HART 4 Devices

User Manual

A-HRT-4I

A-HRT-4O

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aparian

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Revision History

Revision	Date	Comment
1.0	13 Apr 2016	Initial document
1.1	26 June 2016	Updated temperature range
1.2	11 August 2016	Added RoHS2 compliant to certifications
1.3	24 September 2016	Added ODVA EtherNet/IP Conformance Mark
1.4	14 November 2016	Minor change to V19 UDT.
1.5	22 November 2016	Added HART Advanced Diagnostics
1.6	23 May 2017	Add support for two additional interface modes. Add RCM Conformance mark.
1.7	22 August 2017	Remove EDS AOP section as the module does not support this
1.8	20 February 2018	Added support for multidrop Added device list Update Modbus/DNP3 Device Info addresses Added support for burst operation
1.9	23 July 2018	Added indication if channel is enabled and if HART is enabled on that channel.

1. PREFACE

1.1. FEATURES

The HART 4 module can convert up to four analog devices into either EtherNet/IP, Modbus-TCP, or DNP3 TCP/UDP protocols. This includes 4 to 20 mA input and output devices with or without HART communications as well as 0 to 20 ma devices without HART.

The Hart 4 is available in Input or Output variations:

1) **A-HRT-4I** for HART input devices like process instruments.
2) **A-HRT-4O** for HART output devices like valve positioners.

The conversion to EtherNet/IP enables a HART device to be added directly into a Rockwell Automation Logix IO tree. The Modbus-TCP option enables a HART field device to be viewed as a Modbus Slave. The DNP3 option converts a HART field device into a DNP3 Outstation. The DNP3 option, also supports Secure Authentication, ensuring secure communications across the Ethernet network.

In addition, a rich collection of process and diagnostic information is provided directly into Logix, without the use of any explicit messaging. HART commands can also be relayed to the device using an EtherNet/IP message relay object. A DTM (Device Type Manager) is available further simplifying device configuration and management using an FDT frame. A built-in webserver provides detailed diagnostics of system configuration and operation as well as field device specific diagnostics.

The Hart 4 module is configured using the Aparian Slate application. This program can be downloaded from www.aparian.com free of charge.

Hereafter the Hart 4 module will be referred to as the **module**.

1.2. ADDITIONAL INFORMATION

The following documents contain additional information that can assist the user with the module installation and operation.

Resource	Link
Slate Installation	http://www.aparian.com/software/slate
User Manual, Datasheet Example Code & UDTs	http://www.aparian.com/products/hart4
Ethernet wiring standard	www.cisco.com/c/en/us/td/docs/video/cds/cde/cde205_220_420/installation/guide/cde205_220_420_hig/Connectors.html

Table 1.1. - Additional Information

1.3. REFERENCES

Resource	Link
HART Communication Foundation	http://en.hartcomm.org/
DNP3	http://www.dnp.org
CIP Routing	The CIP Networks Library, Volume 1, Appendix C:Data Management
Modbus	http://www.modbus.org

Table 1.2. - References

1.4. SUPPORT

Technical support is provided via the Web (in the form of user manuals, FAQ, datasheets etc.) to assist with installation, operation, and diagnostics.
For additional support the user can use either of the following:

Resource	Link
Contact Us web link	www.aparian.com/contact-us
Support email	support@aparian.com

Table 1.3. – Support Details

2. INSTALLATION

2.1. MODULE LAYOUT

The module has six ports at the bottom of the enclosure as shown in the figure below. The ports are used for Ethernet, the four analog HART channels and power. The power port uses a three-way connector which is used for the DC power supply and the earth connection.

The Ethernet cable must be wired according to industry standards which can be found in the additional information section of this document.



Figure 2.1. – HART-4 (Input) module side view

The module provides six diagnostic LEDs as shown in the front view figure below. These LEDs are used to provide information regarding the module system operation, the Ethernet interface, and the status of each of the four analog HART channels.

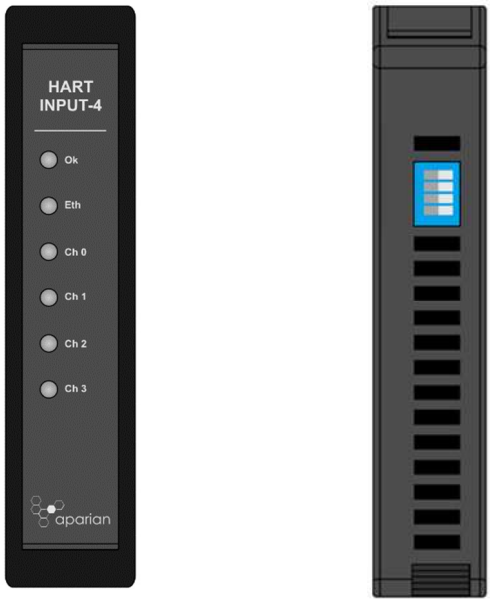


Figure 2.2. – HART 4 (Input) front and top view

The module provides four DIP switches at the top of the enclosure as shown in the top view figure above.

DIP Switch	Description
DIP Switch 1	Used to force the module into “Safe Mode”. When in “Safe Mode” the module will not load the application firmware and will wait for new firmware to be downloaded. This should only be used in the rare occasion when a firmware update was interrupted at a critical stage.
DIP Switch 2	This will force the module into DHCP mode which is useful when the user has forgotten the IP address of the module.
DIP Switch 3	Reserved
DIP Switch 4	Reserved

Table 2.1. - DIP Switch Settings

2.2. MODULE MOUNTING

The module provides a DIN rail clip to mount onto a 35mm DIN rail.

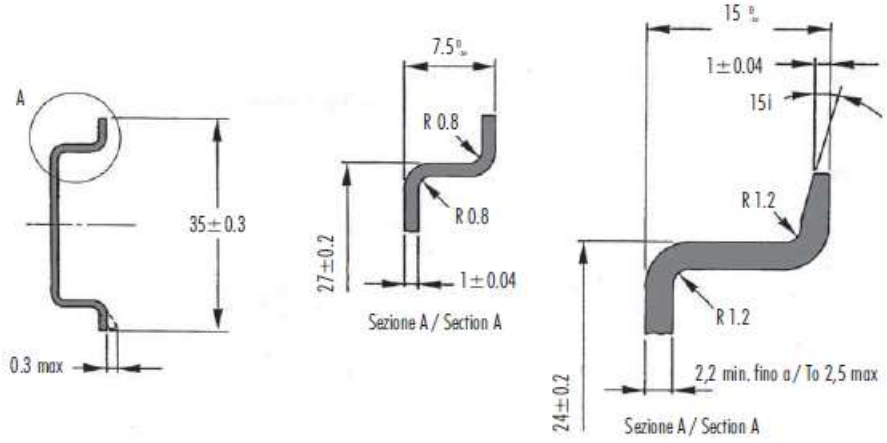


Figure 2.3 - DIN rail specification

The DIN rail clip is mounted on the bottom of the module at the back as shown in the figure below. Use a flat screw driver to pull the clip downward. This will enable the user to mount the module onto the DIN rail. Once the module is mounted onto the DIN rail the clip must be pushed upwards to lock the module onto the DIN rail.

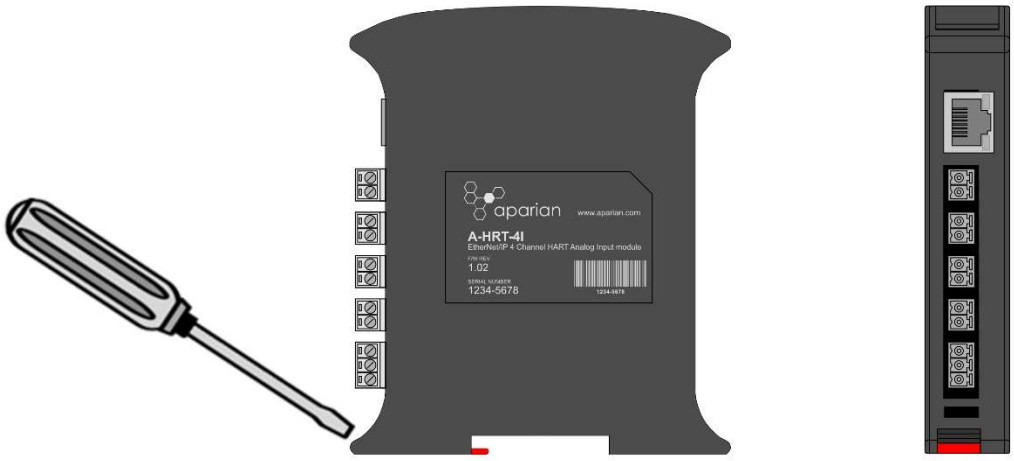


Figure 2.4 - DIN rail mouting

2.3. POWER

A three-way power connector is used to connect Power+, Power– (ground), and earth. The module requires an input voltage of 12 – 28Vdc. **Refer** to the technical specifications section in this document.

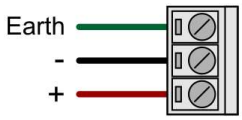


Figure 2.5 - Power connector

2.4. ANALOG (HART)

The Analog HART channels are connected using a two-way connector. The input channels (A-HRT-4I) are internally loop powered and therefore can be connected directly to the field device signal terminals.

The output channels (A-HRT-4O) source the current directly and therefore can also be connected directly to the field device signal terminals. The input and output channels provide internal current limiting and electronic fuse protection.

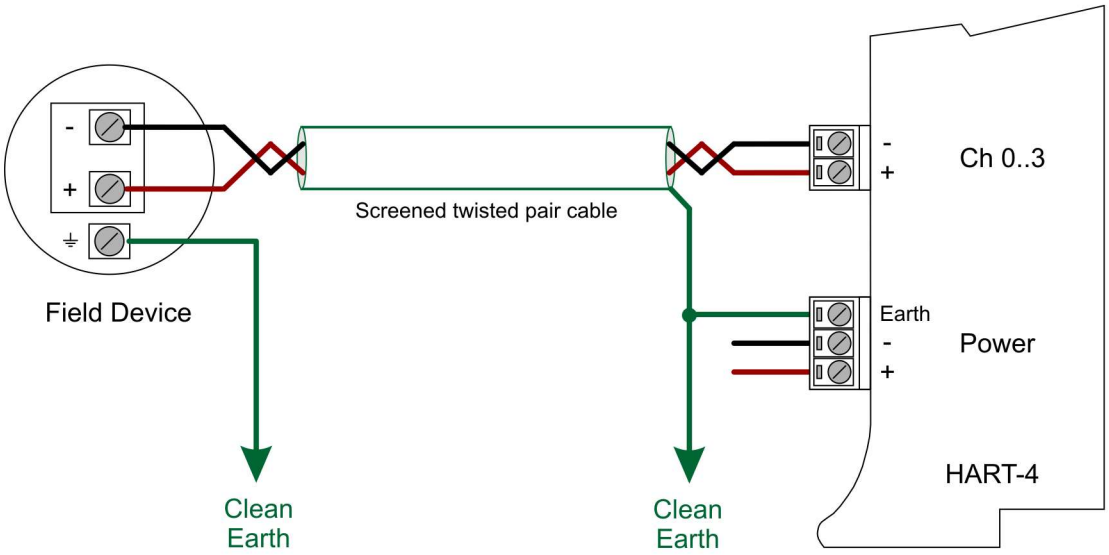


Figure 2.6 – Analog (HART) Connection to Field Device

The equivalent Analog Input and Output circuits are shown below.

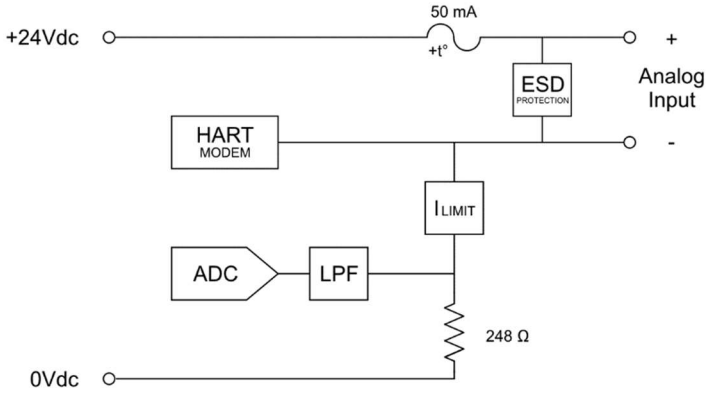


Figure 2.7 – Analog Input Equivalent Circuit

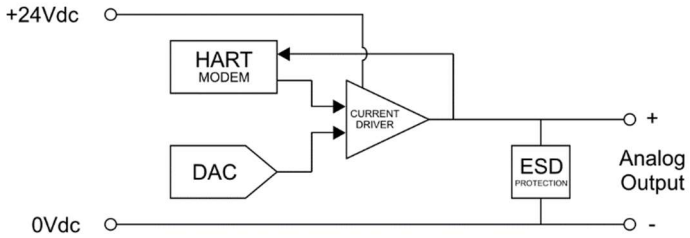


Figure 2.8 – Analog Output Equivalent Circuit

2.5. ETHERNET PORT

The Ethernet connector should be wired according to industry standards. Refer to the additional information section in this document for further details.

3. SETUP

3.1. INSTALL CONFIGURATION SOFTWARE

All the network setup and configuration of the module is achieved by means of the Aparian Slate device configuration environment. This software can be downloaded from http://www.aparian.com/software/slate.

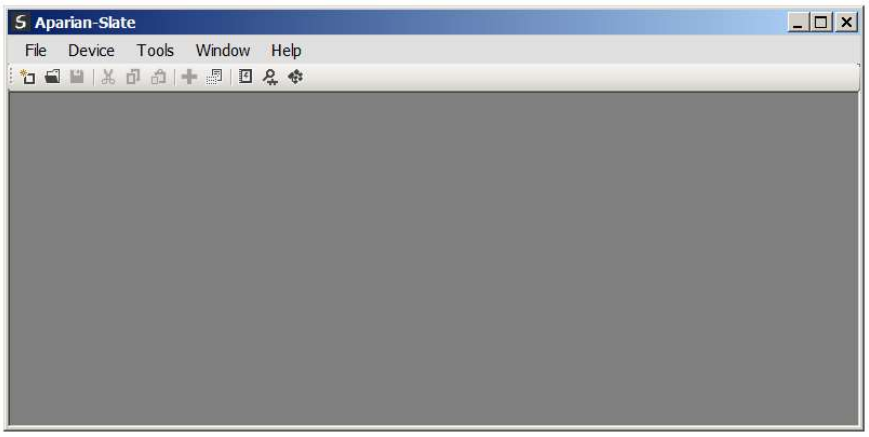


Figure 3.1. - Aparian Slate Environment

3.2. NETWORK PARAMETERS

The module will have DHCP (Dynamic Host Configuration Protocol) enabled as factory default. Thus, a DHCP server must be used to provide the module with the required network parameters (IP address, subnet mask, etc.). There are a number of DHCP utilities available, however it is recommended that the DHCP server in Slate be used.

Within the Slate environment, the DHCP server can be found under the Tools menu.

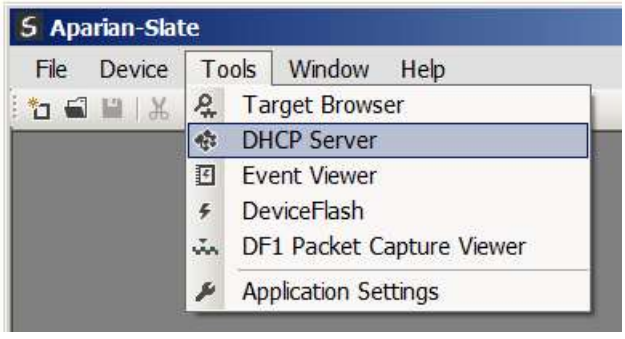


Figure 3.2. - Selecting DHCP Server

Once opened, the DHCP server will listen on all available network adapters for DHCP requests and display their corresponding MAC addresses.

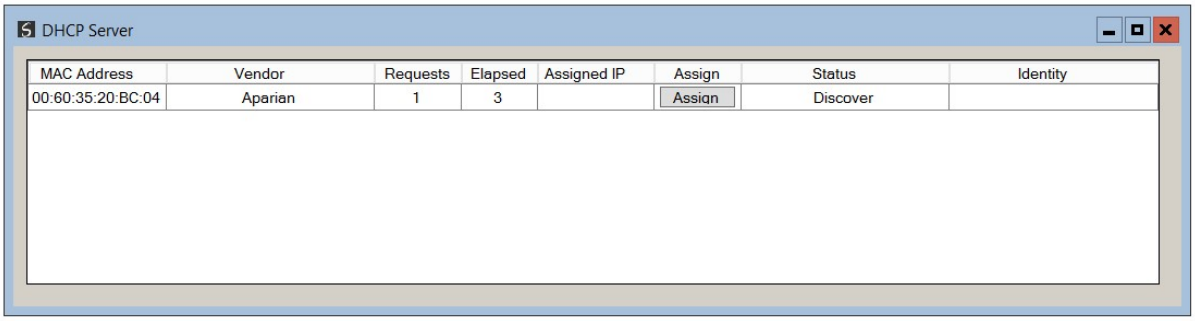


Figure 3.3. - DHCP Server

NOTE: If the DHCP requests are not displayed in the DHCP Server it may be due to the local PC's firewall. During installation the necessary firewall rules are automatically created for the Windows firewall. Another possibility is that another DHCP Server is operational on the network and it has assigned the IP address.

To assign an IP address, click on the corresponding "Assign" button. The IP Address Assignment window will open.

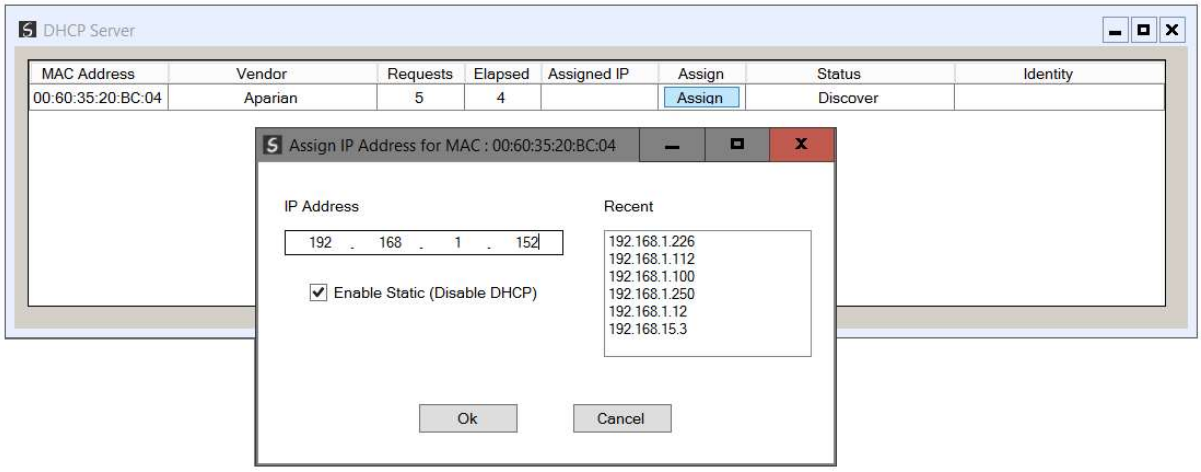


Figure 3.4. - Assigning IP Address

The required IP address can then be either entered, or a recently used IP address can be selected by clicking on an item in the Recent List. If the "Enable Static" checkbox is checked, then the IP address will be set to static after the IP assignment, thereby disabling future DHCP requests.

Once the IP address window has been accepted, the DHCP server will automatically assign the IP address to the module and then read the Identity object Product name from the device.

The successful assignment of the IP address by the device is indicated by the green background of the associated row.

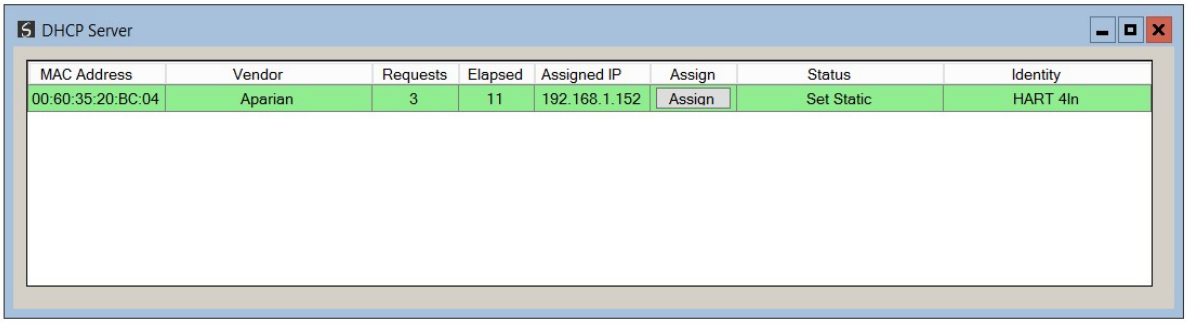


Figure 3.5. - Successful IP address assignment

It is possible to force the module back into DHCP mode by powering up the device with DIP switch 2 set to the On position.
A new IP address can then be assigned by repeating the previous steps.

NOTE: It is important to return DIP switch 2 back to Off position, to avoid the module returning to a DHCP mode after the power is cycled again.

If the module's DIP switch 2 is in the On position during the address assignment, the user will be warned by the following message.



Figure 3.6. - Force DHCP warning

In addition to the setting the IP address, a number of other network parameters can be set during the DHCP process. These settings can be viewed and edited in Slate's Application Settings, in the DHCP Server tab.

Once the DHCP process has been completed, the network settings can be set using the Ethernet Port Configuration via the Target Browser. The Target Browser can be accessed under the Tools menu.

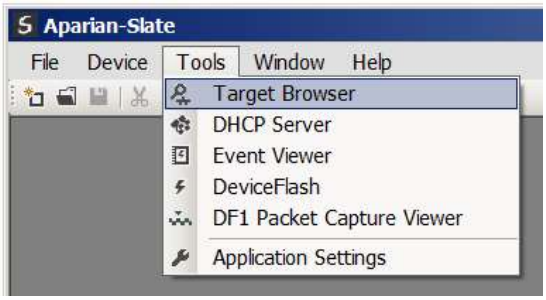


Figure 3.7. - Selecting the Target Browser

The Target Browser automatically scans the Ethernet network for EtherNet/IP devices.

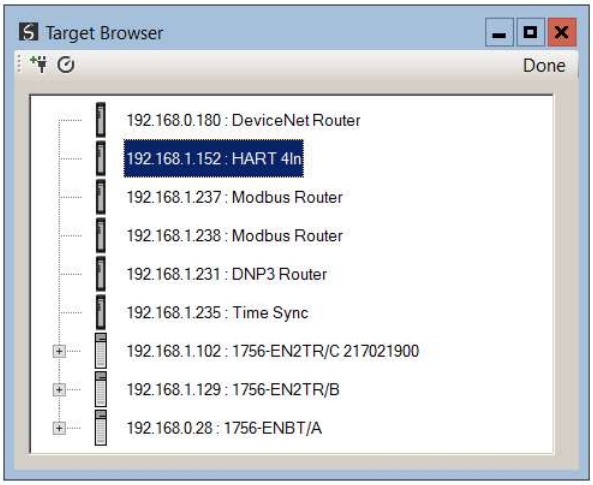


Figure 3.8. - Target Browser

Right-clicking on a device, reveals the context menu, including the Port Configuration option.

