

Calisto™ H1

User Guide



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Preface

This guide is intended for anyone who works with Calisto H1 online hydrogen monitoring sensor. It is assumed that the reader is familiar with professional standards and safety practices.

This document uses two special typefaces to indicate particular kinds of information:

- **Bold**—Used for software controls and user-entered text, such as buttons, check boxes, or other items that are clicked or selected. Example:

Click **Close**.

Also, any text you must type in is shown in this typeface. Example:

Type in **1500 ms**.

- **Monospace**—Used for text displayed in the user interface, such as an error message or prompt. Example:

Uploading test results.

Notes, Cautions, and Warnings

This document uses icons to draw your attention to information of special importance, as follows.



Note: Notes provide supplemental information that may apply to only some circumstances.



Caution: Cautions provide information that prevents damage to hardware or data.



Warning: Warnings provide information about anything that can affect operator health.

Support

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1. Introduction

The Calisto™ H1 is designed to detect and measure hydrogen as a component of transformer oil. The hydrogen-specific solid-state sensing element is designed for ease of use and interface flexibility. The Calisto™ H1 is an online hydrogen monitoring sensor for distribution class transformers. The sensor provides calibrated hydrogen readings through Modbus protocol over a 2-wire RS485 bus. The measured hydrogen is reported as ppm H2 dissolved in oil and is comparable to industry standard DGA measurements. Oil temperature at the sensing element is measured and available through the digital interfaces.

This document has been updated for use with firmware revision 1:18:A.



Note: Pictures of the devices that are shown throughout this guide are representative, and may not be identical to their in practice counterparts due to ongoing product development.



2. Features

Sensor

The Calisto™ H1's hydrogen measurement is based on a solid state palladium alloy sensor.

- Calibrated to measure hydrogen dissolved in transformer oil
- Periodic reference cycles are automatically run to eliminate offsets affecting long term stability
- No maintenance, long life sensing element



Warning: The sensor element may be damaged if exposed to hydrogen concentrations above 5,000 ppm.

Mechanical

The Calisto™ H1 is a rugged waterproof mechanical assembly design for distribution transformer applications. A 3/4"-14 NPT fitting is provided for attachment of the sensor to a transformer. Overall dimensions are shown below.

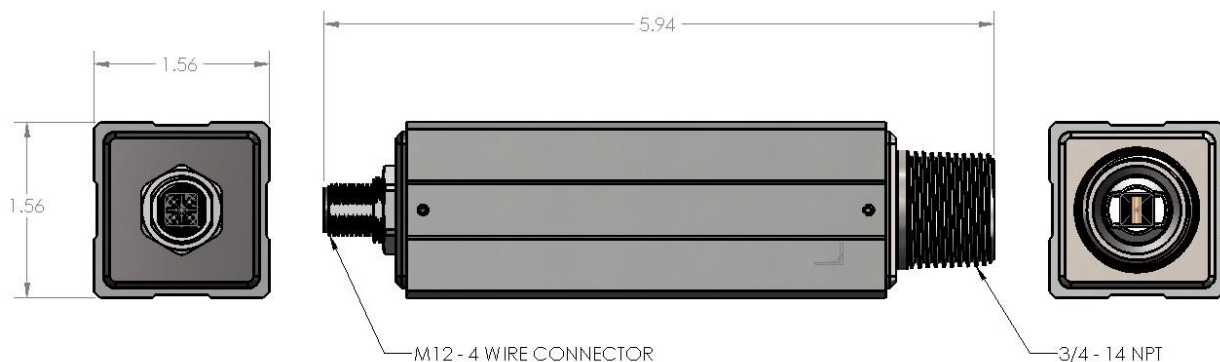


Figure 1 Calisto™ H1

Electrical

The Calisto™ H1 uses a single M12 4-pin connector for power and communications.

- DC power input of 9 to 48 volts, 10 watts
- 2-wire RS485 for Modbus RTU communications

3. Electrical Interface

All electrical connections are supplied through a 4-pin M12 connector. The key location and pin numbers are shown below.

