Using Intelligent SNAP I/O with Allen-Bradley PLC Systems

Introduction

You've heard about intelligent remote SNAP I/O™ from Opto 22 and how it can be used with Allen-Bradley® PLC systems to extend your A-B system and provide new functions. There are at least three reasons why you may be considering using SNAP I/O:

- You need to add remote I/O points to expand your PLC-based system.
- You need to add process control or other heavily analog-based functions.
- You need to acquire data without disturbing the existing system.

SNAP I/O can meet these needs in a PLC-based system, because it provides distributed intelligence that processes I/O at the local level, often without requiring programming.

A-B PLC systems that can use SNAP I/O include ControlLogix®, CompactLogix®, MicroLogix™ 1100 and 1400, and Micro850.

This technical note helps you determine whether SNAP I/O is right for your application and introduces concepts to help you design the way SNAP I/O works within your A-B PLC system. It describes SNAP I/O, discusses explicit and implicit messaging, and provides some architectural details of implicit messaging.

We assume you are already familiar with Allen-Bradley programmable logic controllers (PLCs), Logix™ software, and the EtherNet/IP™ protocol. For additional information, see the following Opto 22 forms, available on our website, www.opto22.com. The easiest way to find a form is to search on its form number.

- *EtherNet/IP for SNAP I/O Protocol Guide* (form 1770)
- *IO4AB User's Guide* (form 1909)

For Help

If you need help determining whether SNAP I/O will work with your PLC system or choosing the I/O most suited to your application, contact your local Opto 22 distributor or Pre-sales Engineering at Opto 22 headquarters in Temecula, California.

Pre-sales engineering is free.

- **Pre-sales Engineering phone:** 951-695-3000
  or toll-free in the U.S.: 800-321-6786
- **Email:** systemseng@opto22.com

If you've already purchased Opto 22 products and need help using them, contact Opto 22 Product Support. Product support is free.

Phone:	800-TEK-OPTO (800-835-6786 toll-free in the U.S. and Canada) 951-695-3080 Monday through Friday, 7 a.m. to 5 p.m. Pacific Time
E-mail:	support@opto22.com
Website:	www.opto22.com

What Is Intelligent Remote I/O?

Fundamentally, in a PLC-based system the programmable logic controller does all the work: it scans all points, solves the logic, and then writes to all points. The speed with which it can do so is usually critical to the system. Depending on how busy the PLC is, adding new I/O points—or new functions such as heavy analog signal processing—may slow down scan rates to an unacceptable level, requiring that an additional PLC be added and programmed to provide more processing power.

A PLC-based system with intelligent remote SNAP I/O works in a different way, however: like a distributed control system (DCS), it distributes control. The PLC doesn't do all the work, but instead parcels out some of it to remote I/O processors. These processors provide communication, like a bus coupler, but also do more. Although they are not programmable like a PLC, they have functions built into them that automatically run once the I/O is configured. This distributed processing takes some of the load off the PLC, so that adding points or functions has much less of an impact on system performance.

Intelligent remote SNAP I/O works like this:

- It scans its own I/O and processes most functions related to it (see list of functions on page 3).
- It holds the data the PLC needs and sends it either at predetermined intervals or when requested by the PLC, and it communicates the PLC's writes to local I/O.
- It continues to process local I/O even if communication with the PLC is lost. If communication is interrupted, it sets outputs to safe, predetermined levels.

SNAP I/O from Opto 22

Opto 22's intelligent remote SNAP I/O supports EtherNet/IP, the protocol many Allen-Bradley PLC systems are based on, which means your PLC can communicate directly with SNAP I/O.

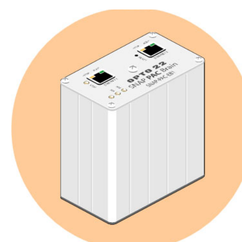
SNAP I/O gives you new choices in the I/O you use to expand or build your PLC system. You may take advantage of the built-in intelligence of SNAP I/O for distributed processing, or you may simply use SNAP I/O as reliable, low-cost, Ethernet-based remote I/O for your industrial PLC system.

Each industrially hardened SNAP I/O unit consists of the following:

- An I/O processor we call the *brain*
- A mounting rack
- Analog, digital, and/or serial I/O modules as required at the remote location

A SNAP I/O unit is illustrated below. This one uses a 16-module mounting rack, which accommodates up to 512 I/O points. If you need fewer modules, you can choose a smaller rack.

