IMPLEMENTATION OF HiQDT SMART DIGITAL RS-485 MODBUS RTU SENSORS WITH CUSTOMER PLC

There exists three different implementation approaches for interfacing the smart digital HiQDT RS-485 MODBUS RTU sensor slaves with your PLC depending upon what is most suitable for your project requirements. Each implementation approach requires progressively more work for implementation and accordingly directly accesses more capabilities.

GENERAL NOTE 1:

For communication to be successful all MODBUS devices on the network must use the same baudrate and have a unique node address assigned. If the baudrate or node of the HiQDT sensor to be interfaced is not known, please use the free of charge Windows software to determine the current baudrate and node address and modify these parameters should it be necessary to ensure a valid & unique node address setting on the network as well as matching baudrates.

GENERAL NOTE 2:

All HiQDT smart digital sensors use the standard RS-485 MODBUS RTU communication configuration of 8-bit, even parity with 1 stop bit. If any other MODBUS devices are sharing the network with the HiQDT must share these settings to ensure proper communication. Please see HiQDT installation guide for additional recommendations & details about commissioning, calibration and troubleshooting.

IMPLEMENTATION APPROACH # 1

Only the core process values are obtained through the PLC with all other tasks such as viewing sensor analytics and diagnostics as well as performing calibrations being performed by either the ASTI supplied free of charge Windows software or else the battery powered handheld communicator.

IMPLEMENTATION APPROACH # 2

The core process values are obtained as well as other all information that can be accessed through calls that require only reading values from the sensor (anything that does not require writing values to be performed). This allows for not just the core process values to be obtained but also for all analytic and diagnostic information as well. The calibrations are obtained for information purposes but not modified with this approach. In this approach any tasks that require writing to the sensor such as changing user adjustable parameters and calibrations being performed by either the ASTI supplied free of charge Windows software or else the battery powered handheld communicator.

IMPLEMENTATION APPROACH # 3

This implementation approach includes all functionality that requires both reading and writing to the sensor. As such this level of implementation means that only the PLC is required to successfully use the sensor in the field with all tasks being performed by the PLC with the sole exception of changing the baud rate and node address which must always be performed by the ASTI supplied free of charge Windows software.

INITIAL SETUP:

The wo parameters that MUST be setup during commissioning by the free of charge ASTI supplied Windows software for the HiQDT sensors are the node address and baudrate. By default, the baudrate is 19,200 kbps and the node address is the same as the sensor type (see MODBUS function code 03 index 35 for details). Best practice to write the sensor type, node address & baudrate on the sensor label for ease of ongoing maintenance. Sensors can be ordered with customized default baudrate and node address upon request (contact factory for ordering information for custom parameter setups).

SAMPLING RATES:

The internal sampling rate of HiQDT sensors is 4 Hz (250ms) with a 1 second dampener applied to the raw values that are set. The engineered values also have a dampener applied with the number of seconds a user adjustable parameter stored in the sensor EEPROM. The maximum recommended sampling rate for read input registers used to obtain process values is 4 Hz (250ms). In some cases, for quite long cable lengths and/or with very many nodes it may be necessary to reduce the sampling rate to 2 Hz (500ms), 1 Hz (1,000ms) or even 0.5 Hz (2,000ms) if timeouts are occurring on the network.

IMPLEMENTATION APPROACH #1 – OBTAIN PROCESS VALUES ONLY

Access to **READ** core process values is gained through MODBUS function code (04) READ INPUT REGISETERS. Four values are available when requesting process values. Values can be called starting at any index and any number of values can be requested so long as it does not exceed the total number available from the starting index of the call. Values are sent in succession from the starting index of the call. If only one value is requested, then just the starting index is sent.

#	Name	Range	Engineered Values	Register	Index
1	Measurement pH	0..18,000	-2.000 to +16.000	30001	0
1	Measurement Standard Range ORP (mV)	0..20,000	-1,000.0 to +1,000.0	30001	0
1	Measurement Wide Range ORP (mV)	0..20,000	-2,000.0 to +2,000.0	30001	0
1	Measurement Dissolved Oxygen (DO) - ppm	0..15,000	0.00 to 150.00	30001	0
2	Measurement °C	0..2,500	-40.0 to +210.0 °C	30002	1
3	Measurement raw mV for pH & Std ORP	5,000..45,000 *	-1,000.0 to +1,000.0	30003	2
3	Measurement raw mV for Wide Range ORP	5,000..45,000 *	-2,000.0 to +2,000.0	30003	2
3	Measurement raw mV for Dissolved Oxygen	0..25,000	+0.00 to +250.00	30003	2
4	Measurement raw °C	0..2,500 **	-40.0 to +210.0 °C	30004	3
5	Measurement DO - % Saturation with Salinity	0..15,000	0.0 to 1,500.0 %	30005	4
6	Measurement DO - % Saturation w/o Salinity	0..15,000	0.0 to 1,500.0 %	30006	5

