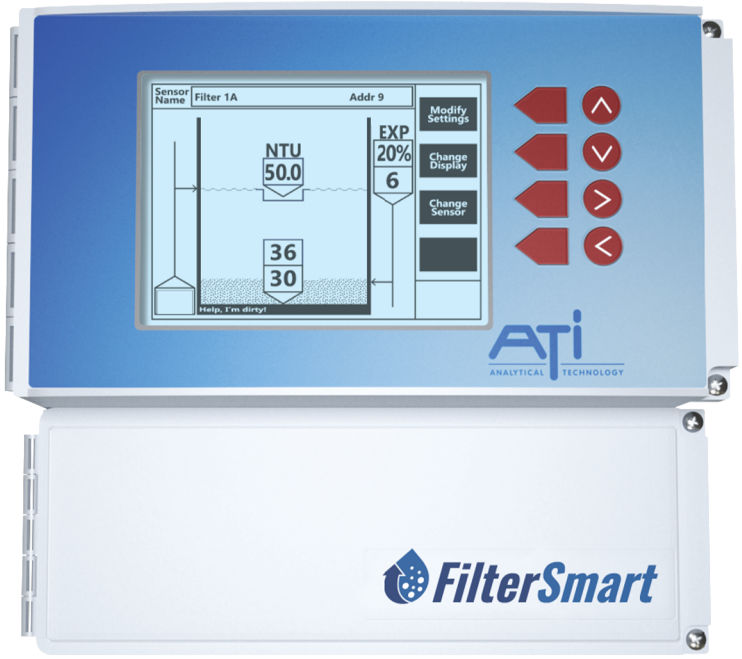
A Badger Meter® Brand

Water Quality Monitor

FilterSmart Modbus



Badger Meter

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User Manual

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FILTERSMART MODBUS AT A GLANCE

The Basics

The supported baud rate is 9600 and the RTU format is 8 bits, no parity, 1 start and 1 stop bit.

The slave address used for polling is each sensor's unique address that was entered when the FilterSmart equipment was commissioned. When multiple sensors are communicating with the Controller, each sensor's address must be polled separately for the desired Modbus value(s).

Getting the Current Measurement(s)

To obtain the current measurement, use Function Code 03 and poll for the following registers:

- Register 40001 for *Media Level*
- Register 40002 for *Turbidity*
- Register 40003 for *Expansion*
- Register 40004 for *Expansion Percentage*

The returned value for *Media Level* and *Expansion* is in the sensor's selected *Units* and is reported as the base measurement multiplied by ten (for example, 42 = 4.2 units). The returned value for *Turbidity* is the current NTU value multiplied by 100 (for example,135 = 1.35 NTU). The returned value for *Expansion Percentage* is percentage value multiplied by ten (for example, 154 = 15.4%).

For the most up-to-date information, retrieve only the desired data from each sensor.

Additional Information

To get information on the status of the sensor and any alerts, use Function Code 01 and poll the following coils:

- *Loss of Signal* – Coil 21
- *Wiper Stalled* – Coil 19
  Wiper Motor Failure – Coil 20
- *Turbidity LED Alarm* – Coil 37
  Turbidity Driver Failure – Coil 38

For information on accessing data from other coils or registers, see *FilterSmart Modbus Specifics*.

MODBUS DESCRIPTION

Protocol Description

The FilterSmart system uses the Modbus RTU Master-Slave protocol. Only one master is connected to the bus. One or several (247 maximum number) slaves' nodes are also connected to the same serial bus. Communication is always initiated by the master node. The slave nodes never transmit data without receiving a request from the master node. The slave nodes never communicate with each other. The master node initiates only one transaction at a time.

Basic Modbus protocol is followed, where the client (host) initiates a transaction. The function code field tells the server what kind of action to perform and the format of the message. Function code "0" is not valid. For Modbus messages, sub-function codes are added to some function codes to define multiple actions.

"FilterSmart Modbus Specifics" on page 16 of this document outlines the specific features and capabilities of the Modbus standard that are implemented.

Maximum Message Length

The sensor supports a maximum packet length of 40 bytes. Messages longer than that are ignored by the sensor.

Sensor (Slave) Address

All connected devices must have a unique device address. This address is used to determine which device on the network responds to the received message. You can modify the *Sensor Address* from the FilterSmart Controller.

Reserved Addresses

Some addresses on the bus are reserved for specific devices. FilterSmart Sensors should not be assigned the reserved addresses. The *Address Assignment Table* in *Figure 1* identifies reserved unit addresses and the range of valid sensor addresses.

Device	Hex Address	Decimal Address
Reserved	0x00	0
FilterSmart Sensors	0x01…0xF8	1…248
Reserved	0xF9…0xFC	249…252
FilterSmart Controller	0xFD	253
FilterSmart Power Supply	0xFE	254
Broadcast Address	0xFF	255

Figure 1: Address assignment table

Transmission Mode

The Modbus protocol defines two serial transmission modes: RTU mode and ASCII mode. The FilterSmart equipment only supports the RTU mode of operation. In this mode, each message is transmitted as a continuous stream of bytes. Interruptions in the data stream are interpreted as the end of message.

RTU Mode Format

The format for each byte is 8 bits, No Parity, 1 Start and 1 Stop bit.

Data Signaling Rate

The baud rate is 9600 baud. Currently, this is the only baud rate supported.

CRC Checking

The generation of the CRC value agrees and is compatible with the standard generation of the CRC value for the Modbus protocol.

The protocol includes an error-checking field that is based on a Cyclical Redundancy Checking (CRC) method performed on the message contents. The CRC field checks the contents of the entire message. It is applied regardless of any parity checking method used for the individual characters of the message.

The CRC field contains a 16-bit value implemented as two 8-bit bytes. The CRC field is appended to the message as the last field in the message. When this is done, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte to be sent in the message. The CRC value is calculated by the sending device, which appends the CRC to the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the actual value it received in the CRC field. If the two values are not equal, the result is an error.

The CRC calculation is started by first pre-loading a 16-bit register to all 1's. A process begins of applying successive 8-bit bytes of the message to the current contents of the register. Only the 8 bits of data in each character are used for generating the CRC. Start and stop bits and the parity bit do not apply to the CRC.