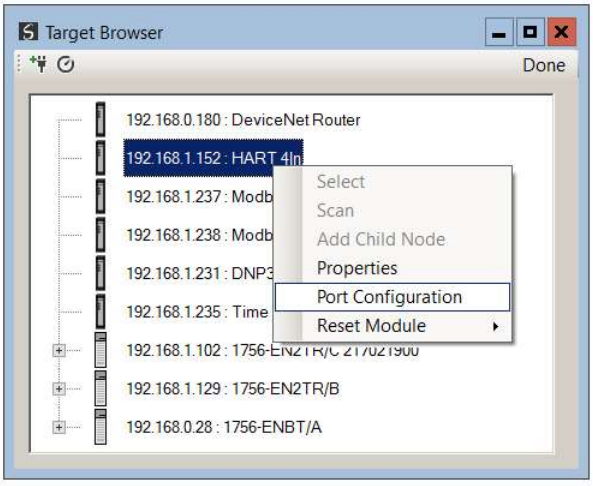


Figure 3.9. - Selecting Port Configuration

All the relevant Ethernet port configuration parameters can be modified using the Port

Configuration window.

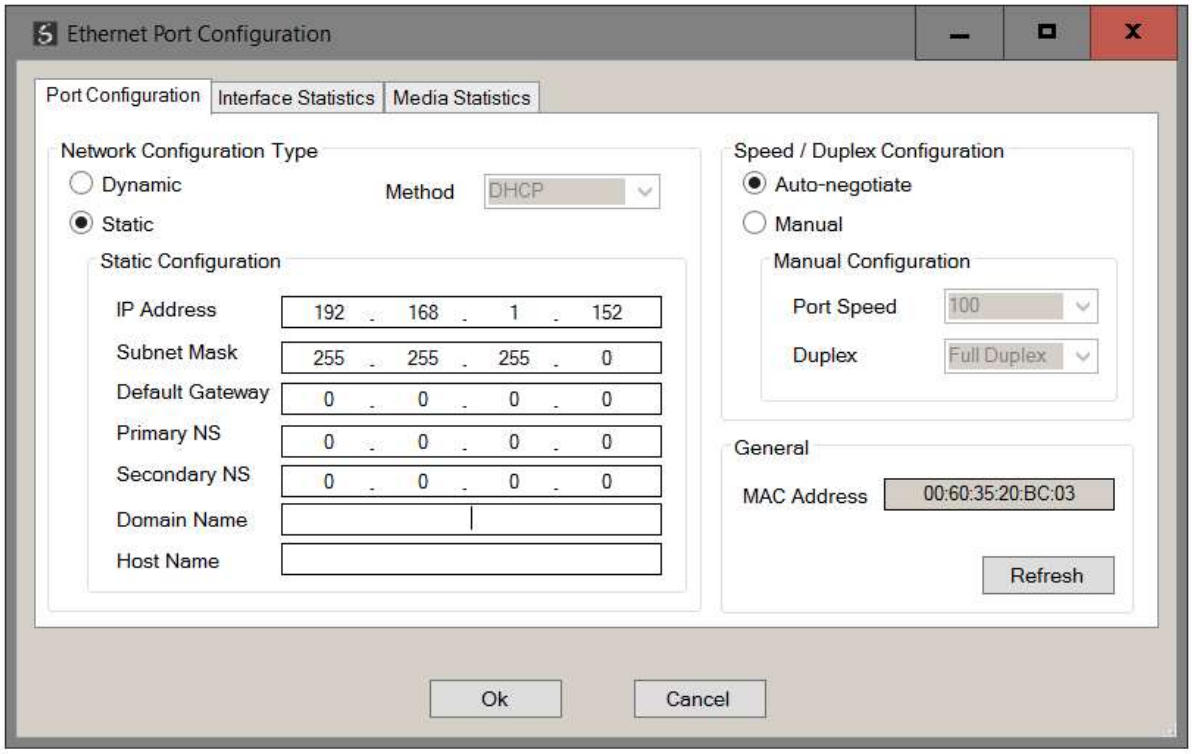


Figure 3.10. - Port Configuration

Alternatively, these parameters can be modified using Rockwell Automation's RSLinx software.

3.3. CREATING A NEW PROJECT

Before the user can configure the module, a new Slate project must be created. Under the File menu, select New.

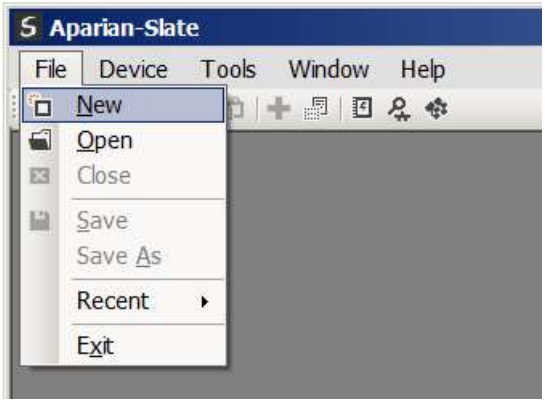


Figure 3.11. - Creating a new project

A Slate project will be created, showing the Project Explorer tree view. To save the project use the Save option under the File menu. A new device can now be added by selecting Add under the Device menu.

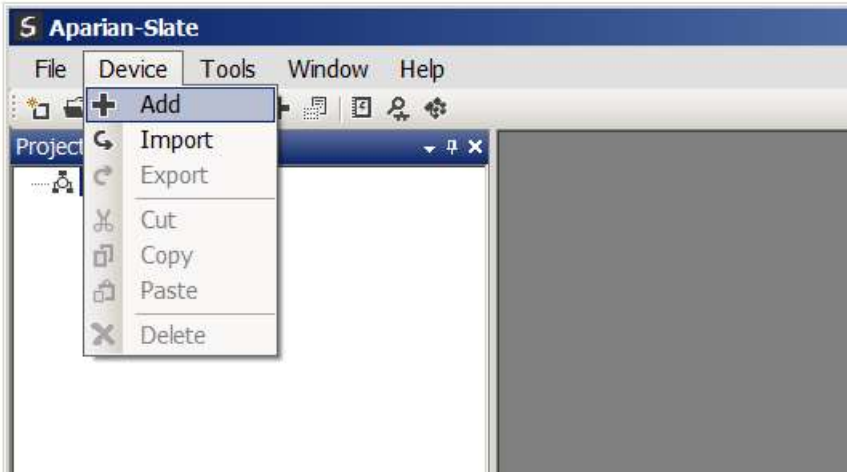


Figure 3.12. - Adding a new device

In the Add New Device window select the HART 4In or HART 4Out module and click the Ok button. The configuration of the HART 4In and HART 4Out modules are almost identical and the two modules will be referred to as the HART 4 module from here on.

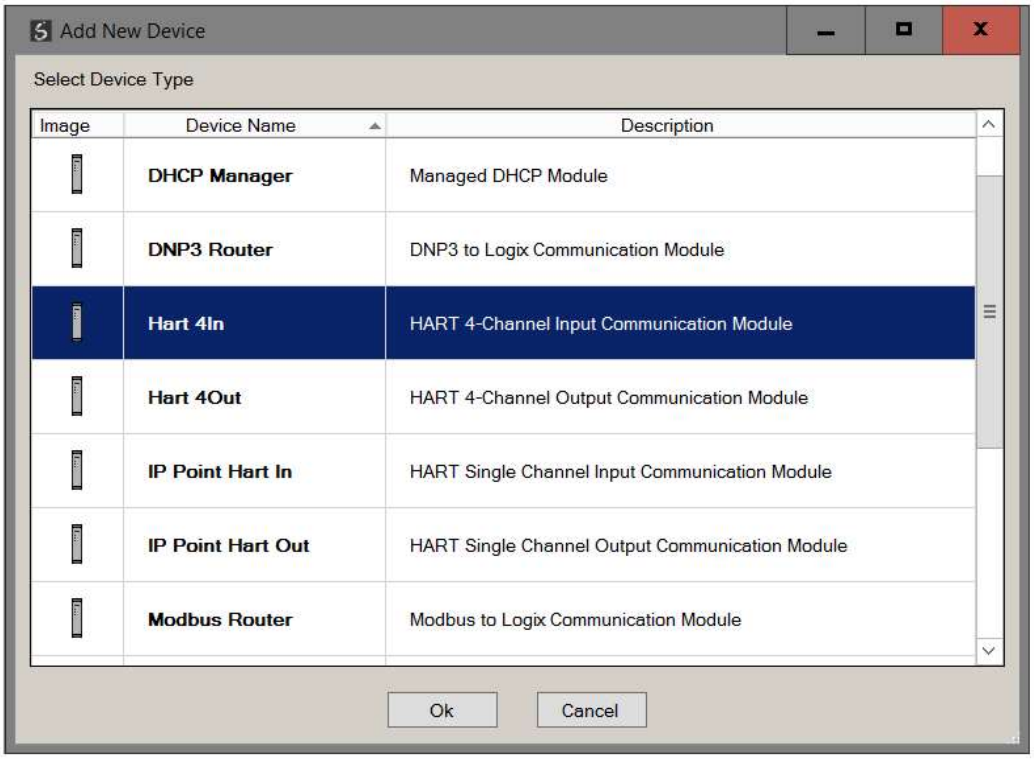


Figure 3.13 – Selecting a new HART 4 module

The device will appear in the Project Explorer tree as shown below, and its configuration

window opened. The device configuration window can be reopened by either double clicking the module in the Project Explorer tree or right-clicking the module and selecting *Configuration*.

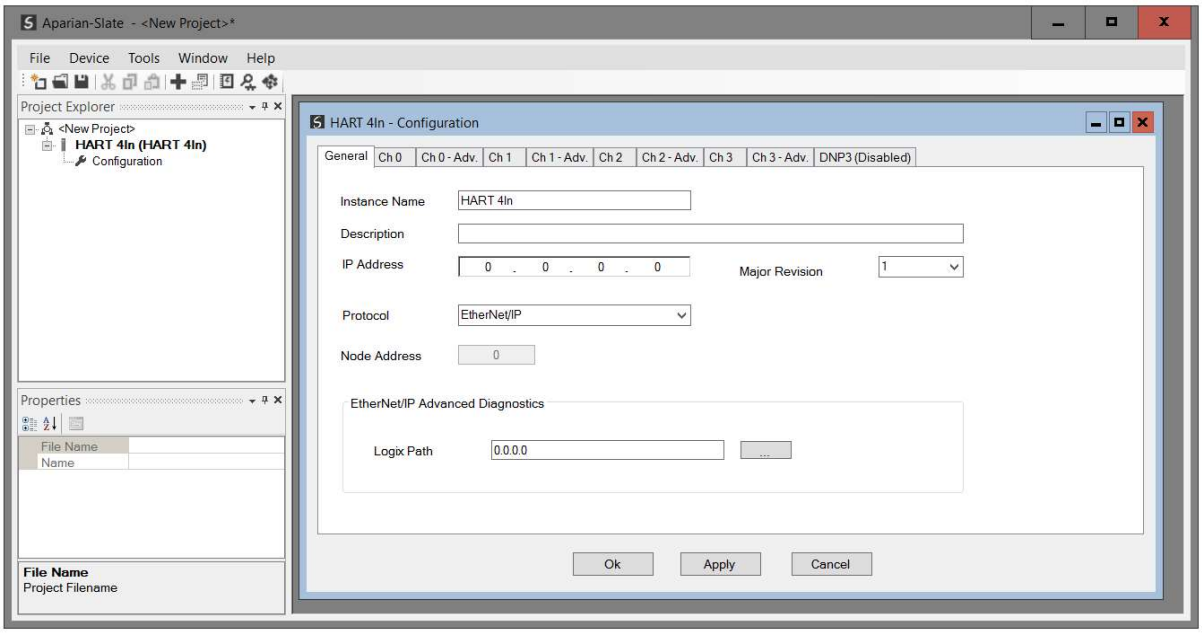


Figure 3.14. – HART 4In module configuration

Refer to the additional information section in this document for Slate's installation and operation documentation.

3.4. HART 4 PARAMETERS

The HART 4 module parameters are configured using the Slate configuration utility. The configuration form is divided into multiple tabs to configure the general, DNP3 and channel specific parameters.

When downloading this configuration into the module it will be saved in non-volatile memory that persists when the module is powered down.

NOTE: When a firmware upgrade is performed the module will clear all HART 4 configuration.

The general configuration consists of the following parameters:

Parameter	Description
Instance Name	This parameter is a user defined name to identify between various HART 4 modules.

Description	This parameter is used to provide a more detail description of the application for the module.
IP Address	The IP address of the target module
Major Revision	The major revision of the module
Protocol	There are four protocols that can be selected for the HART 4 module. **EtherNet/IP** This is the default setting and should be selected when the module is being used with the Rockwell Automation Logix family of controllers. **Modbus TCP** When selected, the device will respond as a Modbus TCP slave. **DNP3 TCP** When selected, the device will respond as a DNP3 Outstation using a TCP. **DNP3 UDP** When selected, the device will respond as a DNP3 Outstation using a UDP.
Node Address	The Modbus/DNP3 node address of the device. Valid only when Modbus TCP or DNP3 TCP/UDP protocol has been selected.
Logix Path	The destination Logix path to where the Advanced Diagnostics will be written.

Table 3.1 - General configuration parameters

The general configuration is shown in the figure below. The HART 4 general configuration window is opened by either double clicking on the module in the tree or right-clicking the module and selecting *Configuration*.

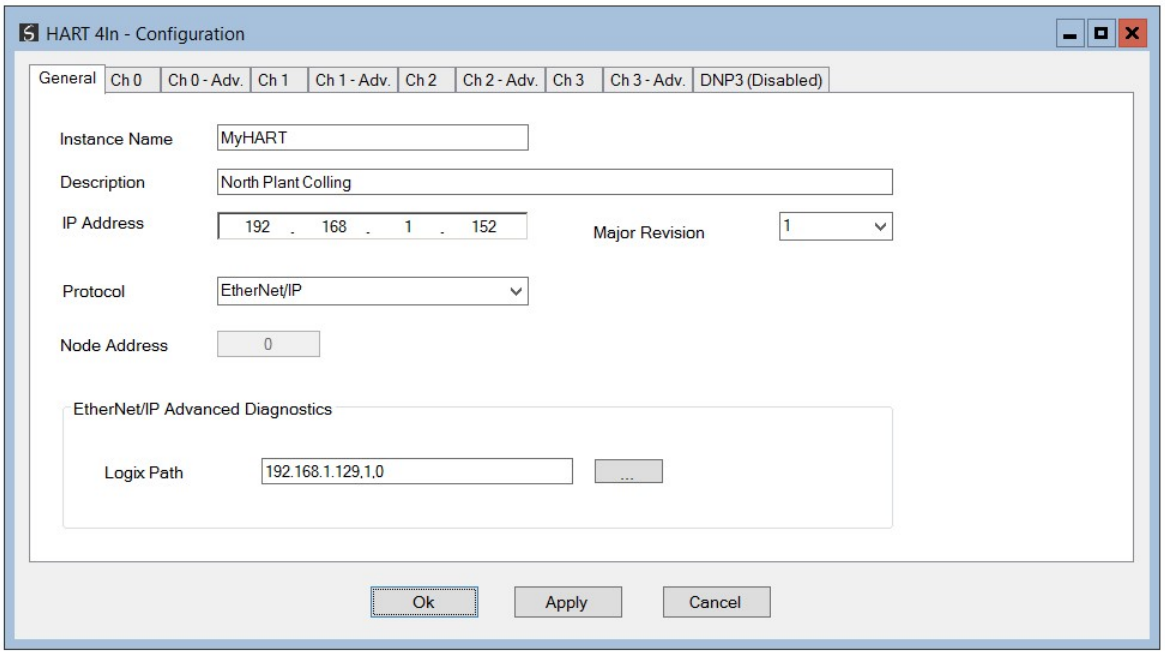


Figure 3.15. - General Configuration

Each of the channel configuration tabs consist of the following parameters:

Parameter	Description
Enable Channel	Used to Enable or Disable the entire analog channel.
Signal	
Range	Select either 4-20mA or 0-20mA. Note that HART communication will be disabled if the 0-20mA range has been selected.
Raw Max	The upper milliamp value to be used for the scaling to engineering units. The scaling to engineering units (EU) is calculated as follows: EU = EUMin + (RawValue – RawMin) * ((EUMax – EUMin) / (RawMax – RawMin))
Raw Min	The lower milliamp value to be used for the scaling to engineering units.
EU Max	The upper engineering value to be used for the scaling to engineering units. The scaled engineering value will equal this value when the current is equal to the Raw Max value.
EU Min	The lower engineering value to be used for the scaling to engineering units. The scaled engineering value will equal this value when the current is equal to the Raw Min value.
Filter	The time constant, in milliseconds, of the first order filter applied to the analog signal. A value of zero implies no filtering.
HART Communications	
Enable HART	Used to Enable or Disable the HART Communication. This should be disabled when using standard (non-HART) analog field devices.
Enable Relay Messages	Used to enable or disable pass through (Class 2) messages, either from Logix (message blocks) or DTMs.
PV Update Rate	The rate at which the HART process variables (PV, SV, TV and FV) are updated. Select from: • Fast (As fast as possible) • 1 second • 2 seconds • 5 seconds • 10 seconds Slowing this rate can enhance the performance of DTM communications. Care must be taken to not adversely affect the primary control.
Adv. Diag. Ratio	The number of process variable updates, between Advanced Diagnostic updates.
Fixed HART Address	The user can fix the address which the HART module will use to communicate with the attached field device. When this is not enable the HART module will search for the device from node address 0 to 63. **NOTE:** This is used with multidrop architecture.
Trend Defaults	

Source	The default source of the trend data can be one of the following: Raw Analog Current - The raw analog signal in milliamps. Filtered Scaled Value – The analog signal in engineering units. Digital Current – The current in milliamps reported by the field device (HART). PV – The Primary Variable in engineering units reported via HART. SV – The Secondary Variable in engineering units reported via HART. TV – The Third Variable in engineering units reported via HART. FV – The Fourth Variable in engineering units reported via HART.
Sample Rate	The period (milliseconds) between sample points. The trend data is a circular buffer of the latest 1000 points, therefore the total trend time is 1000 * Sample Rate.
Note: The following items apply only to the HART 4Out module. ***Fail Mode***	
Prog / Fault Freeze	This configuration is used to determine the behaviour of the output analog signal when the Logix controller enters a faulted or program mode. Enabling this option freezes the output value to its last state, when a program or fault state is detected. Disabling this option forces the output value to the adjacent Fail Value, when a program or fault state is detected. This option is only valid when using the EtherNet/IP protocol.
Fail Value (Prog. / Fault)	The value, in engineering units, to be applied to the output when a program or fault state is detected and the above Freeze option is disabled.
Comm Fail Freeze	This configuration is used to determine the behaviour of the output analog signal when communication from the source (EtherNet/IP, DNP3 or Modbus) is lost. Enabling this option freezes the output value to its last state, when communication is lost. Disabling this option forces the output value to the adjacent Fail Value when communication is lost.
Fail Value (Comm. Fail)	The value, in engineering units, to be applied to the output when communication from the source has been lost and the above Freeze option is disabled.
Time Out	The time, in milliseconds, since the last packet has been received from the source, before the communication is deemed to have been lost.

Table 3.2 - Channel configuration parameters

The Channel (0) configuration is shown in the figure below. This window is opened by either double clicking on the module in the tree or right-clicking the module followed by selecting *Configuration.* Once in the configuration window select the tab corresponding to the required channel.

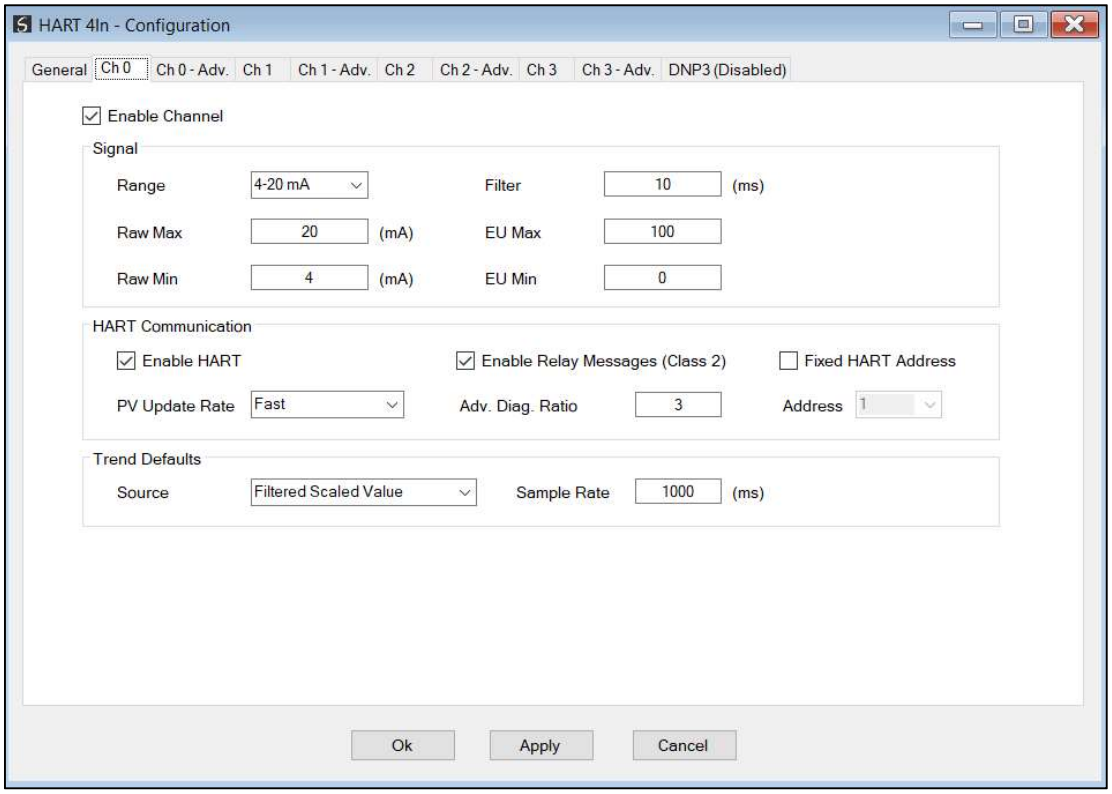


Figure 3.16 - Channel configuration (HART 4In)

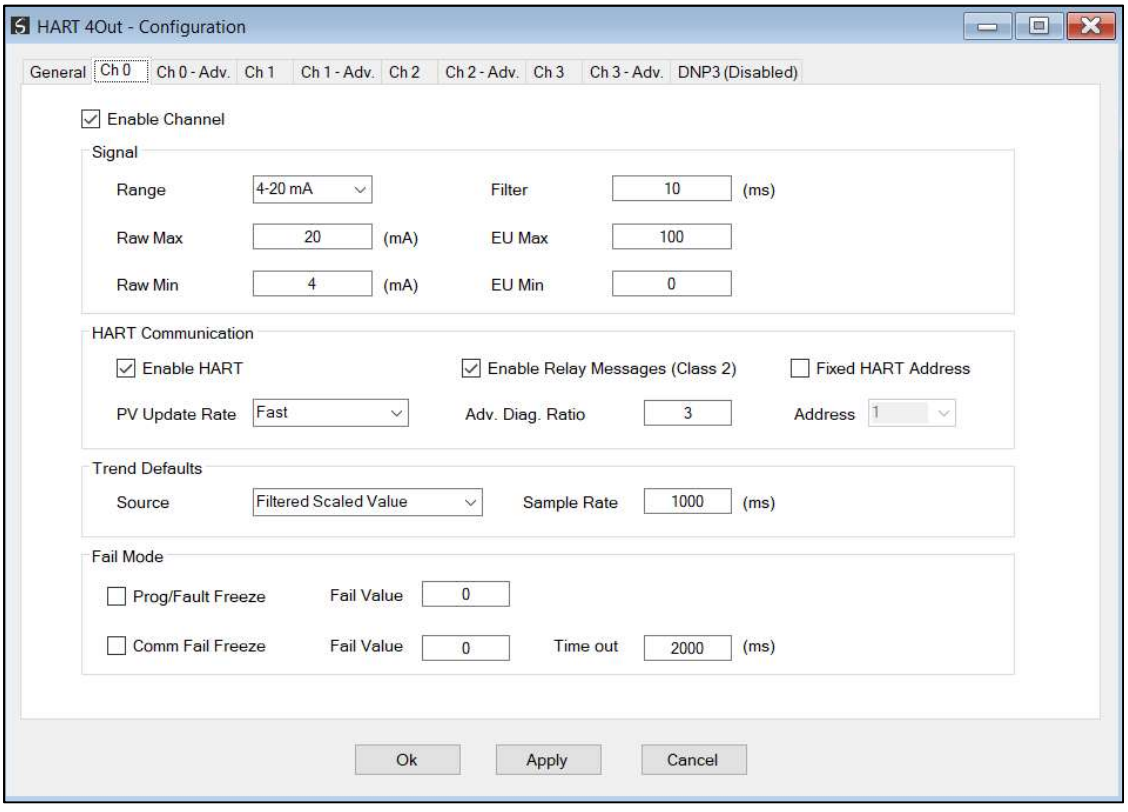


Figure 3.17 - Channel configuration (HART 4Out)

The module supports the asynchronous reading of advanced diagnostic parameters, which are then written directly to Logix tags. The Advanced Diagnostics configuration tab consists of a table comprising the following parameters:

Parameter	Description
Description	A user description for the advanced diagnostic parameter.
Command	The command string used to collect the parameter. (See Advanced Diagnostic Builder below.)
Data Type	The Logix tag data type required to accept the parameter.
Logix Tag	The Logix tag name mapped to receive the parameter.

