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 (1)

Access to **READ** core process values is gained through MODBUS function code (04) READ INPUT REGISTERS. 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
1	Measurement Ion Selective in pION Units	0..18,000	-2.000 to +16.000	30001	0
1	Measurement Temperated Compensated Conductivity (EC)	0..50,000	See Pages 4 & 5 for Range & Scaling Details	30001	0
2	Measurement °C	0..2,500	-40.0 to +210.0 °C	30002	1
3	Measurement raw mV for pH & Std ORP & ISE	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
3	Measurement raw Conductivity	0..50,000	Page 4 & 5 for Details	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
5	Measurement computed salinity when Conductivity Sensor Type 6 (Std/High Range)	0..50,000	0.000 to 50.000 PSU	30005	4
5	Measurement computed resistivity using linear temperature compensation scheme when Conductivity Sensor Type 7 Ultralow Rage	0..50,000	0.000 to 50.000 MΩ	30005	4
6	Measurement DO - % Saturation w/o Salinity	0..15,000	0.0 to 1,500.0 %	30006	5
6	Measurement computed TDS NaCl, 442 or KCl when Conductivity Sensor Type 6 (Std/High)	0..50,000	0 to 100,00 ppm	30006	5
6	Measurement computed resistivity using special non-linear ultrapure water (UPW) temperature compensation scheme when Conductivity Sensor Type 7 Ultralow Rage	0..50,000	0.000 to 50.000 MΩ	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.*

NOTE FOR HiQDT-ISE Ion Selective Sensors:
Please Appendix 0 for instructions on how to convert from the scientific pION units used by this sensor to the common ppm units.

NOTE FOR HiQDT-CON-ISO Conductivity Standard/High Range Type Sensors:
The type of TDS ppm units which are computed is defined by user register 40020 and the default is defined by system register 40051

IMPLEMENTATION APPROACH #1 – OBTAIN PROCESS VALUES ONLY (2)

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 HiQDT-ISE Sensors (Default Node Address 5):
Value 1: Calibrated & Temperature Compensated pION
Range is -2.000 to +16.000 sent as 0 to 18,000 (unsigned integer) yielding resolution of 0.001pION
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-CON(-L) Sensors (Default Node Address 6):
Value 1: Calibrated & Temperature Compensated Conductivity
Range and resolution vary based upon cell constant and operating range mode. Please see pages 4 & 5 for details.
Value 3: Absolute raw Conductivity
Range and resolution vary based upon cell constant and operating range mode. Please see pages 4 & 5 for details.
Values 5 & 6: Computed Salinity and Computed TDS ppm units for Conductivity Sensor Type 6 Standard/High Range Mode
Salinity (value 5) is 0.000 to 50.000 PSU sent as 0-50,000 wile TDS ppm (value 6) is 0 to 100,000 sent as 0-50,000 (both unsigned integers)
Values 5 & 6: Computed MegaOhms (MΩ) resistivity units for Conductivity Sensor Type 7 Ultralow Range Mode
Resistivity w/ linear ATC (value 5) & Resistivity w/ UPW ATC (value 6) is 0.000 to 50.000 MΩ sent as 0-50,000 (both unsigned integers)

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 Type #5: Appendix 0 has instructions on how to convert from the scientific pION units used by this sensor to the common ppm units. The resolution is always 0.001 pION units for all ion selective sensors since this is the linear scientific units. When converting to the non-linear common ppm units the resolution will differ at different concentrations and ions.

Note for Sensor Types #1, #2, #3 & #5: 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

HiQDT-CON-ISO SENSOR CELL & RANGE TABLE FOR STANDARD / HIGH HARDWARE

STANDARD RANGE MODE * - in microSiemens/cm

Range Scaling Factor	200		Max Temp. Compensated Conductivity using 2% per °C Coefficient			
Nominal Cell Int **	Max Raw Input Limit	Resolution ***	Lowest Recommended Measurement @ 25°C	@ 25 °C	@ 75 °C	@ 125°C
1	200	0.004	2	200	100	66.67
2	400	0.008	4	400	200	133.33
5	1,000	0.02	10	1,000	500	333.33
10	2,000	0.04	20	2,000	1,000	666.67
20	4,000	0.08	40	4,000	2,000	1,333.33
50	10,000	0.2	100	10,000	5,000	33,33.33
100	20,000	0.4	200	20,000	10,000	66,66.67
200	40,000	0.8	400	40,000	20,000	13,333.33
300	60,000	1.2	600	60,000	30,000	20,000.00
500	100,000	2	1,000	100,000	50,000	33,333.33
1000	200,000	4	2,000	200,000	100,000	66,666.67
2000	400,000	8	4,000	400,000	200,000	133,333.33

HIGH RANGE MODE * - in microSiemens/cm

Range Scaling Factor	2,000		Max Temp. Compensated Conductivity using 2% per °C Coefficient			
Nominal Cell Int **	Max Raw Input Limit	Resolution ***	Lowest Recommended Measurement @ 25°C	@ 25 °C to 75°C	@ 125°C	@ 175°C
1	2,000	0.04	20	1000	666.67	500
2	4,000	0.08	40	2,000	1,333.33	1,000
5	10,000	0.2	100	5,000	3,333.33	2,500
10	20,000	0.4	200	10,000	6,666.67	5,000
20	40,000	0.8	400	20,000	13,333.33	10,000
50	100,000	2	1,000	50,000	33,333.33	25,000
100	200,000	4	2,000	100,000	66,666.67	50,000
200	400,000	8	4,000	200,000	133,333.33	100,000
300	600,000	12	6,000	300,000	200,000.00	150,000
500	1,000,000	20	10,000	500,000	3333,33.33	250,000
1000	2,000,000	40	20,000	1,000,000	666,666.67	500,000
2000	4,000,000	80	40,000	2,000,000	1,333,333.33	1,000,000