During generation of the CRC, each 8-bit character is exclusive ORed with the register contents. The result is shifted in the direction of the least significant bit (LSB), with a zero filled into the most significant bit (MSB) position. The LSB is extracted and examined. If the LSB was a 1, the register is then exclusive ORed with a preset, fixed value. If the LSB was a 0, no exclusive OR takes place. This process is repeated until eight shifts have been performed. After the last (eighth) shift, the next 8-bit byte is exclusive ORed with the register's current value, and the process repeats for eight more shifts as described above. The final content of the register, after all the bytes of the message have been applied, is the CRC value.

Electrical Interface

The protocol conforms to the Modbus RS-485 Two-Wire definition.

MODBUS FUNCTION CODES

The Modbus function codes provide the basic capability to read and write values from and to the sensor. Function codes provide the capability to read/write single bit values (coils) and 16-bit binary values (registers). The Modbus functions supported by the sensor conform to the standard Modbus specification and are outlined in *Figure 2*.

		Description	Function Code
Data Access	**Bit Access**	Read Coils	01
		Write Single Coil	05
	16 Bit Access Read Holding Registers	Read Holding Registers	03
		Write Single Register	06
		Write Multiple Register	16

Figure 2: Modbus function codes

Read Bit Value (0x01)

This Modbus function code is used to read the status of individual bit values in the sensor. The client (host) specifies the starting address, for example, the address of the first bit value, and the number of bit values. In the sensor, bit values are addressed starting at zero, therefore bit values numbered 1…16 are addressed as 0…15.

The bit values in the response message are packed as one-bit value per bit of the data field. Status is indicated as 1 = ON and 0 = OFF. The LSB of the first data byte contains the output addressed in the query. The other bit values follow toward the high-order end of this byte, and from low-order to high-order in subsequent bytes.

If the returned output quantity is not a multiple of eight, the remaining bits in the final data byte is padded with zeros (toward the high order end of the byte). The *Byte Count* field specifies the quantity of complete bytes of data.

Example of the Read Bit Value Function:

This command is requesting the ON/OFF status of discrete coils 2 to 11 from the sensor with address 01.

Request

01 01 0001 000A EDCD

01: The Slave (Sensor) Address (1 =01 hex)
01: The Function Code (read Coil Status)
0001: The Data Address of the first coil to read. (Coil 2 – 1 = 1 =01 hex)
000A: The total number of coils requested (Coils 2 to 11 = 10 = 0A hex)
EDCD: The CRC (cyclic redundancy check) for error checking.

Response

01 01 02 0302 38CD

01: The Slave Address (1 =01 hex)
01: The Function Code (Read Coil Status)
02: The number of data bytes to follow (10 Coils / 8 bits per byte = 2 bytes)
03: Coils 2 – 9 (0000 0011)
02: Coils 10 – 11 (0000 0010)
38CD: The CRC (cyclic redundancy check).

The more significant bits contain the higher coil variables This shows that coil 2 is on (1) and coil 9 is off (0). Due to the number of coils requested, the last data field02 contains the status of only 2 coils. The three most significant bits in this data field are filled in with zeroes.

Figure 3: Example of reading coils

Read Holding Registers (0x03)

This Modbus function code is used to read the contents of a contiguous block of holding registers in the SSP sensor. The client (host) specifies the starting register address and the number of registers. The registers are addressed starting at zero, therefore registers numbered 1…16 are addressed as 0…15.

The register data in the response message are packed as two bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high-order bits and the second contains the low-order bits.

Example of Read Holding Register Function

Request

This command is requesting the content of holding registers 40103 to 40105 from the slave device with address 01.

01 03 0066 0003 E5D4

01: The Slave Address (1 =01 hex)
03: The Function Code (Read Analog Output Holding Registers)
0066: The Data Address of the first register requested. (40103 – 40001 = 102 =66 hex)
0003: The total number of registers requested. (read 3 registers 40103 to 40105)
E5D4: The CRC (cyclic redundancy check) for error checking.

Response

01 03 06 3134 0000 0000 9490

01: The Slave Address (1 =01 hex)
03: The Function Code (Read Holding Registers)
06: The number of data bytes to follow (3 registers x 2 bytes each = 6 bytes)
3134: The contents of register 40103 (In this case it contains two ASCII chars '1' & '4')
0000: The contents of register 40104
0000: The contents of register 40115
9490: The CRC (cyclic redundancy check).

Since this example was a read of registers 40103 to 40105 which contain a portion of the Sensor Name, the data returned represents ASCII data. Other registers contain other data formats as show elsewhere in this document.

Figure 4: Example of reading registers

Write Single Bit Value (0x05)

This Modbus function code is used to write a single output bit value to either ON (1) or OFF (0) in the sensor. The requested ON/OFF state is specified by a constant in the request data field. A value of 0xFF00 requests the bit value to be ON. A value of 0x0000 requests it to be OFF. All other values are illegal and do not affect the state of the bit value.

The normal response is an echo of the request, returned after the bit value state is written.

Example of a Write Single Bit Value Function

Request

This command is writing the contents of discrete coil 2 to ON in the slave device with address 01.

01 05 0001 FF00 DDFA

01: The Slave Address (1 =01 hex)
05: The Function Code (Force Single Coil)
0001: The Data Address of the coil (coil 2 – 1 = 1 =01 hex)
FF00: The status to write (FF00 = ON, 0000 = OFF)
DDFA: The CRC (cyclic redundancy check) for error checking.

Response

The normal response is an echo of the query, returned after the coil has been writen.

01 05 0001 FF00 DDFA

01: The Slave Address (1 =01 hex)
05: The Function Code (Force Single Coil)
0001: The Data Address of the coil (coil 2 – 1 = 1 =01 hex)
FF00: The status written (FF00 = ON, 0000 = OFF)
DDFA: The CRC (cyclic redundancy check) for error checking

Figure 5: Example of writing a coil

Write Single Register (0x06)

This Modbus function code is used to write a single holding register in the sensor. The client (host) specifies the address of the register to be written. Registers are addressed starting at zero, therefore register number 1 is addressed as 0.

The normal response is an echo of the request, returned after the register contents have been written.

Example of a Write Single Register Function.

Request

This command is writing a 36 to register 40005 in the slave device with address 01.

01 06 0004 0024 C810

01: The Slave Address (1 =01 hex)
06: The Function Code (Preset Single Register)
0004: The Data Address of the register. (40005 – 40001 = 4)
0024: The value to write. (36 = 24 hex)
C810: The CRC (cyclic redundancy check) for error checking.

Response

The normal response is an echo of the query, returned after the register contents have been written.