Brain



The brain provides Ethernet communication and built-in I/O processing functions. It is not programmable; functions are automatic once you configure the I/O. SNAP I/O brains can execute all of the following operations at the I/O level without additional programming:

Engineering unit conversion
Thermocouple linearization
Temperature conversion
PID loop control (up to 96 loops per brain)
Analog scaling
Offset and gain (calibration)
Analog ramping
Output clamping
Filter weight
Minimum and maximum values

Watchdog timeout
Analog and digital totalizing
Time-proportional output (TPO)
Input latching
Pulse generation
On-pulse and off-pulse measurement*
Frequency and period measurement*
High-speed counting (up to 20 kHz)*
Quadrature counting*

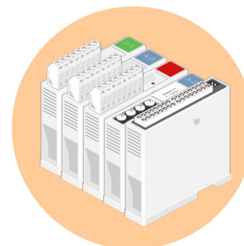
*Requires brain with high-speed digital functions

There are several brains to choose from:

- The **SNAP-PAC-EB1** provides analog, digital, and serial functions and includes the high-speed digital functions listed above.
- The **SNAP-PAC-EB2** provides analog, digital, and serial functions, but no high-speed digital.
- For wireless networks, choose **SNAP-PAC-EB1-W** or **SNAP-PAC-EB2-W**. These models communicate both over a wired Ethernet network and over a standard 802.11a, b, or g wireless LAN. (Wireless communication is not recommended for implicit messaging.)

For specifications on all brains, see Opto 22 form #1689, the *SNAP PAC Brains Data Sheet*. For installation and maintenance, see form #1690, the *SNAP PAC Brains User's Guide*. Both documents are available on our website, www.opto22.com.

I/O Modules



Opto 22's analog, digital, and serial I/O modules are known for their reliability and for their broad range of signal types. All modules are manufactured at our factory in Temecula, California, and each one is individually tested twice before it is shipped to you. Most modules are guaranteed for life.

Available signal types include the following:

Analog	Digital	Serial
Current Voltage Rate Temperature RMS pH/ORP Resistance Power monitoring Load cell	AC DC Dry contact Quadrature	RS-232 RS-485/422 Profibus® Wiegand®

Because SNAP analog I/O modules are software configurable, a single module can handle a variety of signal inputs. For example, the SNAP-AITM-8 provides eight channels of thermocouple or millivolt input. Each channel can be individually configured to accept a type B, C, D, E, G, J, K, N, R, S, or T thermocouple or a -75 to + 75 mV, -50 to +50 mV, or -25 to +25 mV input.

SNAP I/O modules each contain 1 to 32 points, depending on the model. With a 16-module rack of 32-point modules, the maximum number of points on one rack is 512.

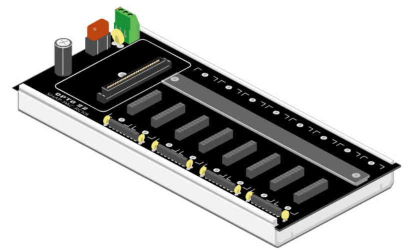
All I/O modules are optically isolated, and all analog modules are transformer isolated. Many models also have channel-to-channel isolation.

Click the Products tab on our website, www.opto22.com, to see the wide range of SNAP I/O modules and their specifications. Module data sheets are listed below:

I/O Module	Data sheet	Form #
Analog input modules	*SNAP Analog Input Modules Data Sheet*	1065
Isolated analog input modules	*SNAP Isolated Analog Input Modules Data Sheet*	1182
Analog output modules	*SNAP Analog Output Modules Data Sheet*	1066
Digital input modules	*SNAP Digital Input Modules Data Sheet*	0773
Digital output modules	*SNAP Digital Output Modules Data Sheet*	1144
High-density digital modules	*SNAP High-Density Digital Modules Data Sheet*	1556
Serial modules	*SNAP Serial Communication Modules Data Sheet*	1184

All documents are available on our website, www.opto22.com. The easiest way to find a document is to search on its form number.