* Range mode defined by register 40018. When register 40018 is 200 then range scaling factor is standard mode. When 40018 is 2,000 then range scaling is high mode. **The range mode can be modified while in use by changing value of register 40018 as desired.**

** The nominal cell constant of conductivity sensor is found by dividing integer obtained from register 40019 by 100.

*** The resolution is always 50,000 steps no matter the nominal cell constant of sensor or range mode that is in operation.

If sensor used is only ever just one cell constant and range mode, then simple scaling of 0-50,000 steps to conductivity range is possible. Procedure below supports any cell constant in any range mode without changing programming of MODBUS RTU master PLC device:

1) Converting registers 30001 & 30003 for conductivity sensors into µS/cm conductivity units

To display calibrated & temperature compensated conductivity in µS/cm units, use the following formula:

uS/cm = ((REG30001 * REG40019) * REG40018) / 50,000

To display calibrated raw conductivity in µS/cm units use register 30003 instead of 30001 in formula above.

2) Converting µS/cm conductivity units into native 0-50,000 step sensor resolution units

When performing the autocalibration calls on the conductivity sensor you will need to convert from the engineered µS/cm conductivity units to the 0 to 50,000 native resolution units of the conductivity sensor using this formula:

Native 0-50,000 sensor resolution units = (uS/cm * 50,000) / (REG40019 * REG40018)

Native 0-50,000 sensor resolution units are what is sent to register 40011 (standard slope) or register 40012 (high slope).

HiQDT-CON-ISO-L SENSOR CELL & RANGE TABLE FOR ULTRALOW HARDWARE

ULTRA-LOW RANGE MODE * - in microSiemens/cm

Range Scaling Factor	2		Max Temp. Compensated Conductivity using 2% per °C Coefficient			
Nominal Cell Int **	Max Raw Input Limit	Resolution ***	Lowest Recommended Measurement @ 25°C	@ 25°C	@ 75°C	@ 125°C
1	2	0.00004	0.02	2	1	0.667
2	4	0.00008	0.04	4	2	1.333
5	10	0.0002	0.1	10	5	3.333
10	20	0.0004	0.2	20	10	6.667
20	40	0.0008	0.4	40	20	13.333
50	100	0.002	1.0	100	50	33.333
100	200	0.004	2.0	200	100	66.667
200	400	0.008	4.0	400	200	133.33
300	600	0.012	6.0	600	300	200
500	1,000	0.02	10.0	1,000	500	333.33
1000	2,000	0.04	20.0	2,000	1,000	666.667
2000	4,000	0.08	40.0	4,000	2,000	1,333.33

* Range mode defined by register 40018. When register 40018 is 2 then range scaling factor is ultralow mode. **This register 40018 is read only for the ultralow mode sensor type.**

** The nominal cell constant of conductivity sensor is found by dividing integer obtained from register 40019 by 100.

*** The resolution is always 50,000 steps no matter the nominal cell constant of sensor or range mode that is in operation.

If sensor used is only ever just one cell constant and range mode, then simple scaling of 0-50,000 steps to conductivity range is possible. Procedure below supports any cell constant in any range mode without changing programming of MODBUS RTU master PLC device:

1) Converting registers 30001 & 30003 for conductivity sensors into µS/cm conductivity units

To display calibrated & temperature compensated conductivity in µS/cm units, use the following formula:

uS/cm = ((REG30001 * REG40019) * REG40018) / 50,000

To display calibrated raw conductivity in µS/cm units use register 30003 instead of 30001 in formula above.

2) Converting µS/cm conductivity units into native 0-50,000 step sensor resolution units

When performing the autocalibration calls on the conductivity sensor you will need to convert from the engineered µS/cm conductivity units to the 0 to 50,000 native resolution units of the conductivity sensor using this formula:

Native 0-50,000 sensor resolution units = (uS/cm * 50,000) / (REG40019 * REG40018)

Native 0-50,000 sensor resolution units are what is sent to register 40011 (ultralow slope) or register 40012 (low slope).

IMPLEMENTATION APPROACH #2 – OBTAIN ALL READ-ONLY VALUES

Access to user parameters & statistics and system parameters is gained through MODBUS READ HOLDING REGISTERS function code (03). Values can be called starting at any index and any valid number of values can be requested. 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. Up to Twenty (20) values are available.

