axis 1 index (module 4, point 2) shows: `04020041`
  `04` = Axis 1, Phase A point (module 1, point 0) from table on page 13
  `02` = trigger on falling edge
  `0041` = quadrature counter index
- Axis 2 index (module 4, point 3) shows: `06020041`
  `06` = Axis 2, Phase A point (module 1, point 2) from table on page 13
  `02` = trigger on falling edge
  `0041` = quadrature counter index

See the following instructions for PAC Manager (below) and for a custom program (page 18).

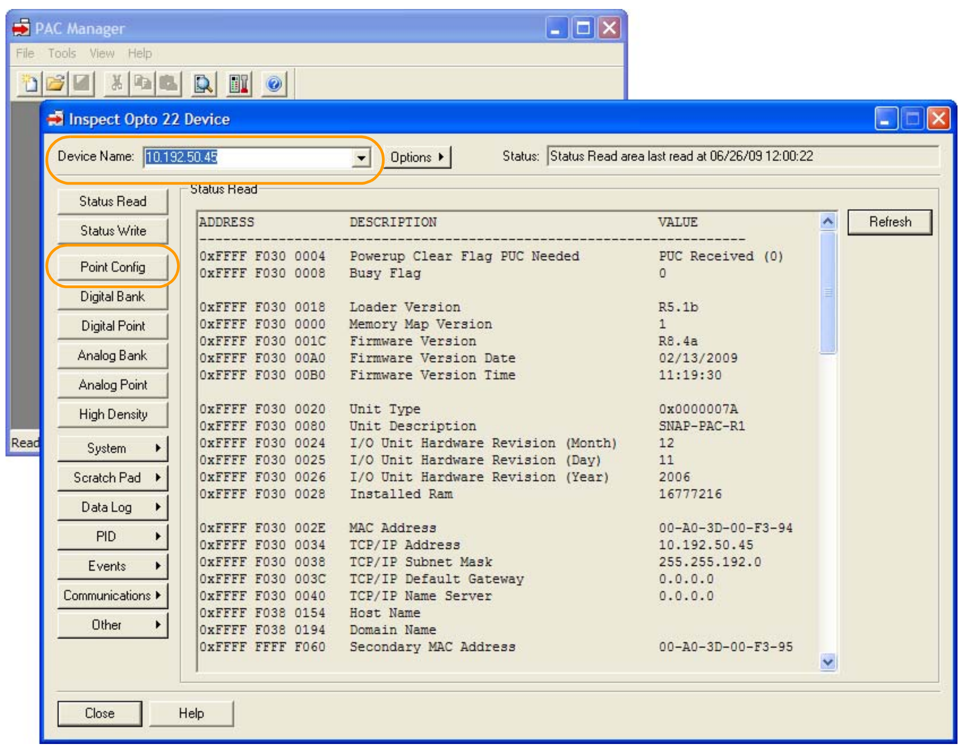
PAC Manager Configuration Example

PAC Manager is on the CD that came with the brain or rack-mounted controller, or you can download it from our website, www.opto22.com. PAC Manager must be installed on a computer that is on the same subnet as the I/O processor for the SNAP-IDC5Q. For more information, see form #1704, the *PAC Manager User's Guide*.

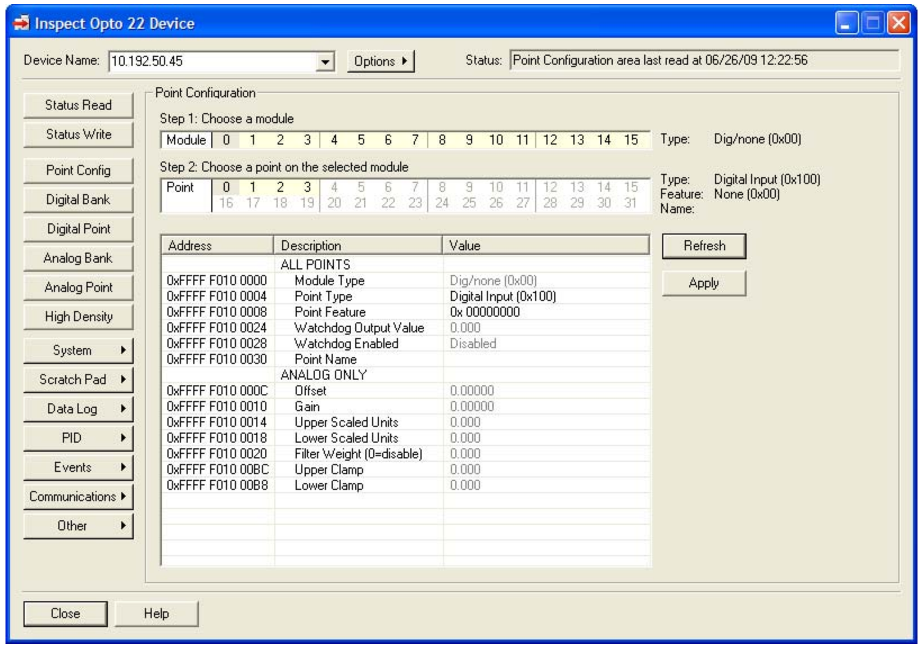
1. Launch PAC Manager by choosing Start→Programs→Opto 22→PAC Project Software→PAC Manager.