01 06 0004 0024 C810

01: The Slave Address (1 =01 hex)
06: The Function Code (Preset Single Register)
0004: The Data Address of the register. (40005 – 40001 = 4)
0024: The value written. (36 = 24 hex)
C810: The CRC (cyclic redundancy check) for error checking.

Figure 6: Example of writing a register

Diagnostics (0x08)

This Modbus function provides a series of tests for checking the communication system between a client (host) device and the sensor, or for checking various internal error conditions within the sensor.

The function uses a two-byte sub-function code field in the query to define the type of test to be performed. The server echoes both the function code and sub-function code in a normal response. Some of the diagnostics cause data to be returned from the remote device in the data field of a normal response.

In general, issuing a diagnostic function to the sensor does not affect the running of the level detection function. However, certain diagnostic functions can optionally reset error counters in the remote device.

The sensor can, however, be forced into *Listen Only Mode* in which it monitors the messages on the communications system but does not respond to them. This can affect the normal response of Modbus messages.

The table in *Figure 7* identifies the diagnostic functions and sub-function codes implemented in the sensor.

Sub Function Code		Name
Hex	Dec	
0x01	1	Restart Communications Option
0x04	4	Force Listen Only Mode
0x0A	10	Clear Counters and Diagnostic Register
0x0B	11	Return Bus Message Count
0x0C	12	Return Bus Communication Error Count
0x0E	14	Return Slave Message Count

Figure 7: Diagnostic sub-function codes

Restart Communications Sub-Code (0x01)

On receipt of this sub-code, the sensor restarts and initializes the RS-485 serial line. In addition, all the communications event counters are cleared. If the RS-485 port is currently in *Listen Only Mode*, no response is returned. This function is the only one that brings the port out of *Listen Only Mode*. If the port is not currently in *Listen Only Mode*, a normal response is returned. This occurs before the restart is executed.

When the sensor receives this request, it attempts a restart and executes its powerup confidence tests. Successful completion of the tests brings the port online.

Force Listen Only Mode Sub-Code (0x04)

This sub-code forces the sensor into its *Listen Only Mode* for Modbus communications. This isolates it from the other Modbus devices on the network, allowing them to continue communicating without interruption from the addressed sensor. No response is returned.

When the sensor enters its *Listen Only Mode*, all active Modbus messages addressed to it or broadcast are monitored, but no actions are taken and no responses are sent. The only function processed after the mode is entered is the *Restart Communications* function (function code 0x08, sub-function 0x01).

Clear Counters and Diagnostic Register Sub-Code (0x0A)

This sub-code clears all counters and the diagnostic register. Counters are also cleared upon powerup.

Return Bus Message Count Sub-Code (0x0B)

The response data field returns the quantity of messages that the sensor has detected on the communications system since its last restart, clear counters operation or powerup. This count includes both Modbus messages and the sensor's proprietary protocol messages.

Return Bus Communication Error Count Sub-Code (0x0C)

The response data field returns the quantity of CRC errors encountered by the sensor since its last restart, clear counters operation, or powerup. This count includes both Modbus messages and the sensor's proprietary protocol messages.

Return Slave Message Count Sub-Code (0x0E)

The response data field returns the quantity of messages addressed to the sensor, or broadcast, that the sensor has processed since its last restart, clear counters operation or powerup. This count includes both Modbus messages and the sensor's proprietary protocol messages.

Write Multiple Registers (0x10)

This Modbus function code is used to write a block of contiguous registers (1…32 registers) in the sensor. The requested written values are specified in the request data field. Data is packed as two bytes per register.

The normal response returns the function code, starting address and quantity of registers written.

Report Slave ID (0x11)

This Modbus function code is used to read the name of the sensor manufacturer, the model number and the contents of the user specific data (Field 1). The data returned shall have the following format:

- Byte Count. Total number of bytes returned.
- A 13-byte string containing the manufacturer name.
- A 5-byte string containing the model number.
- A 16-byte string containing the user specific data in field 1.
- Run status indicator byte. 0x00 = OFF, 0xFF = ON.
- FilterSmart Modbus Specifics

Data values within the sensor are accessed using either bit values (coil) or register values. Bit values are generally used for ON/OFF or YES/NO conditions and register values are used for all other binary values. Some values are read-only, some are write-only, and some are read and write. *Figure 8 on page 16* identifies the specific bit values names and the bit location. *Figure 9 on page 17* identifies the specific register names, data type and length.

FILTERSMART MODBUS SPECIFICS

Polling Rate Information

The Modbus data outlined in *"Bit (Coil) Number Assignment"* and *"Register Number Assignment" on page 17* is available for each sensor in the network. A "Yes" in the *Quick Polling* ("QP") column indicates that the listed value can be retrieved at any desired polling rate. Polling for any data with a "No" in the "QP" column introduces communication delays, especially when multiple sensors are networked.

If communication is lost with a sensor, the "QP" data is still accessible (held at the last known value) for up to one minute. If communication is not regained in that time, there is no response to the query.

Bit (Coil) Number Assignment

All bit values are encoded as either ON (0xFF) or OFF (0). As shown in *Figure 8*, some bit values are write-only where a *Write Single Coil Function* is used to control some function. A read of bit values that are specified as write-only always returns a 0 value.