#	Name	Range	Engineered Units & Values	Register	Index
1	Offset for pH measurement (A.P.)	0..5,000	0 = -250.0mV & 5,000 = +250.0mV	40001	0 **
1	Offset for Standard ORP measurement	0..5,000	0 = +250.0mV & 5,000 = -250.0mV	40001	0 **
1	Offset for Wide ORP measurement	0..10,000	0 = +500.0mV & 10,000 = -500.0mV	40001	0 **
1	Offset for ISE (mV @ ISO-Concentration)	0..20,000	0 = -1,000.00 & 20,000 = +1,000.00 mV	40001	0 **
1	Offset for Conductivity (Zero Dry in Air)	0..1,000	0.00 to 2.00% native resolution units	40001	0 **
2	Slope low pH measurement	600..1,800	600 = 30.0mV & 1,800 = 90.0mV	40002	1 *
2	Slope for Dissolved Oxygen measurement	70..600	70 = 0.70 mV & 600 = 6.00 mV	40002	1 *
2	Slope for Ion Selective Measurement	200..2,000	200 = 10.00mV & 2,000 = 100.00mV	40002	1 *
2	Slope Conductivity Ultralow/Standard	300..1,700	300 = 0.300 & 1,700 = 1.700	40002	1 *
3	Slope high pH measurement	600..1,800	600 = 30.0mV & 1,800 = 90.0mV	40003	2 ***
3	Slope Conductivity High Range Mode	300..1,700	300 = 0.300 & 1,700 = 1.700	40003	2 ***
4	Offset oC measurement	0..500	0 = -25.0 °C & 500= +25.0 °C	40004	3
5	Step change for pH, ORP, Wide ORP, ISE (mV) & Conductivity (% Change)	0..5	0=0.05, 1=0.10, 2=0.20, 3=0.50, 4=1.0, 5=2.0 **Units mV / % Change**	40005	4
5	Salinity for Dissolved Oxygen	0..500	0 = 0.00 & 500 = 50.0 PSU	40005	4
6	Temp Comp Coefficient pH/ISE/Cond(EC)	0..999	µV for pH/ISE | (%/°C)*100 for EC	40006	5 *
6	Air Pressure for Dissolved Oxygen	600..900	600 = 600 & 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 & 1 = 19,200 kbps	40009	8
10	Reference auto calibration pH offset	0..1,800	0 = -2.00 pH & 1,800 = +16.00 pH	40010	9**
10	Reference auto cal Standard ORP offset	0..2,000	0 = -1,000 & 2,000 = +1,000 mV	40010	9**
10	Reference auto cal Wide ORP offset	0..4,000	0 = -2,000 & 4,000 = +2,000 mV	40010	9**
10	Reference auto calibration ISE offset (pION)	0..18,000	0 = -2.000 & 18,000 = +16.000 pION	40010	9 **
11	Reference auto calibration slope low	0..900	0 = -2.00 pH & 900 = +7.00 pH	40011	10 *
11	Reference autocal dissolved oxygen	400..1,800	400 = 4.00 & 1,800 = 18.00 ppm	40011	10
11	Reference auto calibration slope low acid	0..900	0 = -2.00 pH & 900 = +7.00 pH	40011	10 *
11	Reference auto calibration ISE Slope (pION)	0..18,000	0 = -2.000 & 18,000 = +16.000 pION	40011	10 *
11	Reference autocal Conductivity Slope	0..50,000	See Pages 4 & 5 for Details	40011	10 *
12	Reference auto calibration slope high base	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 / EC zero 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
18	Isopotentional Concentration (pION)	0..18,000	0 = -2.000 & 18,000 = +16.000	40018	17 ****
18	Conductivity Range Mode Selector for ultralow & standard/high hardware	2 or 200/2,000	2 = Ultralow (read-only) or else 200 = Standard and 2,000 = High	40018	17*****
19	Nominal mV @ Isopotential Concentration	0..20,000	0 = -1,000.00 & 20,000 = +1,000.00 mV	40019	18 ****
19	Nominal Cell Constant for Conductivity	1..2,000	1 = K=0.01/cm & 2,000 = K=20.0/cm	40019	18*****
20	Formula Weight of Ion (grams per mol)	0..65,535	0 = 0.00 & 65,535 = 655.35 grams/mol	40020	19 ****
20	Selector for TDS ppm unit type	0..2	0 = NaCl, 1 = 442, 2 = KCl	40020	19*****

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..246	See Appendix 3 for Details	40026	25
7	Serial Number (#)	00..255	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

The values in the table below are referred to as system parameters. Up to Seventeen (17) values are available.

#	Name	Range	Engineered Units & Values	Register	Index
1	Type	0..7	1= pH, 2= Standard ORP, 3= Wide ORP, 4 = Dissolved Oxygen, 5 = Ion Selective, 6= Standard/High Range Conductivity 7 = Ultralow Range Conductivity	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 pH/Std ORP/ISE (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 **
10	ASTI default for Isopotential Voltage	0..20,000	0 = -1,000.00 & 20,000 = +1,000.00 mV	40045	44 ****
11	ASTI cal. (slope low)	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40046	45*
11	ASTI Default Slope for ISE	200..2,000	200 = 10.00mV & 2,000 = 100.00mV	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
14	Isopotentional Concentration (pION)	0..18,000	0 = -2.000 & 18,000 = +16.000	40049	48 ****
14	Conductivity Range Mode Selector for ultralow & standard/high styles	2 or 200/2,000	2 = Ultralow or else 200 = Standard and 2,000 = High	40049	48 *****
15	Nominal Isopotential Concentration	0..20,000	0 = -1,000.00 & 20,000 = +1,000.00 mV	40050	49 ****
15	Nominal Cell Constant Conductivity	1..2,000	1 = K=0.01/cm & 2,000 = K=20.00/cm	40050	49 *****
16	Formula Weight Ion (grams per mol)	0..65,535	0 = 0.00 & 65,535 = 655.35 grams/mol	40051	50 ****
16	Selector for TDS ppm unit type	0..2	0 = NaCl, 1 = 442, 2 = KCl	40051	50 *****
17	Sign of slope: Cation (+), Anion (-)	0..1	Cation = 0, Anion = 1	40052	51 ****

