DSS IMPLEMENTATION GUIDE

DSS Smart Digital RS-485 Modbus RTU Sensors

+ interfaced directly with customer supplied PLC

turtletoughsensors.com

Important information about integrating Direct Smart Sensors

TURTLE TOUGH DIRECT SMART SENSORS *(DSS)* are fully supported by a range of factory hardware solutions including SMART Analysers, Handheld Field Communicators, PC Communication tools and field implementation devices such as junction boxes, extensions leads and power supplies. This ecosystem provides a complete solution for reliable connectivity and sensor management.

TURTLE TOUGH sensors may also be directly interfaced with end-user hardware via the MODBUS RTU protocol. Integrating sensors directly into your industrial network requires a moderate to a high level of onsite expertise in system integration and should ONLY be undertaken by someone with the requisite experience. While direct integration provides some significant benefits, it also incurs a higher degree of risk as integrating with 3rd party hardware provides a lot of opportunities for unexpected issues to arise. 3rd party hardware includes any device or component not supplied by Turtle Tough and can include, but is not limited to, PLC's, SCADA systems, DCS's, data loggers, power supplies/isolators, or any other externally sourced interfacing device or component. We suggest you read the sensor implementation guide carefully to understand the full scope and requirement for installation, because:

1. Turtle Tough Pty Ltd and its representatives can provide only limited factory support when integrating sensors with 3rd party hardware. Unexpected behaviour or damage as the result of 3rd party hardware is not the responsibility of Turtle Tough.

2. Product support is limited to the information provided in our field implementation notes and guidelines. The product is fully supported for installation requirements, field implementation and programming protocols in direct relation to our product. It does not extend to the compatibility of our sensor with or the subsequent behaviour of 3rd party hardware. Due to the infinite amount of 3rd party hardware available we are unable to support issues related to 3rd party problems and it is the sole responsibility of the end-user to test and verify the compatibility of our product with their equipment.

3. Turtle Tough and its representatives are unable to provide support on 3rd party hardware or provide trouble-shooting on equipment not supplied by us. If you intend to integrate the sensor directly with your hardware, we highly recommend the following:
   - Read the Field Installation Guide and Sensor Implementation Guide. Make sure you understand the requirements and please contact us if you require clarification or further information.
   - Seek advice from your 3rd party hardware provider and make sure this equipment meets the minimum specification requirement outlined in our support documentation.
   - Purchase a handheld field communicator *(HFC)* from Turtle Tough. This stand-alone device, self-powers the sensor and provides complete diagnostics and communication. The HFC allows us to independently test and verify the sensor performance, independent of your system or hardware and is the single fastest way to rule out any sensor performance issues and be able to identify field installation problems.
   - Alternatively, you may purchase a windows PC interface box. Once again, this factory-supplied and tested component will ensure reliable communication with the sensor and it can be tested independently of your system.

Please note that our quick connect plugs must never be removed or modified in any way. This will immediately void the warranty. Only use Turtle Tough factory interface leads or panel mount connectors to interface with your hardware.

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Implementation of Turtle Tough DSS Smart Digital RS-485 Modbus RTU sensors with customer PLC

There exists three different implementation approaches for interfacing the smart digital DSS 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 DSS 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 and unique node address setting on the network as well as matching baudrates.

General Note 2

All DSS 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 DSS must share these settings to ensure proper communication. Please see DSS installation guide for additional recommendations and 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 TURTLE TOUGH 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 TURTLE TOUGH 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 TURTLE TOUGH supplied free of charge Windows software.

Initial Setup

The two parameters that MUST be setup during commissioning by the free of charge TURTLE TOUGH supplied Windows software for the DSS sensors are the node address and baudrate. By default, the baudrate is 19,200 kbps and the node address are 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 DSS 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
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 and 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 **[1]	-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.