Name	Coil #	R/W	QP	Description
Auto Gain	1	R/W	Yes	Turns Auto Gain Function Off (0) or On (0xFF)
Measure	2	R/W	Yes	Sets measurement mode, Level (0) or Range (0xFF)
Settling Zone	3	R/W	Yes	Turns Settling Zone Off (0) or On (0xFF)
Echo Loss	4	R/W	Yes	Echo Loss Function Off (0) or On (0xFF)
Force Level 4 mA	5	R/W	Yes	Force Level Loop to 4 mA No (0), Yes (0xFF)
Force Level 20 mA	6	R/W	Yes	Force Level Loop to 20 mA No (0), Yes (0xFF)
Force Turbidity 4 mA	7	R/W	Yes	Force Turbidity Loop to 4 mA No (0), Yes (0xFF)
Force Turbidity 20 mA	8	R/W	Yes	Force Turbidity Loop to 20 mA No (0), Yes (0xFF)
Composite Waveform	9	R/W	Yes	Average Waveform (0), Composite Waveform (0xFF)
Waveform Acquisition Control	11	R/W	No	Off (0) or On (0xFF)
High Power Mode	12	R/W	No	Power Mode – Low Power (0), Hi Power (0xFF)
Turbidity Installed	17	R	Yes	Turbidity Installed? No (0), Yes (0xFF)
Wiper Installed	18	R	Yes	Wiper Motor Installed? No (0), Yes (0xFF)
Wiper Stalled	19	R	Yes	Wiper needs attention No (0), Yes (0xFF)
Wiper Motor Failure	20	R	Yes	Wiper motor open circuit or not connected
Loss of Signal Alarm	21	R	Yes	Loss of signal for more than Echo Delay
Stabilize Gain Mode	22	R	Yes	Sensor Initializing in Stabilize Gain Mode
Stabilize Track Mode	23	R	Yes	Sensor Initializing in Stabilize Track Mode
Stabilize Gates Mode	24	R	Yes	Sensor Initializing in Stabilize Gates Mode
Initialization Complete	25	R	Yes	Initialization Complete
Requires Setup	26	R	Yes	Sensor requires setup
Level Loop Active	27	R	Yes	Level loop has excite voltage
Turbidity Loop Active	28	R	Yes	Turbidity loop has excite voltage
Level Loop Error	29	R	Yes	Level loop driver error
Turbidity Loop Error	30	R	Yes	Turbidity loop driver error
Echo Delay Timer	31	R	Yes	Sensor has detected loss of signal
Waveform Data Ready	32	R	No	Data in Waveform Registers is ready
Set Default	33	W[1]	No	Set all parameters to default
Load Parameters	34	W[1]	No	Load all parameters from FLASH
Save Parameters	35	W[1]	No	Save all parameters to FLASH
Reset Sensor	36	W[1]	No	Reset Sensor (same as power on reset)
Turbidity LED Alarm	37	R	Yes	Turbidity LED open or not connected
Turbidity Driver Failure	38	R	Yes	Turbidity driver failure

[1] Write-only registers always return 0 on a read.

Figure 8: Table of bit values

Register Number Assignment

Register values can be encoded in one of several ways. As shown in *Figure 9*, register values have a data format type associated with each: UUI, USUI, UINT, BUI or CHAR. The coding for each type of value is slightly different. See *"Data Format Definitions" on page 18* for the data format definitions for each type.

Name	Register	Data	Len	R/W	QP	Description
Media Level	40001	USUI	1	R	Yes	Reported Media Level
Turbidity NTU	40002	UINT	1	R/W	Yes	NTU value for Turbidity
Expansion Measurement	40003	USUI	1	R/W	Yes	Calculated amount of Expansion
Expansion Percentage	40004	UINT	1	R/W	Yes	Calculated Expansion Percentage
Units	40005	UINT	1	R/W	Yes	Inch, ft, cm, meter
Media Depth	40006	UINT	1	R/W	Yes	Customer-entered Media Depth
Total Measurement Range	40007	UUI	1	R/W	Yes	Depth of water plus depth of media (auto calculated)
Zero Adjust	40008	USI	1	R/W	Yes	Zero Adjust
Sensor Blanking Zone	40009	UUI	1	R/W	Yes	Range directly in front of sensor face
Sensor Measurement Limit	40010	UUI	1	R/W	Yes	Auto set just below top of media
Sensitivity	40011	UINT	1	R/W	Yes	Percentage of tracking Threshold
Wall Zone	40012	UUI	1	R/W	Yes	Wall Zone
Gate Rate	40013	UINT	1	R/W	Yes	Movement rate of LG Min & RG Min
LG Min	40014	UUI	1	R/W	Yes	Minimum distance of left gate
RG Min	40015	UUI	1	R/W	Yes	Minimum distance of right gate
Dampening	40016	UUI	1	R/W	No	Number of updates to average
Sound Speed	40017	BUI	1	R/W	Yes	Speed of Sound in FPS or MPS
Gain Increment	40018	UINT	1	R/W	Yes	Basic step change for gain
Wall Zone AG	40019	UINT	1	R/W	Yes	Gain control in wall zone
AG Set Point	40020	UINT	1	R/W	Yes	Gain control outside of wall zone
Gain Band	40021	UINT	1	R/W	Yes	Allowable gain adjustment
Primary 4…20	40022	UINT	1	R/W	No	Value output on primary 4…20 mA loop
4 mA Set Pt	40023	UUI	1	R/W	No	4 mA output setpoint
20 mA Set Pt	40024	UUI	1	R/W	No	20 mA output setpoint
EL Action	40025	UINT	1	R/W	No	Echo Loss Action
Echo Delay	40026	UINT	1	R/W	No	Echo Delay
CP 4 mA	40027	UINT	1	R/W	No	4 mA Calibration value
CP 20 mA	40028	UINT	1	R/W	No	20 mA Calibration value
Current Gain	40029	UINT	1	R/W	No	Current Gain
Ping Rate Delay	40030	UINT	1	R/W	No	Ping Rate Delay
Update Rate	40031	UINT	1	R/W	No	Update Rate
Smoothing Rate	40032	UINT	1	R/W	No	Smoothing Rate
Delta Smoothing	40033	UINT	1	R/W	No	Delta Smoothing Rate
Wiper Delay	40034	UINT	1	R/W	No	Wiper Timing
Interface	40035	UINT	1	R/W	No	Selects first (0) or last (1)
Gain Band MP	40036	UINT	1	R/W	No	Gain Band Mid Point
Sensor Address	40037	UINT	1	R/W	Yes	Sensor Address
Op Range Index	40038	UINT	1	R	No	Sensor Operating Range Index
TCP 4 mA	40039	UINT	1	R/W	No	4 mA Turbidity Calibration value
TCP 20 mA	40040	UINT	1	R/W	No	20 mA Turbidity Calibration value
Media Percentage	40041	UINT	1	R	Yes	Media Level as a Percentage
Turbidity NTU Percentage	40042	UINT	1	R	Yes	Turbidity Value as Percentage
Hardware Version	40043	UINT	1	R	Yes	Version number of hardware
Software Version	40044	UINT	1	R	Yes	Version number of software
Sensor Name	40101	CHAR	12	R/W	No	Sensor Name
Serial Number	40113	CHAR	6	R	No	Sensor serial number
Waveform Data	40201	UINT	512	R	No	Waveform Data

Figure 9: Table of register values

Data Format Definitions

The sensor uses different data type definitions for the data contained in the registers. Each register specified in *Figure 9 on page 17* has a specific data format associated with the register.