* 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, Dissolved Oxygen or ISE. Value is sent if requested but has no meaning.
**** <u>ONLY</u> valid for Ion Selective Type Sensors. The isopotential concentration for ISE sensor (register 40018) & formula weight of measured ion (register 40020) set at factory & cannot be changed. **Calibrated mV at isopotential concentration is defined by the sum of the nominal mV default value (register 40019) and offset mV from calibration (register 40001).**
***** <u>ONLY</u> valid for Conductivity Type Sensors. Effective calibrated cell constant used to compute raw & temperature compensated conductivity is product of scaled nominal cell (register 40019) & slope gain calibration (register 40002).

Please see Appendix 2B & 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 & 5,000 = +250.0mV	40001	0 **
1	Offset for Standard ORP measurement	0..5,000	0 = +250.0mV & 5,000 = -250.0mV	40001	0 **
1	Offset for Wide ORP measurement	0..10,000	0 = +500.0mV & 10,000 = -500.0mV	40001	0 **
1	Offset for ISE (mV @ ISO-Concentration)	0..20,000	0 = -1,000.00 & 20,000 = +1,000.00 mV	40001	0 **
1	Offset for Conductivity (Zero Dry in Air)	0..1,000	0.00 to 2.00% native resolution units	40001	0 **
2	Slope low pH measurement	600..1,800	600 = 30.0mV & 1,800 = 90.0mV	40002	1 *
2	Slope for Dissolved Oxygen measurement	70..600	70 = 0.70 mV & 600 = 6.00 mV	40002	1 *
2	Slope for Ion Selective Measurement	200..2,000	200 = 10.00mV & 2,000 = 100.00mV	40002	1 *
2	Slope Conductivity Ultralow/Standard	300..1,700	300 = 0.300 & 1,700 = 1.700	40002	1 *
3	Slope high pH measurement	600..1,800	600 = 30.0mV & 1,800 = 90.0mV	40003	2 ***
3	Slope Conductivity High Range Mode	300..1,700	300 = 0.300 & 1,700 = 1.700	40003	2 ***
4	Offset oC measurement	0..500	0 = -25.0 °C & 500= +25.0 °C	40004	3
5	Step change for pH, ORP, Wide ORP, ISE (mV) & Conductivity (% Change)	0..5	0=0.05, 1=0.10, 2=0.20, 3=0.50, 4=1.0, 5=2.0 **Units mV / % Change**	40005	4
5	Salinity for Dissolved Oxygen	0..500	0 = 0.00 & 500 = 50.0 PSU	40005	4
6	Temp Comp Coefficient pH/ISE/Cond(EC)	0..999	µV for pH/ISE | (%/°C)*100 for EC	40006	5 *
6	Air Pressure for Dissolved Oxygen	600..900	600 = 600 & 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
10	Reference auto calibration pH offset	0..1,800	0 = -2.00 pH & 1,800 = +16.00 pH	40010	9**
10	Reference auto cal Standard ORP offset	0..2,000	0 = -1,000 & 2,000 = +1,000 mV	40010	9**
10	Reference auto cal Wide ORP offset	0..4,000	0 = -2,000 & 4,000 = +2,000 mV	40010	9**
10	Reference auto calibration ISE offset (pION)	0..18,000	0 = -2.000 & 18,000 = +16.000 pION	40010	9 **
11	Reference auto calibration slope low	0..900	0 = -2.00 pH & 900 = +7.00 pH	40011	10 *
11	Reference autocal dissolved oxygen	400..1,800	400 = 4.00 & 1,800 = 18.00 ppm	40011	10
11	Reference auto calibration slope low	0..900	0 = -2.00 pH & 900 = +7.00 pH	40011	10 *
11	Reference auto calibration ISE Slope (pION)	0..18,000	0 = -2.000 & 18,000 = +16.000 pION	40011	10 *
11	Reference autocal Conductivity Slope	0..50,000	See Pages 4 & 5 for Details	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
18	Conductivity Range Modes available for standard/high & ultralow hardware	2 or 200/2,000	2 = Ultralow (read-only) or else 200 = Standard & 2,000 = High (Adjustable)	40018	17*****
20	Selector for TDS ppm unit type	0..2	0 = NaCl, 1 = 442, 2 = KCl	40020	19*****

* 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, Dissolved Oxygen or ISE. Value is sent if requested but has no meaning.
**** <u>ONLY</u> valid for Ion Selective Type Sensors. **Calibrated mV at isopotential concentration is defined by the sum of the nominal mV default value (register 40019) set at factory and offset mV from calibration (register 40001).**
***** <u>ONLY</u> valid for Conductivity. Effective calibrated cell constant used to compute raw & temperature compensated values. Effective calibrated cell constant is product of scaled nominal cell (register 40019) & scaled slope gain calibration (register 40002). See pages 4 & 5 for details on standard/high & ultralow range for cell constant of conductivity sensor.