Mounting Rack



SNAP PAC racks mount one brain and up to 4, 8, 12, or 16 I/O modules, so you can choose the size that fits the local requirements at the remote location. Analog, digital, and serial modules can all be mixed and used anywhere on the rack. The rack provides the backplane for communication between the brain and the modules it processes.

Mounting rack part numbers are:

Maximum capacity	Standard models
4 modules	SNAP-PAC-RCK4
8 modules	SNAP-PAC-RCK8
12 modules	SNAP-PAC-RCK12
16 modules	SNAP-PAC-RCK16

About Opto 22

Opto 22 was started in 1974 by one of the co-inventors of the solid-state relay (SSR), who discovered a way to make SSRs more reliable. In the late 1970s we developed the red-white-yellow-black color-coding system for input/output (I/O) modules, which is still a standard in the industry.

The first SNAP I/O modules were introduced in 1996. Just two years later, in 1998, we released the first Ethernet-based I/O unit, SNAP Ethernet I/O, based on the same open standards and protocols as the Internet.

Opto 22 is probably best known for its high-quality SSRs and I/O. Customers also appreciate our commitment to customer service. When you call Opto, you talk with a real person. Free pre-sales engineering and product support are provided by engineers at our headquarters in California. Documentation and training are also free.

Understanding EtherNet/IP Models for Communication

EtherNet/IP, an industrial protocol developed by Allen-Bradley and currently supported by ODVA (Open DeviceNet Vendors Association), provides a widely used, standard communication method between products from various vendors. So a PLC that uses the EtherNet/IP protocol—such as a ControlLogix, CompactLogix, MicroLogix 1100 or 1400, or Micro850—can communicate easily with SNAP I/O, which also supports EtherNet/IP. Compatibility is guaranteed because SNAP I/O is EtherNet/IP conformance tested by ODVA.

Devices using the EtherNet/IP protocol function as either *scanners* or *adapters*.

- PLCs are scanners. They can originate I/O data connection requests with other scanners and with adapters, and they can send or receive messages to or from other EtherNet/IP products.

- SNAP I/O is an adapter. Adapters cannot store or originate the data communication parameters necessary to establish a connection. They send and receive I/O data only when requested to do so by a scanner.

Messaging

PLCs using EtherNet/IP can communicate with SNAP I/O using both *implicit messaging* (often called I/O messaging) and *explicit messaging* (sometimes referred to as handshaking, communication by exception, or simply access).

- Implicit, or I/O, messaging is the familiar way to communicate with remote I/O. Once the PLC has requested the connection initially, it receives blocks of data from the I/O at predetermined intervals (input) and writes data to the I/O, also at predetermined intervals (output).
- Explicit messages, by contrast, are used for request/response transactions between the two devices. The PLC sends a request and the I/O returns a response.

In many cases you will use implicit messaging for communication with SNAP I/O, but sometimes explicit messaging is the better method. Let's take a look at how the two methods compare. The following table summarizes the similarities and differences.

Implicit (I/O) Messaging	Explicit Messaging (Handshaking)
The SNAP I/O unit sends data at regular intervals to one or more PLCs, without waiting for a request. The PLC writes data to the SNAP I/O at regular intervals.	The PLC initiates communication only at specific points in the ladder logic.
The PLC reads or writes blocks of data (for example, the values of all analog points or all counters).	The PLC reads or writes an individual item of data (such as the value of a single analog point or one counter).
Data from the SNAP I/O is always available for use in the PLC.	Data from the SNAP I/O must be specifically read before it can be acted upon.
One or more PLCs can receive the same data from a SNAP I/O unit at the same time.	Each PLC must access the SNAP I/O unit individually.
Highly efficient for high-speed scanning of I/O (uses UDP and multicasting for communication).	Better for a complex command not suited to the repetitive nature of scanning, for example, Read and Clear Counter.
Requires simple I/O configuration.	Requires simple I/O configuration.
I/O functions (thermocouple linearization, ramping, etc.) do not need to be programmed in ladder logic; they are handled automatically by SNAP I/O.	I/O functions (thermocouple linearization, ramping, etc.) do not need to be programmed in ladder logic; they are handled automatically by SNAP I/O.
Assembly instances must be created for each SNAP I/O unit, to define the data to be read or written. Creating assembly instances is quick and easy. Reads and writes are not programmed in ladder logic.	Each read or write must be programmed in ladder logic. If you have many similar but not identical SNAP I/O units, this method may be faster than creating assembly instances for each SNAP I/O unit.
Multicast communication.	Point-to-point communication. Communicates through a router without special setup.