Unsigned Integer (UINT) Format

The value in the register is a binary number representing an *Unsigned Integer* from 0…65535.

Units Unsigned Integer (UUI) Format

The *Units Unsigned Integer* format is used to represent a positive distance measurement. The value in the register represents a dimension based in inches or centimeters. The selection of inches or centimeters is determined by the current setting of the *Units* register (see *"Units (Register 40005)" on page 22*). The value in the register is a binary number representing an unsigned integer from 0…65535.

Units Signed Integer (USI) Format

The *Units Signed Integer* format is used to represent a positive or negative distance measurement. The value in the register represents a dimension based in inches or centimeters. The selection of inches or centimeters is determined by the current setting of the *Units* register (see *"Units (Register 40005)" on page 22*). The value in the register is a binary number representing a signed integer from –32767…32767. The lower 15 bits determine the magnitude of the number, the most significant bit determines the sign of the number. Therefore, the value 0x800A would represent the decimal number –10 and the value 0x000A would represent the decimal number +10.

Units Scaled Unsigned Integer (USUI) Format

The *Units Scaled Unsigned Integer* format is used to represent distances at a slightly higher degree of precision that what is available using the UUI format. The value in the register represents a dimension based on 1/10 of a foot, 1/10 of an inch, 1/10 of a meter or 1/10 of a centimeter. The selection of feet, inches, meters or centimeters is determined by the current setting of the *Units* register (see *"Units (Register 40005)" on page 22*). The value in the register is a binary number representing an unsigned integer from 0…65535. Therefore, the number 345.6 would be represented as 3456 in the USUI format. If the *Units* register is set to 0, the number would represent 345.6 inches.

Basic Units Unsigned Integer (BUI) Format

The *Basic Units Unsigned Integer* format is used to represent a positive distance measurement. The value in the register represents a dimension based in feet or meters. The selection of feet or meters is determined by the current setting of the *Units* register (see *"Units (Register 40005)" on page 22*). The value in the register is a binary number representing an unsigned integer from 0…65535.

NOTE: This format is similar to the UUI format except that the number represents feet/meters instead of inches/centimeters.

Character String (CHAR) Format

The *Character String* format is used to represent ASCII strings. Each register is 16 bits wide and holds two 8-bit ASCII characters. The string is a fixed length long as specified by the number of contiguous registers and is not required to be terminated by a null character.

Bit Values

The table in *Figure 8 on page 16* identifies several bit values. Each of these bit values is referenced by a coil number in the Modbus standard. This section identifies each coil value and the associated function.

Auto Gain (Coil 1)

The *Auto Gain* bit determines if the sensor automatically adapts the operating gain. If the bit is clear (0), the *Auto Gain* function is OFF. If the bit is set (1), the *Auto Gain* function is ON. When the *Auto Gain* function is OFF, the amount of operating gain can be controlled using the *Current Gain* register (see *"Current Gain (Register 40029)" on page 24*). When the *Auto Gain* function is ON, the *Current Gain* register can be used to read the *Current Gain* value, but while the *Auto Gain* is ON, the *Current Gain* register cannot be used to alter the gain setting.

Measure (Coil 2)

The *Measure* bit determines if the *Media Level* displays as a *Level* or a *Range* value. See *"Media Level (Register 40001)" on page 21*. If the *Measure* bit is clear (0), the measurement displays as the *Level*. If the *Measure* bit is set (1), the measurement displays as the *Range*. *Level* measurement provides the distance of the interface level from the bottom of the tank. *Range* measurement provides the distance of the interface level to the top of the tank.

Settling Zone (Coil 3)

If the bit is clear (0), the *Settling Zone* is OFF. If the bit is set (1), the *Settling Zone* is ON.

Echo Loss (Coil 4)

If the *Echo Loss* bit is set (1), the sensor indicates that condition on the 4…20 mA current loop when the sensor is unable to determine a valid interface. The *Echo Loss* condition is reported based on the *Echo Delay* and *Echo Loss (EL) Action* registers. See *"Echo Delay Timer (Coil 31)" on page 20* and *"Echo Loss (EL) Action (Register 40025)" on page 24*.

Force Level 4 mA (Coil 5)

If the *Force Level 4 mA* bit is set (1), the sensor sends a 4 mA signal on the 4…20 mA current loop used for the level information. This bit cannot be set when the *Force Level 20 mA* bit is set.

Force Level 20 mA (Coil 6)

If the *Force Level 20 mA* bit is set (1), the sensor sends a 20 mA signal on the 4…20 mA current loop used for the level information. This bit cannot be set when the *Force Level 4 mA* bit is set.

Force Turbidity 4 mA (Coil 7)

If the *Force Turbidity 4 mA* bit is set (1), the sensor sends a 4 mA signal on the 4…20 mA current loop used for the turbidity information. This bit cannot be set when the *Force Turbidity 20 mA* bit is set.

Force Turbidity 20 mA (Coil 8)

If the *Force Turbidity 20 mA* bit is set (1), the sensor sends a 20 mA signal on the 4…20 mA current loop used for the turbidity information. This bit cannot be set when the *Force Turbidity 4 mA* bit is set.

Composite Waveform (Coil 9)

The sensor gathers a number of 1024 waveforms prior to analysis. The number of waveforms collected is determined by the *Update Rate* register (see *"Update Rate (Register 40031)" on page 25*). As each waveform is captured, it is added to the prior waveform. The *Composite Waveform* coil determines how the waveforms are added. If the *Composite Waveform* coil is set (1), the resultant waveform is composed of the maximum amplitude for each of the 1024 data points, resulting in the final *Composite Waveform* having the maximum detected signal level for each of the 1024 sample points. If the *Composite Waveform* coil is clear (0), the waveforms are added by performing an arithmetical average for each of the 1024 data points.

Waveform Acquisition Ctrl (Coil 11)

The *Waveform Acquisition* bit allows the sensor to gather *Waveform Data*. This bit defaults to the ON (1) state. If the bit is OFF, the sensor does not acquire any *Waveform Data*. Set this bit to OFF when uploading *Waveform Data* from the sensor to a host device. If the *Waveform Acquisition* bit is left in the OFF state for more than 1 minute, the sensor automatically sets the *Waveform Acquisition* bit to the ON state to prevent the sensor from being inadvertently disabled.