2. Choose Tools→Inspect or click the Inspect button .

   If you've used the Inspect button before, your window will look something like the following. If you have not used the Inspect button, the window will not contain data.

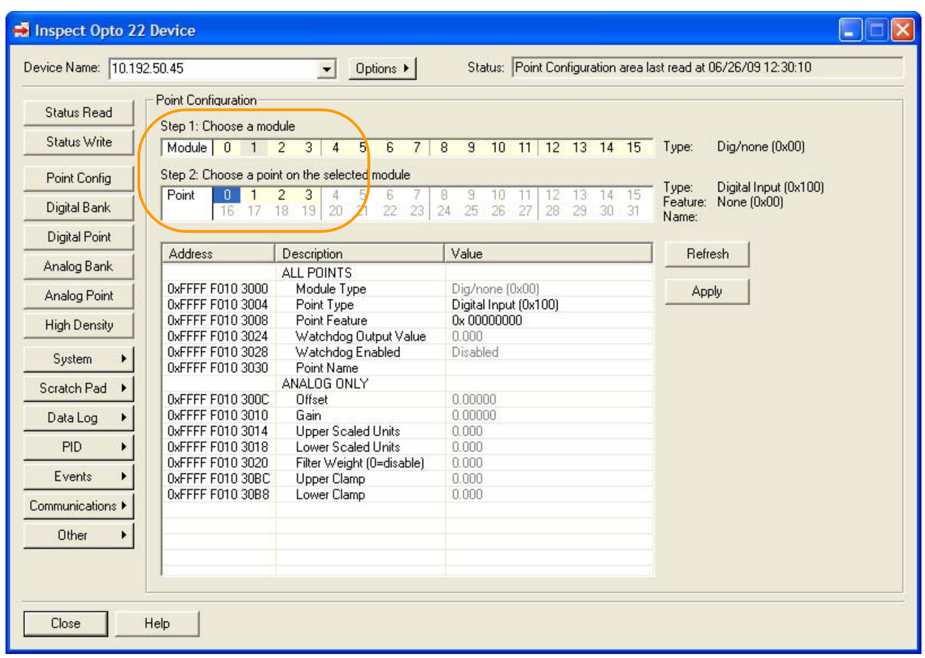


3. In the Device Name field, enter the IP address of the I/O processor. Then click the Point Config button.



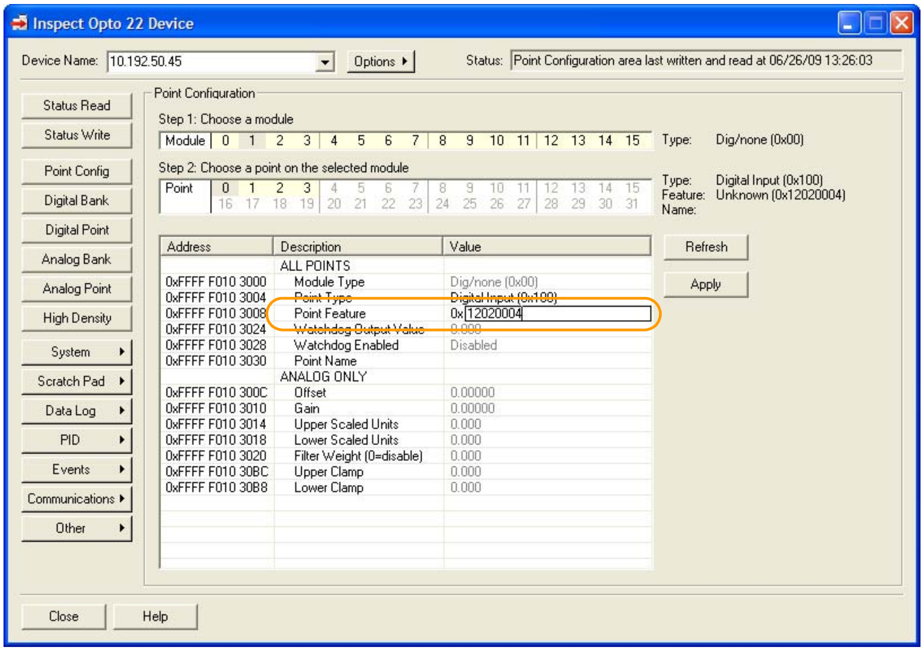
4. Click the position of the SNAP-IDC5Q module on the rack and then the point number of the Phase A or Phase B point you want to configure.