i.e. <node> <code> <index> <#values>

** When raw mV is below engineered value limit, then this is indicated by the integer 4,999 being sent for this index.*
** When raw mV is above engineered value limit, then this is indicated by the integer 45,001 being sent for this index.*
*** When raw °C is above engineered value limit, then this is indicated by the integer 2,501 being sent for this index.*

For HiQDT-pH Sensors (Default Node Address 1):
Value 1: Calibrated & Temperature Compensated pH
Range is -2.000 to +16.000 sent as 0 to 18,000 (unsigned integer) yielding resolution of 0.001pH
Value 3: Absolute raw mV values
Range is -1,000.0 to +1,000.0 mV sent as 25,000 ± 20,000 (unsigned integer) yielding resolution of 0.05mV

For HiQDT-ORP Standard Range Sensors (Default Node Address 2):
Value 1: Calibrated Standard ORP mV
Range is -1,000.0 to +1,000.0 sent as 0 to 20,000 (unsigned integer) yielding resolution of 0.1mV
Value 3: Absolute raw mV values
Range is -1,000.0 to +1,000.0 mV sent as 25,000 ± 20,000 (unsigned integer) yielding resolution of 0.05mV

For HiQDT-ORP Wide Range Sensors (Default Node Address 3):
Value 1: Calibrated Wide Range ORP mV
Range is -2,000.0 to +2,000.0 sent as 0 to 20,000 (unsigned integer) yielding resolution of 0.2mV
Value 3: Absolute raw mV values
Range is -2,000.0 to +2,000.0 mV sent as 25,000 ± 20,000 (unsigned integer) yielding resolution of 0.1mV

For HiQDT-DO Sensors (Default Node Address 4):
Value 1: Calibrated & Temperature Compensated Dissolved Oxygen ppm
Range is 0.00 to 150.00 sent as 0 to 15,000 (unsigned integer) yielding resolution of 0.01ppm
Value 3: Absolute raw mV values
Range is 0.00 to 250.00 mV sent as 0 to 25,000 (unsigned integer) yielding resolution of 0.01mV
Value 5: Percent (%) Saturation Dissolved Oxygen for Measurement w/ Temperature, mmHg & Salinity Corrections **– Computed Unit**
Value 6: Percent (%) Saturation Dissolved Oxygen for Calibration with Temperature & mmHg Corrections Only **– Computed Unit**
Range is 0.0 to 1,500.00 sent as 0 to 15,000 (unsigned integer) yielding resolution of 0.1%

For ALL HiQDT Sensor Types:
Value 2: Calibrated Temperature
Range is -40.0 to +210.0 °C sent as 0 to 2,500 (unsigned integer) yielding resolution of 0.1°C
Value 4: Absolute Raw Temperature
Range is -40.0 to +210.0 °C sent as 0 to 2,500 (unsigned integer) yielding resolution of 0.1°C

Note for Sensor Type #1: pH values should be rounded from the received three decimal places (0.001pH resolution) down to two decimals places (0.01pH resolution) to ensure that only significant figures are shown and/or recorded.

Note for Sensor Types #2 & #3: ORP values should be rounded from the receive one decimal place (0.1mV/0.2mV) resolution) down to whole mV units (1mV resolution) to ensure only significant figures are shown and/or recorded.

Note for Sensor Types #1, #2 & #3: If Index 4 or 5 (registers 30005 & 30006) is called then dummy value of 0 will be returned.

Please see Appendix 1 for MODBUS Poll screenshots obtaining these values for pH sensor type as an example

IMPLEMENTATION APPROACH #2 – OBTAIN ALL READ-ONLY VALUES

Access to user parameters, user statistics and system parameters is gained through the MODBUS function code (03) READ HOLDING REGISTERS. Values can be called starting at any index and any number of values can be requested so long as it does not exceed the total number available from the starting index of the call. Values are sent in succession from the starting index of the call. If only one value is requested, then just the starting index is sent.