Table 3.3 – Advanced Diagnostics parameters

The Advanced Diagnostic configuration is shown in the figure below. The IP Point HART Advanced Diagnostic configuration window is opened by either double clicking on the module in the tree or right-clicking the module and selecting Ch 0 - *Adv*.

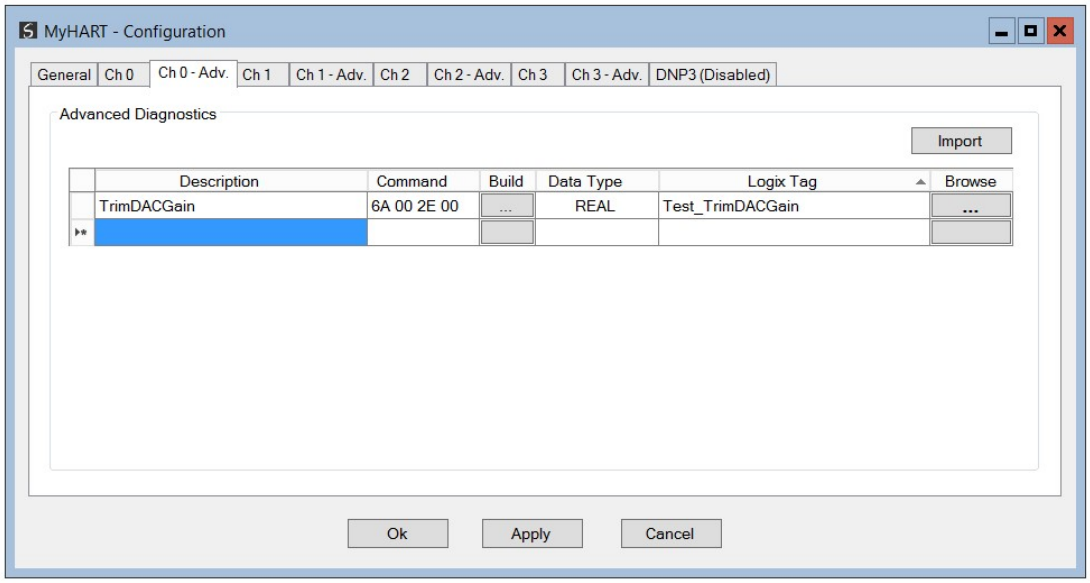


Figure 3.18. – Advanced Diagnostic Configuration

To create a new Advanced Diagnostic item, select the Build button. The HART Advanced Diagnostic Builder will open.

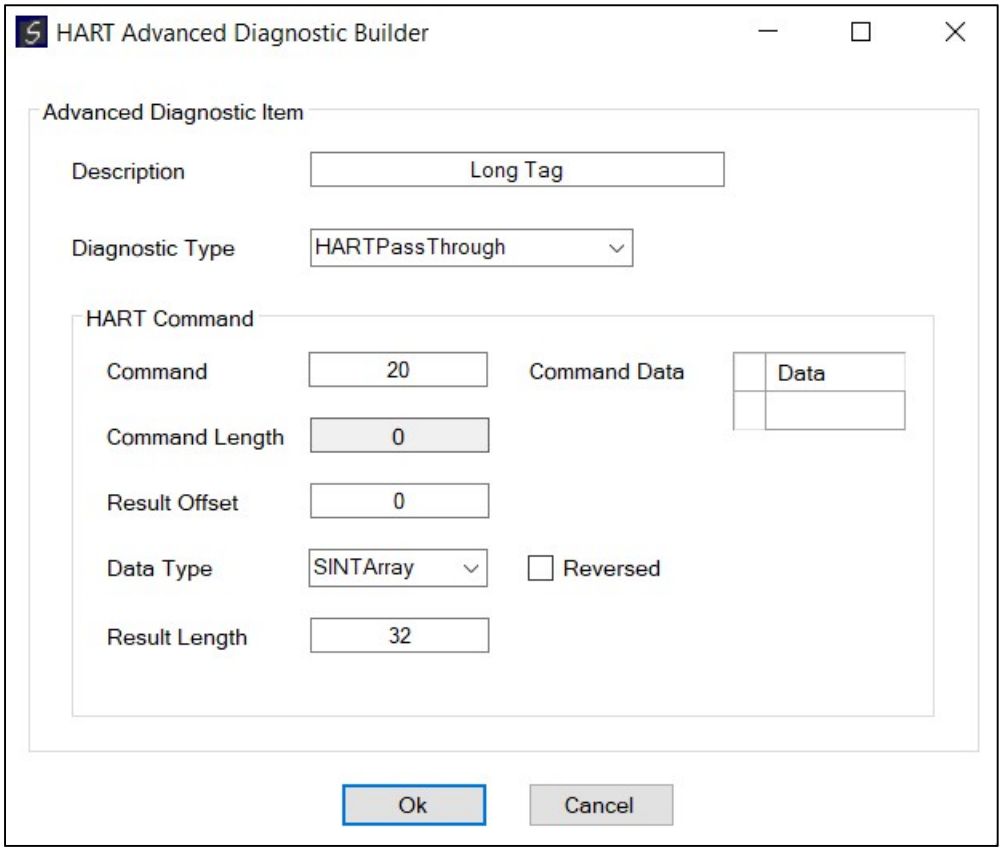


Figure 3.19. – Advanced Diagnostic Builder

The builder is used to generate the command, and to define the Data Type. The following parameters need to be defined:

Parameter	Description
Description	A user description for the advanced diagnostic parameter.
Diagnostic Type	Select ***HART Pass Through*** option.
HART Command	The HART command code. (decimal)
Command Length	This is the length of the data that must be sent with the command.
Result Offset	The byte offset in the response where the required parameter starts.
Data Type	The Logix tag data type required to accept the parameter.
Response Length	This is the size of the data that must be copied to the Logix Tag. **NOTE:** This is only relevant for SINT Array Data Types.
Command Data	Additional request parameters required by the HART command.

Table 3.4 – Advanced Diagnostics Build parameters

Once accepted, the full command string will be built, and the current map item will be

populated accordingly.

A Logix tag can now be associated with the Advanced Diagnostic parameter. This can be done by either entering the tag name or by using the Tag Browser to browse for a tag.

NOTE: It is important to ensure that the selected Logix tag type matches that of the expected HART command parameter. Failing to do so can cause unexpected results.

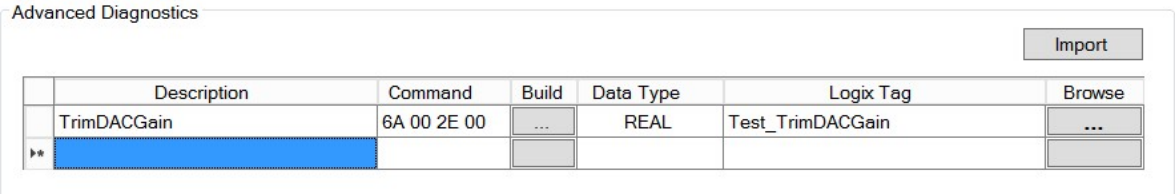


Figure 3.20. – Complete Advanced Diagnostic item

If one of the DNP3 protocols (DNP3 TCP or DNP3 UDP) have been selected, then the DNP3 Security tab will be enabled. This DNP3 Security configuration consists of the following parameters:

Parameter	Description
Enable Security	DNP3 Secure Authentication can be enabled or disabled. When enabled there will be no unsecured exchange of data (for critical functions).
Key Change Method	This setting determines the method by which security keys are exchanged between two devices. Currently the HART 4 only supports the Pre-Shared Key method. This method requires both devices to have update keys entered by means outside the DNP3 protocol, (i.e. using Slate).
MAC Algorithm	The MAC algorithm is used to encrypt the challenge data for secure authentication. DNP3 allows for various encryption standards in different formats to be used for secure authentication: HMAC SHA-1 encryption (4 octets – serial) – for legacy support HMAC SHA-1 encryption (8 octets – serial) HMAC SHA-1 encryption (10 octets – networked) HMAC SHA-256 encryption (8 octets – serial) HMAC SHA-256 encryption (16 octets – networked) AES-GMAC (12 octets)
Key Wrap Algorithm	DNP3 uses various keys for secure authentication. The keys that are used for data exchange and called the session keys and these keys may be updated frequently. To exchange the session keys between two DNP3 devices the update key (refer to the Secure Authentication section for further detail) is used to encrypt the data and session keys before exchanging it between parties. DNP3 allows for two standards to encrypt the session keys:

	AES-128 Key Wrap AES-256 Key Wrap
Aggressive Mode	To reduce the bandwidth used for secure authentication the user can select aggressive mode which allows the message initiator to anticipate and provide the required authentication in the request message. Thus from a network point of view there is a two message exchange for secure authentication compared to the normal four message exchange for secure authentication.
Secure Optional Critical Functions	When secure authentication is enabled there are various mandatory and optional application functions that must be authenticated before data can be exchanged. The optional functions can be selected in the box. Mandatory functions, e.g. Operate, are therefore not included in the options list.

Table 3.3 – DNP3 configuration parameters

NOTE: For further information regarding the security settings refer to the Security section.

The security configuration is shown in the figure below. The DNP3 Security configuration window is opened by either double clicking on the module in the tree or right-clicking the module and selecting *Configuration.* Once in the configuration window select the *DNP3* tab at the top.

NOTE: The actual pre-shared key cannot be included in the configuration. It can only be written to the HART 4 module when online via the Status window.

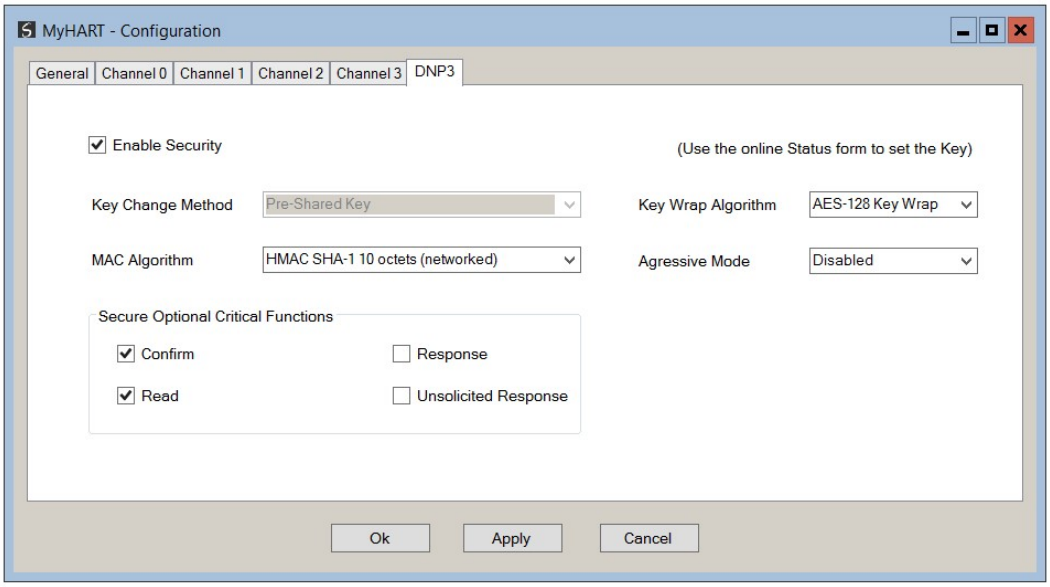


Figure 3.21 – DNP3 security configuration

3.5. MODULE DOWNLOAD

Once the HART 4 module configuration has been completed, it must be downloaded to the module.

Before downloading the Connection Path of the module should be set. This path will automatically default to the IP address of the module, as set in the module configuration. It can however be modified, if the HART 4 module is not on a local network.

The Connection path can be set by right-clicking on the module and selecting the Connection Path option.

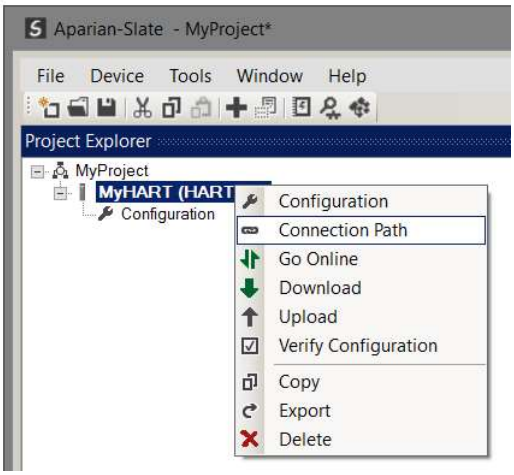


Figure 3.22. - Selecting Connection Path

The new connection path can then be either entered manually or selected by means of the Target Browser.

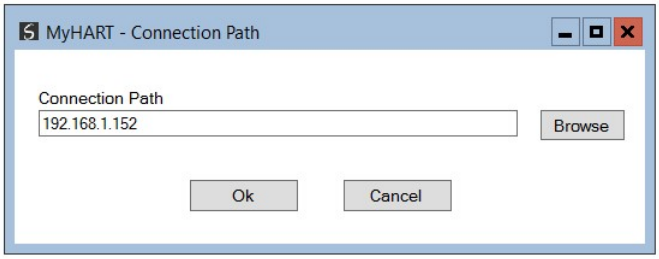


Figure 3.23. - Connection Path

To initiate the download, right-click on the module and select the Download option.

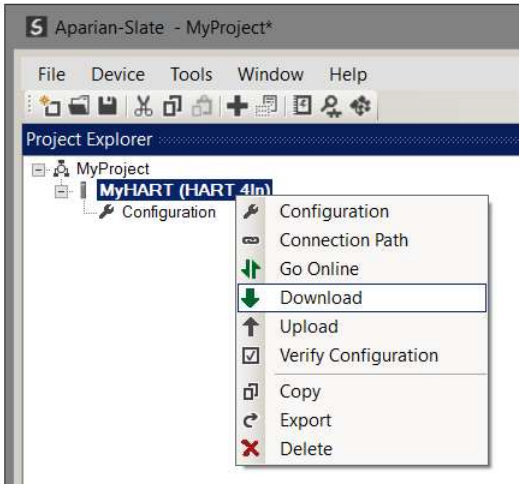


Figure 3.24. - Selecting Download

Once complete, the user will be notified that the download was successful.



Figure 3.25. - Successful download

Within the Slate environment the module will be in the Online state, indicated by the green circle around the module. The module is now configured and will start operating immediately.

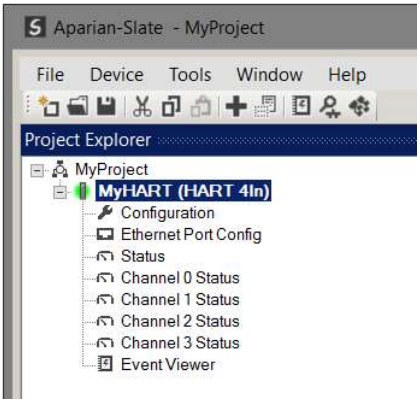


Figure 3.26. - Module online

3.6. LOGIX INTEGRATION

The Hart4 modules can be easily integrated with Allen-Bradley Logix family of controllers. The module must be added using a Generic Profile which is described below.

3.6.1. ADD MODULE TO I/O CONFIGURATION

The HART 4 module must be added to the RSLogix 5000 I/O tree as a generic Ethernet module. This is achieved by right clicking on the Ethernet Bridge in the RSLogix 5000 and selecting *New Module* after which the *ETHERNET-MODULE* is selected to be added as shown in the figure below.

NOTE: See the next section for importing the configuration (L5X).

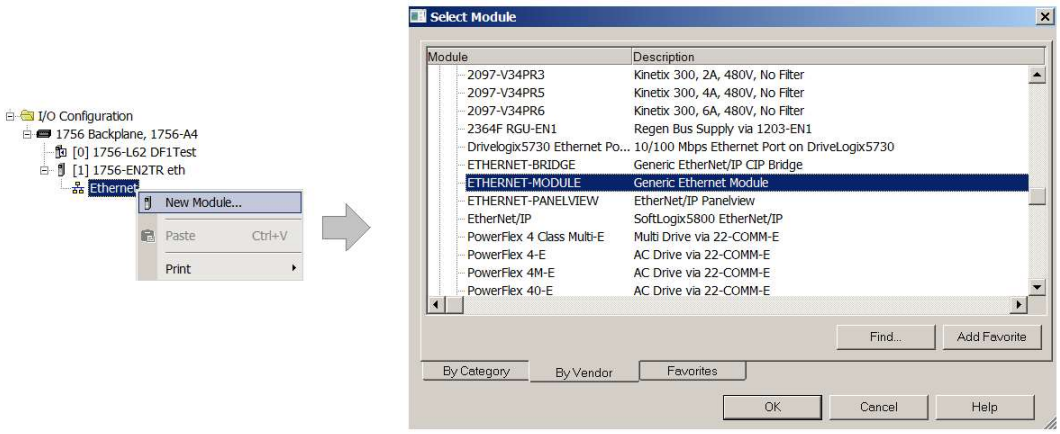


Figure 3.27 - Add a Generic Ethernet Module in RSLogix 5000

NOTE: The module configuration for the HART 4In and HART 4Out modules are not identical.

The user must enter the IP address of the HART 4 module that will be used. The assembly instance and size must also be added for the input, output, and configuration in the connection parameters section. The required connection parameters for the HART 4In module are shown below:

Connection Parameter	Assembly Instance	Size
Input	113	119 (32-bit)
Output	116	1 (32-bit)
Configuration	102	0 (8-bit)

Table 3.4 - RSLogix class 1 connection parameters for the **HART 4In** module

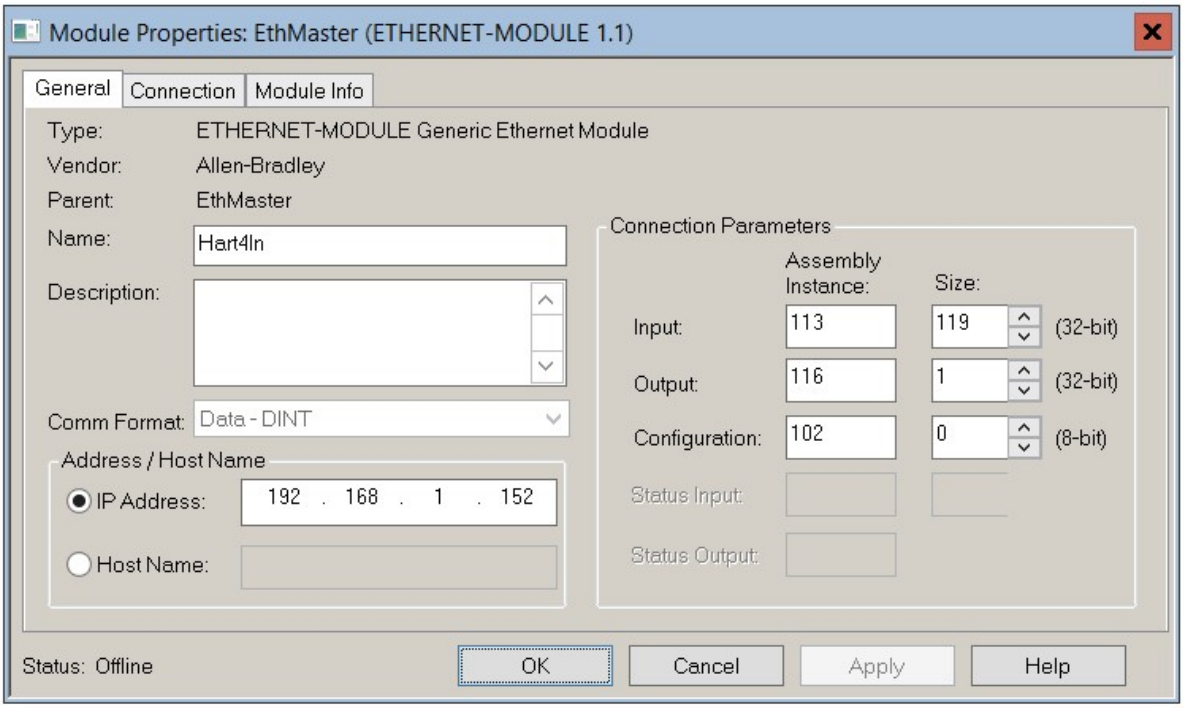


Figure 3.28 - RSLogix 5000 General module properties for **HART 4In** module

The required connection parameters for the HART 4Out module are shown below:

Connection Parameter	**Assembly Instance**	**Size**
Input	113	119 (32-bit)
Output	115	4 (32-bit)
Configuration	102	0 (8-bit)

Table 3.5 - RSLogix class 1 connection parameters for the **HART 4Out** module

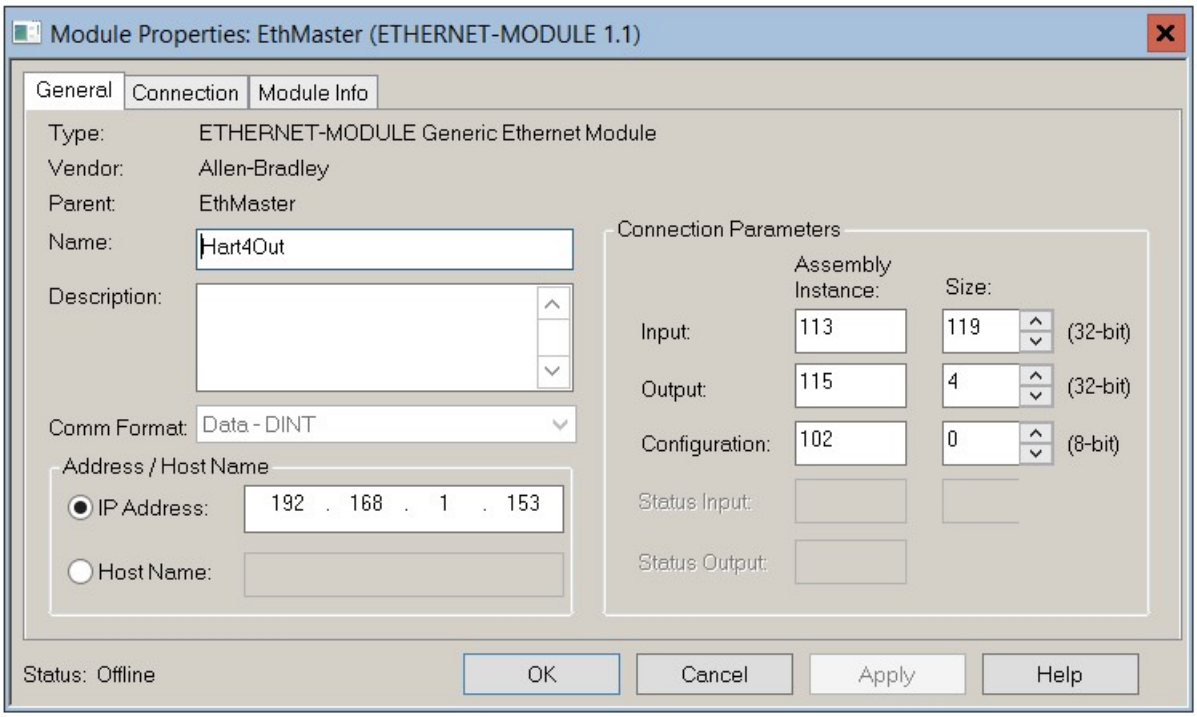


Figure 3.29 - RSLogix 5000 General module properties for **HART 4Out** module

NOTE: The user will need to enter the exact connection parameters before the module will establish a class 1 connection with the Logix controller.