For our configuration example (see page 14), that would be module 1, point 0:



5. In the Value column for Point Feature, enter the hex configuration value.

For our example, the value is: `12020004`

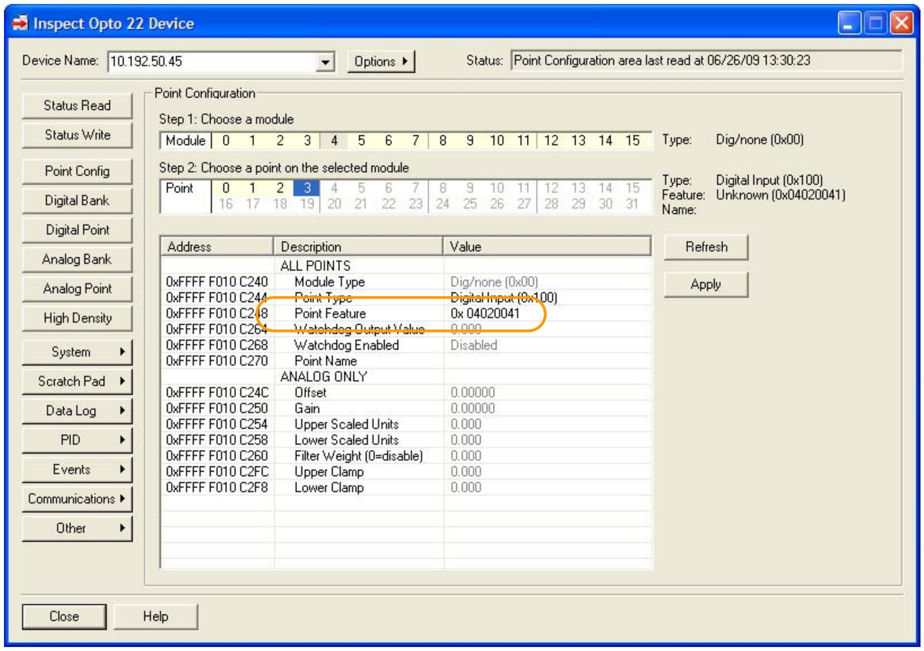


6. Click the Apply button on the right.
7. Now choose the module and point for Axis 2 and enter the point feature value for it. Remember to click Apply.

Configuration is complete. Be sure to store the configuration to flash memory.

You can check configuration by seeing whether the index points were automatically configured. To do so, choose the module and point for one of the index points. Look at the value for the Point Feature.

For our example, the Axis 2 index point was on module 4, point 3. This point shows the correct point feature value: `04020041`



Custom Program Configuration Example

Use the Analog and Digital Point Configuration section of the Memory Map Appendix in form #1465 (*OptoMMP Protocol Guide*).

For our example (see page 14), locate the addresses for Point Feature for points 0 and 2 at the module's position. (These are the Phase A points on the module.) Write the following point feature values to these two addresses:

- To address F010 3008 (point feature for module 1, point 0), write: `12020004`
- To address F010 3188 (point feature for module 1, point 2), write: `13020004`

Configuring these Phase A points automatically configures the Phase B points and the index points. Be sure to store the configuration to flash memory.