Calibration 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, Ion Selective (ISE) & Conductivity	40198	197	N/A ****
Autocalibration Offset oC	40199	198	N/A ****
Autocalibration Slope for pH, Dissolved Oxygen, Ion Selective (ISE) & Conductivity	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

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

<u>GENERAL NOTE AUTOCALIBRATION:</u>
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.

<u>NOTE for Offset Autocalibration for ISE Sensors</u>
The autocalibration value must be sent in pION units to register 40010 before invoking offset calibration command. **Calibrated mV at isopotential concentration is defined by the sum of the nominal mV (register 40019) and offset mV from calibration (register 40001) default value. If calibration call would exceed offset limits an error will be returned.**

<u>NOTE for Slope Autocalibration for ISE Sensors</u>
mV per pION (register 40002) slope can be from 10.00 to 100.00 mV. Autocalibration value must be sent in pION units to register 40011 before invoking slope calibration command. **If magnitude of slope computed from autocalibration call is outside boundary conditions or else if the sign of the slope computed from autocalibration call is incorrect for type of ion measured (cation vs anion) then an error will be returned.**

<u>NOTE FOR CREATING pION VALUES FOR HiQDT-ISE Ion Selective Sensors:</u>
Appendix 0 has instructions for convert from common ppm units to scientific pION units used by sensor. It is required that all reference values for autocalibration on the HiQDT-ISE Ion Selective Sensors are sent in the scientific pION units.

<u>For HiQDT-pH Sensors:</u>
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)

For HiQDT-ISE 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 pION Value
Calibrated pION Value for IsoPotential → Limit ±1000 mV * from default
The pION value to which reading is adjusted is sent as 0 to 18,000 corresponding to -2.000 to +16.000 pION (FC16 Index 9)

Adjust Slope
Calibrated pION Value for Slope → Limit 10.00 to 100.00 mV per pION unit
The pION value to which reading is adjusted is sent as 0 to 18,000 corresponding to -2.000 to +16.000 pH (FC16 Index 10)

For HiQDT-CON 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, Reg. 40013)

Offset Adjust Conductivity Value
Zero Dry in Air → 0.00 to 2.00 % of the native resolution units (REFERENCE VALUE IS ALWAYS 0)
Result of zero dry in air calibration sent as 0-1,000 corresponds to 0.00-2.00% of native resolution units (FC16 Index 9, Reg. 40010)

Adjust Slope (a.k.a. Gain) on Conductivity Sensor
Calibrated Conductivity Value for Span → Limit 0.300 to 1.700 times nominal cell constant for effective apparent cell
See pages 4 & 5 for instructions on how to convert the desired conductivity unit to be used as the basis for the slope gain calibration into the native 0-50,000 resolution units for the conductivity sensors. (FC16 Index 10, Reg. 40011)

Note for Ion Selective Sensors:
Appendix 0 has instructions on how to convert from the scientific pION units used by this sensor to the common ppm units. The resolution is always 0.001 pION units for all ion selective sensors since this is the linear scientific units. When converting to the non-linear common ppm units the resolution will differ at different concentrations and sensor types.

APPENDIX 0 – CONVERTING BETWEEN pION & PPM UNITS

The ion selective sensors operate in the linear scientific pION units. If you wish to operate in the common non-linear ppm units, please use the instruction provided below to program your MODBUS RTU master. If you wish to operate in the native scientific pION units then no special conversion is required.

BACKGROUND:

The units that are commonly used for ion measurements are ppm. The ion selective sensor does not have a linear response to the parts per million (ppm) units. Instead the ion selective sensor has a linear response to the pION units which is the ion selective corollary to the pH unit since pH sensors are in fact a very special type of ion selective sensor that measures hydrogen ion activity. Similarly, ion selective sensors measure ion activity for the specific type of cation or anion for which they have been designed and fabricated. The instructions below allow you to convert from the linear scientific pION units in which these ion selective sensors natively operate to the common non-linear ppm units if desired.

CONVERT FROM pION to PPM:

Starting with the familiar pH sensor let us consider the pH units:

pH = - $\log_{10}$ [Hydrogen Ion Activity in Molarity Units]

This indicates that the pH is the negative decadic log of the hydrogen ion activity in Molarity units.

So for the ion selective sensor we then have:

pION = - $\log_{10}$ [Analyte Ion Activity in Molarity Units]

The analyte ion is the measured ion of interest. This indicates that the pION is the negative decadic log for the activity of the analyte ion in Molarity units. Solving for the Analyte Ion Activity in Molarity Units we get the following:

[Analyte Ion Activity in Molarity Units] = $10^{\wedge\text{-pION}}$

To get the floating point pION value from the integer sent from register 30001 divide by 1000 and subtract by 2.000. This will switch the 0 to 18,000 integer value sent from register 30001 to -2.000 to +16.000 floating point pION value. To get the Molarity units from the pION you take a base 10 exponential to the negative pION floating point number.