Next the user needs to add the connection requested packet interval (RPI). This is the rate at which the input and output assemblies are exchanged. The recommended value is 200ms. Refer to the technical specification section in this document for further details on the limits of the RPI.

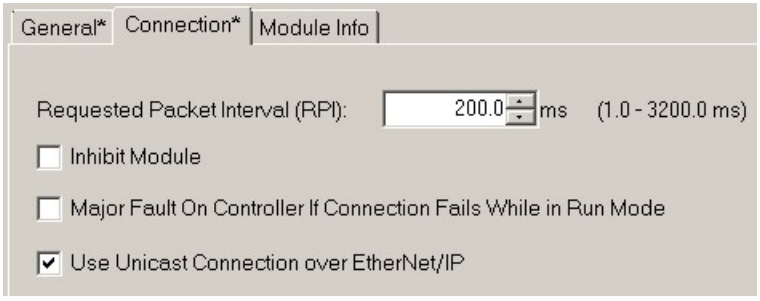


Figure 3.30 - Connection module properties in RSLogix 5000

Once the module has been added to the RSLogix 5000 I/O tree the user must assign the User Defined Types (UDTs) to the input and output assemblies. The user can import the required UDTs by right-clicking on *User-Defined* sub-folder in the *Data Types* folder of the I/O tree and selecting *Import Data Type*. The assemblies are then assigned to the UDTs with a ladder copy instruction (COP) as shown in the figure below.

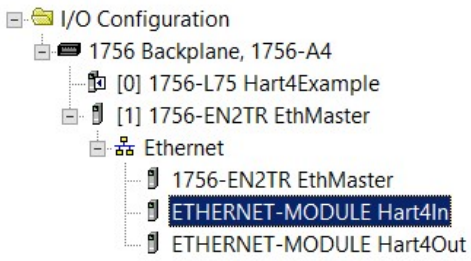


Figure 3.31 – RSLogix 5000 I/O module tree

3.6.2. IMPORTING UDTS AND MAPPING ROUTINES

To simplify the mapping of the input image, an RSLogix 5000 Routine Partial Import (L5X) file is provided. This file can be imported by right-clicking on the required Program and selecting the Import Routine option.

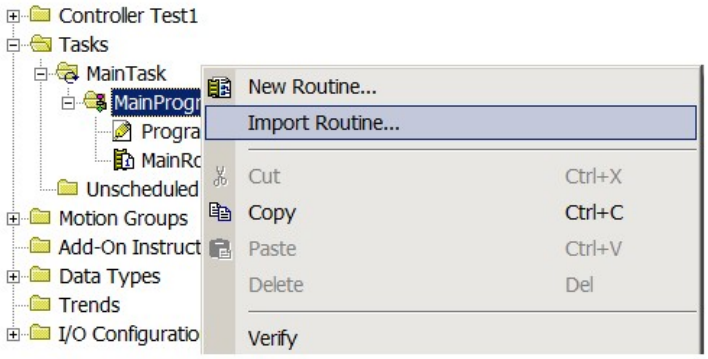


Figure 3.32. – RSLogix 5000 Importing HART 4 module specific routine and UDTs

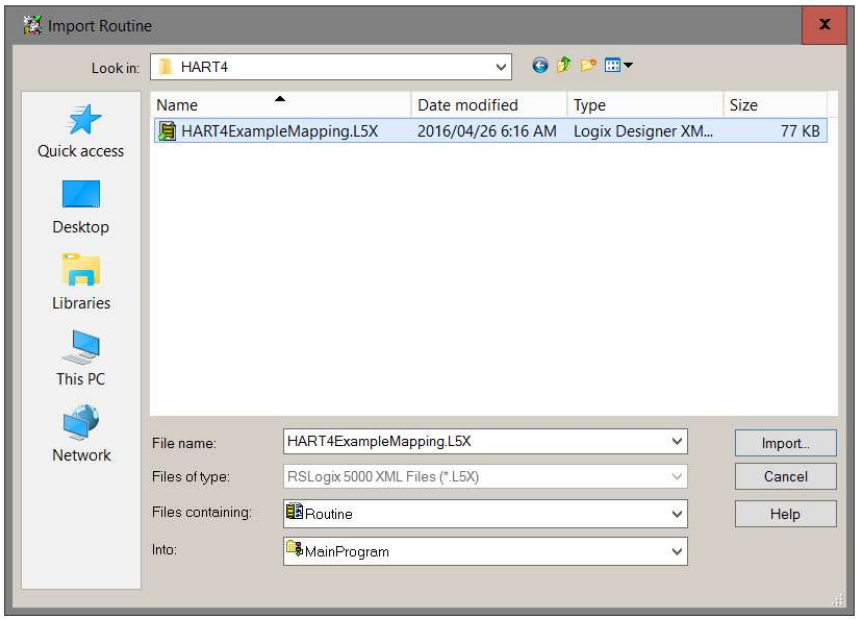


Figure 3.33. - Selecting partial import file

The import will create the following:

- The required UDTs (user defined data types)
- Controller tags representing the Input and Output assemblies.
- A routine mapping the HART4In and HART4Out modules to the aforementioned tags.

The user may need to change the routine to map to the correct HART-4 module instance name, and make sure that the mapping routine is called by the Program's Main Routine.

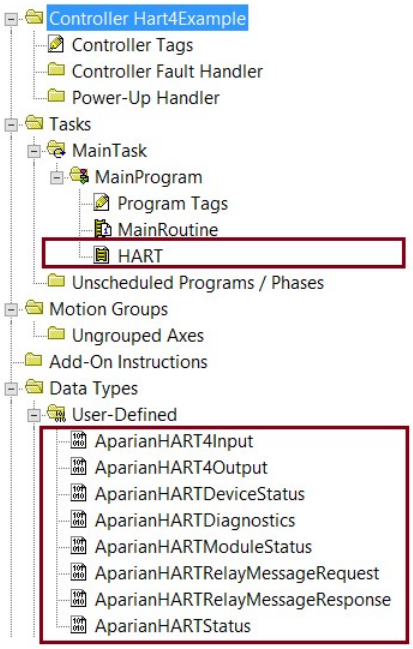


Figure 3.34. - Imported RSLogix 5000 objects

Refer to the additional information section of this document for an example RSLogix 5000 project as well as the required UDTs.

Name	Value	Style	Data Type
Hart4In_I	{...}		AparianHART4Input
Hart4In_I.Instance	''		AparianSTRING16
Hart4In_I.Status	{...}		AparianHARTModuleStatus
Hart4In_I.Temperature	0.0	Float	REAL
Hart4In_I.Ch0_ManufacturerID	0	Decimal	SINT
Hart4In_I.Ch0_ManufacturerDeviceType	0	Decimal	SINT
Hart4In_I.Ch0_DeviceID	0	Decimal	DINT
Hart4In_I.Ch0_Tag	''		AparianSTRING8
Hart4In_I.Ch0_Descriptor	''		AparianSTRING16
Hart4In_I.Ch0_DeviceStatus	{...}		AparianHARTDeviceStatus
Hart4In_I.Ch0_DeviceStatus.LoopOpen	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.CurrentUnderrange	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.CurrentOverrange	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.LoopShorted	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.CalibrationBusy	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.CalibrationFaulted	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.HARTCommsFault	0	Decimal	BOOL
Hart4In_I.Ch0_DeviceStatus.RelayMessagesInhibited	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus	{...}		AparianHARTStatus
Hart4In_I.Ch0_HARTStatus.ParityError	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.OverrunError	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.FramingError	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.ChecksumError	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.RxBufferOverflow	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.ValueTooLarge	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.ValueTooSmall	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.NotEnoughBytesInCommand	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.TransmitterSpecificCmdError	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.InWriteProtectMode	0	Decimal	BOOL
Hart4In_I.Ch0_HARTStatus.UpdateFailed	0	Decimal	BOOL

Figure 3.35. – UDT Input Assembly

4. OPERATION

Once the HART 4 module has been configured it will exchange HART information between the HART field device and a Logix controller, DNP3 Master or Modbus TCP master.

4.1. LOGIX 5000

When the module operates in a Logix “owned” mode the Logix controller will establish a class 1 cyclic communication connection with the HART 4 module. An input and output assembly is exchanged at a fix interval.

4.1.1. INPUT ASSEMBLY

The following parameters are used in the input assembly of the HART 4In and HART 4Out modules.

Parameter	Datatype	Description
Instance	STRING	The instance name of the module that was configured under the general HART 4 module configuration in Slate.
Temperature	REAL	The internal temperature of the module in °C.
Module Status	DINT	Bit 0 – Configuration Valid Bit 1 – Channel 0 Enabled Bit 2 – Channel 1 Enabled Bit 3 – Channel 2 Enabled Bit 4 – Channel 3 Enabled Bit 5 – Channel 0 HART Enabled Bit 6 – Channel 1 HART Enabled Bit 7 – Channel 2 HART Enabled Bit 8 – Channel 3 HART Enabled
Channel Data The next section is repeated for each of the 4 channels. Where x represents the channel number (0-3).		
Chx_ManufacturerID	SINT	The unique manufacturer identification code.
Chx_ManufacturerDeviceType	SINT	The device type code specified by the manufacturer.
Chx_DeviceID	DINT	The device identification code specified by the manufacturer.
Chx_Tag	STRING8	Tag name of the field device.
Chx_Descriptor	STRING16	Descriptor of the field device.
Chx_DeviceStatus	SINT	Device Status comprising the following bits:

Chx_DeviceStatus.LoopOpen	BOOL	Loop open circuit detected. (Current < 3.6 mA)
Chx_DeviceStatus.CurrentUnderrange	BOOL	Loop current under range. (Current < 3.8 mA)
Chx_DeviceStatus.CurrentOverrange	BOOL	Loop current over range. (Current > 20.5 mA)
Chx_DeviceStatus.LoopShorted	BOOL	Loop short circuit detected. (Current > 21.0 mA)
Chx_DeviceStatus.CalibrationBusy	BOOL	Analog current calibration busy.
Chx_DeviceStatus.CalibrationFaulted	BOOL	Analog calibration failed.
Chx_DeviceStatus.HARTCommsFault	BOOL	HART communication failure.
Chx_DeviceStatus.RelayMessagesInhibited	BOOL	Relay HART messages inhibited, as set in configuration. This will prevent DTM and other class 2 communications.
Chx_HARTStatus	DINT	HART Status information as reported by field device.
Chx_HARTStatus.ParityError	BOOL	Parity error detected by field device.
Chx_HARTStatus.OverrunError	BOOL	Field device buffer overrun.
Chx_HARTStatus.FramingError	BOOL	HART Framing error detected by field device.
Chx_HARTStatus.ChecksumError	BOOL	Checksum error detected by field device.
Chx_HARTStatus.RxBufferOverflow	BOOL	Field device receive buffer overflow.
Chx_HARTStatus.ValueTooLarge	BOOL	Value too large in previous HART command.
Chx_HARTStatus.ValueTooSmall	BOOL	Value too small in previous HART command.
Chx_HARTStatus.NotEnoughBytesInCommand	BOOL	Insufficient bytes in previous HART command.
Chx_HARTStatus.TransmitterSpecificCmdError	BOOL	Specific error in previous HART command.
Chx_HARTStatus.InWriteProtectMode	BOOL	Previous command rejected due to field device being in Write-Protect mode.
Chx_HARTStatus.UpdateFailed	BOOL	Previous parameter update failed.
Chx_HARTStatus.AppliedProcessTooHigh	BOOL	Applied process too high or out of range.
Chx_HARTStatus.AppliedProcessTooLow	BOOL	Applied process too low or out of range.
Chx_HARTStatus.InMultidropMode	BOOL	Field device current in multi-drop mode.
Chx_HARTStatus.InvalidUnitCode	BOOL	Invalid unit code received in command.
Chx_HARTStatus.BothRangeValuesOutOfLimits	BOOL	Configured range units out of range.
Chx_HARTStatus.PushedUpperRangeValueOverLimit	BOOL	Upper range out of limits.
Chx_HARTStatus.AccessRestricted	BOOL	Access Restricted.
Chx_HARTStatus.DeviceBusy	BOOL	Device Busy.
Chx_HARTStatus.CommandNotImplemented	BOOL	Command not supported.
Chx_HARTStatus.DeviceMalfunction	BOOL	Device Malfunction.
Chx_HARTStatus.ConfigurationChanged	BOOL	Configuration changed.

Chx_HARTStatus.Coldstart	BOOL	Field device power failure or device reset has occurred.
Chx_HARTStatus.MoreStatusAvailable	BOOL	Additional status information is available.
Chx_HARTStatus.LoopCurrentFixed	BOOL	The Loop Current is set at a fixed value and is not responding to process variations
Chx_HARTStatus.LoopCurrentSaturated	BOOL	The Loop Current has reached its upper or lower limit.
Chx_HARTStatus.NonPrimaryVariableOutOFLimits	BOOL	A variable other than the PV is beyond its operating limits.
Chx_HARTStatus.PrimaryVariableOutOfLimites	BOOL	The PV is beyond its operating limits.
Chx_RawCurrent	REAL	Raw analog current in mA.
Chx_ScaledValue	REAL	Scaled and filtered PV in engineering units.
Chx_DigitialCurrent	REAL	The field device's target current.
Chx_PV	REAL	Primary Variable in engineering units.
Chx_SV	REAL	Secondary Variable in engineering units.
Chx_TV	REAL	Third Variable in engineering units.
Chx_FV	REAL	Fourth Variable in engineering units.
Chx_PVUnitCode	SINT	Primary Variable engineering units code.
Chx_SVUnitCode	SINT	Secondary Variable engineering units code.
Chx_TVUnitCode	SINT	Third Variable engineering units code.
Chx_FVUnitCode	SINT	Fourth Variable engineering units code.
Chx_Diagnostics.DeviceSpecificStatus0_0 - 5	SINTs	Additional device specific status information. Refer to the specific field device documentation.
Chx_ Diagnostics.OperationalModes_0 - 1	SINTs	Operation mode of the field device.
Chx_ Diagnostics.StandardizedStatus0	SINT	Standardized Status byte 0
Chx_ Diagnostics.StandardizedStatus1	SINT	Standardized Status byte 1
Chx_ Diagnostics.AnalogChannelSaturated	SINT	
Chx_ Diagnostics.StandardizedStatus2	SINT	Standardized Status byte 2
Chx_ Diagnostics.StandardizedStatus3	SINT	Standardized Status byte 3
Chx_ Diagnostics.AnalogChannelFixed	SINT	
Chx_ Diagnostics.DeviceSpecificStatus1_0 - 10	SINTs	Additional device specific status information. Refer to the specific field device documentation.

Table 4.1 – HART 4 Logix 5000 input assembly parameters

4.1.2. OUTPUT ASSEMBLY

The following parameters are used in the output assembly of the **HART 4Out** module.

Parameter	Datatype	Description
Ch0_Data	REAL	Analog output value (in engineering units) for Channel 0.
Ch1_Data	REAL	Analog output value (in engineering units) for Channel 1.
Ch2_Data	REAL	Analog output value (in engineering units) for Channel 2.
Ch3_Data	REAL	Analog output value (in engineering units) for Channel 3.

Table 4.2 – HART 4Out Logix 5000 output assembly parameters

4.1.3. HART RELAY MESSAGE

The module supports the relaying of custom HART commands to the field device. This is achieved by building the HART command request and then sending it to the module using an explicit message instruction. An example of this is shown in the figure below.

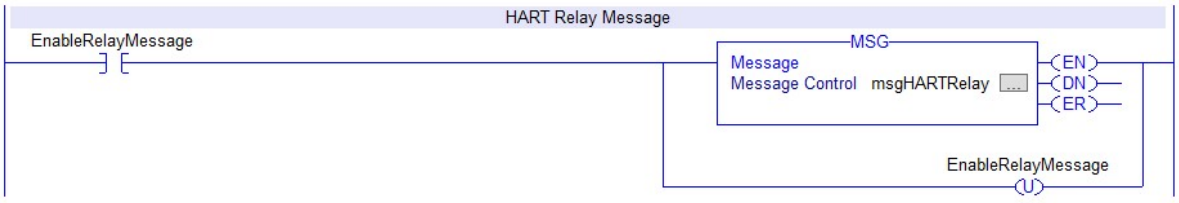


Figure 4.1. – Relay HART Message

The required attributes for the message instruction are as follows:

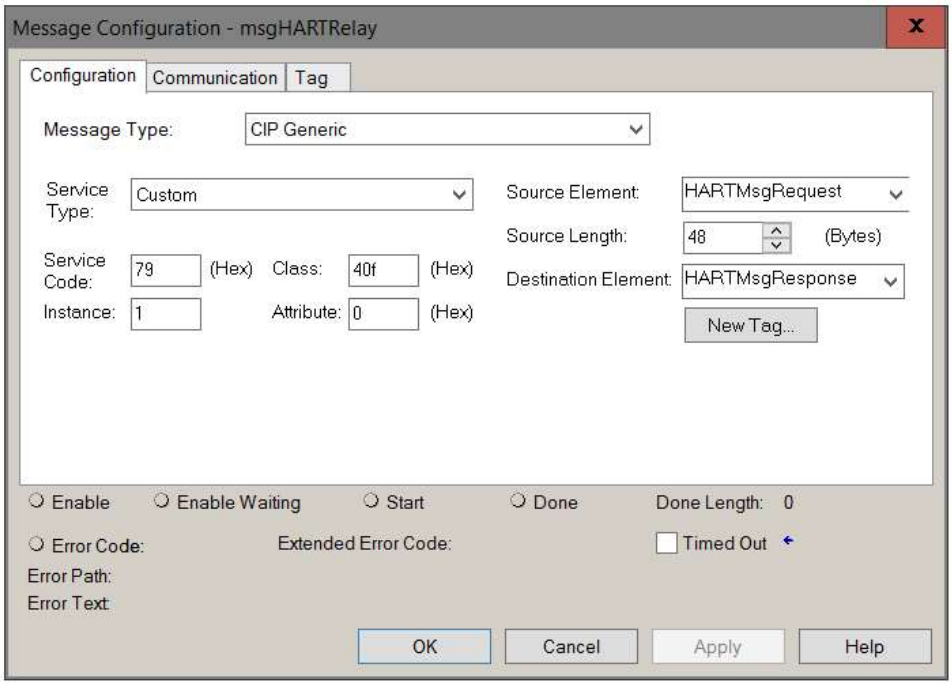


Figure 4.2. – Relay HART Message Configuration

Parameter	Value / Description
Message Type	CIP Generic
Service Type	Custom
Service Code	79 Hex (Relay HART Message service)
Class	40F Hex
Instance	Channel value + 1 1 for Channel 0 2 for Channel 1 3 for Channel 2 4 for Channel 3
Attribute	0
Source Element	Tag of type AparianHARTRelayMessageRequest
Source Length	48
Destination Element	Tag of type AparianHARTRelayMessageResponse

Table 4.3 – Relay HART Message Parameters

The required Request and Response HART Command structures are defined as follows:

HART Command Request		
Byte Offset	Data Type	Description
0	INT	Request Length
2	SINT	Start Character (0x82 for Long Address)
3	SINT	Long Address 0 (0x80 + Manufacturer ID)
4	SINT	Long Address 1 (Device Type Code)
5	SINT	Long Address 2 (Device ID Byte 0)
6	SINT	Long Address 3 (Device ID Byte 1)
7	SINT	Long Address 4 (Device ID Byte 2)
8	SINT	Command Code
9	SINT	Command Data Length (in bytes)
10	SINT[]	Command Data (If required)

Table 4.4 – Relay HART Message Request Structure

HART Command Response		
Byte Offset	Data Type	Description
0	INT	Status (See table below)
2	INT	Packet Length
4	SINT	Start Character
5	SINT	Long Address 0
6	SINT	Long Address 1
7	SINT	Long Address 2
8	SINT	Long Address 3
9	SINT	Long Address 4
10	SINT	Command Code (Echoed)
11	SINT	Reply Data Length
12	INT	Status (Same as at byte 0 above).
14	SINT[]	Command Reply Data

Table 4.5 – Relay HART Message Response Structure

4.1.3.1. HART COMMAND STATUS ENCODING

The Status code returned in the HART relay command can be decoded as follows:

To determine which table to use, first examine the value of the bit 7 in the first byte.

If Byte 0 Bit 7 = 0 then:	
First Byte : Command Errors	
Value	Description
0	No error

1	(Undefined)
2	Invalid selection
3	Passed parameter too large
4	Passed parameter too small
5	Too few data bytes received
6	Transmitter specific error
7	In write-protect mode
8-15	Command specific error
16	Access restricted
32	Device is busy
64	Command not implemented
Second Byte : Device Status	
Bit	Description
0	PV out of limits
1	Variable (non-PV) out of limits
2	Analog output saturated
3	Output current fixed
4	(Undefined)
5	Cold Start
6	Configuration Changed

Table 4.6 - Status Decoding (when first byte bit 7 = 0)

If Byte 0 Bit 7 = 1 then:	
First Byte : Communication Errors	
Bit	Description
0	(Undefined)
1	Rx buffer overflow
2	(Undefined)
3	Checksum error
4	Framing error
5	Overrun error
6	Parity error
Second Byte : Not defined	
Value	Description
0	(Always zero)

Table 4.7 - Status Decoding (when first byte bit 7 = 1)

4.1.3.2. HART COMMAND EXAMPLE

In the example below a Logix message instruction is used to Read the Unique Identifier of the device. This makes use of the Universal Command #0. The field device is connected to channel 0, hence the Instance value set to 1.