Reading and Writing to a Quadrature Counter with Index

To read the quadrature count for one axis, read the counter data for any of its three points, depending on the information you need:

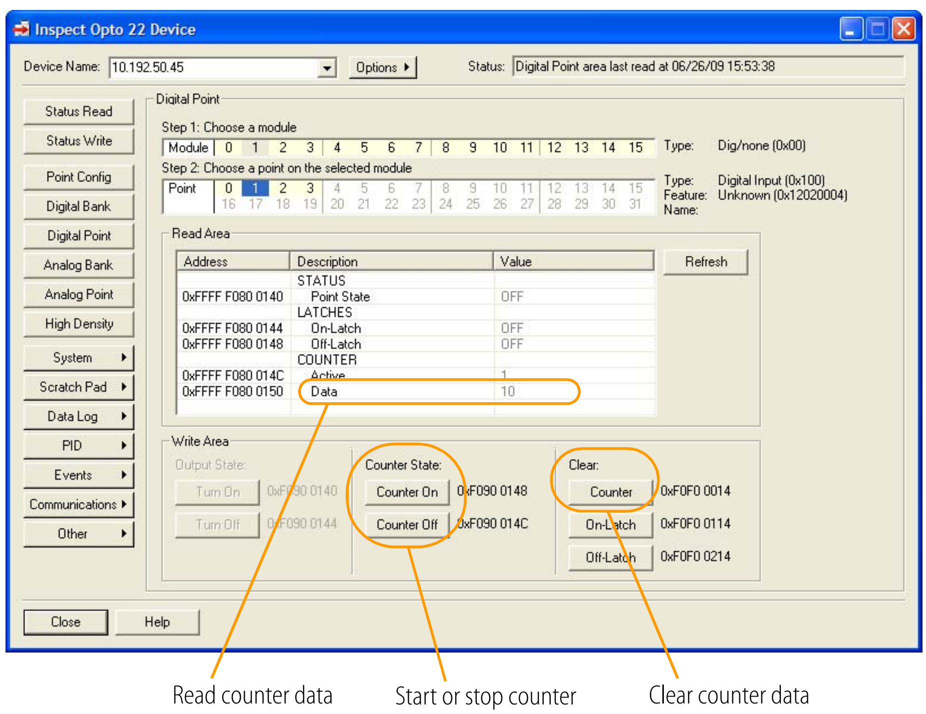
- The Phase A point (0 or 2) shows the current quadrature count.
- The Phase B point (1 or 3) shows the quadrature count since the index was triggered.
- The index point shows the count at the time the index was triggered.

You can also read & clear data or start and stop counters.

Testing in PAC Manager

In most cases, you'll use PAC Manager to configure the quadrature counter and then use other tools to control it. For testing, however, you can read and write to it in PAC Manager once it is configured.

1. In PAC Manager's Inspect window, enter the I/O unit's IP address and click the Digital Point button.
2. Click the module and point numbers for the point you want (Phase A, Phase B, or index).
3. Read and write on this page as shown below.