The values in the table below are referred to as user parameters. Seventeen values are available.

#	Name	Range	Engineered Units & Values	Register	Index
1	Offset for pH measurement (A.P.)	0..5,000	0 = -250.0mV and 5,000 = +250.0mV	40001	0 **
1	Offset for Standard ORP measurement	0..5,000	0 = +250.0mV and 5,000 = -250.0mV	40001	0 **
1	Offset for Wide ORP measurement	0..10,000	0 = +500.0mV and 10,000 = -500.0mV	40001	0 **
2	Slope low pH measurement	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40002	1 *
2	Slope for Dissolved Oxygen measurement	70..600	70 = 0.70 mV and 600 = 6.00 mV	40002	1 *
3	Slope high pH measurement	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40003	2 ***
4	Offset oC measurement	0..500	0 = -25.0 °C and 500= +25.0 °C	40004	3
5	Step change for pH, ORP & Wide ORP	0..5	0=0.05, 1=0.10, 2=0.20, 3=0.50, 4=1.0, 5=2.0 **Units are mV**	40005	4
5	Salinity for Dissolved Oxygen	0..500	0 = 0.00 and 500 = 50.0 PSU	40005	4
6	Temp coefficient for pH compensation	0..999	µV (microvolts)	40006	5 *
6	Air Pressure for Dissolved Oxygen	600..900	600 = 600 and 900 = 900 mmHg	40006	5
7	Dampener	0..9	0=1, 1=2, 2=3, 3=4, 4=5, 5=8, 6=10, 7=15, 8=20, 9=30 **Units are Seconds**	40007	6
8	Output delay	0..9	0=1, 1=2, 2=3, 3=4, 4=5, 5=8, 6=10, 7=15, 8=20, 9=30 **Units are Seconds**	40008	7
9	Modbus baudrate	0..1	0 = 9,600 kbps and 1 = 19,200 kbps	40009	8
10	Reference auto calibration pH offset	0..1,800	0 = -2.00 pH and 1,800 = +16.00 pH	40010	9**
10	Reference auto cal Standard ORP offset	0..2,000	0 = -1,000 and 2,000 = +1,000 mV	40010	9**
10	Reference auto cal Wide ORP offset	0..4,000	0 = -2,000 and 4,000 = +2,000 mV	40010	9**
11	Reference auto calibration slope low	0..900	0 = -2.00 pH and 900 = +7.00 pH	40011	10 *
11	Reference autocal dissolved oxygen	400..1,800	400 = 4.00 and 1,800 = 18.00 ppm	40011	10
12	Reference auto calibration slope high	900..1,800	900 = +7.00 pH & 1,800 = +16.00 pH	40012	11 ***
13	Reference auto calibration oC offset	0..2,500	0 = -40.0 °C and 2,500= +210.0 °C	40013	12
14	Hours since mV offset adjustment	0..65,535	Units are Hours (Max 2,730 days)	40014	13
15	Hours since slope low pH/DO adjustment	0..65,535	Units are Hours (Max 2,730 days)	40015	14 *
16	Hours since slope high adjustment	0..65,535	Units are Hours (Max 2,730 days)	40016	15 ***
17	Hours since oC offset adjustment	0..65,535	Units are Hours (Max 2,730 days)	40017	16

i.e. <node> <code> <index> <#values>

* N/A for ORP. Value is sent but is invalid.
** N/A for Dissolved Oxygen. Value is sent but is invalid. Galvanic DO cell requires no offset calibration.
*** N/A for ORP nor Dissolved Oxygen. Value is sent but is invalid.

Please see Appendix 2A for MODBUS Poll screenshots obtaining these values for the pH sensor type

The values in the table below are referred to as user statistics. Eleven (11) values are available.