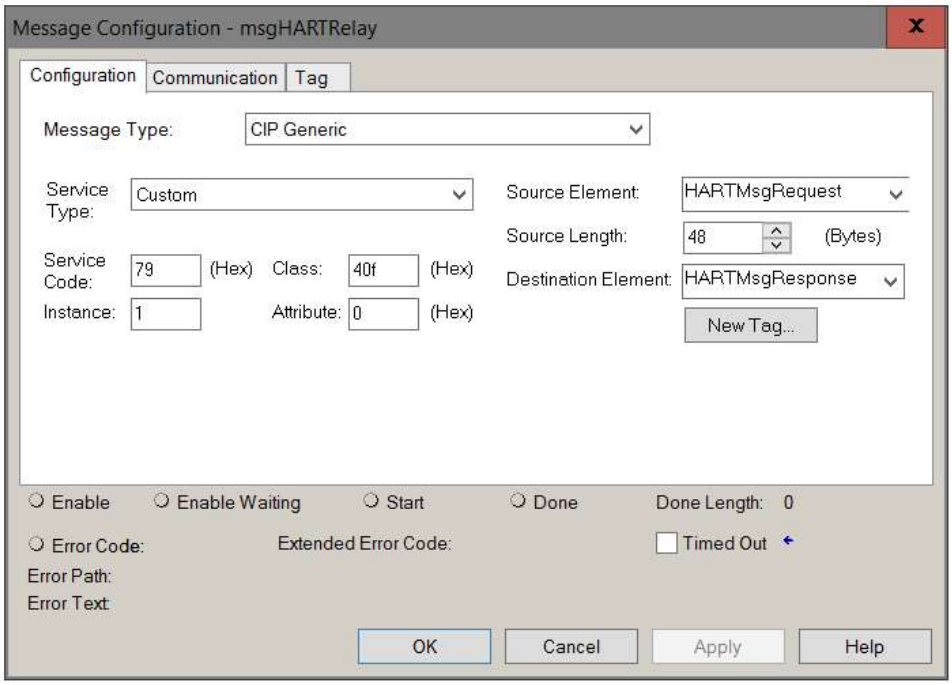


Figure 4.3. – Relay HART Message Example Configuration

HARTMsgRequest	{...}		AparianHARTRelayMessageRequest	
HARTMsgRequest.Length	8	Decimal	INT	Length = 8 bytes
HARTMsgRequest.StartCharacter	16#82	Hex	SINT	Start = 0x82 (Long Address)
HARTMsgRequest.AddressByte0	16#91	Hex	SINT	0x80 + ManufacturerID
HARTMsgRequest.AddressByte1	16#38	Hex	SINT	Device Type Code = 56 = 0x38
HARTMsgRequest.AddressByte2	16#79	Hex	SINT	DeviceID = 0xFF4F79
HARTMsgRequest.AddressByte3	16#4f	Hex	SINT	
HARTMsgRequest.AddressByte4	16#ff	Hex	SINT	
HARTMsgRequest.CommandData	{...}	Hex	SINT[40]	
HARTMsgRequest.CommandData[0]	16#00	Hex	SINT	Command = 0 Read Unique Identifier
HARTMsgRequest.CommandData[1]	16#00	Hex	SINT	Command Data Length = 0
HARTMsgRequest.CommandData[2]	16#00	Hex	SINT	Command Data (Not required for Cmd 0)
HARTMsgRequest.CommandData[3]	16#00	Hex	SINT	
HARTMsgRequest.CommandData[4]	16#00	Hex	SINT	
HARTMsgRequest.CommandData[5]	16#00	Hex	SINT	
HARTMsgRequest.CommandData[6]	16#00	Hex	SINT	

Figure 4.4. – Relay HART Command Example – Request

HARTMsgResponse	{...}		AparianHARTRelayMessageResponse	
HARTMsgResponse.Status	16#4000	Hex	INT	Status = 0x4000
HARTMsgResponse.PacketLength	32	Decimal	INT	
HARTMsgResponse.StartCharacter	16#86	Hex	SINT	Long Address
HARTMsgResponse.AddressByte0	16#91	Hex	SINT	
HARTMsgResponse.AddressByte1	16#38	Hex	SINT	
HARTMsgResponse.AddressByte2	16#79	Hex	SINT	
HARTMsgResponse.AddressByte3	16#4f	Hex	SINT	
HARTMsgResponse.AddressByte4	16#ff	Hex	SINT	
HARTMsgResponse.Command	0	Decimal	SINT	Command Echo
HARTMsgResponse.ByteCount	24	Decimal	SINT	Reply Length = 24
HARTMsgResponse.Data	{...}	Hex	SINT[50]	
HARTMsgResponse.Data[0]	16#00	Hex	SINT	Status = 0x4000 (repeated)
HARTMsgResponse.Data[1]	16#40	Hex	SINT	
HARTMsgResponse.Data[2]	16#fe	Hex	SINT	Command 0 Reply Data: Format 254
HARTMsgResponse.Data[3]	16#11	Hex	SINT	Command 0 Reply Data: ManufacturerID
HARTMsgResponse.Data[4]	16#38	Hex	SINT	Command 0 Reply Data: Device Type Code
HARTMsgResponse.Data[5]	16#05	Hex	SINT	Command 0 Reply Data: Number of Preambles
HARTMsgResponse.Data[6]	16#07	Hex	SINT	Command 0 Reply Data: Universal Cmd Rev
HARTMsgResponse.Data[7]	16#03	Hex	SINT	Command 0 Reply Data: Specific Cmd Rev
HARTMsgResponse.Data[8]	16#03	Hex	SINT	Command 0 Reply Data: Software Rev
HARTMsgResponse.Data[9]	16#08	Hex	SINT	Command 0 Reply Data: Hardware Rev

Figure 4.5. – Relay HART Command Example – Response

NOTE: The HART Long Address for a device is comprised of the Manufacturer ID, Device Type Code and Device ID. These values are displayed on the Channel Status screen in Slate when the device is Online.

4.2. DNP3 OPERATION

The DNP3 operation is enabled when the configuration protocol is set to either DNP3 TCP or DNP3 UDP. The HART 4 module will then operate as a DNP3 Outstation supporting the following DNP3 objects.

Group:	**10 - Counters**					
Variation:	**5**					
Functions:	**Read**					
Parameter	Length	Item				
		General	Channel 0	Channel 1	Channel 2	Channel 3
Application Messages Received	1	0	-	-	-	-
Application Messages Sent	1	1	-	-	-	-
Critical Messages Received	1	2	-	-	-	-
Critical Messages Sent	1	3	-	-	-	-
Discarded Messages	1	4	-	-	-	-
Error Messages Sent	1	5	-	-	-	-
Error Messages Received	1	6	-	-	-	-
Checksum Error	1	7	-	-	-	-
HART Tx Count	1	-	20	30	40	50
HART Rx Count	1	-	21	31	41	51
Communication Errors	1	-	22	32	42	52
Command Errors	1	-	23	33	43	53
Time-Out Errors	1	-	24	34	44	54

Group:	**30 - Analog Inputs**					
Variation:	**1,2,3,4,5,6**					
Functions:	**Read**					
Parameter	Length	Item				
		General	Channel 0	Channel 1	Channel 2	Channel 3
Raw Current	1	-	10	20	30	40
Scaled Value	1	-	11	21	31	41
Digital Current	1	-	12	22	32	42
PV - Primary Value	1	-	13	23	33	43
SV - Secondary Value	1	-	14	24	34	44
TV - Tertiary Value	1	-	15	25	35	45
FV - Fourth Value	1	-	16	26	36	46

Group:	**41 - Analog Outputs**					
Variation:	**1,2,3,4**					
Functions:	**Select, Operate, Direct Operate, Direct Operate w/o Ack.**					
Parameter	Length	Item				
		General	Channel 0	Channel 1	Channel 2	Channel 3
Output Value	1	-	0	10	20	30

Group:	**102 - Unsigned 8 bit Integers**					
Variation:	**1**					
Functions:	**Read**					
Parameter	Length	Item				
		General	Channel 0	Channel 1	Channel 2	Channel 3
Module Status Bit 0 – Configuration Valid Bit 1 – Channel 0 Enabled Bit 2 – Channel 1 Enabled Bit 3 – Channel 2 Enabled Bit 4 – Channel 3 Enabled Bit 5 – Channel 0 HART Enabled Bit 6 – Channel 1 HART Enabled Bit 7 – Channel 2 HART Enabled Bit 8 – Channel 3 HART Enabled	1	0	-	-	-	-
PV Units Code	1	-	10	20	30	40
SV Units Code	1	-	11	21	31	41
TV Units Code	1	-	12	22	32	42
FV Units Code	1	-	13	23	33	43
Manufacturer ID	1	-	100	200	300	400
Manufacturer Device Type Code	1	-	101	201	301	401
Number of Preambles Required	1	-	102	202	302	402
Universal Command Rev	1	-	103	203	303	403
Specific Command Rev	1	-	104	204	304	404
Software Rev	1	-	105	205	305	405
Hardware Rev	1	-	106	206	306	406
Device Function Flags	1	-	107	207	307	407
Device ID Number	3	-	108	208	308	408
Pad Byte	1	-	109	209	309	409
Sensor Serial Number	3	-	112	212	312	412
Units Code for Sensor	1	-	115	215	315	415
Sensor Upper Limit	4	-	116	216	316	416
Sensor Lower Limit	4	-	120	220	320	420
Sensor Minimum Span	4	-	124	224	324	424
Tag	8	-	128	228	328	428
Descriptor	16	-	136	236	336	436
Date	3	-	152	252	352	452

Table 4.8 - DNP3 Object Implementation



NOTE: When using the Select, Operate, Direct Operate and Direct Operate without Acknowledge functions, only one item can be addressed at a time.

4.2.1. DNP3 SECURITY

DNP3 offers Secure Authentication for links at risk of being attacked. There are various Key

Change methods, Message Authentication Code (MAC) algorithms, and Authentication methods provided in the DNP3 protocol specification.

Various keys are used in DNP3 Secure Authentication. Session keys are used most frequently as it is used for Authentication of the requests. These keys are updated by the DNP3 master at a certain interval or every time there has been a message failure. The DNP3 master encrypts these keys before sending them across the wire using the Key Wrap Algorithm selected and the Update key. The Update Key can be updated in numerous ways (including sending it across the wire with another set of Keys encrypting that message).

The HART 4 modules support DNP3 Secure Authentication 5, using the Pre-Shared Key method for Key Changes. Thus, the Update Key needs to be entered into each device by means outside of the DNP3 protocol.

In Slate the user can write the Update Key into the HART 4 module using the Key tab in the Online Status window. The key entered must match the Key Wrap Algorithm selected. Thus, if AES-128 Key Wrap was selected the Update Key must be 128-bit (16 bytes) long. If AES-256 Key Wrap was selected the Update Key must be 256-bit (32 bytes) long. The user can either enter a predetermined hexadecimal code of create a new code in Slate as shown below. This key is encrypted and sent to the HART 4 module where it is saved into the NV memory of the module.



NOTE: The Key update method in Slate is a **write-only** function. Thus once the key has been downloaded the user will not be able to view the key again. Thus the user must make provision to document or save the key in a secure manner.



NOTE: The DNP3 master device must have the same Update Key and security configuration settings as that of the HART 4 module. Failing to do this will result in failed data exchange for critical messages.

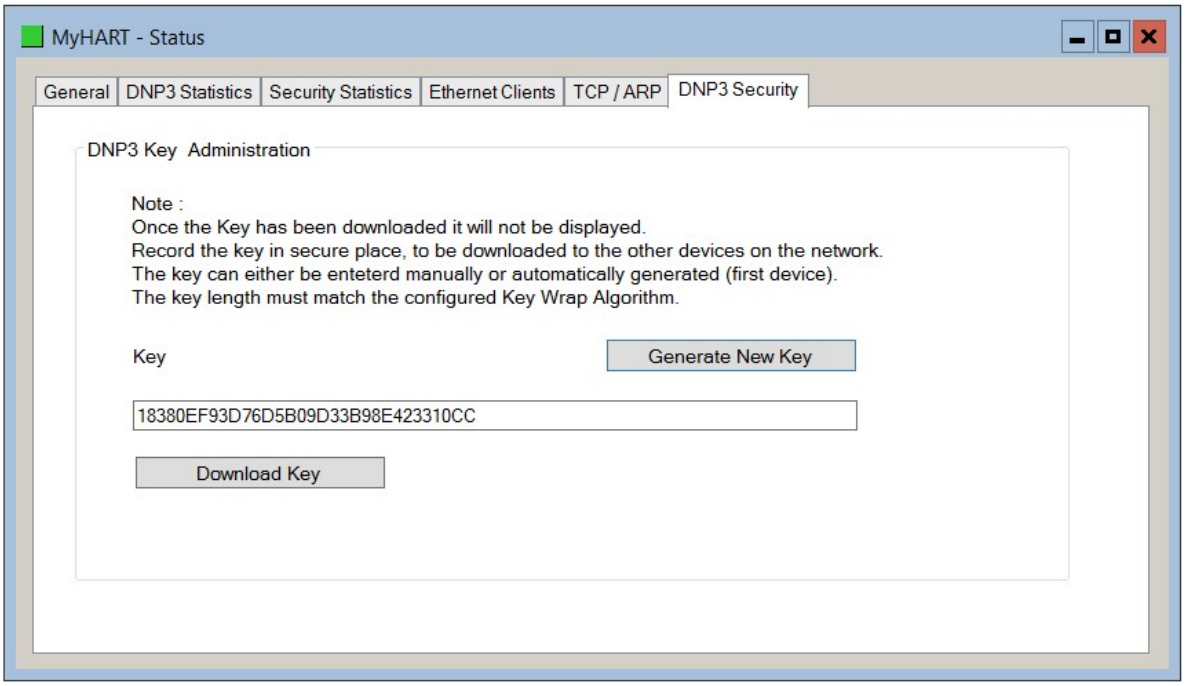


Figure 4.6 - HART 4 DNP3 key update method.

The module supports all DNP3 MAC algorithms and Key Wrap algorithms. The module also supports Aggressive Authentication mode which reduces the amount of traffic on the network (which could be required on busy networks or serial communication).

4.3. MODBUS TCP OPERATION

The Modbus TCP operation is enabled when the configuration protocol is set to either Modbus TCP. The HART 4 module will then operate as a Modbus TCP Slave supporting the following Modbus registers.

Register Type:	**Holding Registers**						
Parameter	Byte Length	Date Type	Register				
			General	Channel 0	Channel 1	Channel 2	Channel 3
Module Status Bit 0 – Configuration Valid Bit 1 – Channel 0 Enabled Bit 2 – Channel 1 Enabled Bit 3 – Channel 2 Enabled Bit 4 – Channel 3 Enabled Bit 5 – Channel 0 HART Enabled Bit 6 – Channel 1 HART Enabled	2	INT	0	-	-	-	-

Bit 7 – Channel 2 HART Enabled Bit 8 – Channel 3 HART Enabled							
Modbus Statistics							
Rx Packet Count	4	DINT	20	-	-	-	-
Tx Packet Count	4	DINT	22	-	-	-	-
Node Mismatch	4	DINT	24	-	-	-	-
Error Messages Sent	4	DINT	26	-	-	-	-
Device Info							
Manufacturer ID	1	BYTE	-	100	200	300	400
Manufacturer Device Type Code	1	BYTE	-				
Number of Preambles Required	1	BYTE	-	101	201	301	401
Universal Command Rev	1	BYTE	-				
Device Specific Command Rev	1	BYTE	-	102	202	302	402
Software Rev	1	BYTE	-				
Hardware Rev	1	BYTE	-	103	203	303	403
Device Function Flags	1	BYTE	-				
Device ID Number	3	BYTE[3]	-	104	204	304	404
Pad Byte	1	BYTE	-				
Sensor Serial Number	3	BYTE[3]	-	106	206	306	406
Units Code for Sensor	1	BYTE	-				
Sensor Upper Limit	4	REAL	-	108	208	308	408
Sensor Lower Limit	4	REAL	-	110	210	310	410
Sensor Minimum Span	4	REAL	-	112	212	312	412
Tag	8	BYTE[8]	-	114	214	314	414
Descriptor	16	BYTE[16]	-	118	218	318	418
Date	3	BYTE[3]	-	126	226	326	426
HART Statistics							
HART Tx Count	4	DINT	-	500	600	700	800
HART Rx Count	4	DINT	-	502	602	702	802
Communication Errors	4	DINT	-	504	604	704	804
Command Errors	4	DINT	-	506	606	706	806
Parity Errors	4	DINT	-	508	608	708	808

Register Type:	**Input Registers**						
Parameter	Byte Length	Date Type	Register				
			General	Channel 0	Channel 1	Channel 2	Channel 3
Device Process Variables							
Raw current	4	REAL	-	0	100	200	300
Scaled Value	4	REAL	-	2	102	202	302
Digital current	4	REAL	-	4	104	204	304
PV	4	REAL	-	6	106	206	306
SV	4	REAL	-	8	108	208	308
TV	4	REAL	-	10	110	210	310
FV	4	REAL	-	12	112	212	312

PV units code	1	SINT	-	14	114	214	314
SV units code	1	SINT	-				
TV units code	1	SINT	-	15	115	215	315
FV units code	1	SINT	-				
Device Status							
Device Status	1	BYTE	-	400	500	600	700
HART Status	2	INT	-	401	501	601	701
Device Specific Status 0	6	BYTE[6]	-	402	502	602	702
Operational Modes	2	BYTE[2]	-	405	505	605	705
Standardized Status 0	1	BYTE	-	406	506	606	706
Standardized_status1	1	BYTE	-				
Analog channel saturated	1	BYTE	-	407	507	607	707
Standardized_status2	1	BYTE	-				
Standardized_status3	1	BYTE	-	408	508	608	708
Analog channel fixed	1	BYTE	-				
Device Specific Status 1	11	BYTE[11]	-	409	509	609	709
Output Data							
Output Process Variable	4	REAL	-	800	900	1000	1100

Table 4.9 - Modbus Register Map

5. DIAGNOSTICS

5.1. LEDS

The module provides six LEDs for diagnostics purposes as shown in the front view figure below. A description of each LED is given in the table below.

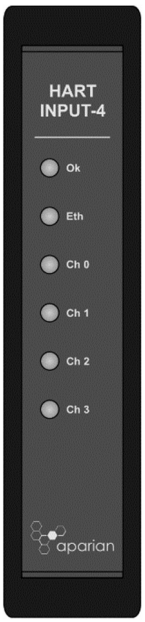


Figure 5.1 - HART 4 module front view

LED	Description
Module	The module LED will provide information regarding the system-level operation of the module. Thus if the LED is red then the module is not operating correctly. For example if the module application firmware has been corrupted or there is a hardware fault the module will have a red Module LED. If the LED is green then the module has booted and is running correctly.
Ethernet	The Ethernet LED will light up when an Ethernet link has been detected (by plugging in a connected Ethernet cable). The LED will flash when traffic is detected.
Channels (0-3)	Each channel LED represents the status of that specific analog channel. The LED will be green when the loop current is within the acceptable range (3.8mA to 20.5 mA) and HART communication has been established to the field device. Otherwise the LED will be red. The LED will flash green each time a HART response was received from the connected field device. If there was a HART communication error (eg. checksum failure) then the LED will flash red.

Table 5.1 - Module LED operation

5.2. MODULE STATUS MONITORING IN SLATE

The HART 4 module can provide a range of statistics which can assist with module operation, maintenance, and fault finding. The statistics can be accessed in full by Slate or using the web server in the module.

To view the module's status in the Aparian-Slate environment, the module must be online. If the module is not already Online (following a recent configuration download), then right-click on the module and select the *Go Online* option.

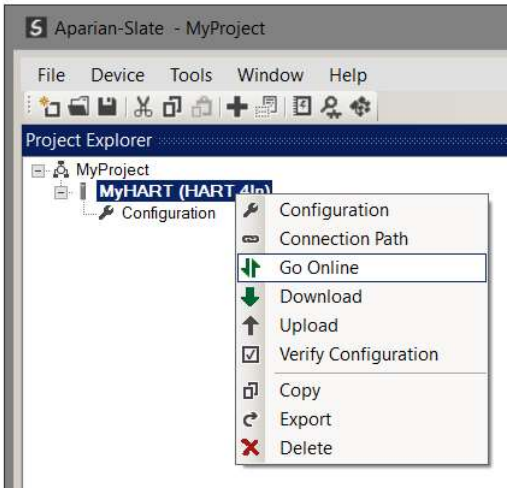


Figure 5.2. - Selecting to Go Online

The Online mode is indicated by the green circle behind the module in the Project Explorer tree.

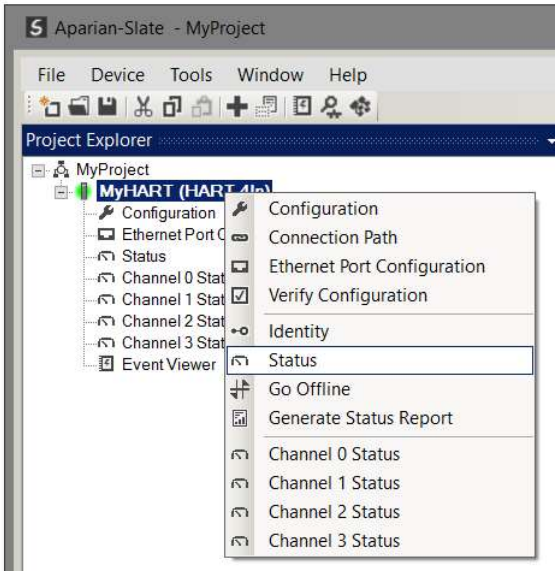


Figure 5.3. - Selecting online Status

The Status monitoring window can be opened by either double-clicking on the *Status* item in the Project Explorer tree, or by right-clicking on the module and selecting *Status*.

The status window contains multiple tabs to display the current status of the module. Most of these parameters in the status windows are self-explanatory or have been discussed in previous sections.

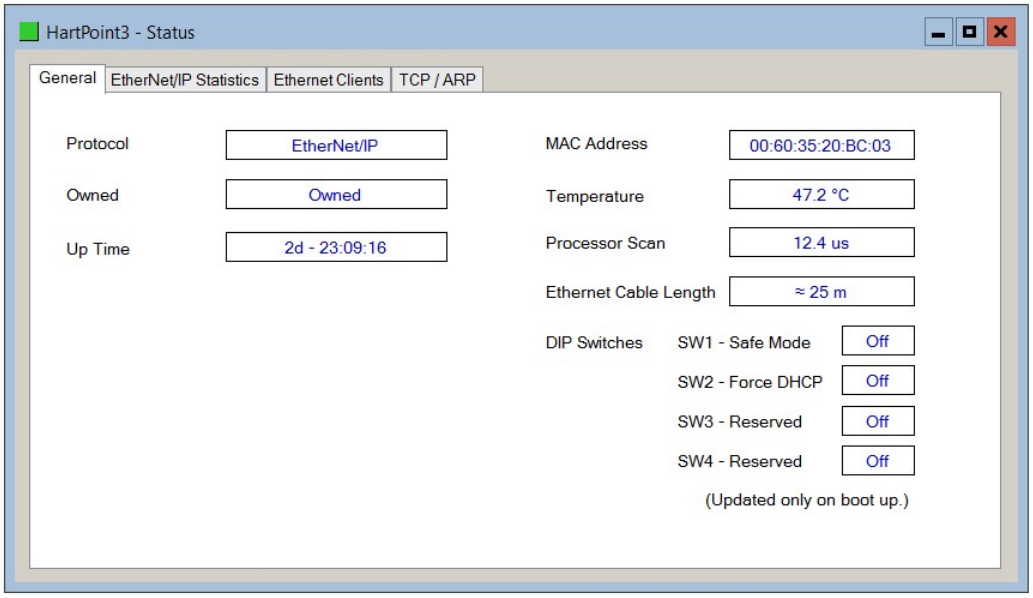


Figure 5.4. - Status monitoring – General

The General tab displays the following general parameters and can also be used to set the module time to the PC time:

Parameter	Description
Protocol	Indicates the current configured protocol: EtherNet/IP DNP3 TCP DNP3 UDP Modbus TCP
Owned	Indicates whether or not the module is currently owned (Class 1) by a Logix controller.
Up Time	Indicates the elapsed time since the module was powered-up.
MAC Address	Displays the module's unique Ethernet MAC address.
Temperature	The internal temperature of the module.
Processor Scan	The amount of time (microseconds) taken by the module's processor in the last scan.

Ethernet Cable Length	An estimate on the Ethernet cable length. (From the device to switch or media converter.) The accuracy is approximately 5m. A large discrepancy in this length may be indicative of an Ethernet cable issue.
DIP Switch Position	The status of the DIP switches when the module booted. Note that this status will not change if the DIP switches are altered when the module is running.

Table 5.2 - Parameters displayed in the Status Monitoring – General Tab

The subsequent Status tabs depend on the configured protocol.