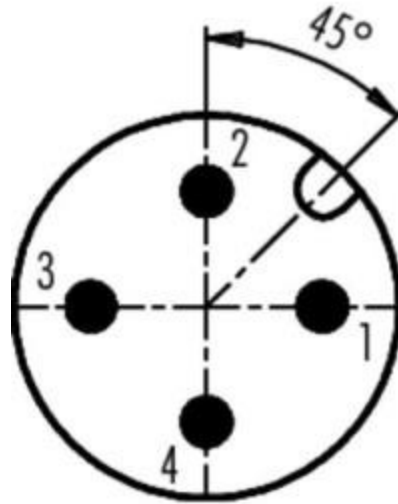


Figure 2 Key Location and Pin Numbers

Power Supply

Connect a DC power source rated for 9 to 48 volts, 10 watts to pin 1. 28 VDC or 48 VDC power supply is recommended.

Ground

Connect DC ground to pin 2.

Data+

Connect the RS485 Data+ signal to pin 3.

Data-

Connect the RS485 Data- signal to pin 4.

RS485 Interface

The RS485 input is isolated inside the Calisto H1 to improve noise immunity in harsh electrical environments. The Calisto H1 does not have line biasing built into the device.

When networking the device to a supervisory device, please ensure that line biasing is provided by another device on the same network bus. A 120-ohm termination resistor, between Data+ and Data- is installed in the Calisto H1.

4. Default settings

Calisto H1 Default Settings

Please note the following default settings for the Calisto™ H1 when setting up a device:

- Baud Rate: 19200
- Word Length: 8
- Parity: None
- Stop Bits: 1
- Modbus slave address: 1

5. Installation

Attach the sensor to ¾"-14 NPT fitting on the oil tank. Adapter bushing for larger ID fittings can be used; however, do not use adapters to smaller ID fittings or pipes. The sensor should be mounted in a horizontal position to prevent an air bubble from forming around the sensor element. Any piping or valves between the sensor and oil tank should have an inner diameter greater than 1" and a total length less than 8". Additional installation notes are listed below.

- Do not allow debris to accumulate around the sensor element
- Use thread-sealing tape
- Provide means to evacuate gas bubbles in pipe fittings between sensor and oil tank
- Do not install sensor in turbulent oil flow

Handling Precautions

The following precautions must be followed to ensure the sensor assembly is not damaged during handling.

- Do not poke anything into the open end around the sensor element
- Place wrench close to the threaded end when tightening
- Do not overtighten

6. Operation

Startup

After connecting the cable and turning on the power supply, the sensor executes a warm-up sequence lasting several minutes. The following operations are done during the warm-up sequence:

- Performs system self-test
- Restores configuration settings from non-volatile memory
- Starts the sampling system to measure hydrogen and oil temperature
- Runs autocalibration sequence to stabilize sensor as needed

Approximate hydrogen readings will be reported by the sensor within 30 minutes. On new installations, the sensor will take up to 16 hours to reach equilibrium and report an accurate hydrogen reading.

Status register 111 bit 15 indicates Not Ready until the first valid hydrogen measurement and then report the most recent measurements.



Warning: If an error is reported, turn off power to the sensor. Then double-check the electrical connections and power supply voltage before turning on power again. If the error condition persists, contact Doble customer service for assistance.

During normal operation, the sensor will periodically measure oil temperature (approximately once/hour) to provide temperature-compensated dissolved gas readings. The unit will also periodically go through an internal calibration check (called reference cycle). These are automatic activities, and no user interaction is required.

7. Modbus

Table 1 Modbus Read Request Packet

Byte	Modbus Parameter	Range	Meaning
1	Slave address	1-247	Unit ID Address
2	Function Code	03	Read Holding Register
3	Starting Address Hi	0x00-0xFF	Holding Register Hi Byte
4	Starting Address Lo	0x00-0xFF	Holding Register Lo Byte
5	Number of registers Hi	0	Limited by Modbus spec V1.1b
6	Number of Registers Lo	1-125	Number of 16-bit registers Lo Byte
7	CRC Low	0x00-0xFF	CRC Low Byte
8	CRC Hi	0x00-0xFF	CRC High Byte

Table 2 Modbus Read Response Packet

Byte #	Modbus Parameter	Range	Meaning
1	Slave address	1-247	Unit ID Address
2	Function Code	06	Returning Holding Registers
3	Byte Count	7-255	Number of data bytes returned = N
4	1st Data Value HI	0x00-0xFF	
5	1st Data Value Low	0x00-0xFF	
6	2nd Data Value Hi	0x00-0xFF	
7	2nd Data Value Low	0x00-0xFF	
...	...		