High Power Mode (Coil 12)

The *High Power Mode* bit indicates if the sensor is in high power (full operation) or low power (standby) mode. If the bit is clear (0), the sensor is in standby mode. While in standby mode, the sensor does not generate new measurement values or operate the 4…20 mA current loops but does respond to all communication requests. If the bit is set (1), the sensor is in *High Power Mode* and is fully operational.

Turbidity Installed (Coil 17)

The *Turbidity Installed* bit indicates if the sensor has been equipped with a *Turbidity* module. If the bit is clear (0), no *Turbidity* module is installed. If the bit is set (1), the sensor is equipped with a *Turbidity* module. The coil is read-only.

Wiper Installed (Coil 18)

The *Wiper Installed* bit indicates if the sensor has been equipped with a wiper. If the bit is clear (0), no wiper is installed. If the bit is set (1), the sensor is equipped with a wiper. The coil is read-only.

Wiper Stalled (Coil 19)

When set (1), the *Wiper Stalled* bit indicates that the sensor has detected a wiper overcurrent or is not detecting the wiper blade.

Wiper Motor Failure (Coil 20)

When set (1), the *Wiper Motor Failure* bit indicates that the sensor has detected that the wiper motor is open-circuited or the motor is not connected.

Loss of Signal Alarm (Coil 21)

When set (1), the *Loss of Signal Alarm* bit indicates that the sensor has detected a loss of signal condition for more than the *Echo Delay* register value. See *"Units (Register 40005)" on page 22*.

Stabilize Gain Mode (Coil 22)

When set (1), the sensor is in the *Stabilize Gain Mode* of the initialization process.

Stabilize Track Mode (Coil 23)

When set (1), this sensor is in the *Stabilize Track Mode* of the initialization process.

Stabilize Gates Mode (Coil 24)

When set (1), this sensor is in the *Stabilize Gates Mode* of the initialization process.

Initialization Complete (Coil 25)

When set (1), the sensor has completed the initialization process and is now operating normally. The *Current Interface Value* is not available until the initialization process is complete.

Requires Setup (Coil 26)

When set (1), the *Requires Setup* bit indicates that the sensor has been configured at the factory but requires field configuration (*Tank Depth*, *Zero Adjust* and so on) prior to initial use.

Level Loop Active (Coil 27)

When set (1), the *Level Loop Active* bit indicates that the 4…20 mA *Level* current loop has the proper voltage applied and is now active. Use this to coil to alarm malfunctions.

Turbidity Loop Active (Coil 28)

When set (1), the *Turbidity Loop Active* bit indicates that the 4…20 mA *Turbidity* current loop has the proper voltage applied and is now active. Use this to coil to alarm malfunctions.

Level Loop Error (Coil 29)

When set (1), the *Level Loop Error* bit indicates that the sensor has detected an error in the driver circuit for the 4…20 mA current loop for the *Level*. Use this to coil to alarm malfunctions.

Turbidity Loop Error (Coil 30)

When set (1), the *Turbidity Loop Error* bit indicates that the sensor has detected an error in the driver circuit for the 4…20 mA current loop for the *Turbidity*. Use this to coil to alarm malfunctions.

Echo Delay Timer (Coil 31)

When set (1), the *Echo Delay Timer* bit indicates that the sensor has detected a loss of echo signal but is waiting for the *Echo Delay* to be satisfied to activate the *Echo Loss Action*. See *"Echo Delay (Register 40026)" on page 24* and *"Echo Loss (EL) Action (Register 40025)" on page 24*.

Waveform Data Ready (Coil 32)

When the *Waveform Data Ready* bit is set (1), the data in the *Waveform Registers* is ready to upload to a host. See *"Waveform Data (Registers 40201…40712)" on page 26*. This bit is only set after the *Waveform Acquisition Control* coil is set to 0 and the sensor has placed new data in the *Waveform Registers*. See *"Waveform Acquisition Ctrl (Coil 11)" on page 19*.

Set Defaults (Coil 33)

The *Set Default* bit is used to restore all the sensor parameters back to the factory defaults. To activate this command, set the bit to 1. At the completion of the requested action, the bit automatically resets back to 0. There is no need to reset the bit back to 0.

Load Parameters (Coil 34)

The *Load Parameters* bit is used to read all the saved parameters from the EEPROM and place them in working memory. To activate this command, set the bit to 1. At the completion of the requested action, the bit automatically resets back to 0. There is no need to reset the bit back to 0.

Save Parameters (Coil 35)

The *Save Parameters* bit is used to save all the parameters in the working memory to EEPROM. This action is required so that on the next power cycle the sensor automatically restores all parameter values. To activate this command, set the bit to 1. At the completion of the requested action the bit automatically resets back to 0. There is no need to reset the bit back to 0.

Reset Sensor (Coil 36)

The *Reset Sensor* bit is used to cause a complete hardware and software reset of the sensor. To activate this command, set the bit to 1. At the completion of the requested action, the bit automatically resets back to 0. There is no need to reset the bit back to 0. If the sensor has the auto power selection, the sensor enters the low power mode after reset.

Turbidity LED Alarm (Coil 37)

When set (1), the *Turbidity LED Alarm* bit indicates that the sensor detected that the LED used for the *Turbidity* sensor is open-circuited or the *Turbidity* sensor is not connected.

Turbidity Driver Failure (Coil 38)

When set (1), the *Turbidity Driver Failure* bit indicates that the sensor detected that the I.C. driver for the turbidity sensor LED has failed.

Register Values

The table in *Figure 9 on page 17* identifies several data values. Each of these data values is referenced by a register number in the Modbus standard. This section identifies each register and the associated function.

Media Level (Register 40001)

The *Media Level* register indicates the location of the expandable media, both at rest and during bed expansion. The setting of the *Units* register determines the base number representation as shown in *Figure 10 on page 22*. See *"Units (Register 40005)" on page 22*. In all cases, the binary number presented represents the base measurement multiplied by 10 (for example, 200 = 20.0 units). See *Figure 10 on page 22* for a description of the USUI format and additional information on the format of the number contained in this register.

Turbidity NTU (Register 40002)

The *Turbidity NTU* register returns the current turbidity NTU value multiplied by 100 (0…5000). Divide the returned number by 100 to get the actual NTU value. If the turbidity option is not installed and enabled, the register returns a 0 value. See *"Turbidity Installed (Coil 17)" on page 19*.Trying to write to this register returns an error.