For DSS-pH Sensors (Default Node Address 1)

Value 1: Calibrated and Temperature Compensated pH

Note for DSS-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 DSS-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

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 DSS-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 DSS-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 DSS-DO Sensors (Default Node Address 4)
Value 1: Calibrated and 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 and salinity corrections
–**Computed Unit**
Value 6: Percent (%) Saturation Dissolved Oxygen for calibration with temperature and 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 DSS-ISE Sensors (Default Node Address 5)
Value 1: Calibrated and 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 DSS-CON(-L) Sensors (Default Node Address 6)
Value 1: Calibrated and Temperature Compensated Conductivity
Range and resolution vary based upon cell constant and operating range mode. *See pages 4 & 5 for details.*
Value 3: Absolute raw Conductivity
Range and resolution vary based upon cell constant and operating range mode. *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) and Resistivity w/ UPW ATC (value 6) is 0.000 to 50.000 MΩ sent as 0-50,000 (both unsigned integers)

For ALL DSS 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

DSS-CON-ISO Sensor cell & range table for Standard/High Hardware

Standard range mode* - in microSiemens/cm
Range scaling factor 200

Nominal Cell Int**	Max Raw Input Limit	Resolution***	Max Temp. Compensated Conductivity using 2% per °C coefficient			
			Lowest Recommended Measurement at 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

Nominal Cell Int**	Max Raw Input Limit	Resolution***	Max Temp. Compensated Conductivity using 2% per °C coefficient			
			Lowest Recommended Measurement at 25°C	25°C -75°C	125°C	175°C
1	2,000	0.04	20	1,000	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	100,000,000	20	10,000	500,000	3333,33.33	250,000
1000	200,000,000	40	20,000	1,000,000	666,666.67	500,000
2000	400,000,000	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 the 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).

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DSS-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 at 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 and 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 and 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 and 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 **
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 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 *
2	Slope for Ion Selective Measurement	200..2,000	200 = 10.00mV & 2,000 = 100.00mV	40002	1 *
2	Slope Conductivity Standard Range Mode	300..1,700	300 = 0.300 & 1,700 = 1.700	40002	1 *
3	Slope high pH measurement	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40003	2 ***
3	Slope Conductivity High Range Mode	300..1,700	300 = 0.300 & 1,700 = 1.700	40002	2 ***
4	Offset °C measurement	0..500	0 = -25.0 °C and 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 and 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 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**
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 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 *
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 Std	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 ***
12	Reference autocal Conductivity Slope High	0..50,000	See Pages 4 & 5 for details	40012	11 ***
13	Reference auto calibration °C 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 °C 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 and Values	Register	Index
1	TURTLE TOUGH: manufacture date (Year)	00..99	00 = 2000 and 99 = 2099	40021	20
2	TURTLE TOUGH: manufacture date (Month)	01..12	1 = January....12 = December	40022	21
3	TURTLE TOUGH: manufacture date (Day)	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 and 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 and Values	Register	Index
1	Type	0..255	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 (Day)	1..31	Day of Month	40040	39
6	Factory cal. (mV gain)	1..255	N/A (Factory Designation Only)	40041	40
7	Factory cal. (°C offset)	1..255	N/A (Factory Designation Only)	40042	41
8	Factory cal. (°C 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	TURTLE TOUGH cal for pH and Standard ORP (mV offset)	0..5,000	0 = -250.0mV and 5,000 = +250.0mV	40045	44**
10	TURTLE TOUGH cal for Wide ORP (mV offset)	0..10,000	0 = -500.0mV and 10,000 = +500.0mV	40045	44**
10	TURTLE TOUGH default for Isopotential Voltage	0..20,000	0 = -1,000.00 & 20,000 = +1,000.00 mV	40045	44 ****
11	TURTLE TOUGH cal. (slope low)	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40046	45*
11	TURTLE TOUGHDefault Slope for ISE	200..2,000	200 = 10.00mV & 2,000 = 100.00mV	40046	45 ****
12	TURTLE TOUGH cal. (slope high)	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40047	46***
13	TURTLE TOUGH cal. (°C 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 *****[1]
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.*

**** **ONLY** *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).***

***** **ONLY** *valid for Conductivity Type Sensors. Effective calibrated cell constant used to compute raw and temperature compensated conductivity is product of scaled nominal cell (register 40019) & slope gain calibration (register 40002).*