Implicit (I/O) Messaging	Explicit Messaging (Handshaking)
Quantity of data exchanged cannot exceed ~1000 bytes of input data or ~500 bytes of output data (~500 bytes input and ~250 bytes output for MicroLogix 1100/1400).	Data size limitation of ~500 bytes for each explicit request (~250 bytes for MicroLogix 1100/1400). No limit on number of requests.
Maximum 16 connections, depending on system configuration.	Maximum 16 connections, depending on system configuration.

Models for Implicit and Explicit Messaging

Implicit messaging in EtherNet/IP uses the producer-consumer model of communication. In the producer-consumer model, communication parameters are set up ahead of time. The producer does not wait for a data request but instead sends predetermined data at specified intervals. This data is multicast to one or more targets. The consumer listens for the data it wants and ignores other data.

In contrast, **explicit messaging** uses the master-slave (request-response) model of communication, which is familiar to many control engineers through its use in Modbus and many other protocols. In master-slave communication, the master requests data from the slave, and the slave responds by delivering the data requested. Each communication is directed to a specific device (point-to-point).

Many customers using SNAP I/O with A-B ControLogix or CompactLogix PLCs start with implicit messaging, which requires only configuring I/O and creating assembly instances for use in Logix. Explicit messaging requires configuring I/O and programming in Logix. This method is used by MicroLogix and Micro850 customers and may also be used by Studio 5000 Logix Designer (formerly RSLogix 5000) customers.

For more detail on both messaging types, see form #1770, the *EtherNet/IP for SNAP PAC Protocol Guide,* and form #1909, the *IO4AB User's Guide.*

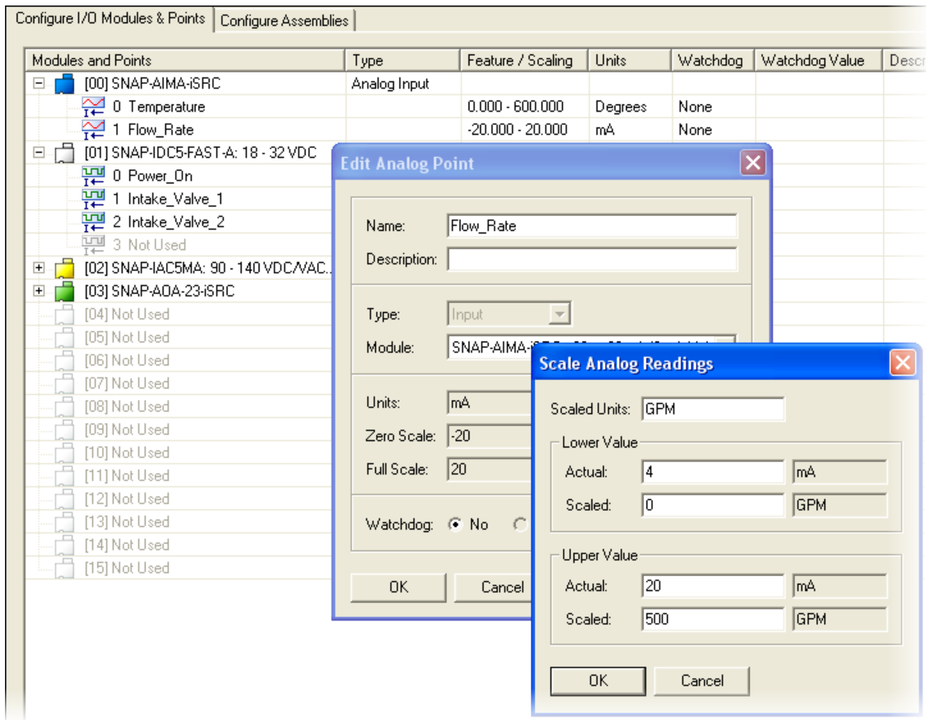
Configuring I/O

Configuring I/O simply means defining the SNAP I/O hardware and its features to be used. This is easily done in **EtherNet/IP Configurator**, a free utility software program available on the Opto 22 website. Detailed instructions are in form #1770, the *EtherNet/IP for SNAP I/O Protocol Guide*, included with the download and also available separately on our website.