Expansion Measurement (Register 40003)

The *Expansion Measurement* register reports the positive change in bed level. The setting of the *Units* register determines the base number representation as shown in *Figure 10 on page 22*. See *"Units (Register 40005)" on page 22*. In all cases, the binary number presented represents the base measurement multiplied by 10 (for example, 200 = 20.0 units). See *Figure 10 on page 22* for a description of the USUI format and additional information on the format of the number contained in this register.

Expansion Percentage (Register 40004)

The *Expansion Percentage* register reports the percentage of expansion that has occurred in the expandable media based on the recorded bed depth and the current media expansion. Divide the returned number by 10 to get the percentage.

Units (Register 40005)

The *Units* register specifies the base units for the system to use: Metric or English. The *Units* value determines what units the UUI, USI, USUI and BUI numbers represent. See *"Data Format Definitions" on page 18* for definitions of each. *Figure 10* identifies how various data formats are interpreted based on the setting of the *Units* register.

Value	Base	UUI Base	USI Base	USUI Base	BUI Base
0	feet	inches	inches	feet * 10	feet
1	inches	inches	inches	inches * 10	feet
2	meters	cm	cm	meters * 10	meters
3	cm	cm	cm	cm * 10	meters

Figure 10: Units settings

When changing the *Units* register, the sensor automatically re-scales all the registers that are based in UUI, USI, USUI and BUI units.

Media Depth (Register 40006)

Media Depth is the amount of expandable media in the filter. You must enter an accurate value during setup for the correct *Media Level* to be reported and for accurate expansion percentage calculations.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Total Measurement Range (Register 40007)

Total Measurement Range is the distance from the surface of the water to the bottom of the expandable media. This value is automatically set during the sensor initialization process, based on the entry of *Media Level*. Changes to this parameter value after initialization impacts the indicated *Media Level*.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Zero Adjust (Register 40008)

Zero Adjust is an offset value that locates the face of the sensor above or below the surface of the water level of the tank. This value modifies the level/range measurement to adjust for the sensor location. The value can be positive (sensor face installed below the water level) or negative (sensor face installed above the water level—for example, in a standpipe).

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Sensor Blanking Zone (Register 40009)

Sensor Blanking Zone is an adjustable value that determines the minimum distance the sensor measurea. This number is always positive and must be less than the *Total Measurement Limit*.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Sensor Measurement Limit (Register 40010)

Sensor Measurement Limit is an adjustable value that determines the maximum distance the sensor measures. Generally, this number is set 4 inches (10 cm) deeper than the top of the expandable media (*Total Measurement Range* minus *Media Depth*).

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Sensitivity (Register 40011)

Interfaces are detected by analysis of wave form derivatives. *Sensitivity* is an adjustable threshold that determines which derivatives are valid for tracking. Valid range of numbers is 0…100.

Wall Zone (Register 40012)

The *Wall Zone* value determines the size of the adjustable distance above the tank bottom.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters then the number represents the measurement in centimeters.

Gate Rate (Register 40013)

The *Gate Rate* value determines the maximum movement of the gates in any one update. Valid range of the number is 0…50.

LG Min (Register 40014)

The *LG Min* value determines the minimum distance that the left gate can be placed from the current track value.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

RG Min (Register 40015)

The *RG Min* value determines the minimum distance that the right gate can be placed from the current track value.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Dampening (Register 40016)

The *Dampening* register is used to average the current track location (reported interface location). The *Dampening* value determines the number of updates to average together to provide a track location. Valid range of the number is 1…250.

Sound Speed (Register 40017)

The *Sound Speed* register is used to adjust the speed of sound used for all sensor distance measurements.

If the *Units* register is set for feet or inches, the binary number represents the measurement in feet per second (FPS). See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in meters per second (MPS).

Gain Increment (Register 40018)

The *Gain Increment* register determines the step size in the auto-gain adjustment. Valid range of the number is 5…50. The reported binary value is 10 times the value used by the sensor (for example, 5 = 0.5).

Wall Zone AG (Register 40019)

The *Wall Zone AG* controls the amount of gain applied to amplify the waveform in the *Wall Zone* when the *Auto Gain* coil is set to 1 (ON). See *"Wall Zone (Register 40012)" on page 23* and *"Auto Gain (Coil 1)" on page 18*. The valid range of the register is 0…100 with 10 as default. Lowering this number decreases the gain applied to the waveform. Raising this number increases the amount of gain.

AG Set Point (Register 40020)

The *AG Set Point* controls the amount of gain applied to amplify the waveform not in the *Wall Zone* when the *Auto Gain* coil is set to 1 (ON). See *"Wall Zone (Register 40012)" on page 23* and *"Auto Gain (Coil 1)" on page 18*. The valid range of the register is 0…50 with 10 as default. Lowering this number decreases the gain applied to the waveform. Raising this number increases the amount of gain.

Gain Band (Register 40021)

The *Gain Band* register is the range in which the gain is permitted to fluctuate ± the *Gain Band Mid Point* value (see *"Gain Band MP (Register 40036)" on page 25*). Valid range is 5…30.

Primary 4…20 mA (Register 40022)

The *Primary 4…20 mA* register indicates what value is output on the primary 4…20 mA current loop. The table below shows the available options:

Register Value	Output on Primary 4…20 mA Current Loop
0	Media Level
1	Media Expansion Value
2	Media Expansion Percentage

Figure 11: Primary 4…20 mA loop options

4 mA Set Point (SP) (Register 40023)

The *4 mA Set Point (SP)* register is used to specify the value used as the 4 mA set point for the analog output scaling. This value is typically set to zero.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

20 mA Set Point (SP) (Register 40024)

The *20 mA Set Point (SP)* register is used to specify the value used as the 20 mA set point for the analog output scaling. This value should match the 20 mA scaling at the control system.

If the *Units* register is set for feet or inches, the binary number represents the measurement in inches. See *"Units (Register 40005)" on page 22*. If the *Units* register is set for meters or centimeters, the number represents the measurement in centimeters.

Echo Loss (EL) Action (Register 40025)

The *Echo Loss (EL) Action* register determines the action to be taken on the Level current loop if there is a loss of echo for the duration of the *Echo Delay*. See *"Units (Register 40005)" on page 22*. For this action to be valid, the *Echo Loss* coil must be set ON. See *"Echo Loss (Coil 4)" on page 19*. *Figure 12* identifies the valid *Echo Loss Actions*.