#	Name	Range	Engineered Units & Values	Register	Index
1	ASTI: manufacture date (Year)	00..99	00 = 2000 and 99 = 2099	40021	20
2	ASTI: manufacture date (Month)	01..12	1 = January….12 = December	40022	21
3	ASTI: manufacture date (Date)	01..31	Day of Month	40023	22
4	Serial Number (year)	00..99	00 = 2000 and 99 = 2099	40024	23
5	Serial Number (month)	01..12	1 = January….12 = December	40025	24
6	Serial Number (letter)	0..18	0=A, 1=b, 2=C, 3=d, 4=E, 5=F, 6=g, 7=H, 8=i, 9=J, 10=L, 11=n, 12=o, 13=P, 14=r, 15=S, 16=t, 17=U, 18=Y	40026	25
7	Serial Number (#)	00..99	Unique Identifier in Alpha Block	40027	26
8	Item Number	0..65,535	Unique Identifier for Sensor Configuration & Options	40028	27
9	Sensor: Min. temperature in use	0..2,500	0 = -40.0 °C and 2,500= +210.0 °C	40029	28
10	Sensor: Max temperature in use	0.2,500	0 = -40.0 °C and 2,500= +210.0 °C	40030	29
11	Sensor: Total days in use	0..65,535	Units are Hours (Max 2,730 days)	40031	30

i.e. <node> <code> <index> <#values>

Please see Appendix 2B for MODBUS Poll screenshots obtaining these values for the pH sensor type

The values in the table below are referred to as system parameters. Thirteen (13) values are available.

#	Name	Range	Engineered Units & Values	Register	Index
1	Type	0..255	1 = pH, 2 = Standard ORP, 3 = Wide Range ORP, 4 = Dissolved Oxygen	40036	35
2	SW revision	0..255	Check factory for most current rev #	40037	36
3	Production date (Year)	0..99	00 = 2000 and 99 = 2099	40038	37
4	Production date (Month)	1..12	1 = January….12 = December	40039	38
5	Production date (Date)	1..31	Day of Month	40040	39
6	Factory cal. (mV gain)	1..255	N/A (Factory Designation Only)	40041	40
7	Factory cal. (oC offset)	1..255	N/A (Factory Designation Only)	40042	41
8	Factory cal. (oC gain)	0..255	N/A (Factory Designation Only)	40043	42
9	Factory cal. (mV offset)	1..65,535	N/A (Factory Designation Only)	40044	43
10	ASTI cal for pH & Standard ORP (mV offset)	0..5,000	0 = -250.0mV and 5,000 = +250.0mV	40045	44**
10	ASTI cal for Wide ORP (mV offset)	0..10,000	0 = -500.0mV and 10,000 = +500.0mV	40045	44**
11	ASTI cal. (slope low)	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40046	45*
12	ASTI cal. (slope high)	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40047	46***
13	ASTI cal. (oC offset)	0..500	0 = -25.0 °C and 500= +25.0 °C	40048	47

i.e. <node> <code> <index> <#values>

* N/A for ORP. Value is sent but is invalid.
** N/A for Dissolved Oxygen. Value is sent but is invalid. Galvanic DO cell requires no offset calibration.
*** N/A for ORP nor Dissolved Oxygen. Value is sent but is invalid.

Please see Appendix 2C for MODBUS Poll screenshots obtaining these values for the pH sensor type

IMPLEMENTATION APPROACH #3
WRITE ALL USER PARAMETERS & REGISTERS

Access for all **WRITE** type parameters is gained through MODBUS function code (16) preset multiple registers. Values can be written starting at any index and any number of values can be written so long as it does not exceed the total number of parameters that are available from the starting index of the call. Values are to be written in succession from the starting index of the call. If only one value is to be written, then just the value of the starting index is written.