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

Implementation approach 3: Write all user parameters and 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 and 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 **
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 and 1,800 = 90.0mV	40002	1 *
2	Slope for Dissolved Oxygen measurement	70..600	70 = 0.70mV and 600 = 6.00mV	40002	1 *
2	Slope for Ion Selective Measurement	200..2,000	200 = 10.00mV & 2,000 = 100.00mV	40002	
2	Slope Conductivity Standard Range Mode	300..1,700	300 = 0.300 & 1,700 = 1.700	40002	
3	Slope high pH measurement	600..1,800	600 = 30.0mV and 1,800 = 90.0mV	40003	2 ***
3	Slope Conductivity High Range Mode	300..1,700	300 = 0.300 & 1,700 = 1.700	40002	2 ***
4	Offset °C measurement	0..500	0 = -25.0 °C and 500= +25.0 °C	40004	3
5	Step change for pH, ORP, Wide ORP, ISE (mV) and 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 and 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 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
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**
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 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
11	Reference auto calibration slope low	0..900	0 = -2.00 pH and 900 = +7.00 pH	40011	10 *
11	Reference auto calibration ISE slope (pION)	0..18,000	0 = -2.000 and 18,000 = +16.000 pION	40011	10 *
11	Reference autocal conductivity slope Std	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 ***
12	Reference autocal conductivity slope high	0..50,000	*See pages 4 & 5 for details*	40012	11 ***
13	Reference auto calibration °C 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.*
***** **ONLY** 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).
****** **ONLY** 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 TURTLE TOUGH 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 °C	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*

Important note about slope calibration for pH and ISE 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.

Note for Offset Autocalibration for ISE Sensors

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.

Note for Slope Autocalibration for ISE Sensors

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.

Note for creating pION values for HiQDT-ISE Ion Selective Sensors

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 DSS-ISE Ion Selective Sensors are sent in the scientific pION units.

---

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

For DSS-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 DSS-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 DSS-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 DSS-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 DSS-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 at 100% (FC16 Index 10)

For DSS-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 DSS-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 à 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 & 11, Reg. 40011 & 40012)

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 and 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 = - log10 [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 = - log10 [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^-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^-((REG30001/1,000) - 2.000) * ((REG40020/100) * 1,000) }*

Example 1: Ammonium (NH4+) 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 positive 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 negative 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 NH4+) ion
Since Ammonium (NH4+) 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 (NH4+) ion selective sensors find the table for reference below:

pNH4	pm 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.

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 = - log10 [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 = - log10 [(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 (NH4+) ion. This indicates a type 5 cation ISE sensor measures Ammonium (NH4+) ions.

See table below for example of converting selected ppm values to pION for ammonium (NH4+) 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

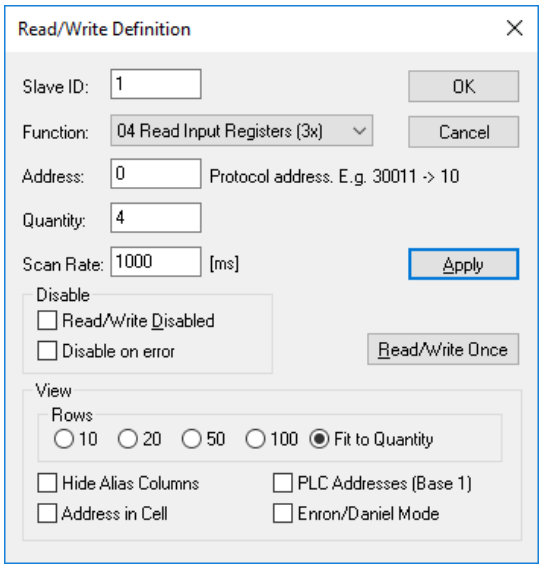
Register 40036 = 5
This means that this is an ion selective (ISE) sensor
Register 40020 = 1900
Dividing by 100 we get 19.00 which is the formula weight for the Fluoride (F-) ion. This indicates that this type 5 anion selective sensor measures Fluoride (F-) ion activity.
See table below for example of converting selected ppm values to pION for fluoride (F-) ion selective sensors find the table for reference below:

ppm F- pF	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 and 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