Register Value	Action
0	Force 4 mA level (Drive Low)
1	Force 20 mA level (Drive High)
2	Cycle – Alternate Low and High

Figure 12: Echo loss action values

Echo Delay (Register 40026)

The *Echo Delay* register determines the number of minutes the sensor must experience a loss of signal condition before the sensor initiates the *Echo Loss Action*. See *"Units (Register 40005)" on page 22*.If the *Echo Loss* coil is turned OFF, the value in the *Echo Delay* register is ignored and the sensor does not initiate the *Echo Loss Action*. See *"Echo Loss (Coil 4)" on page 19*)

CP 4 mA (Register 40027)

The *4 mA Calibration Point (CP)* register contains the binary number necessary to write to the hardware to generate a 4 mA signal on the current loop used for the level.

CP 20 mA (Register 40028)

The *20 mA Calibration Point (CP)* register contains the binary number necessary to write to the hardware to generate a 20 mA signal on the current loop used for the level.

Current Gain (Register 40029)

When the *Auto Gain* coil is OFF, the *Current Gain* register is used to control the gain amplification value. See *"Auto Gain (Coil 1)" on page 18*. In this mode the *Current Gain* register provides read/write capability. When the *Auto Gain* coil is ON, the *Current Gain* register is read-only and provides an indication of the *Current Gain* value. Valid Range of number is – 4095…4095.

Ping Rate Delay (Register 40030)

The sensor normally collects *Waveform Data* at a pre-programmed rate. The *Ping Rate Delay* register is used to add a delay into the waveform collection sequence. Valid range of the register is 0…100. The rate for each number is in 10 mS units. If the *Ping Rate Delay* register is set to 0, there is no delay added. If the *Ping Rate Delay* register is set to 5, there would be a 50 mS delay between the collection of each waveform.

Update Rate (Register 40031)

The *Update Rate* register is used to determine how many waveforms are combined into a single waveform that is used for analysis. With a setting of 1, the sensor averages 8 waveforms. The maximum setting of 20 results in a total of 160 waveforms combined into the resulting final waveform.

NOTE: An *Update Rate* of 0 provides a single non-combined waveform.

Smoothing Rate (Register 40032)

The *Smoothing Rate* register is used to smooth the 1024 cells to produce the final waveform for analysis. Valid range of numbers is 0…25. A value of 0 provides no smoothing.

Delta Smoothing (Register 40033)

The *Delta Smoothing Rate* register is used to smooth the derivative waveform in the same manner as *"Smoothing Rate (Register 40032)" on page 25*.

Wiper Delay (Register 40034)

The *Wiper Delay* register determines the number of seconds that the wiper (when installed) is off between cycles. Valid range of the number is 0…240. A value of 0 indicates that the wiper is OFF and should not be cycled.

Interface (Register 40035)

The *Interface* register determines how the sensor interprets the *Waveform Data*. If the register is set to 0, the sensor selects the first (closest to the sensor) derivative that satisfies the *Sensitivity* threshold. See *"Sensitivity (Register 40011)" on page 23*. If the register value is set to 1, the sensor selects the last (farthest from the sensor) interface.

Gain Band MP (Register 40036)

The *Gain Band Mid Point (MP)* register is used to position the *Gain Band*. During initialization, the sensor calculates a *Gain Band* mid point. When *Auto Gain* is enabled, the sensor automatically adjusts the gain about this mid point. See *"Auto Gain (Coil 1)" on page 18*. The amount of adjustment is determined by the *Gain Band* register. See *"Gain Band (Register 40021)" on page 23*.

Sensor Address (Register 40037)

The *Sensor Address* register contains the network address for the sensor. Once this register is changed, the sensor communicates using the new network address.

Op Range Index (Register 40038)

This read-only register is used to indicate the operating range that the sensor is currently using. Since the operating range determines the basic sensor sample timing, this register is used to determine the timing used for sample points in the *Waveform Data*.

Index	Operating Range	Sample Time
0	5 ft (1.524 m)	2.501687886 uSec
1	10 ft (3.048 m)	5.003375771 uSec
2	20 ft (6.096 m)	10.00675154 uSec
3	30 ft (9.144 m)	15.01012731 uSec

Operating range values

TCP 4 mA (Register 40039)

The *4 mA Turbidity Calibration Point (TCP)* register contains the binary number necessary to write to the hardware to generate a 4 mA signal on the current loop used for the turbidity.

TCP 20 mA (Register 40040)

The *20 mA Turbidity Calibration Point (TCP)* register contains the binary number necessary to write to the hardware to generate a 20 mA signal on the current loop used for the turbidity.

Media Percentage (Register 40041)

The *Media Percentage* register returns the current *Level* as a percentage of *Total Measurement Range*. The value in the register is the actual percentage multiplied by 10 (0…10000). Divide the returned number by 10 to get the actual percentage. Trying to write to this register returns an error.

Turbidity NTU Percentage (Register 40042)

The *Turbidity NTU Percentage* register returns the current *Turbidity NTU Percentage* value multiplied by 100 (0…10000). Divide the returned number by 100 to get the actual NTU percentage value. If the *Turbidity Installed* coil is not set, the register returns a 0 value. See *"Turbidity Installed (Coil 17)" on page 19*. Trying to write to this register returns an error.

Hardware Version (Register 40043)

The *Hardware Version* register returns the version number of the hardware. Trying to write to this register returns an error.

Software Version (Register 40044)

The *Software Version* register returns the version number of the software. Trying to write to this register returns an error.

Sensor Name (Registers 40101…40112)

The *Sensor Name* is contained in a series of 12 successive registers. Each register contains two ASCII characters.

Serial Number (Registers 40113…40118)

The sensor *Serial Number* is contained in a series of 6 successive registers. Each register contains two ASCII characters.

Waveform Data (Registers 40201…40712)

Waveform Data exists as a series of 1024 data points. Each data point is a byte value with a valid range of 0…255. Each register is a 16-bit value and contains 2 of the 1024 data points. Register 40200 contains data points 0 and 1 and Register 40711 contains data points 1022 and 1023.

NOTE: When reading multiple register values (Modbus Function Code 03), you can only access a maximum of 15 consecutive registers.

Prior to reading the *Waveform Data* registers, the host should disable the *Waveform Acquisition Control* bit. See *"Waveform Acquisition Ctrl (Coil 11)" on page 19*. Failure to disable this control corrupts the data in the *Waveform Data* registers. The current status of the *Waveform Data* registers can be determined by reading the *Waveform Data Ready* coil. See *"Waveform Data Ready (Coil 32)" on page 20*.

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