#	Name	Range	Engineered Units & Values	Register	Index
1	Offset for pH measurement (A.P.)	0..5,000	0 = -250.0mV and 5,000 = +250.0mV	40001	0 **
1	Offset for Standard ORP measurement	0..5,000	0 = +250.0mV and 5,000 = -250.0mV	40001	0 **
1	Offset for Wide ORP measurement	0..10,000	0 = +500.0mV and 10,000 = -500.0mV	40001	0 **
2	Slope low pH measurement	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40002	1 *
2	Slope for Dissolved Oxygen measurement	70..600	70 = 0.70 mV and 600 = 6.00 mV	40002	1 *
3	Slope high pH measurement	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40003	2 ***
4	Offset oC measurement	0..500	0 = -25.0 °C and 500= +25.0 °C	40004	3
5	Step change for pH, ORP & Wide ORP	0..5	0=0.05, 1=0.10, 2=0.20, 3=0.50, 4=1.0, 5=2.0 **Units are mV**	40005	4
5	Salinity for Dissolved Oxygen	0..500	0 = 0.00 and 500 = 50.0 PSU	40005	4
6	Temp coefficient for pH compensation	0..999	µV (microvolts)	40006	5 *
6	Air Pressure for Dissolved Oxygen	600..900	600 = 600 and 900 = 900 mmHg	40006	5
7	Dampener	0..9	0=1, 1=2, 2=3, 3=4, 4=5, 5=8, 6=10, 7=15, 8=20, 9=30 **Units are Seconds**	40007	6
8	Output delay	0..9	0=1, 1=2, 2=3, 3=4, 4=5, 5=8, 6=10, 7=15, 8=20, 9=30 **Units are Seconds**	40008	7
9	Modbus baudrate	0..1	0 = 9,600 kbps and 1 = 19,200 kbps	40009	8
10	Reference auto calibration pH offset	0..1,800	0 = -2.00 pH and 1,800 = +16.00 pH	40010	9**
10	Reference auto cal Standard ORP offset	0..2,000	0 = -1,000 and 2,000 = +1,000 mV	40010	9**
10	Reference auto cal Wide ORP offset	0..4,000	0 = -2,000 and 4,000 = +2,000 mV	40010	9**
11	Reference auto calibration slope low	0..900	0 = -2.00 pH and 900 = +7.00 pH	40011	10 *
11	Reference autocal dissolved oxygen	400..1,800	400 = 4.00 and 1,800 = 18.00 ppm	40011	10
12	Reference auto calibration slope high	900..1,800	900 = +7.00 pH & 1,800 = +16.00 pH	40012	11 ***
13	Reference auto calibration oC offset	0..2,500	0 = -40.0 °C and 2,500= +210.0 °C	40013	12
14	Hours since mV offset adjustment	0..65,535	Units are Hours (Max 2,730 days)	40014	13
15	Hours since slope low pH/DO adjustment	0..65,535	Units are Hours (Max 2,730 days)	40015	14 *
16	Hours since slope high adjustment	0..65,535	Units are Hours (Max 2,730 days)	40016	15 ***
17	Hours since oC offset adjustment	0..65,535	Units are Hours (Max 2,730 days)	40017	16

Commands

Name	Register	Index	Value
Reset calibrations to ASTI settings	40148	147	118
Reset address to type	40148	147	199
Autocalibration Offset for pH & ORP	40198	197	N/A ****
Autocalibration Offset oC	40199	198	N/A ****
Autocalibration Slope for pH & DO	40200	199 *	N/A ****

* N/A for ORP. Value is sent but is invalid.
** N/A for Dissolved Oxygen. Value is sent but is invalid. Galvanic DO cell requires no offset calibration.
*** N/A for ORP nor Dissolved Oxygen. Value is sent but is invalid.
**** Autocalibration is invoked by either writing value to this register or else just calling index without sending any value

IMPORTANT NOTE ABOUT SLOPE CALIBRATION FOR pH SENSORS:
Before using "Autocalibration Slope" command for pH sensor you **MUST** previously performed an offset calibration.

GENERAL NOTE AUTOCALIBRATION:
The index defining the value to which the autocalibration will be performed should always be written BEFORE invoking command **(except for DO sensors that write their own reference value).** The value of the measured parameter will be adjusted to the reference value defined for the autocalibration after the delay to which the dampener is currently set.

For HiQDT-pH Sensors:
Offset Adjust Temperature
Calibrated Temperature Value
Limit ±25.0 °C * from raw value
The temperature to which reading is adjusted is sent as 0 to 2,500 corresponding to -40.0 to +210.0 °C (FC16 Index 12)

Offset Adjust pH Value
Asymmetric Potential
Calibrated pH Value for A.P.
Limit ±250 mV * from default
The pH value to which reading is adjusted is sent as 0 to 1,800 corresponding to -2.00 to +16.00 pH (FC16 Index 9)

Adjust Acidic Slope
This slope used when pH less than 7
Calibrated pH Value - Acid Slope
Limit 30 to 90 mV per pH unit
The pH value to which reading is adjusted is sent as 0 to 1,800 corresponding to -2.00 to +16.00 pH (FC16 Index 10)

Adjust Alkaline Slope
This slope used when pH greater than 7
Calibrated pH Value - Base Slope
Limit 30 to 90 mV per pH unit
The pH value to which reading is adjusted is sent as 0 to 1,800 corresponding to -2.00 to +16.00 pH (FC16 Index 11)

NOTE: The HiQDT-pH sensor will automatically assign the slope calibration call as acidic or alkaline based upon when the pH value to be adjusted is less than or greater than 7