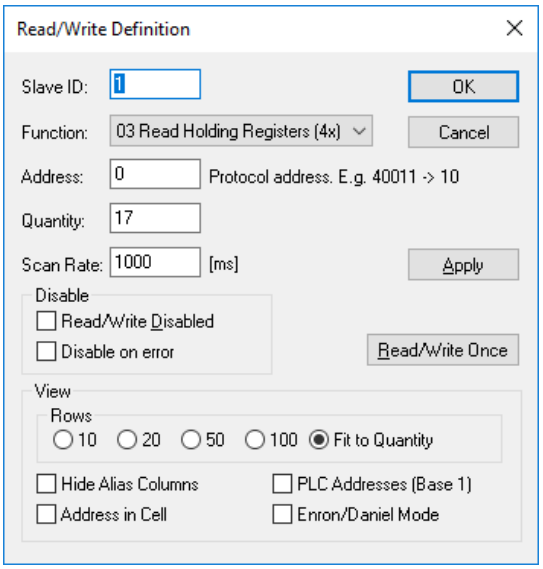
Engineered values from integer values shown from read input registers:

#	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 (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



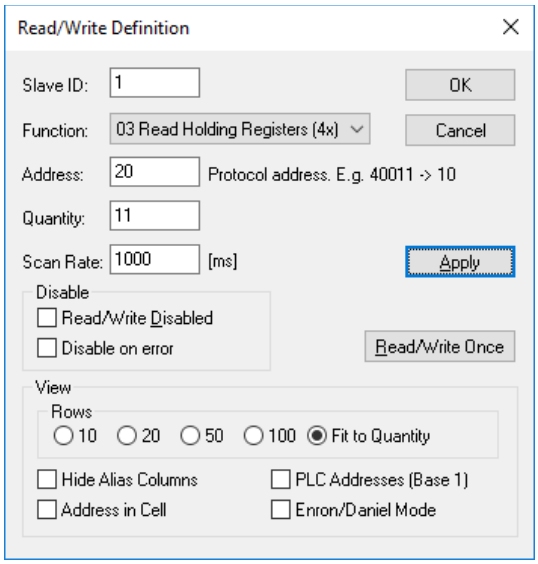
	Alias	4x0001
1	Offset mV measurement	2358
2	Slope low pH measurement	1196
3	Slope high pH measurement	1105
4	Offset oC measurement	251
5	Step change	5
6	Temperature coefficient for pH compensation	198
7	Dampener	6
8	Output delay	0
9	Modbus baudrate	1
10	Reference auto calibration pH offset	900
11	Reference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

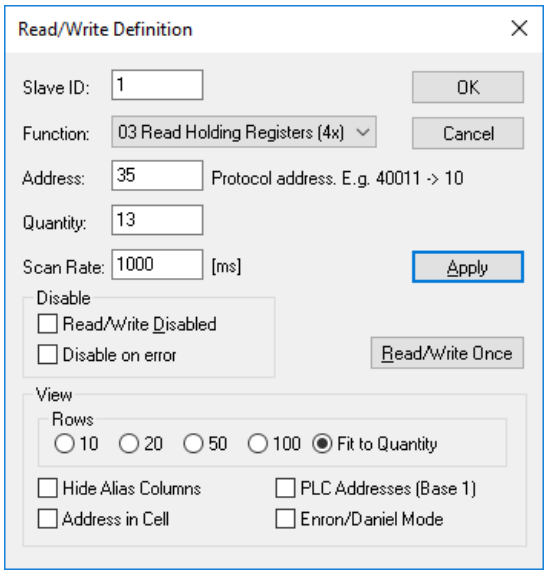
Engineered values from integer values shown from read input registers:

#	Name	Integer Value	Engineered Value	Register	Index
1	TURTLE TOUGH: manufacture date (Year)	18	2018	40021	20
2	TURTLE TOUGH: manufacture date (Month)	9	September	40022	21
3	TURTLE TOUGH: manufacture date (Day)	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 (Day)	6	6	40040	39
6	Factory cal. (mV gain)	196	N/A (Factory Designation Only)	40041	40
7	Factory cal. (°C offset)	57	N/A (Factory Designation Only)	40042	41
8	Factory cal. (°C gain)	227	N/A (Factory Designation Only)	40043	42
9	Factory cal. (mV offset)	16233	N/A (Factory Designation Only)	40044	43
10	TURTLE TOUGH cal. (mV offset)	2500	0.0 mV	40045	44
11	TURTLE TOUGH cal. (slope low)	1183	59.15 mV per pH unit	40046	45
12	TURTLE TOUGH cal. (slope high)	1183	59.15 mV per pH unit	40047	46
13	TURTLE TOUGH cal. (°C offset)	250	0.0 °C	40048	47