...	...		
2N+4	CRC Lo	0x00-0xFF	CRC Low Byte
2N+5	CRC Hi	0x00-0xFF	CRC High Byte



Note: N is the number of bytes returned, based on the number of registers requested. If N registers are requested, then 2N+5 bytes are returned.

Table 3 Modbus Write Request Packet

Byte	Modbus Parameter	Range	Meaning
1	Slave Address	1-247	Unit ID Address
2	Function Code	06	Write Holding Registers
3	Register Address Hi	0x00-0xFF	Unit Register Address Hi Byte
4	Register Address Lo	0x00-0xFF	Unit Register Address Lo Byte
5	Data Value Hi Byte	0x00-0xFF	
6	Data Value Lo Byte	0x00-0xFF	
7	CRC Lo	0x00-0xFF	CRC Low Byte
8	CRC Hi	0x00-0xFF	CRC High Byte

Table 4 Modbus Write Response Packet

Byte	Modbus Parameter	Range	Meaning
1	Slave Address	1-247	Unit ID Address
2	Function Code	06	
3	Register Address Hi Byte	0x00-0xFF	Unit Register Address Hi Byte
4	Register Address Lo Byte	0x00-0xFF	Unit Register Address Low Byte
5	Data Value Hi Byte	0x00-0xFF	
6	Data Value Lo Byte	0x00-0xFF	
7	CRC Lo	0x00-0xFF	CRC Low Byte
8	CRC Hi	0x00-0xFF	CRC High Byte

Exception Response

In a normal communications query and response due to a communication error, the master device sends a query to the slave device. Upon receiving the query, the slave processes the request and returns a response to the master device. An abnormal communication between the two devices produces one of four possible events:

1. If the slave does not receive the query due to a communications error, then no response is returned from the slave and the master device will eventually process a timeout condition for the query.
2. If the slave receives the query but detects a communication error (UART or CRC), then no response is returned from the slave and the master device will eventually process a timeout condition for the query.
3. If the slave receives the query without a communications error and takes longer than the master's timeout setting, then no response is returned from the slave. The master device eventually processes a timeout condition for the query. To prevent this condition, the master timeout must be set longer than the maximum response time of the slave (10,000 milliseconds).
4. If the slave receives the query without a communications error but cannot process it due to reading or writing to a non-existent slave command register, then the slave returns an exception response message informing the master of the error.

The exception response message has two fields that differentiate it from a normal response. The first is the function code – byte 2. This code will have the high order bit set to a one (i.e., 0x83 for a read exception and 0x86 for a write exception). The second

differentiating field is the exception code – byte 3. In addition, the total exception response length is 5 bytes rather than the normal message length.

Table 5 Exception Response Packet

Byte	Modbus Parameter	Range	Meaning
1	Slave Address	1-247	
2	Function Code	0x83 or 0x86	Read or write
3	Exception Code	See table below	
4	CRC High	0x00-0xFF	
5	CRC Low	0x00-0xFF	

Table 6 Exception Response Codes

Code	Name	Description
1	Illegal Function Code	The function code received in the query is not an allowable action for the slave. This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the slave is in the wrong state to process a request of this type, for example because it is not configured and is being asked to return register values.
2	Illegal Data Address	The data address received in the query is not an allowable address for the slave. More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, the PDU addresses the first register as 0, and the last one as 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 4, then this request will successfully operate (address-wise at least) on registers 96, 97, 98, 99. If a request is submitted with a starting register address of 96 and a quantity of registers of 5, then this request will fail with Exception Code 0x02 “Illegal Data Address” since it attempts to operate on registers 96, 97, 98, 99 and 100, and there is no register with address 100.

3	Illegal Data Value	A value contained in the query data field is not an allowable value for slave. This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the MODBUS protocol is unaware of the significance.
4	Slave Device Failure	An unrecoverable error occurred while the slave was attempting to perform the requested action.

Modbus Command Register Definitions

The Command Register definitions for the Gen5 Hydrogen Sensor are identified in Table 7.