For HiQDT-ORP Standard Range ORP Sensors:
Offset Adjust Temperature
Calibrated Temperature Value
Limit ±25.0 °C * from raw value
The temperature to which reading is adjusted is sent as 0 to 2,500 corresponding to -40.0 to +210.0 °C (FC16 Index 12)

Offset Adjust mV Value
Calibrated mV Value Std ORP
Limit ±250 mV * from default
The mV value to which reading is adjusted is sent as 0 to 2,000 corresponding -1,000 to +1,000 mV (FC16 Index 9)

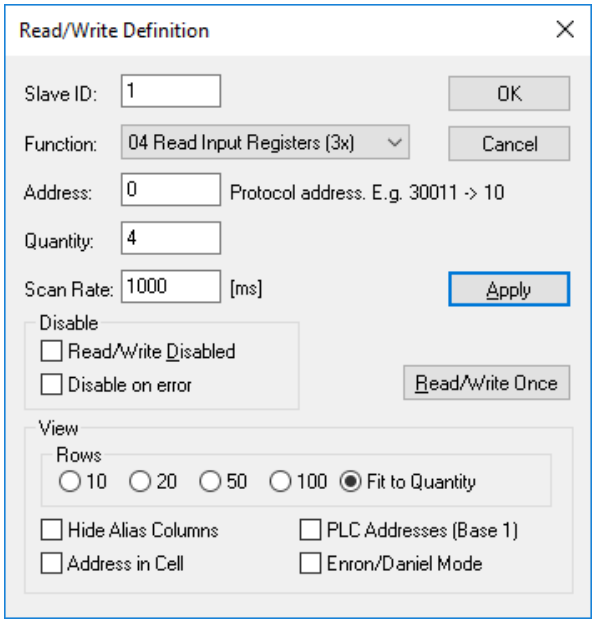
For HiQDT-ORP Wide Range ORP Sensors:
Offset Adjust Temperature
Calibrated Temperature Value
Limit ±25.0 °C * from raw value
The temperature to which reading is adjusted is sent as 0 to 2,500 corresponding to -40.0 to +210.0 °C (FC16 Index 12)

Offset Adjust mV Value
Calibrated mV Value Wide ORP
Limit ±250 mV * from default
The mV value to which reading is adjusted is sent as 0 to 4,000 corresponding -2,000 to +2,000 mV (FC16 Index 9)

For HiQDT-DO Dissolved Oxygen Sensors:
Offset Adjust Temperature
Calibrated Temperature Value | Limit ±25.0 °C * from raw value
The temperature to which reading is adjusted is sent as 0 to 2,500 corresponding to -40.0 to +210.0 °C (FC16 Index 12)

Adjust Slope
Calibrated Dissolved Oxygen Value at 100% Saturation Condition| Limit 0.70 to 6.00 mV per DO ppm unit
The DO value to which reading is adjusted is sent as 400 to 1,800 corresponding to 4.00 to 18.00 DO ppm @ 100% (FC16 Index 10)

APPENDIX 1 – READ INPUT REGISTERS MODBUS POLL SCREENSHOTS



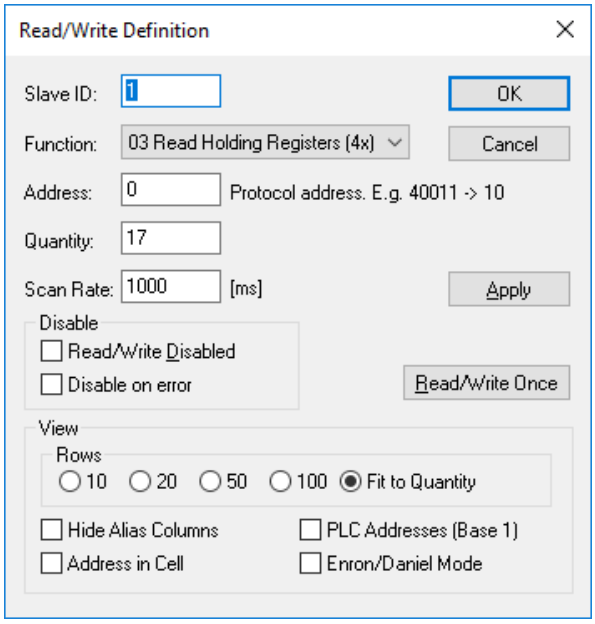
	Alias	3x0001
1	Measurement pH	6057
2	Measurement °C	615
3	Measurement raw mV for pH	28201
4	Measurement raw °C	616