Warranty

Product Warranty

Every Turtle Tough product is thoroughly inspected and tested before leaving the factory and prior to shipping. In addition to any statutory rights and remedies you may have, Turtle Tough warrants all its products against defective workmanship and faulty materials for 12 months from the date of purchase and undertakes, at its option, to repair or replace, free of charge, each product or part thereof on condition that:

- The complete product is returned to Turtle Tough or one of its authorised service agents, in person or freight pre-paid by you, and found, on examination, to be suffering from a manufacturing defect.
- The product or relevant part has not been subject to misuse, neglect, or been involved in an accident.
- The repairs are not required as a result of normal wear and tear.
- Damage caused by wear and tear, inadequate maintenance, improper installation, corrosion, or by the effects of chemical processes is excluded from this warranty coverage.

Sensor Warranty

Turtle Tough sensors are electrochemical devices and as such have a limited operating life. Life expectancy depends on the field of application such as the medium, pressure and temperature. It can vary between a number of weeks to several years. There are special cases in extreme environments where operating life will only be a few days. Characteristic and response time will also change with aging. As such electrochemical sensors are articles of consumption and are not subject to a common guarantee. Replacements or exchanges are generally excluded unless a manufacturing defect is determined to be the cause. It is not possible to predict the rate of deterioration for a particular process, nor can we provide a guarantee on sensor life because it is impossible to predict the rate of exposure, contamination and deterioration. Damage caused by wear and tear, inadequate maintenance, faulty installations, corrosion, or the effects of chemical processes is excluded from this warranty coverage. Our agents or representatives may provide you with a life expectancy guide based on similar applications we have experienced, however, this in no way constitutes a warranty of performance and is a general indicator.

Shelf Life Warranty

The standard shelf life for a Turtle Tough sensor is one year from the date of shipment. Sensors stored longer than this period may still be functional but are no longer under warranty. Sensors should be stored in a cool, dry location with the sensor tip *(where the pH/ORP element is located)* oriented toward the ground. All pH/ ORP/ISE sensors come standard with a conditioning solution in the cap. This conditioning solution is 50% pH 4 buffer and 50% saturated potassium chloride *(mixed by volume)*. The sensor cap should be kept tightly affixed to the sensor body and sealed with common piping Teflon tape when the sensor is not in use. Sensors that are to be returned for a shelf-life warranty claim must have the original sensor cap and conditioning solution intact to be eligible for warranty replacement.

Damage to Internal Electronics

Damage to the sensor's internal electronic components is not covered under warranty. Analogue sensors with internal preamplifiers are sensitive to electrostatic discharge. Sensors with preamps are clearly marked and extra care must be taken when handling these sensors as human contact with the electrical connections can discharge static to the preamplifier causing it to blow. This will render the product inoperable. Additionally, sensors containing digital RS485 boards are susceptible to damage when powered incorrectly or improperly installed. Sensors containing internal electronic boards undergo additional quality checks prior to shipment to ensure that components are 100% operational upon delivery. Ground loop and 3rd party hardware problems (including but not limited to power supplies) may also cause blown electronics or damage to the sensor components and as such faulty installations are not covered by warranty.

IMPORTANT: Ground loops, poor earthing and faulty electrical installations are a common cause of sensor damage. If you are experiencing unusual or erratic readings, please refer to our support document on ground loops.

Damage to Cables and Connectors

Please note that integral sensor cables, connectors and plugs must NOT be cut, removed or modified in any way. Sensors contain sensitive internal electronics and our cables and connectors are designed to protect the integrity of these components. Any modification or alteration to cables and connectors can compromise their integrity and will void the warranty. Always use factory-approved/manufactured cables and connectors. Additionally, the cable contains a unique identifier laminated to the cable end and this must not be removed or it will also void the warranty.