Table 7 Command Register Locations

Register	Parameter	Function	Data Type	Data Range	Access
Measurements					
0	Hydrogen, ppm H ₂	High word	32-bit binary number	0 to 20,000,000	R
1	Hydrogen, ppm H ₂	Low word	32-bit binary number	0 to 20,000,000	R
2-6	Reserved for future use				
7	PCB Temperature, Celsius	x100 scale; 100 offset ($T=V/100-100$)	16-bit binary number	-100 to +200	R
8	Oil Temperature, Celsius	x100 scale; 100 offset ($T=V/100-100$)	16-bit binary number	-100 to +200	R
9-12	Reserved for future use				
13	Rate of Change, ppm H ₂ per Day +20,000,000 offset	High word	32-bit binary number	-100 to +200	R
14	Rate of Change, ppm H ₂ per Day +20,000,000 offset	Low word	32-bit binary number	-20,000,000 to +20,000,000	R
15	Rate of Change, ppm H ₂ per Week	High word	32-bit binary number	-20,000,000 to +20,000,000	R

	+20,000,000 off-set				
16	Rate of Change, ppm H2 per Week +20,000,000 off-set	Low word	32-bit binary number	-20,000,000 to +20,000,000	R
17	Rate of Change, ppm H2 per Month +20,000,000 off-set	High word	32-bit binary number	-20,000,000 to +20,000,000	R
18	Rate of Change, ppm H2 per Month +20,000,000 off-set	Low word	32-bit binary number	-20,000,000 to +20,000,000	R
19-30	Reserved for future use				
Information					
31-40	Model Number		ASCII String		R
41-50	Product Serial Number		ASCII String		R
51-60	Sensor Serial Number		ASCII String		R
61-70	Sensor Board Serial Number		ASCII String		R
71-80	Reserved for future use				
81	Manufacturing Date	High byte: Month Low byte: Day	32-bit binary value		R

82	Manufacturing Date	Year	32-bit binary value		R
83	Factory Calibration Date	High byte: Month Low byte: Day	32-bit binary value		R
84	Factory Calibration Date	Year	32-bit binary value		R
85-86	Reserved for future use				
87	Dissolved Gas Calibration Date	High byte: Month Low byte: Day			R
88	Dissolved Gas Calibration Date	Year			R
89-98	Firmware Revision		ASCII String		R
99-110	Reserved for future use				
Status/Error Information					
111	Status	Refer to Unit Status section	16-bit binary flags	See Table 8	R
112	Error Status	Refer to Error Status section High word	32-bit binary flags	See Table 9	R
113	Error Status	Refer to Error Status section Low word	32-bit binary flags	See Table 9	R
114-120	Reserved for future use				
Calibration Functions					
121	DA Command		None	Section	W

122	DB Command	Write reg 126-129 first	None	Section	W
123-124	Reserved for future use				
125	DC Command	Clear DGA calibration	None		W
126	Calibration Gas, ppm H2	High word	32-bit binary number	0 to 1,000,000	R/W
127	Calibration Gas, ppm H2	Low word	32-bit binary number		R/W
128	Calibration Date	High byte: Month Low byte: Day	32-bit binary number		R/W
129	Calibration Date	Year	32-bit binary number		R/W
130-135	Reserved for future use				
Configuration Settings					
136-143	User-defined oil type name	Refer to user-defined oil type configuration section.	ASCII String		R/W
144	Ostwald Slope, m	Refer to user-defined oil type configuration section.	16-bit binary number		R/W
145	Ostwald Slope, m	Refer to user-defined oil type configuration section.	16-bit binary number		R/W

146	Ostwald Slope, b	Refer to user-defined oil type configuration section.	16-bit binary number		
147	Ostwald Slope, b	Refer to user-defined oil type configuration section.	16-bit binary number		
148	Oil type operations	Refer to user-defined oil type configuration section.	16-bit binary number	1 = open edit 2 = close edit 3 = abort edit	R/W
149	Reserved for future use				
150	Set Unit ID		8-bit binary number	1 to 247	R/W
151	Operating Mode		16-bit binary number	0 = Field 1 = Lab	R/W
152	Oil type selection	Select oil type	16-bit binary number	0 = Mineral 1 = Silicone 2 = FR3 3 = MIDE L	R/W
153-159	Reserved for future use				
160	Baud Rate		8-bit binary	1 = 9600 2 = 14400 3 = 19200 4 = 38400 5 = 57600 6 = 115200 Note: device must be	R/W