ENGINEERED VALUES FROM INTEGER VALUES SHOWN FROM READ INPUT REGISTERS:

#	Name	Integer Value	Engineered Value	Register	Index
1	Measurement pH	6057	4.057	30001	0
2	Measurement °C	615	21.5	30002	1
3	Measurement raw mV for pH	28201	160.05	30003	2
4	Measurement raw °C	616	21.6	30004	3

Note: You must determine the sensor type before being able to assign engineered values for the read input registers. The sensor type is defined by read input registers function call index 35 (register 40036).

APPENDIX 2A - READ HOLDING REGISTERS MODBUS POLL SCREENSHOTS

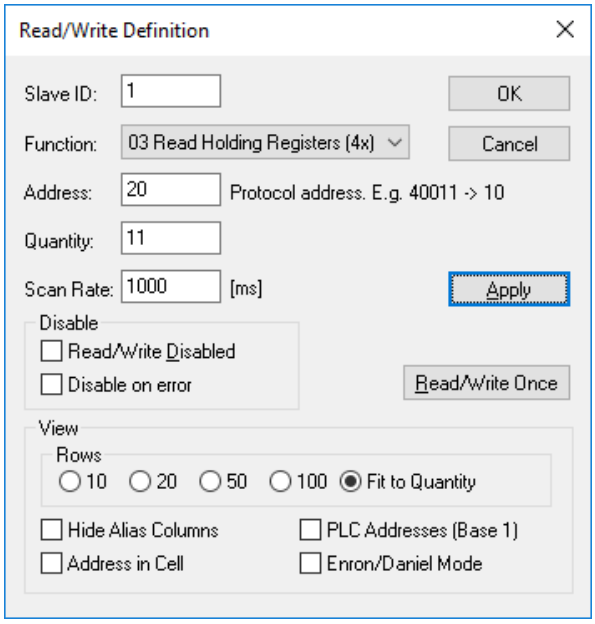


	Alias	4x0001
1	Offset mV measurement	2358
2	Slope low pH measurement	1196
3	Slope high pH measurement	1105
4	Offset oC measurement	251
5	Step change	5
6	Temperature coefficient for pH compensation	198
7	Dampener	6
8	Output delay	0
9	Modbus baudrate	1
10	Reference auto calibration pH offset	900
11	Reference auto calibration slope low	600
12	Reference auto calibration slope high	1205
13	Reference auto calibration oC offset	650
14	Hours since pH offset adjustment	0
15	Hours since slope low pH adjustment	0
16	Hours since slope high adjustment	0
17	Hours since oC offset adjustment	0

ENGINEERED VALUES FROM INTEGER VALUES SHOWN FROM READ INPUT REGISTERS:

#	Name	Integer Value	Engineered Value	Register	Index
1	Offset pH/mV measurement	2358	-14.2 mV	40001	0
2	Slope low pH measurement	1196	59.80mV per pH unit	40002	1
3	Slope high pH measurement	1105	55.25mV per pH unit	40003	2
4	Offset oC measurement	251	0 = -25.0 °C and 500= +25.0 °C	40004	3
5	Step change	5	2.0 mV	40005	4
6	Temp coefficient for pH compensation	198	198µV (microvolts)	40006	5
7	Dampener	6	10 seconds	40007	6
8	Output delay	0	1 second	40008	7
9	Modbus baudrate	1	19,200 kbps	40009	8
10	Reference auto calibration pH offset	900	+7.00 pH	40010	9
11	Reference auto calibration slope low	600	+4.00 pH	40011	10
12	Reference auto calibration slope high	1205	+10.05 pH	40012	11
13	Reference auto calibration oC offset	650	+25.0 °C	40013	12
14	Hours since mV offset adjustment	0	0 hours	40014	13
15	Hours since slope low pH adjustment	0	0 hours	40015	14
16	Hours since slope high adjustment	0	0 hours	40016	15
17	Hours since oC offset adjustment	0	0 hours	40017	16