Since we desired ppm units, we need to convert from the molarity units to the ppm units. This requires knowing the formula weight of the ion which is measured which is provided by register 40020. Take the integer value from register 40020 and divide it by 100 to get the formula weight of the ion in grams per mol units as a floating point number.

ppm = { [Molarity of Analyte Ion] * ((Formula Weight of Ion in grams per mol) * 1,000) }

Making all the substitutions we get the following referencing only the register numbers. It may be necessary to convert from the unsigned integer data type to the floating number data type when reading in registers 30001 and 40020.

ppm = { $10^{\wedge\text{-((REG30001/1,000) - 2.000)}}$ * ((REG40020/100) * 1,000) }

Example 1: Ammonium (NH_4^+) ion selective sensors detect ammonium ion activity. Since ammonium ion is positively charged cation the response from ammonium ion selective sensors will always produce a slope with a <u>positive</u> value.

Example 2: Fluoride (F^-) ion selective sensors detect fluoride ion activity. Since fluoride ion is negatively charged anion the response from fluoride ion selective sensors will always produce a slope with a <u>negative</u> value.

NOTE ABOUT SLOPE: Since the charge of the ion measured is intrinsic to the ion selective sensor type the permitted sign of the slope is programmed at the factory and cannot be changed in the field. Contact factory for assistance if there is any question about the type of ion selective sensor which is being employed and how it relates to the permitted sign of slope.

AMMONIUM ION SELECTIVE SENSOR EXAMPLE FOR pION TO PPM CONVERSION

Register 40036 = 5 This means that this is an ion selective (ISE) sensor (Default Node Address 5)
Register 40020 = 1804 Dividing by 100 we get 18.04 which is the formula weight for the Ammonium (NH_4^+) ion
Since Ammonium (NH_4^+) is a positively charged cation, the sign of slope for this sensor type will always be positive

Making the conversion from pION to ppm for ammonium (NH_4^+) ion selective sensors find the table for reference below:

pNH4	ppm NH4+
6.000	0.018
5.000	0.18
4.000	1.80
3.000	18.04
2.000	180.40
1.000	1804.00
0.000	18040.00
-1.000	180400.00

FLUORIDE ION SELECTIVE SENSOR EXAMPLE FOR pION TO PPM CONVERSION

Register 40036 = 5 This means that this is an ion selective (ISE) sensor (Default Node Address 5)
Register 40020 = 1900 Dividing by 100 we get 19.00 which is the formula weight for the Fluoride (F^-) ion
Since Fluoride (F^-) is a negatively charged anion, the sign of slope for this sensor type will always be negative

Making the conversion from pION to ppm for fluoride (F^-) ion selective sensors find the table for reference below:

pF	ppm F-
6.000	0.019
5.000	0.19
4.000	1.90
3.000	19.00
2.000	190.00
1.000	1900.00
0.000	19000.00
-1.000	190000.00

NOTE ON SIGNIFICANT FIGURES OF COMPUTED PPM UNITS:
While the significant figures are always just 3 as obtained from the source pION value the computed non-linear ppm unit may have many more digits showing. This does not mean that the number of significant figures has increased.

NOTE ON NON-LINEARITY OF PPM UNITS THEMSELVES:
As can be seen from inspection above the exact same pION value for different types of ions results in different ppm units. While the pION concentrations are systematic no matter the ion measured the ppm concentrations vary from one ion to another depending upon the differences in the formula weight of the ion measured.

NOTE ON NON-LINEARITY OF ISE SENSORS TO PPMS UNITS:
The mV response of the ion selective sensor is linear to the pION units. From inspection it is clear then that the mV response is NOT linearity to the computed non-linear, non-systematic common ppm units due to the nature of this scale.

APPENDIX 0 – CONVERT FROM PPM to pION FOR CALIBRATION CALLS:

When sending the reference values for the autocalibration calls for the ion selective sensors (register 40010 for the offset and register 40011 for the slope) these must be provided in the scientific pION units. If you have the value in the common ppm units instead, please use the procedure below to convert from your ppm units to the pION units. Due to the nature of the ppm units themselves you will need to have the formula weight of the ion which can be obtained from register 40020 as well as the ppm value in order to compute the pION value. The first step is to convert the ppm concentration into Molarity units. This is done using the formula below:

[Analyte Ion Activity in Molarity Units] = (**ppm** / ((REG40020/100)*1,000))

The ppm value is provided by the user as desired for the offset or slope calibration call. The register 40020 for the connected sensor divided by 100 is the formula weight of the ion. Dividing the ppm to be used for the autocalibration call by the formula weight of the ion divided by 1,000. It may be necessary to convert from the unsigned integer data type to the floating number data type when reading in register 40020 depending your particular PLC.

The overall equation for computing pION is shown below:

pION = - $\log_{10}$ [Analyte Ion Activity in Molarity Units]

Making the substitution for [Analyte Ion Activity in Molarity Units] = (**ppm** / ((REG40020/100)*1,000))
We get the following complete equation:

pION = - $\log_{10}$ [(ppm / ((REG40020/100)*1,000))]

AMMONIUM ION SELECTIVE SENSOR EXAMPLE FOR ppm to pION CONVERSION

Register 40036 = 5
This means that this is an ion selective (ISE) sensor

Register 40020 = 1804
Dividing by 100 we get 18.04 which is the formula weight for the Ammonium (NH_4^+) ion. This indicates a type 5 cation ISE sensor measures Ammonium (NH_4^+) ions.