Using EtherNet/IP Configurator and following the steps in form #1770, you create a configuration file for the I/O unit. You assign the brain an IP address for communication and configure functions that apply to the entire SNAP I/O unit, such as whether temperature readings should be in Fahrenheit or Celsius, and whether to use a watchdog timeout for communication with the PLC.

In the configuration file you also show which I/O module is in each position on the mounting rack and configure each point on the module: give it a name, choose its engineering units or range (you can also use counts), and select features such as counting, pulsing, scaling, and so forth. Some other I/O functions—minimum/ maximum values and thermocouple linearization, for example—are automatic and need no configuration.

Configuration is simple because the dialog boxes present choices clearly. For example, here are the dialog boxes for configuring an analog input point. Notice how the modules and points are laid out in a tree behind the dialog boxes.



How-to videos on our website show you the steps for configuring I/O using the Configurator. (Go to www.opto22.com, click the Watch tab, and then click IO4AB Videos.)

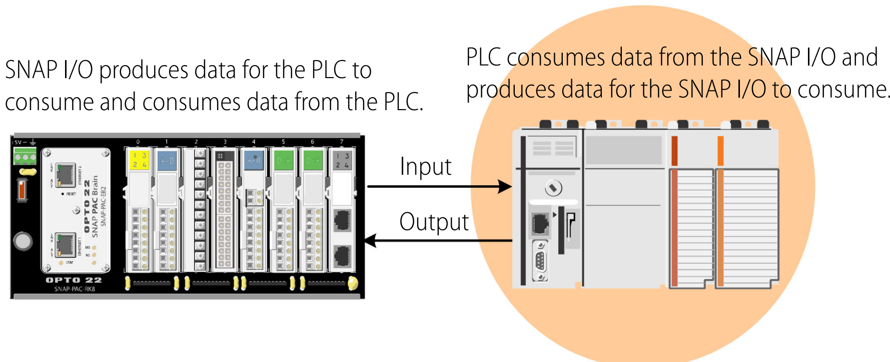
Once the I/O is configured, you will do one of two things:

- For explicit messaging, program in ladder logic.
- For implicit messaging, continue to use the EtherNet/IP Configurator to set up assembly instances.

The rest of this technical note explains implicit messaging in more detail.

Implicit Messaging in SNAP I/O and Logix

Opto 22 SNAP I/O and A-B Logix PLCs communicate using bidirectional implicit messaging, which means that data flows at specified intervals in both directions and that each end of the connection acts as both producer and consumer. For example, the PLC is a consumer of input data from the SNAP I/O and a producer of output data to the SNAP I/O. The SNAP I/O produces data that it sends for the PLC to consume, and it consumes data the PLC produces for it.



So for each implicit messaging connection, there are two producer-consumer relationships, one for each direction of data flow. To accomplish this double data flow, the data structures are defined by creating assembly instances.

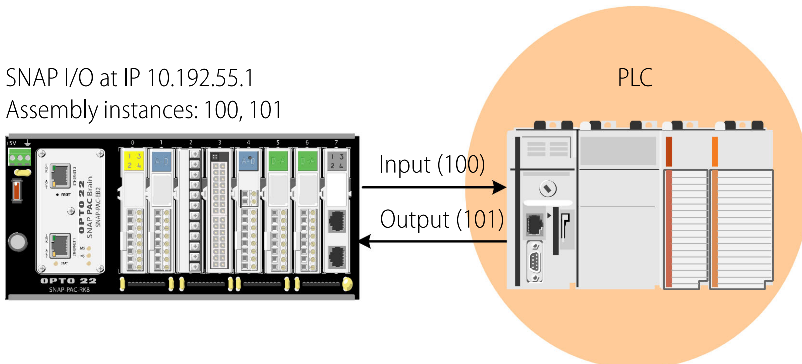
Creating Assembly Instances

Each data flow direction requires one assembly instance. Again following the steps in the *EtherNet/IP for SNAP I/O Protocol Guide* (form #1770), you use EtherNet/IP Configurator to create these assembly instances and then download them to the SNAP I/O units. Then you'll enter the assembly instance numbers in Logix for the PLC.