				power cycled for baud rate change to take place.	
161-174	Reserved for future use				
Diagnostics					
175	Month/Year	Date & Time; read register 175 first; order high-byte / low-byte; add 2000 to year (64-bit)	Two bytes		R/W
176	Hour/Day	Date & Time; read register 175 first; order high-byte / low-byte; add 2000 to year (64-bit)	Two bytes		R/W
177	Second/Minute	Date & Time; read register 175 first; order high-byte / low-byte; add 2000 to year (64-bit)	Two bytes		R/W
178	Millisecond	Date & Time;	16-bit bin-		R/W

		read register 175 first; order high-byte / low-byte; add 2000 to year (64-bit)	ary number		
179-200	Reserved for future use				
User Information					
201-210	Owner ID	Must start reading from low address Must write high and low addresses to save string	ASCII String		R/W
211-220	Substation ID	Must start reading from low address Must write high and low addresses to save string	ASCII String		R/W
221-230	Transformer ID	Must start reading from low address Must write high and low addresses to save string	ASCII String		R/W
231-255	Reserved for future use				



Note: When reading registers containing 32 or 64-bit integers the user must read the high order word first, then the lower order word(s). Reading of the high order word causes the low order to be saved in a temporary location for the next register read. The second register is then



automatically read from the temporary location by the firmware. Likewise, with a write, the high value is stored until the second value is received at which time both values are written to the instrument.

Unit Status

Unit status information is maintained in Modbus register 111. The bit map for this status word is described below.

Table 8 Unit Status

Bit #	Description
2-0	Unlisted Bits are not used and may be 0 or 1
5-3	Sensor A state Information: 001 – Hydrogen measurement cycle 010 – Oil temperature measurement cycle 011 – Auto calibration cycle 100 – Oil temperature too high
6	Unlisted bits are not used and may be 0 or 1
7	
8	
9	
10	
11	
12	Error, indicates an unrecoverable error occurred, read Reg 112,113 for more information
13	Unlisted bits are not used and may be 0 or 1
14	New measurement data available, auto-clear after register read
15	Unit Ready, hydrogen readings are valid

Error Status

When the error flag (bit 12) of the Unit Status register 111 is set, this 32-bit register has more information about what is causing the error. The bit map is shown below, unlisted bits are reserved.

Table 9 Error Status

Bit #	Hex Value	Description
31	0x8000 0000	Sensor – Heater fault
30	0x4000 0000	Sensor - Temperature Sensor Fault
29	0x2000 0000	Sensor – Hydrogen Sensor Fault
3-28	0x1000 0000 -0x0000 0008	Unlisted bits are not used and may be 0 or 1.
2	0x0000 0004	PCB Temperature greater than 105C
1	0x0000 0002	Configuration data not available
0	0x0000 0001	Configuration data not valid

User-Defined Oil Type Configuration Window

GRIDSCAN 5000 can operate in a variety of oil types and comes configured for four popular types: Mineral, Silicone, Natural Ester (FR3), and Synthetic Ester (Midel). The end user can select one of programmed oil types or modify the fourth, user configurable oil type. The Oil Type Configuration Window registers are used to read and modify the user-defined Oil Type configuration data structure. This includes the name, and Ostwald values for slope and offset.



Note: These values are a critical part of the hydrogen calculation. Incorrect values impede the measurement and monitoring capabilities of the sensor.

For example: programming the Ostwald values for Midel 7131 $m=0.000093$, $b=0.039739$ are used in the following instructions.

The sequence of operations to program a new oil type are:

1. Write register 148 with 0x0001 to open the user configurable oil type for edit

2. Write registers 136-143 with the name of the oil
3. Write registers 144,145 with the Ostwald slope
4. Write registers 146,147 with the Ostwald offset
5. Write register 148 with 0x0002 to save the values and close

User-Defined Oil Type Name

The name of the user defined oil type is accessed in registers 136-143. Reading these registers will return the current value. Write these registers with a null terminated string to modify the name. The default value is "Synthetic Ester\0" for Midel 7131.