APPENDIX 2B - READ HOLDING REGISTERS MODBUS POLL SCREENSHOTS



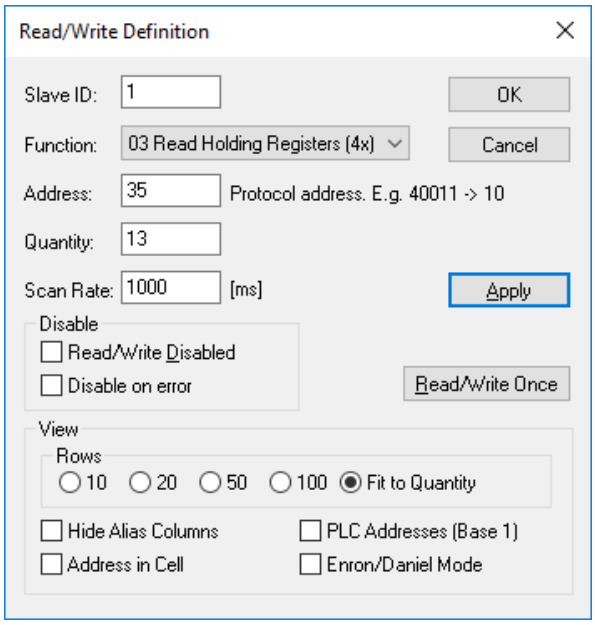
	Alias	4x0021
21	ASTI: manufacture date (Year)	18
22	ASTI: manufacture date (Month)	9
23	ASTI: manufacture date (Date)	22
24	Serial Number (year)	18
25	Serial Number (month)	9
26	Serial Number (letter)	1
27	Serial Number (#)	0
28	Item Number	1418
29	Sensor: Min. temperature in use	609
30	Sensor: Max temperature in use	650
31	Sensor: Total hours in use	2

ENGINEERED VALUES FROM INTEGER VALUES SHOWN FROM READ INPUT REGISTERS:

#	Name	Integer Value	Engineered Value	Register	Index
1	ASTI: manufacture date (Year)	18	2018	40021	20
2	ASTI: manufacture date (Month)	9	September	40022	21
3	ASTI: manufacture date (Date)	22	22	40023	22
4	Serial Number (year)	18	2018	40024	23
5	Serial Number (month)	9	September	40025	24
6	Serial Number (letter)	0	A	40026	25
7	Serial Number (#)	0	00	40027	26
8	Item Number	1418	1418	40028	27
9	Sensor: Min. temperature in use	609	+20.9 °C	40029	28
10	Sensor: Max temperature in use	650	+25.0 °C	40030	29
11	Sensor: Total days in use	2	2 hours	40031	30

Note for Serial Number:
Complete serial number is typically shown as follow string of indexes <23>.<24>-<25>.<26>
Based upon the values returned for these indexes in the example above the serial number would be shown as: 18.09-A.00
The serial number is heat-shrink sealed near the end of sensor cable in the format as detailed above.

APPENDIX 2C - READ HOLDING REGISTERS MODBUS POLL SCREENSHOTS



	Alias	4x0036
36	Type	1
37	SW revision	1
38	Production date (Year)	18
39	Production date (Month)	9
40	Production date (Date)	6
41	Factory cal. (mV gain)	196
42	Factory cal. (oC offset)	57
43	Factory cal. (oC gain)	227
44	Factory cal. (mV offset)	16233
45	ASTI cal. (mV offset)	2500
46	ASTI cal. (slope low)	1183
47	ASTI cal. (slope high)	1183
48	ASTI cal. (oC offset)	250

ENGINEERED VALUES FROM INTEGER VALUES SHOWN FROM READ INPUT REGISTERS:

#	Name	Integer Value	Engineered Value	Register	Index
1	Type	1	pH	40036	35
2	SW revision	1	1	40037	36
3	Production date (Year)	18	2018	40038	37
4	Production date (Month)	9	September	40039	38
5	Production date (Date)	6	6	40040	39
6	Factory cal. (mV gain)	196	N/A (Factory Designation Only)	40041	40
7	Factory cal. (oC offset)	57	N/A (Factory Designation Only)	40042	41
8	Factory cal. (oC gain)	227	N/A (Factory Designation Only)	40043	42
9	Factory cal. (mV offset)	16233	N/A (Factory Designation Only)	40044	43
10	ASTI cal. (mV offset)	2500	0.0 mV	40045	44
11	ASTI cal. (slope low)	1183	59.15 mV per pH unit	40046	45
12	ASTI cal. (slope high)	1183	59.15 mV per pH unit	40047	46
13	ASTI cal. (oC offset)	250	0.0 °C	40048	47