When creating assembly instances for implicit messaging, think of each one as containing a specific set of data, either input or output:

- **Input instance**—the PLC needs to *read* this data from a SNAP I/O unit
- **Output instance**—the PLC needs to *write* this data to a SNAP I/O unit

For example, you might create input assembly instance 100 for data a PLC needs to read from a SNAP I/O unit at IP address 10.192.55.1. Communication is bidirectional and the PLC needs to write data to this SNAP I/O, so you would also create output assembly instance 101.

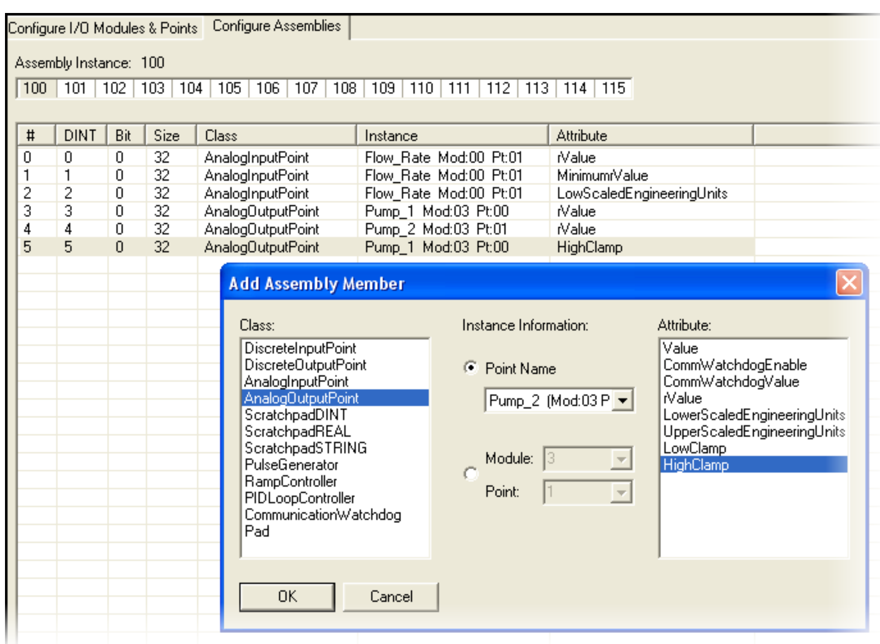


What's in the Assembly Instance?

The advantages of using SNAP I/O become apparent when you look at the contents of an assembly instance. While most manufacturers' remote I/O lets you read and write only status (or values in counts), SNAP I/O lets you read and write multiple attributes.

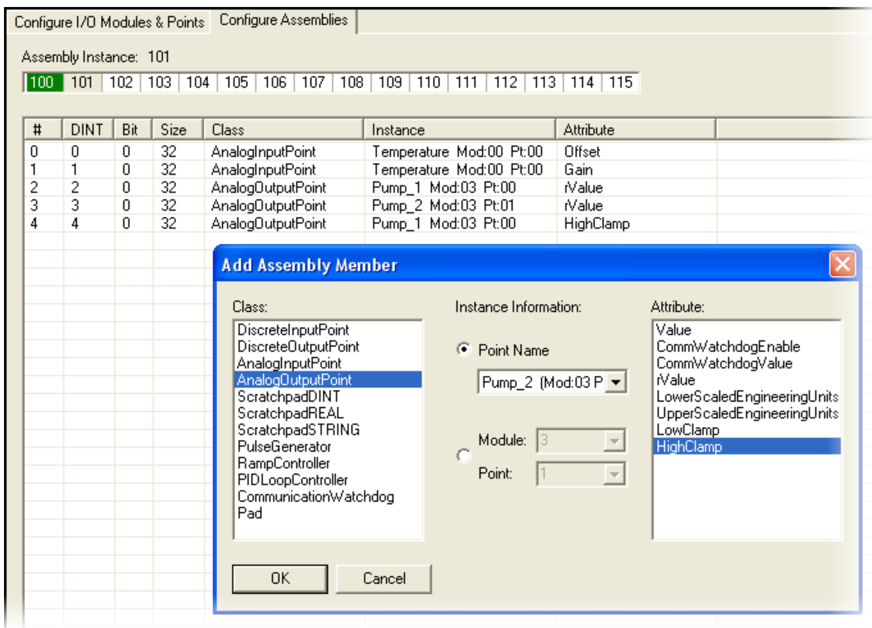
The next page shows an example of an input assembly instance as created in EtherNet/IP Configurator. Notice that in this input assembly you read both input and output points. Attributes include not only point values in Engineering Units (rValue), but also minimum value and low scale for the input, plus high clamp value for the outputs.