5.2.1. EtherNet/IP Status

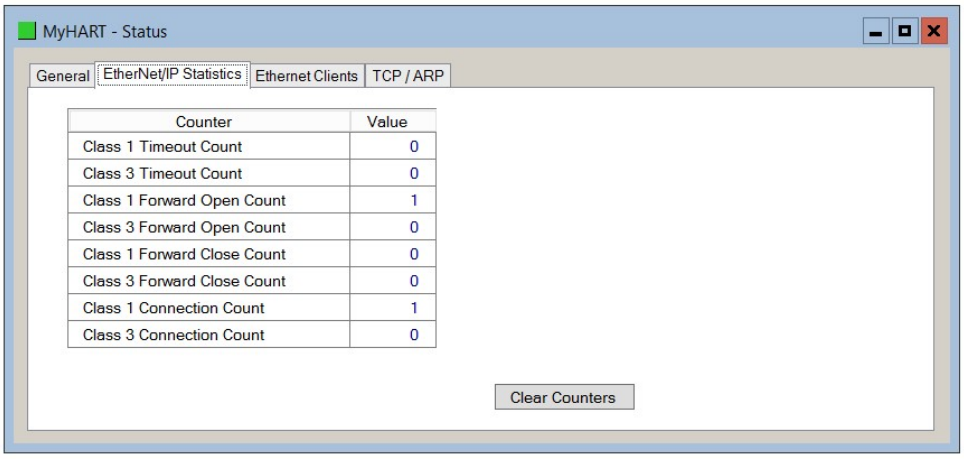


Figure 5.5 - EtherNet/IP Statistics

Statistic	Description
Class 1 Timeout Count	The number of Class 1 connections closed due to Timeouts.
Class 3 Timeout Count	The number of Class 3 connections closed due to Timeouts.
Class 1 Forward Open Count	The number of Class 1 Forward Open (connection establishment) messages sent.
Class 3 Forward Open Count	The number of Class 3 Forward Open (connection establishment) messages sent.
Class 1 Forward Close Count	The number of Class 1 Forward Close (connection termination) messages sent.
Class 3 Forward Close Count	The number of Class 3 Forward Close (connection termination) messages sent.
Class 1 Connection Count	The current number of active Class 1 connections.
Class 3 Connection Count	The current number of active Class 3 connections.

Table 5.3 - EtherNet/IP Statistics

5.2.2. DNP3

The DNP3 Statistics and DNP3 Security Statistics will be displayed if either of the two DNP3 protocols have been configured.

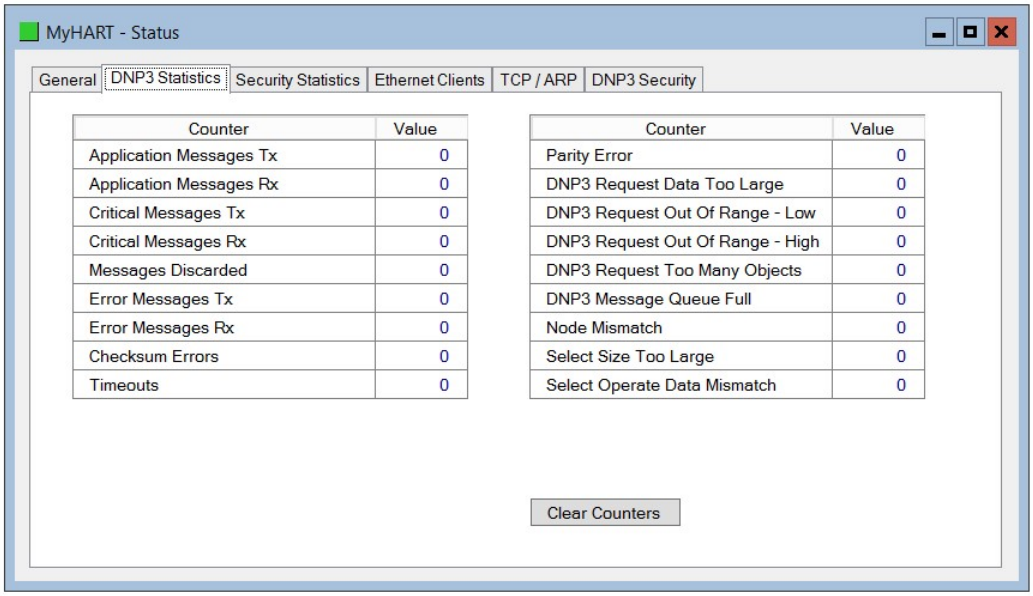


Figure 5.6 - DNP3 Statistics

Statistic	Description
Application Messages Tx	The number of application DNP3 packets sent by the module.
Application Messages Rx	The number of application DNP3 packets received by the module.
Critical Messages Tx	The number of critical DNP3 packets sent by the module when security is enabled.
Critical Messages Rx	The number of critical DNP3 packets received by the module when security is enabled.
Messages Discarded	The number of DNP3 packets discarded by the module.
Error Messages Tx	The number of error DNP3 packets sent by the module.
Error Messages Rx	The number of error DNP3 packets received by the module.
Checksum errors	The number of corrupted DNP3 packets received by the module.
Timeouts	The number of message response timeouts the module has encountered.
Parity errors	The number of bytes with parity errors received by the module.
DNP3 Request Data Too Large	The request/response data is too big. The Hart 4 module allows for a maximum of 1000 bytes per transaction.
DNP3 Request Out of Range – Low	The DNP3 request has a range that is outside of the implemented DNP3 bounds for the specific group and variation. This error is specific to the range being lower than the implemented range.

DNP3 Request Out of Range – High	The DNP3 request has a range that is outside of the implemented DNP3 bounds for the specific group and variation. This error is specific to the range being higher than the implemented range.
DNP3 Request Too Many Objects	The Hart 4 module supports a maximum of 10 DNP3 objects in a single DNP3 request. This statistic indicates that more than 10 DNP3 objects were found in a single request.
DNP3 Message Queue Full	The Hart 4 module has received too many simultaneous messages to process.
Node Mismatch	The received message node number did not match the Hart 4 module configured node address.
Select Size Too Large	When the Select/Operate functionality is used the Hart 4 module supports a maximum of 255 bytes per transaction (or one full DNP3 message).
Select Operate Data Mismatch	The Select/Operate functionality requires that the response to the Select function matches the Select request.

Table 5.4 – DNP3 statistics

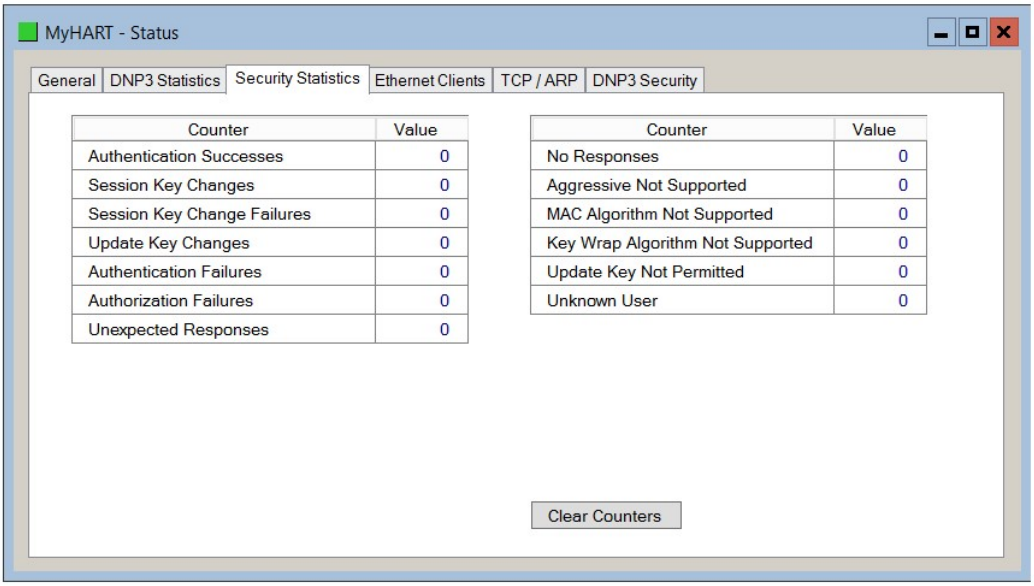


Figure 5.7 - DNP3 Security Statistics

Statistic	**Description**
Authentication Successes	Increases every time the device successfully authenticates a message.
Session Key Changes	When the session keys have been successfully updated.
Session Key Change Failures	When the session keys have failed to update.
Update Key Changes	The Update Key has changed.
Authentication Failures	The other device has provided invalid authentication information such as an incorrect MAC.

Authorization Failures	Increases when a user is not authorized to perform a requested operation.
Unexpected Responses	The other device has responded with a message that was not expected during the authentication process.
No Responses	The other device has not replied during the authentication process.
Aggressive Not Supported	When Aggressive Mode Authentication is not supported this will increase.
MAC Algorithm Not Supported	The MAC algorithm requested is not supported
Key Wrap Algorithm Not Supported	The Key Wrap algorithm requested is not supported.
Update Key Not Permitted	Updating of a key was not permitted.
Unknown User	The user used for authentication was unknown. The default user (1) is the only user supported.

Table 5.5 – DNP3 Security statistics

5.2.3. MODBUS

The Modbus Statistics will be displayed if the Modbus TCP protocol has been configured.

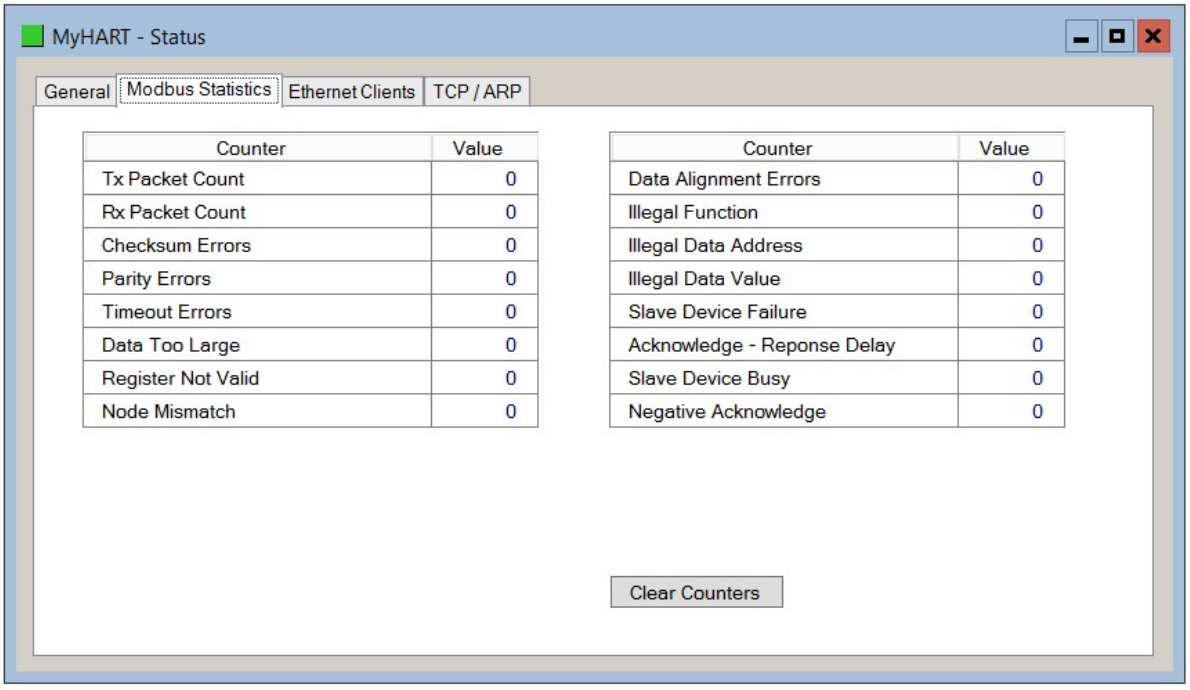


Figure 5.8. - Modbus Statistics

Statistic	**Description**
Tx Packet Count	The number of Modbus packets sent by the module.

Rx Packet Count	The number of Modbus packets received by the module.
Checksum errors	The number of corrupted Modbus packets received by the module.
Parity errors	The number of bytes with parity errors received by the module.
Timeout Errors	The number of message response timeouts the module has encountered.
Data Too Large	The number of Modbus requests or responses where the data was too large to process.
Register Not Valid	A request was received for a register which is not defined.
Node Mismatch	The received Modbus request did not match the module's Modbus node address.
Data Alignment Errors	The Modbus request and associated mapped item is not byte aligned with the destination.
Illegal Function	The number of times the Modbus device responded with an Illegal Function exception.
Illegal Data Address	The number of times the Modbus device responded with an Illegal Data Address exception.
Illegal Data Value	The number of times the Modbus device responded with an Illegal Data Value exception.
Slave Device Failure	The number of times the Modbus device responded with a Device Failure exception.
Acknowledge –Response Delay	The number of times the Modbus device responded with an Acknowledge exception.
Slave Device Busy	The number of times the Modbus device responded with a Slave Busy exception.
Negative Acknowledge	The number of times the Modbus device responded with a Negative Acknowledge exception.
Memory Parity Error	The number of times the Modbus device responded with a Memory Parity exception.

Table 5.6 – Modbus statistics

5.3. CHANNEL STATUS

The status of a specific channel can be monitored by double-clicking on the *Channel x Status* in the tree, or by right-clicking on the device and selecting the *Channel x Status* item.

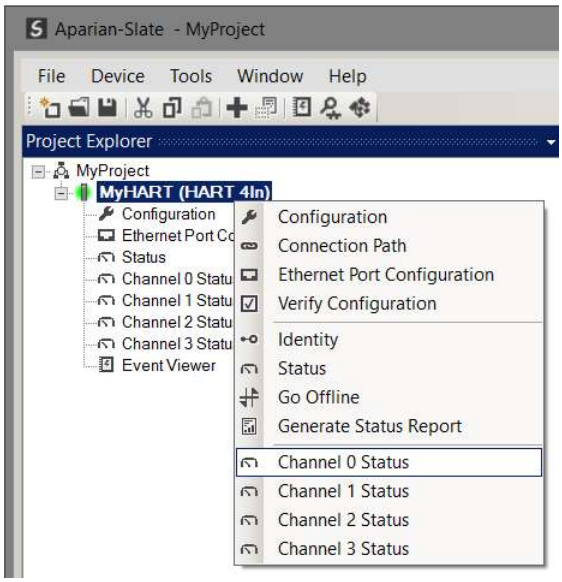


Figure 5.9 - Select Online Channel Status

The channel status window contains multiple tabs to display the current status of that specific channel. The General tab displays a summary of the common HART parameters.

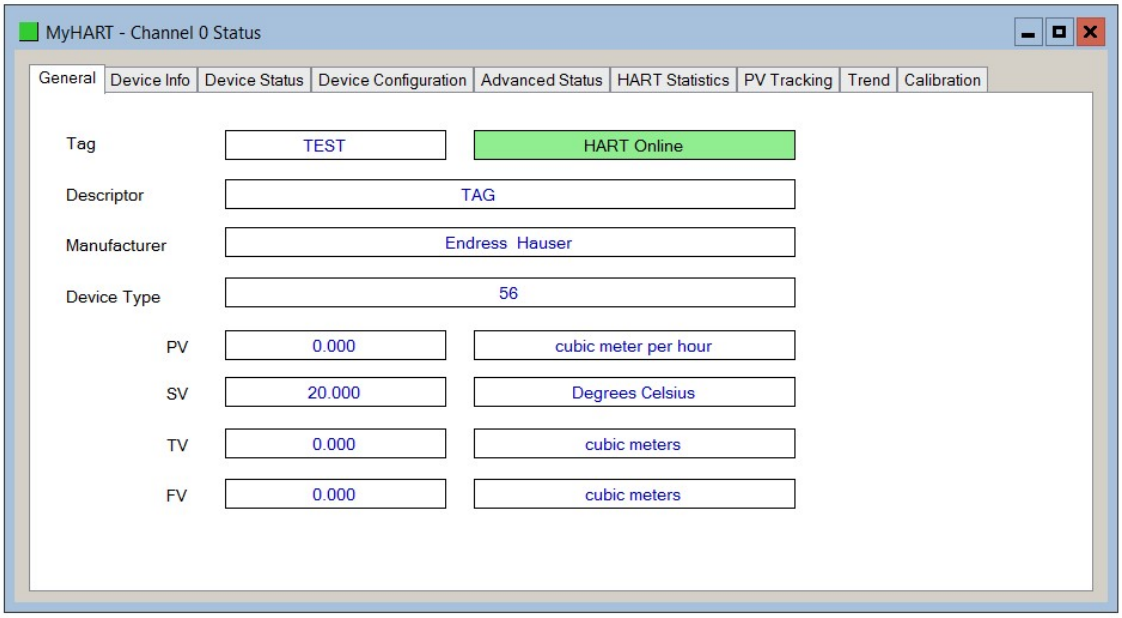


Figure 5.10 - Channel Status – General

Parameter	Description
Tag	The user tag name configured in the field device. (8 characters)
Status	The current status of the HART communication.
Descriptor	The user descriptor configured in the field device. (16 characters)
Manufacturer	The field device manufacturer.

Device Type	The device type code assigned by the manufacturer.
PV (and Units)	The primary variable displayed in engineering units, with the engineering unit enumeration.
SV (and Units)	The secondary variable displayed in engineering units, with the engineering unit enumeration.
TV (and Units)	The third variable displayed in engineering units, with the engineering unit enumeration.
FV (and Units)	The fourth variable displayed in engineering units, with the engineering unit enumeration.

Table 5.7 - Channel Status Parameters – General

The Device Info tab displays a more detailed information of the field device.

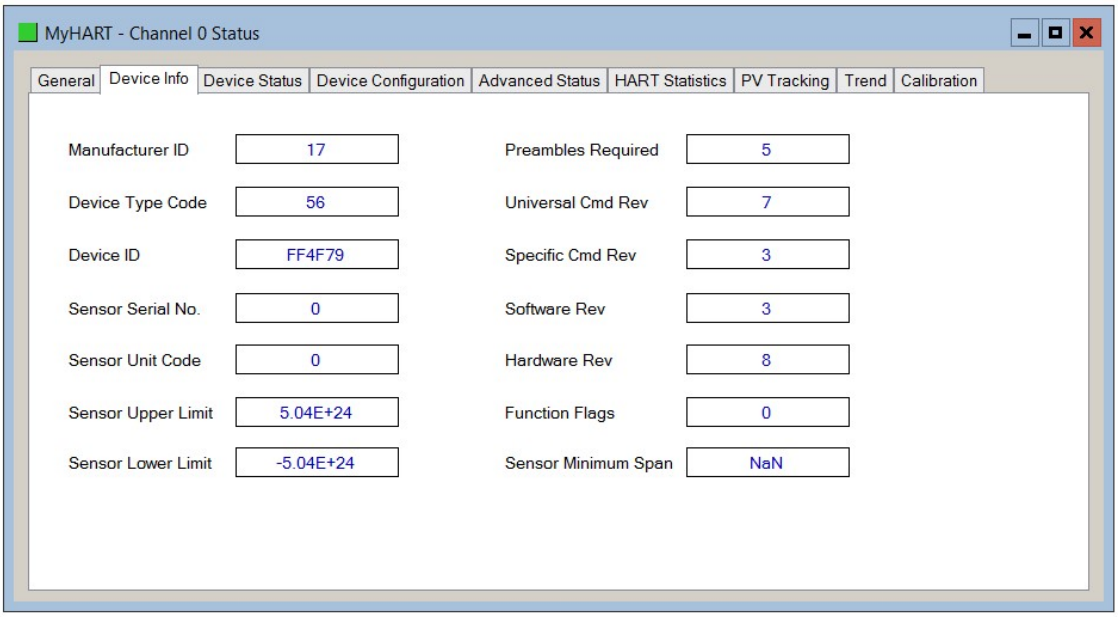


Figure 5.11 - Channel Status – Device Info

Parameter	**Description**
Manufacturer ID	The field device manufacturer unique identification code.
Device Type Code	The device type code assigned by the manufacturer.
Device ID	The device identification code assigned by the manufacturer.
Sensor Serial Number	The serial number of the field device sensor.
Sensor Unit Code	The engineering unit code used for the sensor limits.
Sensor Upper Limit	The upper limit of the sensor in the aforementioned engineering units.
Sensor Lower Limit	The lower limit of the sensor in the aforementioned engineering units.

Preambles Required	The minimum number of preambles required by the field device to process a HART request.
Universal Command Revision	The universal command revision supported by the field device.
Specific Command Revision	The specific command revision supported by the field device.
Software Revision	The software revision of the field device.
Hardware Revision	The hardware revision of the field device electronics.
Function Flags	The Device Function Flags as reported by the field device.
Sensor Minimum Span	The minimum span allowed by the sensor.

Table 5.8 - Channel Status Parameters – Device Info

The Device Status tab displays the status of the analog and HART interaction with the module.

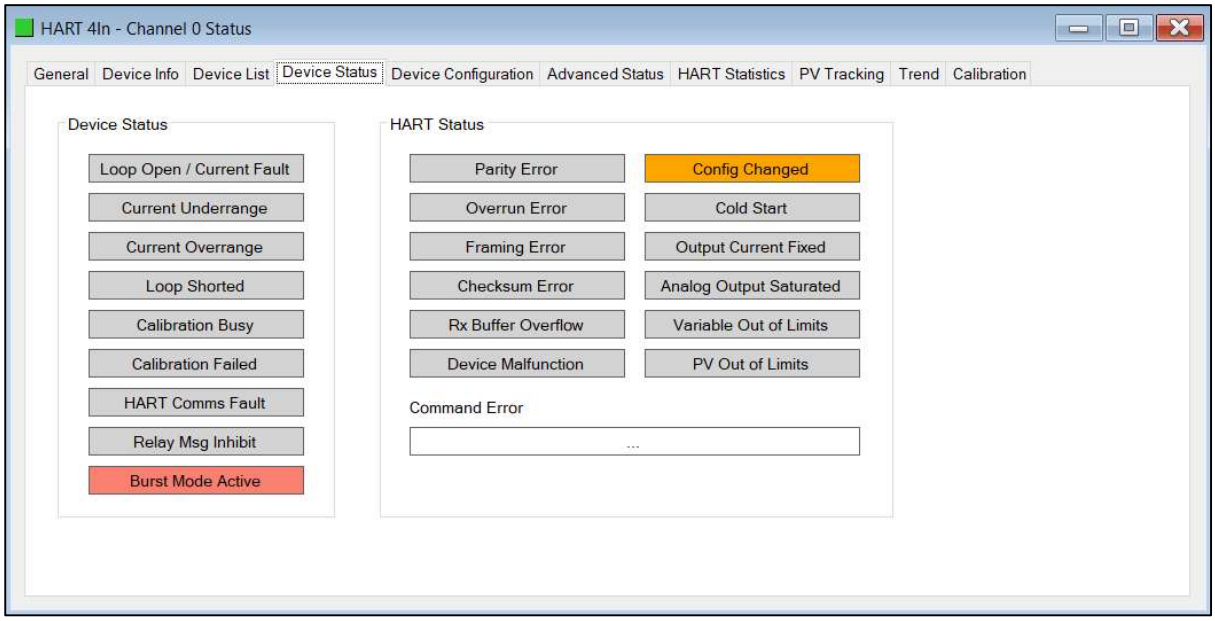


Figure 5.12 - Channel Status – Device Status

Parameter	Description
Loop Open / Current Fault	Flagged if the current loop is either below 3.6mA or above 21.0 mA.
Current Under-range	Flagged if the current is below 3.8mA.
Current Over-range	Flagged if the current is above 20.5 mA.
Loop Shorted	Flagged if a loop short is detected.
Calibration Busy	Flagged when the module is busy being calibrated.
Calibration Failed	Flagged if the calibration data is invalid or corrupt.
HART Comms Fault	Flagged if HART communication is enabled but not active.