Return Goods

For all return goods the following information must be included in the letter accompanying the returned goods:

- Model Code and Serial Number
- Original Purchase Order and Date
- Length of time in service and description of the process
- Description of the fault and circumstances of the failure
- Process/environmental conditions that may be related to the failure of the sensor
- Statement as to whether warranty or non-warranty service is requested
- Complete shipping and billing instructions for return of material, plus the name and phone number of a contact person that can be reached for further information
- Clean Statement: returned goods that have been in contact with process fluids must be decontaminated and disinfected prior to shipment. Goods should carry a certificate to this effect, for the health and safety of our employees. Material Safety Datasheets must be included for all components of the process to which the sensor(s) have been exposed.

All sensor returns are to be accompanied by a completed Return Material Authorisation Document clearly stating the reason for the return and with the Clean Statement filled in.

See the warranty and returns section under support on our website turtletoughsensors.com for details.

Support

For technical support please contact head office on +61 (0)3 9872 5055 or visit our website turtletoughsensors.com for information on sensor care, calibration, wiring and installation-related issues.

IMPORTANT INFORMATION ABOUT INTEGRATING DIRECT SMART SENSORS

TURTLE TOUGH DIRECT SMART SENSORS *(DSS)* are fully supported by a range of factory hardware solutions including SMART Analysers, Handheld Field Communicators, PC Communication tools and field implementation devices such as junction boxes, extensions leads and power supplies. This ecosystem provides a complete solution for reliable connectivity and sensor management.

TURTLE TOUGH sensors may also be directly interfaced with end-user hardware via the MODBUS RTU protocol. Integrating sensors directly into your industrial network requires a moderate to a high level of onsite expertise in system integration and should ONLY be undertaken by someone with the requisite experience. While direct integration provides some significant benefits, it also incurs a higher degree of risk as integrating with 3rd party hardware provides a lot of opportunities for unexpected issues to arise. 3rd party hardware includes any device or component not supplied by Turtle Tough and can include, but is not limited to, PLC's, SCADA systems, DCS's, data loggers, power supplies/isolators, or any other externally sourced interfacing device or component. We suggest you read the sensor implementation guide carefully to understand the full scope and requirement for installation, because:

1. Turtle Tough Pty Ltd and its representatives can provide only limited factory support when integrating sensors with 3rd party hardware. Unexpected behaviour or damage as the result of 3rd party hardware is not the responsibility of Turtle Tough.

2. Product support is limited to the information provided in our field implementation notes and guidelines. The product is fully supported for installation requirements, field implementation and programming protocols in direct relation to our product. It does not extend to the compatibility of our sensor with or the subsequent behaviour of 3rd party hardware. Due to the infinite amount of 3rd party hardware available we are unable to support issues related to 3rd party problems and it is the sole responsibility of the end-user to test and verify the compatibility of our product with their equipment.

3. Turtle Tough and its representatives are unable to provide support on 3rd party hardware or provide trouble-shooting on equipment not supplied by us. If you intend to integrate the sensor directly with your hardware, we highly recommend the following:
   - Read the Field Installation Guide and Sensor Implementation Guide. Make sure you understand the requirements and please contact us if you require clarification or further information.
   - Seek advice from your 3rd party hardware provider and make sure this equipment meets the minimum specification requirement outlined in our support documentation.
   - Purchase a handheld field communicator *(HFC)* from Turtle Tough. This stand-alone device, self-powers the sensor and provides complete diagnostics and communication. The HFC allows us to independently test and verify the sensor performance, independent of your system or hardware and is the single fastest way to rule out any sensor performance issues and be able to identify field installation problems.
   - Alternatively, you may purchase a windows PC interface box. Once again, this factory-supplied and tested component will ensure reliable communication with the sensor and it can be tested independently of your system.

Please note that our quick connect plugs must never be removed or modified in any way. This will immediately void the warranty. Only use Turtle Tough factory interface leads or panel mount connectors to interface with your hardware.

TURTLE TOUGH