This input assembly currently includes 6 DINTs; you can include up to 125 for Logix 5000 PLCs.



Output assemblies can be equally flexible. Here's output assembly 101 as an example. Here you are writing values in Engineering Units (rValue) and HighClamp values to output points. But you are also writing data to an input point—in this case, calibration values (Offset and Gain).

Note that this ability to read and write to both input and output points in input and output assemblies adds a great deal of flexibility. On an analog output point, for example, you could read the current HighClamp value, then write a new HighClamp value to the point, and then read it again to verify that it actually clamped at the value you specified.



Attribute Data Available

Assembly instances can include all of the following attribute data, shown below in tables by class. All attributes are detailed in the CIP chapter of the *EtherNet/IP for SNAP PAC Protocol Guide* (form #1770).

Discrete Input Point

To do this	Choose this attribute	In assembly
Read the state of the point	Value	Input
Read on- or off-latch	On-latch, off-latch	Input
Read the value of any feature you've configured on the point (counter, on- or off-pulse, frequency, on- or off-totalizer)	FeatureValue	Input
Clear the value of the configured feature	ClearFeatureValue	Output
Read which feature is currently configured	FeatureSelect	Input
Select a different feature and enable it	FeatureSelect, then FeatureEnable	Output

Discrete Output Point

To do this	Choose this attribute	In assembly
Read the current state of the point	Value	Input
Turn the point on or off	Value	Output
Write the value to set the point to in the event of communication failure	CommWatchdogValue	Output
Enable a communication watchdog on the point	CommWatchdogEnable	Output

Analog Input Point

To do this	Choose this attribute	In assembly
Read the value of the point in counts	Value	Input
Read the value of the point in Engineering Units	rValue	Input
Read the minimum or maximum value in Engineering Units	MinimumrValue MaximumrValue	Input
Read the current low scale or high scale settings for the point in Engineering Units	LowScaledEngineeringUnits HighScaledEngineeringUnits	Input
Write new low scale or high scale settings in Engineering Units	LowScaledEngineeringUnits HighScaledEngineeringUnits	Output
Write calibration values to the point	Offset, Gain	Output
Write an average filter weight value to the point	AveragingFilterWeight	Output

Analog Output Point

To do this	Choose this attribute	In assembly
Read the value of the point in counts Read the value of the point in Engineering Units	Value rValue	Input
Write a value to the point in counts Write a value to the point in Engineering Units	Value rValue	Output
Read current point scaling in Engineering Units	LowerScaledEngineeringUnits UpperScaledEngineeringUnits	Input
Write new point scaling in Engineering Units	LowerScaledEngineeringUnits UpperScaledEngineeringUnits	Output
Read the current low or high clamp on the point	LowClamp, HighClamp	Input
Write a new low or high clamp to the point	LowClamp, HighClamp	Output
Enable communication watchdog on the point Set the watchdog value for the point	CommWatchdogEnable CommWatchdogValue	Output

Pulse Generator

To do this	Attributes	In assembly
Read current pulse attributes	Period PulseQuantity Percent State Delay PulsesRemaining	Input
Write new pulse attributes	Period PulseQuantity Percent State Delay PulsesRemaining Invert	Output
Start or stop the pulse generator	Start, Stop	Output

Ramp Controller

To do this	Attributes	In assembly
Read current ramping attributes	EndValue Rate	Input
Write new ramping attributes (To start ramping, write a non-zero value to Rate; to stop ramping, write a zero to Rate)	EndValue Rate	Output
Find out whether ramping is occuring now	State	Input

Communication Watchdog

To do this	Attributes	In assembly
Read current timeout value for communication watchdog	Timeout	Input
Write new timeout value for communication watchdog	Timeout	Output