Relay Message Inhibit	Flagged when Class 2 HART relay messages have been disabled in the configuration.
Burst Mode Active	Flagged if the field device is operating in burst mode.
Parity Error	Flagged if the field device received a message with a parity error
Overrun Error	Flagged if the field device receive buffer is overrun.
Framing Error	Flagged if the field device receives a message with an invalid stop delimiter.
Checksum Error	Flagged if the field device receives a message with an invalid checksum.
Rx Buffer Overflow	Flagged if the field device receives a message too long for the receive buffer.
Device Malfunction	Flagged if the field device has detected an error or suffered some hardware failure.
Config Changed	Flagged if an operation resulted in the configuration changing.
Cold Start	Flagged if the field device has experienced a power failure or reset.
Output Current Fixed	Flagged if the loop current is set at a fixed value and is not responding to process variations
Analog Output Saturated	Flagged if the Loop Current has reached its upper or lower limit
Variable Out of Limits	Flagged if a variable other than the PV is beyond its operating limits.
PV Out of Limits	Flagged if the PV is beyond its operating limits.
Command Error	An enumerated error in response to the last command issued.

Table 5.9 - Channel Status Parameters – Device Status

The Device Configuration tab provides the facility to display and modify common HART parameters in the field device.

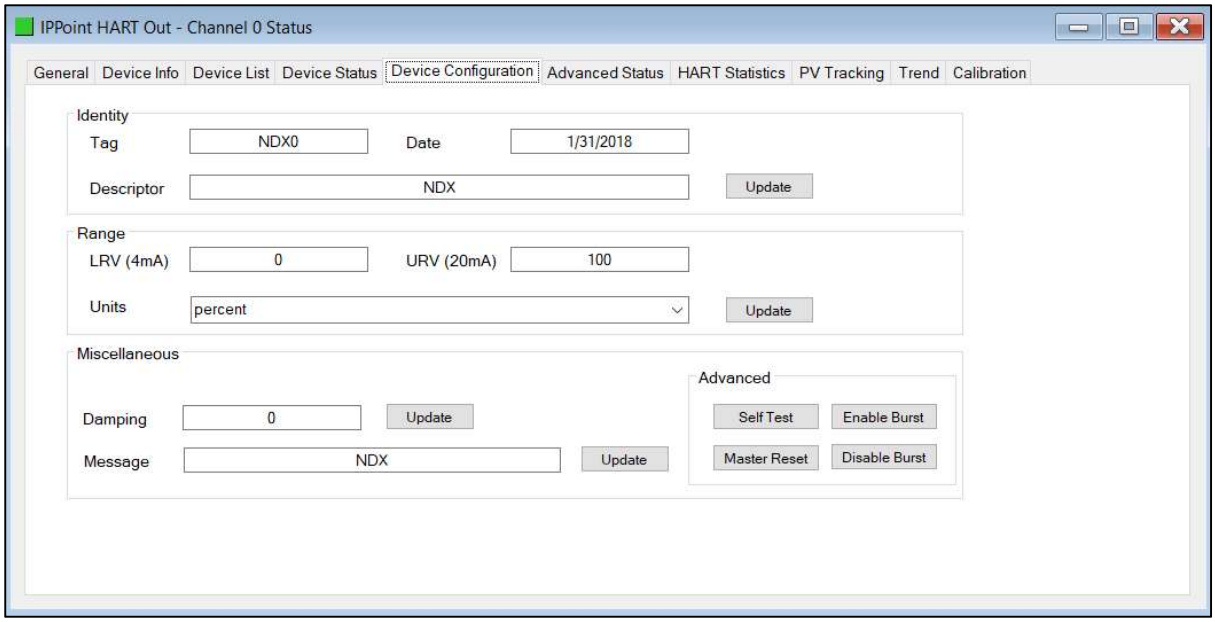


Figure 5.13 - Channel Status – Device Configuration

Parameter	Description
Tag	The user tag name configured in the field device. (8 characters). Note: The Tag, Descriptor and Date are updated together.
Descriptor	The user descriptor configured in the field device. (16 characters). Note: The Tag, Descriptor and Date are updated together.
Date	The date when the tag and descriptor configuration was last modified. Note: The Tag, Descriptor and Date are updated together.
LRV	The Lower Range Value in engineering units represented by the 4mA analog signal. Note: The LRV, URV and Range Units are updated together.
URV	The Upper Range Value in engineering units represented by the 20mA analog signal. Note: The LRV, URV and Range Units are updated together.
Range Units	The engineering units in which the LRV and URV values are specified. Note: The LRV, URV and Range Units are updated together.
Damping	The damping value specified in seconds. Damping refers to the digital filtering of process variables to remove transient and potentially erroneous deviations from the actual measure variable.
Message	A user defined 32-character message stored in the field device.
Master Reset	Resets the field device
Enable Burst Mode	This instructs the field device to enter burst mode. Note that only Burst of HART command 3 is supported
Disable Burst Mode	This instructs the field device to exit burst mode.

Table 5.10 - Channel Status Parameters – Device Configuration

A parameter can be modified by entering the new value into the appropriate text box and clicking the adjacent Update button. When the parameter is pending, that is, edited but not yet committed, then the text box will be shaded yellow. Once the value has been written (updated) the value will be written to the field device and then re-read from the field device, after which the parameter background will return to normal.

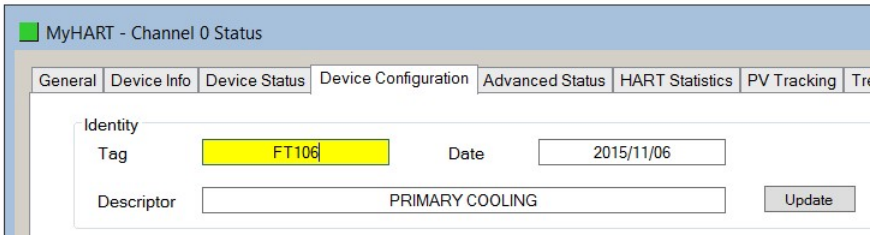


Figure 5.14 - Updating Device Parameters

The Advanced Status tab displays the advanced and device specific status information of the field device. Due to the manufacturer specific encoding of these parameters, consult the field device manufacturer's documentation for more information.

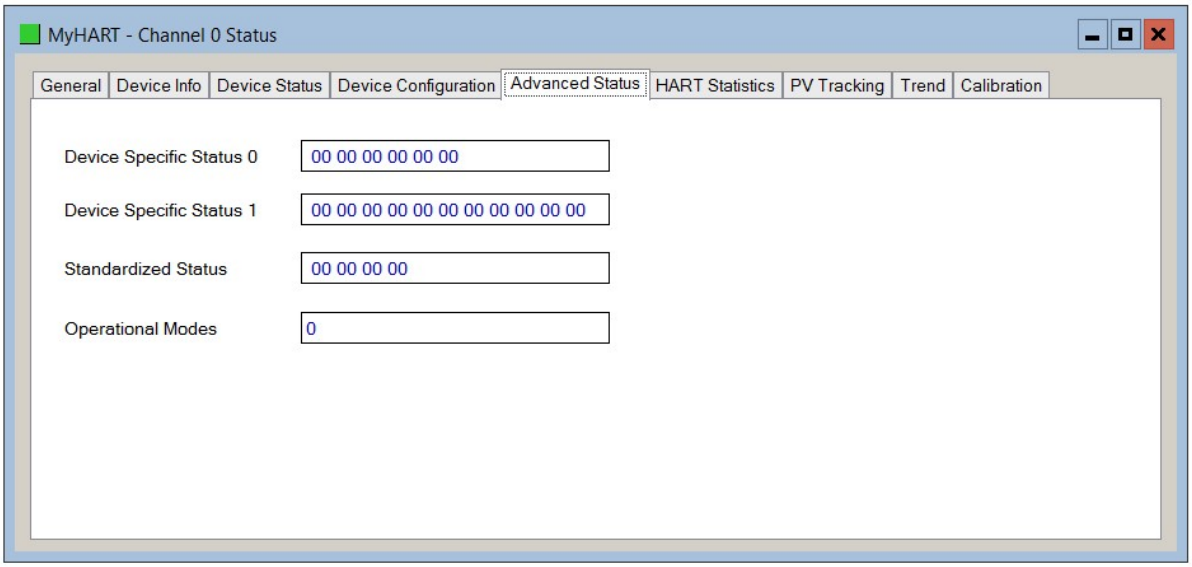
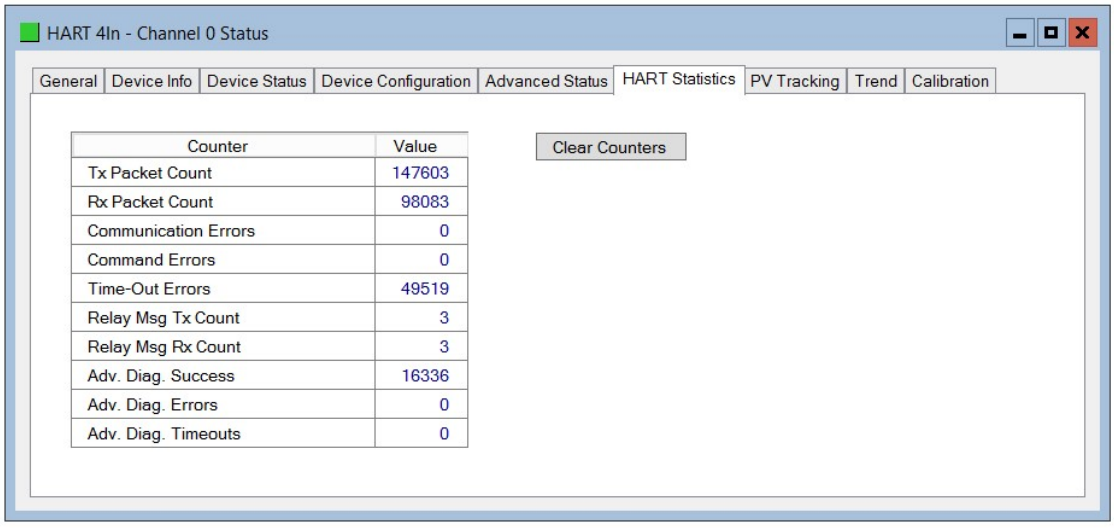


Figure 5.15 - Channel Status – Advanced Status

The HART Statistics tab displays the communication statistics.



Counter	Value
Tx Packet Count	147603
Rx Packet Count	98083
Communication Errors	0
Command Errors	0
Time-Out Errors	49519
Relay Msg Tx Count	3
Relay Msg Rx Count	3
Adv. Diag. Success	16336
Adv. Diag. Errors	0
Adv. Diag. Timeouts	0

Figure 5.16 - Channel Status – HART Communication Statistics

Parameter	Description
Tx Packet Count	The number of HART packets sent.
Rx Packet Count	The number of HART packets received.
Communication Errors	The number of communication errors experienced.

Command Errors	The number of command errors experienced.
Time-Out Errors	The number of HART time-out errors experienced.
Relay Message Tx Count	The number of HART packets sent via relay (Class 2) messages (DTMs etc.)
Relay Message Rx Count	The number of HART packets received for relay (Class 2) messages (DTMs etc.)
Adv. Diag. Success	The number of successful advanced diagnostic reads.
Adv. Diag. Errors	The number of advanced diagnostic reads that failed. (Illegal HART command etc.)
Adv. Diag. Timeouts	The number of advanced diagnostic reads where no reply was received.

Table 5.11 - Channel Status Parameters HART Communication Statistics

The PV Tracking Status tab displays the current, minimum and maximum value of the common process variables. The Reset button can be used to reset the maximum and minimum values.

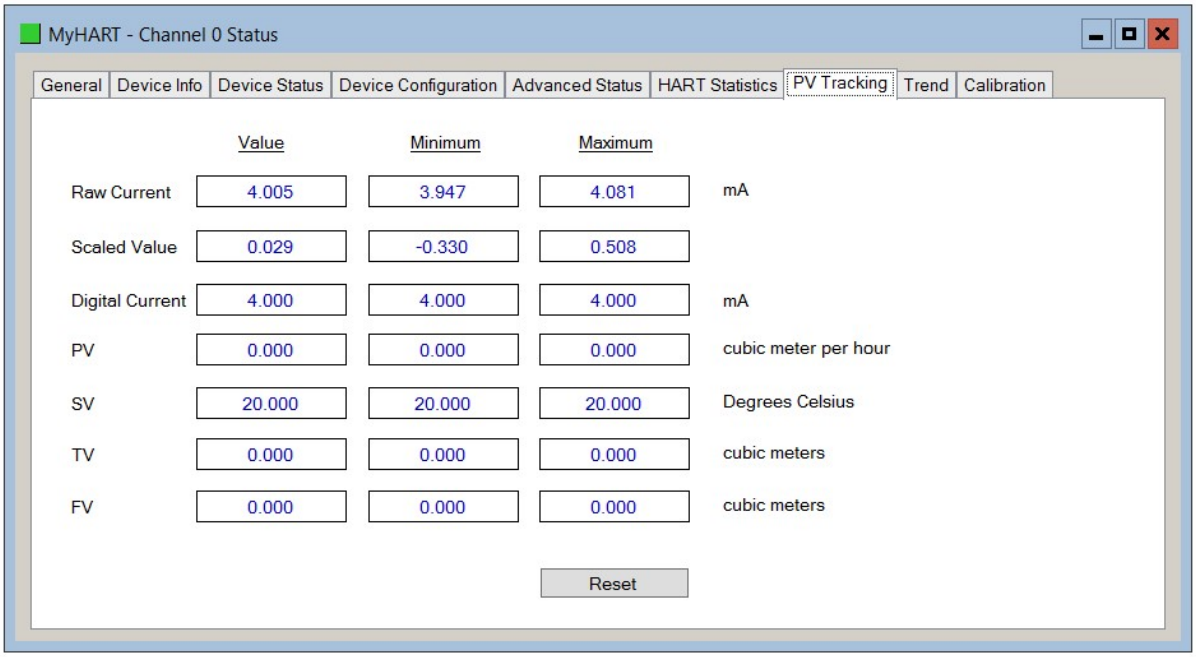


Figure 5.17 - Channel Status – PV Tracking

The Trend tab displays the status of the analog and HART interaction with the module.
The HART 4 module is capable of storing up to 1000 trend points which are sampled at a user-configurable interval. The user can choose between one of the following sources:

- Raw Analog Current (4-20mA)
- Filtered Scaled Value
- Digital Current
- Primary Variable (PV)
- Secondary Variable (SV)
- Third Variable (TV)

- Fourth Variable (FV)

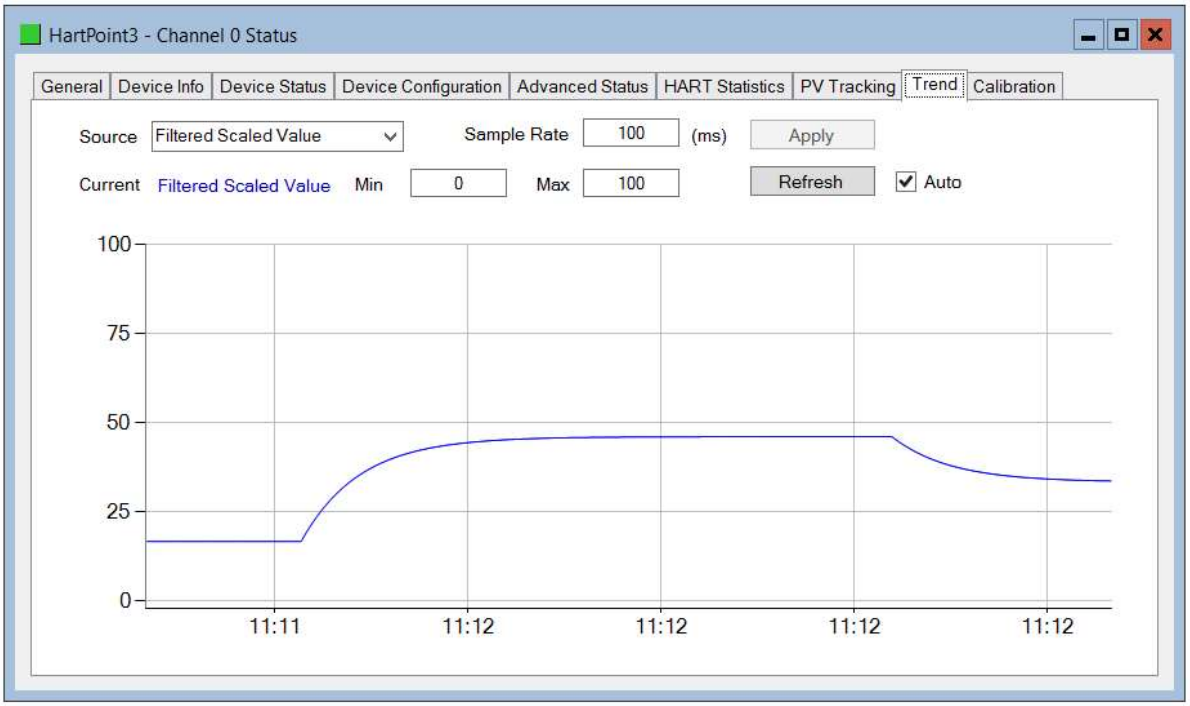


Figure 5.18 - Channel Status – Trend

Once the source or sample rate has been modified, the *Apply* button must be clicked for the changes to take effect. This will also result in the existing trend data being cleared. The Y axis scale can be modified by adjusting the *Min* and *Max* value and clicking the *Refresh* button. To automatically update the trend every second, the *Auto* check box can be selected.

5.4. DEVICE LIST

The module supports scanning the channel to determine at which short address the field device(s) are. The user can select the start and end address to minimize the scan time. Once the scan is completed and a device is found the devices details will be displayed in the list as shown below. When the user is using multiple devices on a single channel then more than one device will be displayed in this list.

NOTE: When multiple devices are used on a single channel then the user must ensure that each device is at a unique address. The user can change the short node address in the options by right-clicking on the device and selecting Write Address.

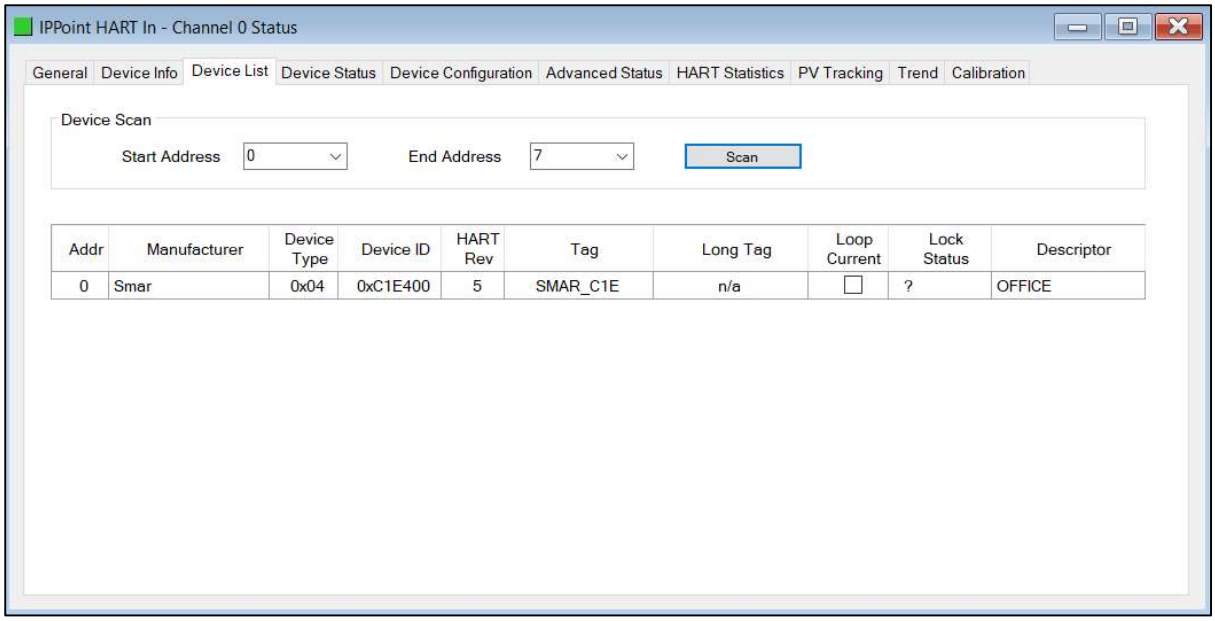


Figure 5.19 – Device List

There are various options the user can execute per device found in the device list. Some of the options will only be relevant depending on the HART Rev (eg. the Long Tag is only support with HART 6/7).

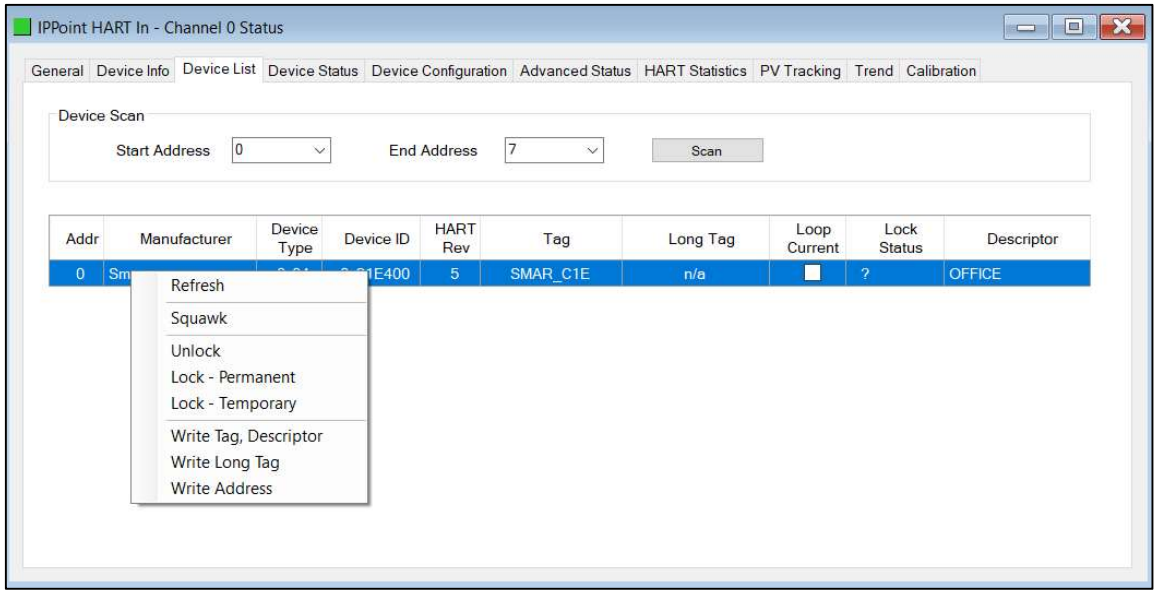


Figure 5.20 – Device List Options

5.5. CALIBRATION

The Calibration tab in the Channel status monitoring form, can be used to display and modify the calibration parameters.

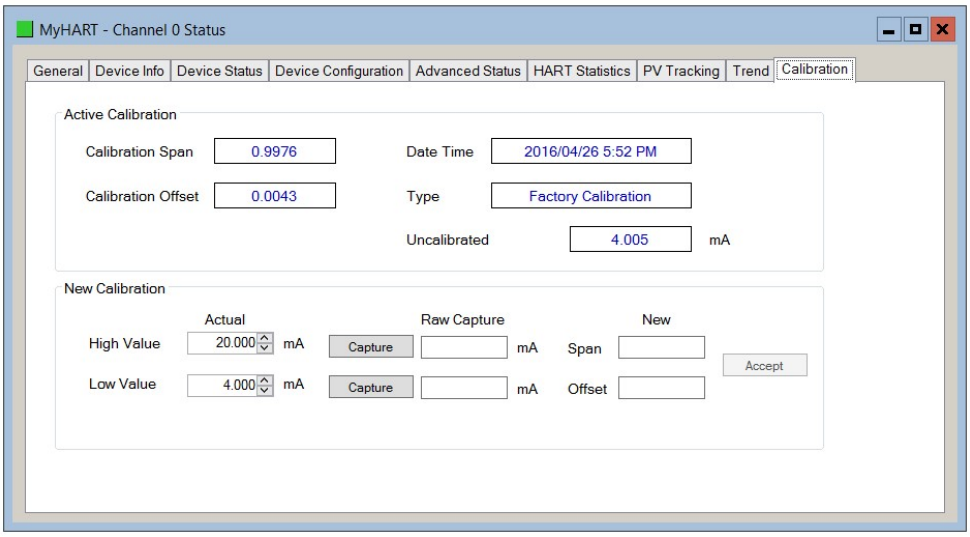


Figure 5.21 – Channel Status – Input Calibration

The module is Factory Calibrated, and should not require any further calibration before use. To re-calibrate the module, the User Calibration methods described below can be implemented.