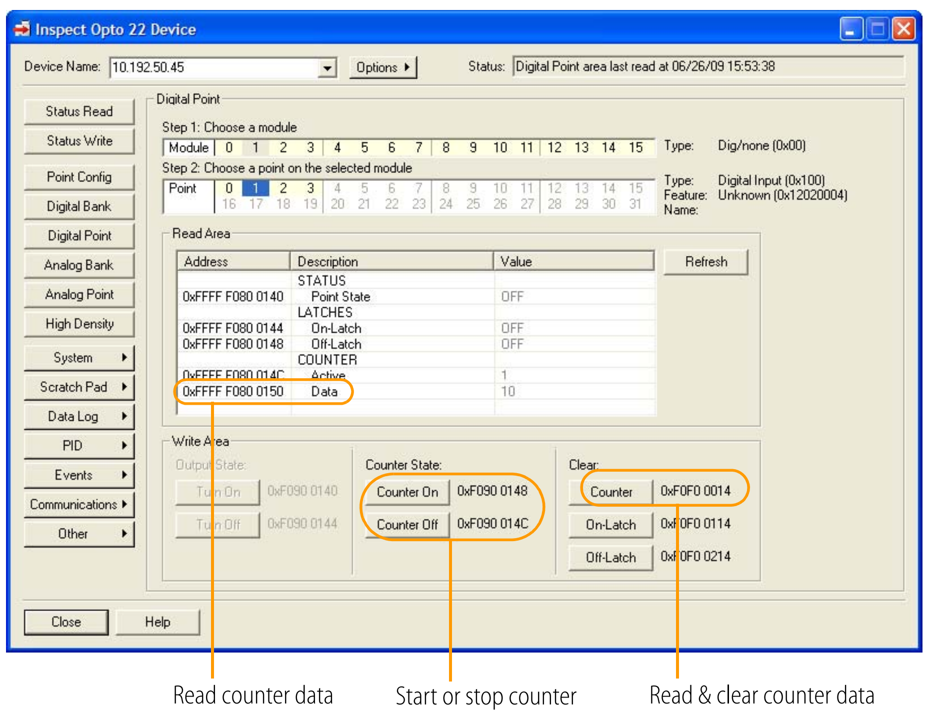
PAC Control

Once the quadrature counter with index is configured in PAC Manager, you can read it in PAC Control using the I/O Unit command "Read Number from I/O Unit Memory Map." To read & clear counters or start and stop them, use "Write Number to I/O Unit Memory Map."

In the Mem address parameter of either command, enter the memory map address for the point (Phase A, Phase B, or index) you want to read. You can get these addresses either from the Memory Map Appendix in form #1465 or from the Inspect window in PAC Manager.

In the Memory Map Appendix, see the Digital Point Read, Digital Point Write, and either the (Old) or (Expanded) Digital Point Read & Clear areas.

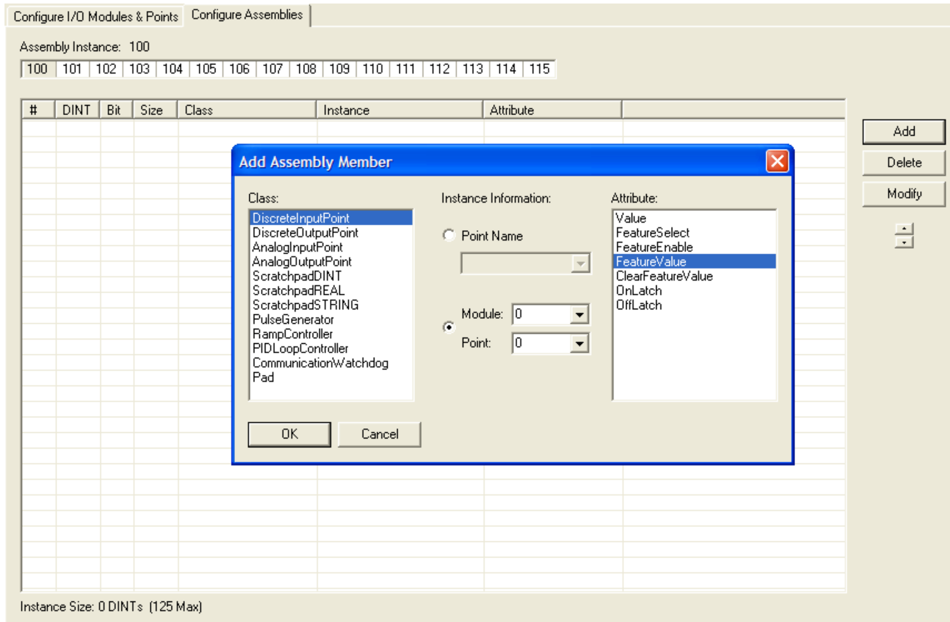
In the PAC Manager Inspect window, enter the I/O unit's IP address and click the Digital Point button. Click the module and point numbers for the point you want. Here's an example of addresses you can use:



EtherNet/IP

Once the quadrature counter with index is configured in PAC Manager, you can add assembly members for its control in the EtherNet/IP Configurator. Create or add to an input assembly to read counter data; create or add to an output assembly to write to the counter.

1. In the EtherNet/IP Configurator, click the Configure Assemblies tab. Click the Assembly Instance number you want to use.
2. Click the Add button.



3. For Class, choose DiscreteInputPoint.
4. Choose the module and point number you want to read or write to. For example, to read the Axis 2 Phase B point in our example, choose Module 1, Point 3.
5. Choose the Attribute you need:
   – FeatureValue to read the counter
   – ClearFeatureValue to clear the data after reading
   – FeatureEnable to start or stop the counter
6. Click OK to add the assembly member to the assembly instance.

Follow instructions in form #1770 to download the assembly instances to the I/O unit and work with RSLogix.

Custom Program

See form #1465 for memory map addresses. Use the Digital Point Read, Digital Point Write, and (Old) or (Expanded) Digital Point Read & Clear areas of the memory map the same way you would for other counters. Just make sure to choose the address for the point you want—Phase A, Phase B, or index—as their data varies (see “Reading and Writing to a Quadrature Counter with Index” on page 19).