PID Loop Controller

To do this	Choose this attribute	In assembly
Read the current attributes of the PID loop	Algorithm Mode ScanRate InputSource InputLowRange InputHighRange SetpointSource OutputDestination OutputLowerClamp OutputUpperClamp MinimumOutputChange MaximumOutputChange OutputWhenInputLow OutputWhenInputHigh Input Setpoint Output FeedForward Gain Integral Derivative FeedForwardGain ScanCount CurrentError CurrentTermP CurrenTermI CurrentTermD CurrentIntegral	Input
Set or change the attributes of the PID loop	Algorithm Mode ScanRate InputSource InputLowRange InputHighRange SetpointSource OutputDestination OutputLowerClamp OutputUpperClamp MinimumOutputChange MaximumOutputChange OutputWhenInputLow OutputWhenInputHigh Input Setpoint Output FeedForward Gain Integral Derivative FeedForwardGain ScanCount CurrentError CurrentTermP CurrenTermI CurrentTermD CurrentIntegral	Output

More Complex Communication with Implicit Messaging

So far we've assumed that you're using just one PLC to communicate with just one SNAP I/O unit. But the system you need may involve far more than this. Here are two examples to give you an idea of how to handle more complex communication.

Example: One PLC with Multiple SNAP I/O Units

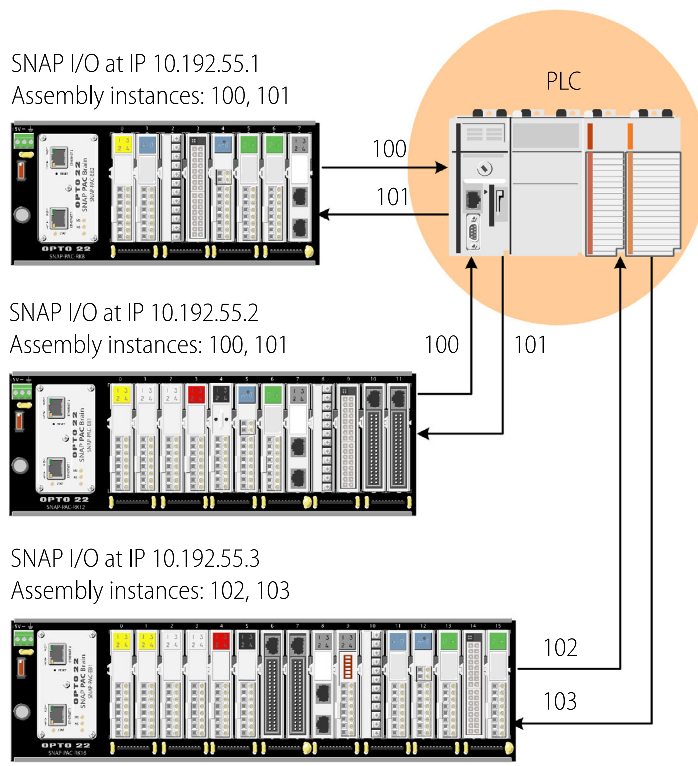
If one PLC needs to communicate with multiple SNAP I/O units, you'll create input and output assembly instances for each SNAP I/O. Up to 16 assembly instances can be created for each SNAP I/O unit using assembly numbers 100–115. It doesn't matter which numbers you use as long as they are within that range.

Since communication requires both the assembly numbers and the IP address of the target, you can use the same assembly numbers for different SNAP I/O units or not, as you wish.

In the diagram at right, the PLC is communicating with three SNAP I/O units.

The PLC reads data from them via input instances and controls them (writes to them) via output instances.

Since communication uses a combination of assembly numbers and IP addresses, you can use the same or different assembly numbers for different SNAP I/O units.



Architecture for Your System

In addition to the information in this tech note, be sure to check other sources for help when you're planning your PLC system's architecture to include intelligent remote SNAP I/O.

- Pre-sales help from your distributor or Opto 22 engineers is available for free. See the contact information on page 1.
- Opto 22 Product Support is also free. See page 1.
- EtherNet/IP Configurator is a free download on our website, www.opto22.com.
- All product documentation is on our website. See *EtherNet/IP for SNAP I/O Protocol Guide* (form 1770) and *IO4AB User's Guide* (form 1909).
- And videos on our website demonstrate using EtherNet/IP Configurator.

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