5.5.1. INPUT CALIBRATION:

To re-calibrate a HART 4 Input module,

1. Using an external milliamp source, adjust the current to 4mA, or as close as possible to 4mA.
2. Enter the exact milliamp value, read from an external meter, into the ***Low Value Actual*** numeric inputs.
3. Press the ***Low Value*** (4mA) ***Capture*** button, to capture the current (un-calibrated value) into the ***Raw Capture*** field.
4. Using the external milliamp source, adjust the current to 20mA, or as close as possible to 20mA.
5. Enter the exact milliamp value, read from an external meter, into the ***High Value Actual*** numeric inputs.
6. Press the ***High Value*** (20mA) ***Capture*** button, to capture the current (un-calibrated value) into the ***Raw Capture*** field.
7. The new ***Span*** and ***Offset*** calibration settings will be automatically calculated. (See figure below).
8. Press ***Accept*** to write these new calibration figures to the module.
9. The Calibration Type will then change to User Calibration, to reflect the changes.

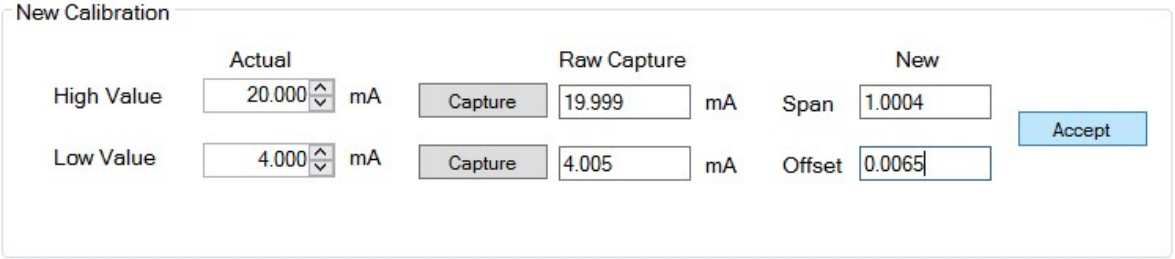


Figure 5.22 – User Calibration – Input

NOTE: Before commencing with input calibration ensure that it is safe to do so. The simulated current values could translate to extreme process variables in the connected control system which may cause unexpected results. Failure to do so could result in severe equipment damage and personal injury.

5.5.2. OUTPUT CALIBRATION:

To re-calibrate a HART 4 Output module:

1. Ensure the channel configuration has both the ***Prog/Fault Freeze*** and ***Comm Fail Freeze*** options checked, and that the module is disconnected from the EtherNet/IP (Logix), DNP3 or Modbus source.
2. Click the ***Set 4mA*** button. The output current will change to 4mA.
3. Using an external meter, measure the actual loop current and enter the milliamp value in the ***Low Value*** (4mA) ***Actual Measured*** textbox.
4. Click the ***Set 20mA*** button. The output current will change to 20mA.
5. Using an external meter, measure the actual loop current and enter the milliamp value in the ***High Value*** (20mA) ***Actual Measured*** textbox.
6. The new ***Span*** and ***Offset*** calibration settings will be automatically calculated. (See figure below).
7. Press ***Accept*** to write these new calibration figures to the module.
8. The Calibration Type will then change to User Calibration, to reflect the changes.

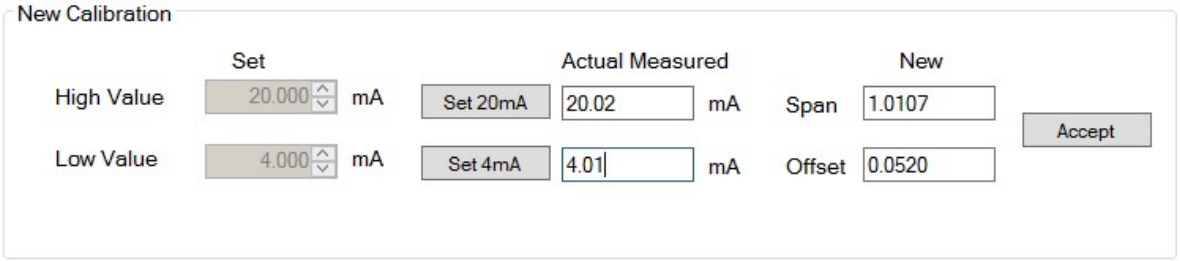


Figure 5.23 – User Calibration - Output

NOTE: Before commencing with output calibration ensure that it is safe to do so. The field device should be either isolated from the process mechanically or the process be in such a state that variations in the output signal cannot cause a disruption to the process. Failure to do so could result in severe equipment damage and personal injury.

NOTE: The ***Set 20mA*** and ***Set 4mA*** buttons will be disabled if the configuration has either the ***Prog/Fault Freeze*** or ***Comm Fail Freeze*** options not checked.

NOTE: If the module's data source (EtherNet/IP (Logix), DNP3 or Modbus) is not disconnected or disabled, then the simulated milliamp value will be constantly over-written negating the calibration procedure.

5.6. MODULE EVENT LOG

The HART 4 module logs various diagnostic records to an internal event log. These logs are stored in non-volatile memory and can be displayed using Slate or via the web interface.
To view them in Slate, select the Event Viewer option in the Project Explorer tree.

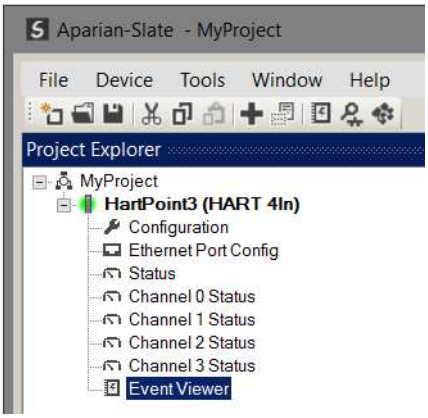


Figure 5.24. - Selecting the module Event Log

The Event Log window will open and automatically read all the events from the module. The log entries are sorted so as to have the latest record at the top. Custom sorting is achieved by double-clicking on the column headings.

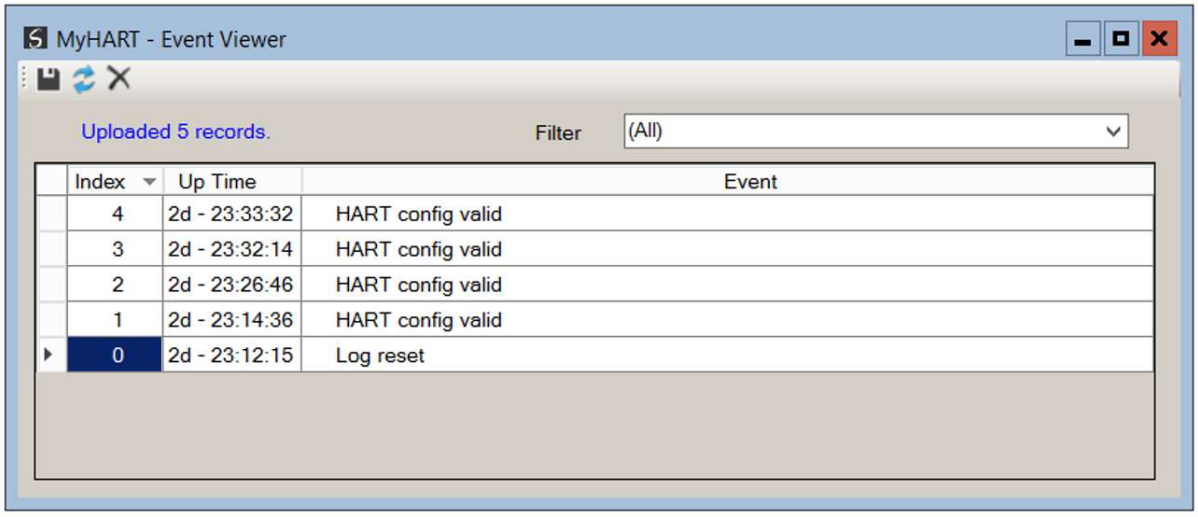


Figure 5.25. – Module Event Log

The log can also be stored to a file for future analysis, by selecting the Save button in the tool menu. To view previously saved files, use the Event Log Viewer option under the tools menu.

5.7. WEB SERVER

The HART 4 module provides a web server allowing a user without Slate or RSLogix 5000 to view various diagnostics of the module. This includes Ethernet parameters, system event log, advanced diagnostics, and application diagnostics.

NOTE: The web server is view **only** and thus no parameters or configuration can be altered from the web interface.

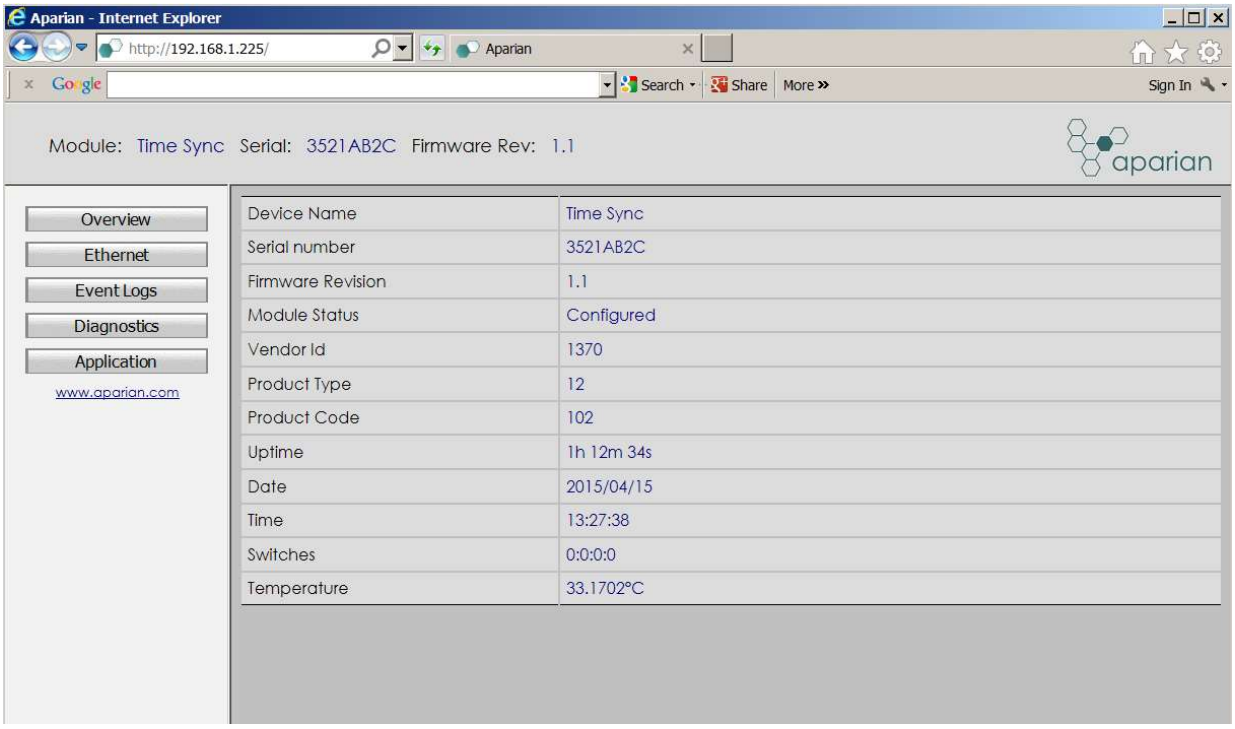


Figure 5.26. - Web interface

6. ASSET MANAGEMENT FDT – DTM TECHNOLOGY

The HART 4 module supports FDT / DTM technology, allowing the user to configure any field device using its DTM (Device Type Manager) in any standard FDT Frame (Field Device Tool). To use a field device DTM with the HART 4 module, the following Aparian DTMs will need to first be installed:

- EtherNet/IP CommDTM (Communication DTM)
- HART 4In/Out (Gateway DTM)

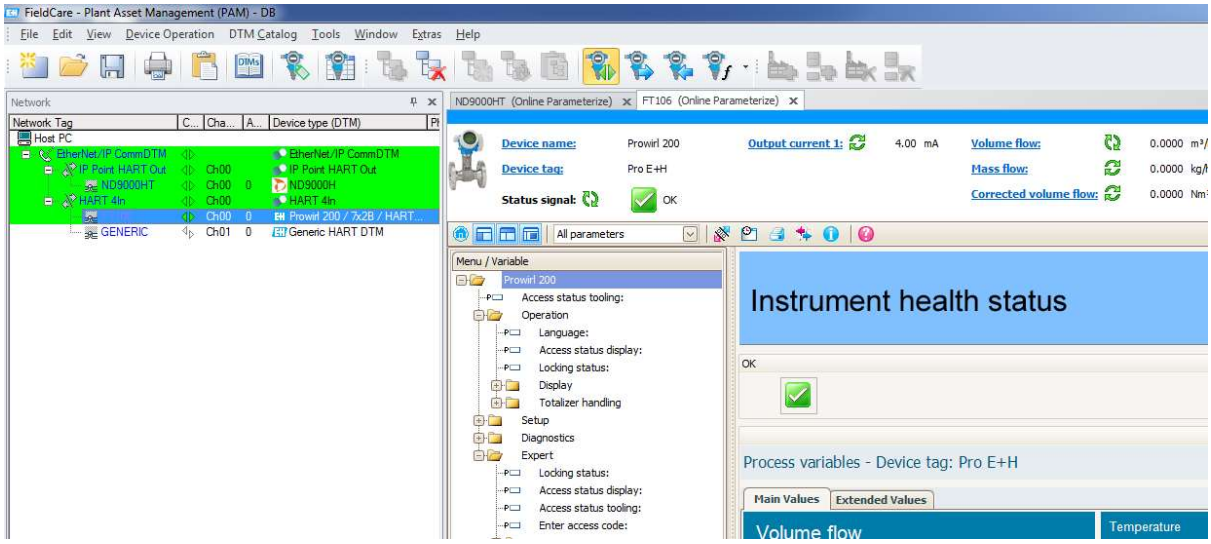


Figure 6.1 – FDT / DTM Example

7. WHAT IS HART

7.1. INTRODUCTION TO HART

HART is an acronym for Highway Addressable Remote Transducer. HART is able to transfer digital information across a standard 4-20 mA loop, by superimposing the digital data on the analog signal using Frequency Shift Keying (FSK). As the name implies FSK changes the frequency of the carrier to represent the binary data 0 or 1. A frequency of 1200 Hz represents a logical 1 and a frequency of 2200 Hz represents a logic 0. Therefor HART has a maximum transfer rate of 1200 bits per second (bps).

The amplitude of the FSK modulation is typically 1mA. Due to the relatively high frequency in comparison to changes of the analog signal, a low pass filter can be employed to prevent the modulation from affecting the analog signal.

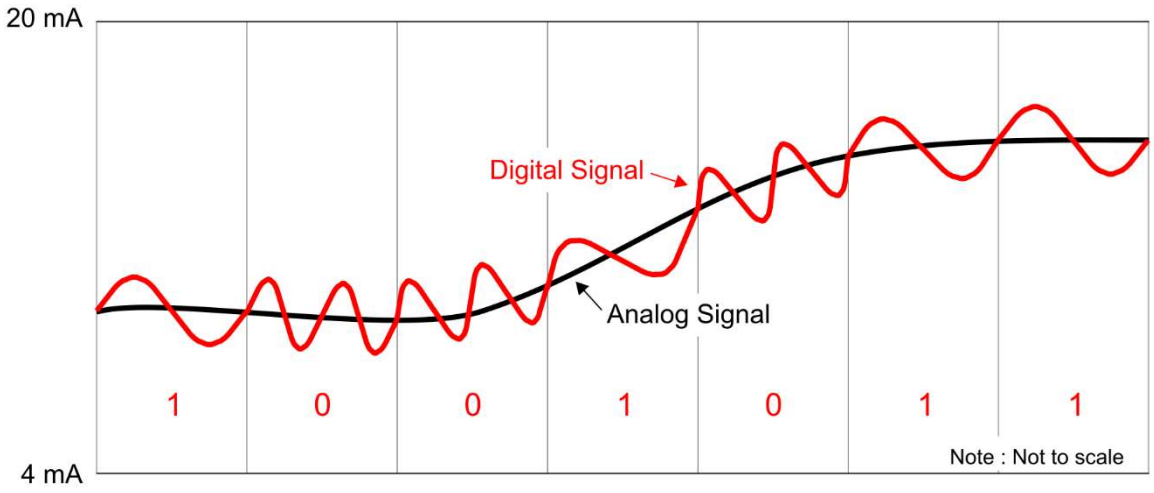


Figure 7.1. – HART FSK Modulation

8. TECHNICAL SPECIFICATIONS

8.1. DIMENSIONS

Below are the enclosure dimensions as well as the required DIN rail dimensions. All dimensions are in millimetres.

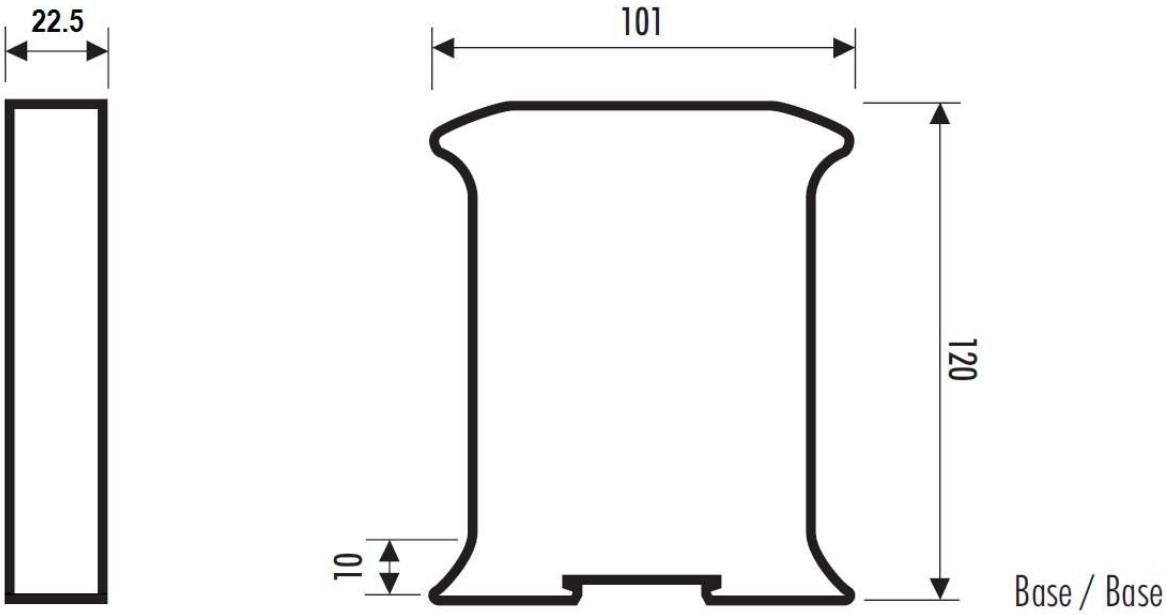


Figure 8.1 – HART 4 module enclosure dimensions

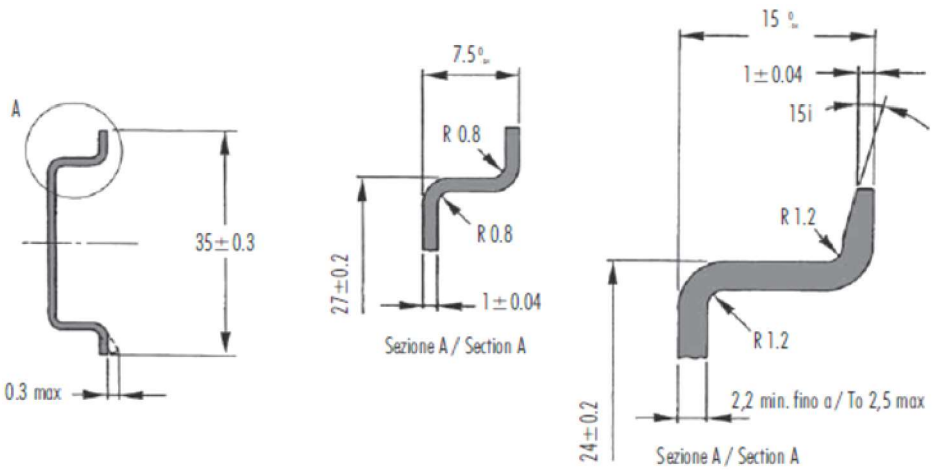


Figure 8.2 - Required DIN dimensions

8.2. ELECTRICAL

Specification	Rating
Power requirements	Input: 12 – 28V DC, 35mA @ 24 VDC – With no field devices attached. 130mA @ 24 VDC - With 4 field devices at 22mA each. 64mA @12 VDC - With no field devices attached. 160mA @ 12 VDC - With 4 field devices at 22mA each.
Power consumption	0.9 W – With no field devices attached. 3.1 W – With 4 field devices at 22mA each. 4.3 W – With input channels shorted. (HART 4In)
Connector (Power)	3-way terminal
Connector (Analog)	2-way terminal
Conductors	24 – 18 AWG
Enclosure rating	IP20, NEMA/UL Open Type
Temperature	-20 – 70 °C
Earth connection	Yes, terminal based
Emissions	IEC61000-6-4
ESD Immunity	EN 61000-4-2
Radiated RF Immunity	IEC 61000-4-3
EFT/B Immunity	EFT: IEC 61000-4-4
Surge Immunity	Surge: IEC 61000-4-5
Conducted RF Immunity	IEC 61000-4-6

Table 8.1 - Electrical specification

8.3. ETHERNET

Specification	Rating
Connector	RJ45
Conductors	CAT5 STP/UTP
ARP connections	Max 20
TCP connections	Max 20
CIP connections	Max 10
Communication rate	10/100Mbps
Duplex mode	Full/Half

Auto-MDIX support	Yes

Table 8.2 - Ethernet specification

8.4. ANALOG INPUT CHANNEL (HART 4 IN)

Specification	Rating
Number of channels	4
ADC resolution	12 bit
Input impedance	247.5 Ω
Accuracy (calibrated 25°C)	< 0.15 %
Accuracy (uncalibrated)	< 0.30 %
Range	0 – 22 mA
Current limit	34 mA

Table 8.3 - Analog Input channel specification

8.5. ANALOG OUTPUT CHANNEL (HART 4 OUT)

Specification	Rating
Number of channels	4
DAC resolution	16 bit
Drive	50 – 1170 Ω Resistive < 50 mH Inductive
Accuracy (calibrated 25°C)	< 0.15 %
Accuracy (uncalibrated)	< 0.30 %
Range	0 – 22 mA

Table 8.4 - Analog Output channel specification

8.6. CERTIFICATIONS

Certification	Mark
CE Mark	CE

RoHS2 Compliant	RoHS2
ODVA Conformance	EtherNet/IP™ * F/W 1.004
RCM	

Table 8.5 – Certifications

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