See table below for example of converting selected ppm values to pION for ammonium (NH_4^+) ion selective sensors find the table for reference below:

ppm NH4+	pNH4
0.1	5.256
1	4.256
10	3.256
100	2.256
1000	1.256
10000	0.256
100000	-0.744

FLUORIDE ION SELECTIVE SENSOR EXAMPLE ppm to pION CONVERSION

Register 40036 = 5
This means that this is an ion selective (ISE) sensor

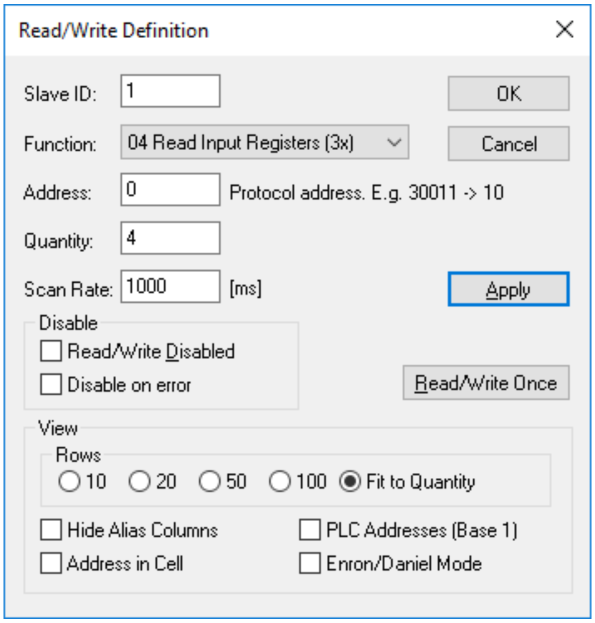
Register 40020 = 1900
Dividing by 100 we get 19.00 which is the formula weight for the Fluoride (F^-) ion. This indicates that this type 5 anion selective sensor measures Fluoride (F^-) ion activity.

See table below for example of converting selected ppm values to pION for fluoride (F^-) ion selective sensors find the table for reference below:

ppm F-	pF
0.1	5.279
1	4.279
10	3.279
100	2.279
1000	1.279
10000	0.279
100000	-0.721

NOTE: Reference values for offset & slope calibration calls need to be sent as unsigned integers. This means converting from floating-point pION value by multiplying by 1,000 and adding 2,000. The pION floating point value of 5.256 would be sent as the integer value of 7,256 to register 40010 for offset or register 40011 for slope calibrations.

APPENDIX 1 – READ INPUT REGISTERS MODBUS POLL SCREENSHOTS



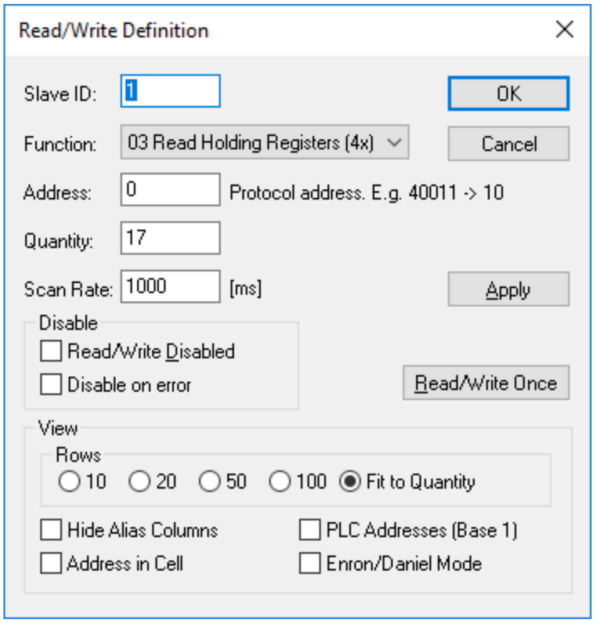
	Alias	3x0001
1	Measurement pH	6057
2	Measurement °C	615
3	Measurement raw mV for pH	28201
4	Measurement raw °C	616

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

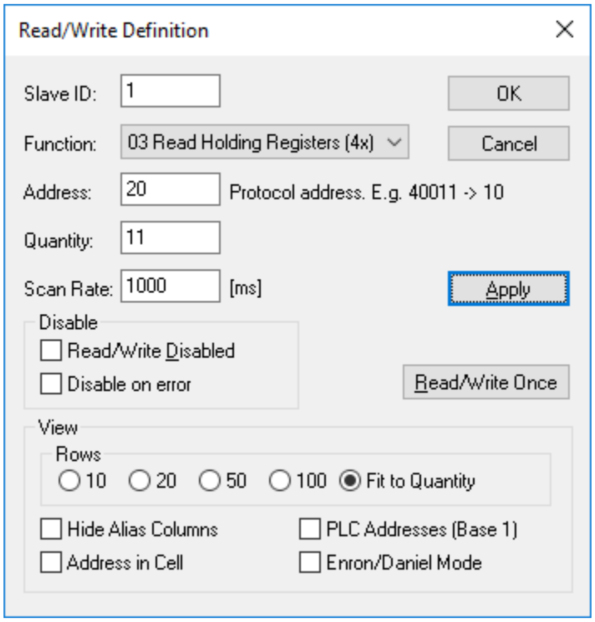


	Alias	4x0001
1	Offset mV measurement	2358
2	Slope low pH measurement	1196
3	Slope high pH measurement	1105
4	Offset oC measurement	251
5	Step change	5
6	Temperature coefficient for pH compensation	198
7	Dampener	6
8	Output delay	0
9	Modbus baudrate	1
10	Reference auto calibration pH offset	900
11	Reference 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



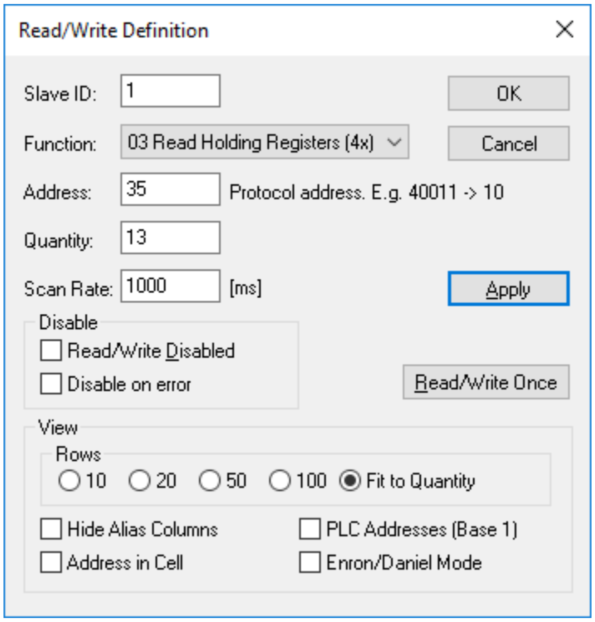
	Alias	4x0021
21	ASTI: manufacture date (Year)	18
22	ASTI: manufacture date (Month)	9
23	ASTI: manufacture date (Date)	22
24	Serial Number (year)	18
25	Serial Number (month)	9
26	Serial Number (letter)	1
27	Serial Number (#)	0
28	Item Number	1418
29	Sensor: Min. temperature in use	609
30	Sensor: Max temperature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

APPENDIX 3 FOR REGISTER 40026

A	0	bA	38	dA	76	FA	114	HA	152	JA	190	nA	228
b	1	bb	39	db	77	Fb	115	Hb	153	Jb	191	nb	229
C	2	bC	40	dC	78	FC	116	HC	154	JC	192	nC	230
d	3	bd	41	dd	79	Fd	117	Hd	155	Jd	193	nd	231
E	4	bE	42	dE	80	FE	118	HE	156	JE	194	nE	232
F	5	bF	43	dF	81	FF	119	HF	157	JF	195	nF	233
g	6	bg	44	dg	82	Fg	120	Hg	158	Jg	196	ng	234
H	7	bH	45	dH	83	FH	121	HH	159	JH	197	nH	235
i	8	bi	46	di	84	Fi	122	Hi	160	Ji	198	ni	236
J	9	bJ	47	dJ	85	FJ	123	HJ	161	JJ	199	nJ	237
L	10	bL	48	dL	86	FL	124	HL	162	JL	200	nL	238
n	11	bn	49	dn	87	Fn	125	Hn	163	Jn	201	nn	239
o	12	bo	50	do	88	Fo	126	Ho	164	Jo	202	no	240
P	13	bP	51	dP	89	FP	127	HP	165	JP	203	nP	241
r	14	br	52	dr	90	Fr	128	Hr	166	Jr	204	nr	242
S	15	bS	53	dS	91	FS	129	HS	167	JS	205	nS	243
t	16	bt	54	dt	92	Ft	130	Ht	168	Jt	206	nt	244
U	17	bU	55	dU	93	FU	131	HU	169	JU	207	nU	245
Y	18	bY	56	dY	94	FY	132	HY	170	JY	208	nY	246
AA	19	CA	57	EA	95	gA	133	iA	171	LA	209		
Ab	20	Cb	58	Eb	96	gb	134	ib	172	Lb	210		
AC	21	CC	59	EC	97	gC	135	iC	173	LC	211		
Ad	22	Cd	60	Ed	98	gd	136	id	174	Ld	212		
AE	23	CE	61	EE	99	gE	137	iE	175	LE	213		
AF	24	CF	62	EF	100	gF	138	iF	176	LF	214		
Ag	25	Cg	63	Eg	101	gg	139	ig	177	Lg	215		
AH	26	CH	64	EH	102	gH	140	iH	178	LH	216		
Ai	27	Ci	65	Ei	103	gi	141	ii	179	Li	217		
AJ	28	CJ	66	EJ	104	gJ	142	iJ	180	LJ	218		
AL	29	CL	67	EL	105	gL	143	iL	181	LL	219		
An	30	Cn	68	En	106	gn	144	in	182	Ln	220		
Ao	31	Co	69	Eo	107	go	145	io	183	Lo	221		
AP	32	CP	70	EP	108	gP	146	iP	184	LP	222		
Ar	33	Cr	71	Er	109	gr	147	ir	185	Lr	223		
AS	34	CS	72	ES	110	gS	148	iS	186	LS	224		
At	35	Ct	73	Et	111	gt	149	it	187	Lt	225		
AU	36	CU	74	EU	112	gU	150	iU	188	LU	226		
AY	37	CY	75	EY	113	gY	151	iY	189	LY	227		