- A string length 15 characters
- Null-terminated with at least one byte of 0x00

Ostwald Slope, Slope (m)

The default value is 1093 (0x0000,0x0445) for Midel 7131. This is calculated using a scale factor of 1,000,000 and an offset of +1,000; $\text{Data32} = (m + 1,000) * 1,000,000$.

- Register 144, High 16-Bit value of Data32 (0x0000)
- Register 145, Low 16-Bit value of Data32 (0x0445)

Ostwald Offset, Offset (b)

The default value is 40,739 (0x0000, 0x9F23) for Midel 7131. This is calculated using a scale factor of 1,000,000 and an offset of +1,000; $\text{Data32} = (m + 1,000) * 1,000,000$.

- Register 146, High 16-Bit value of Data32 (0x0000)
- Register 147, Low 16-Bit value of Data32 (0x9F23)

Oil Type Operations

Writing register 148 is used initiate operations to edit and save the user defined oil type.

- Value = 1, starts configuration edit for user-defined Oil type.
- Value = 2, ends the edit and saves the new configuration settings
- Value = 3, aborts the operation and nothing is changed

8. Firmware Upgrade

Calisto™ H1 firmware is field upgradable. Instructions and PC software will be provided by Doble as needed.

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Global Telephone: 617-926-4900

Email: support@doble.com

Web: www.doble.com

B. Modbus Address Programming

Note the following before you start modbus address programming:

- A USB to RS485 converter is required to program the address on Calisto H1. The USB to RS485 converter must have line biasing on the RS485 line. Recommended USB adapter: EZSync010 - <https://purenitetechnology.com/product/ezsync010/>
 - Download Modbus Tester application using this link - https://www.se.com/library/SCHNEIDER_ELECTRIC/SE_LOCAL/APS/209280_3412/Tester.exe
1. Power the Calisto H1 using a DC power supply and connect it to your PC using a USB to RS485 dongle.
- Connect the RS485 data wires from Calisto H1 to the USB to RS485 converter and make sure the polarity is correct.

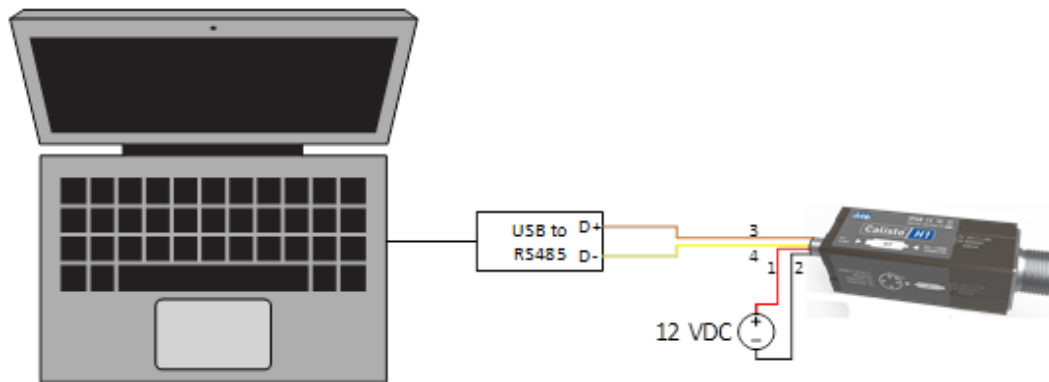


Figure 3 Connection Setup

2. Open the Device Manager on your PC and identify the COM port assigned to your converter when the USB to RS485 is connected. See the example below, in which the USB dongle was assigned COM4:

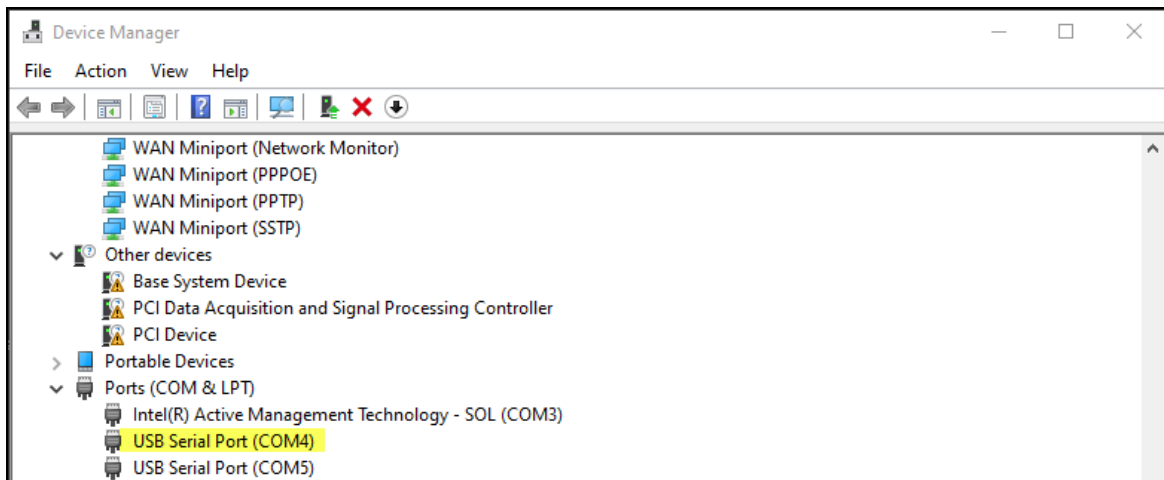


Figure 4 Device Manager Ports

3. Open the Modbus applicaiton - **Modbus Tester**.

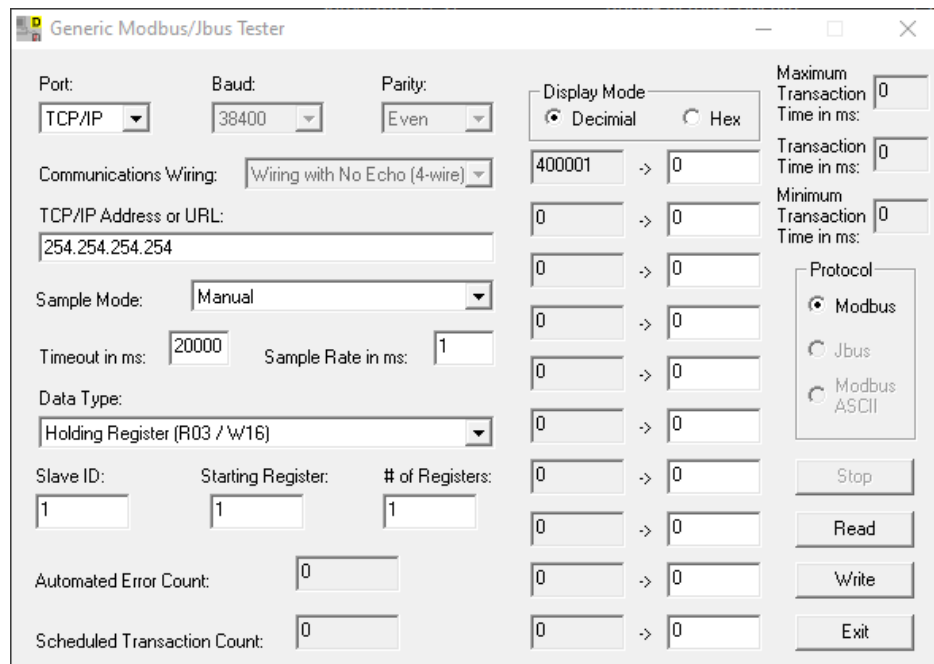


Figure 5 Modbus Tester Default Settings

Update the following fields:

- Port: COM4 (Might be a different COM on your PC)
- Baud: 19200
- Parity: None
- Data Type: Holding Register (R03 / W16)
- Slave ID: 0 (broadcast address)

- Starting Register: 151 (Set unit ID register)
- # of Registers: 1

Now enter the desired Modbus address that you want to set on the unit. Type in the desired address in the field to the right of the unit ID box. You don't need to know the current address on the unit to set the new address, that's the purpose of using the broadcast address. On this example the address is set to 2.

Figure 6 Modbus Address Entry

Figure 7 Modbus Configured to Write Address 2 to N1

Now click 'Write', at bottom-right of the screen, to send the write command to the unit. There is no confirmation the address was successfully written. A good indication the command was successful is if there is no CRC error popping up or the application not becoming unresponsive.



Figure 8 CRC Error

This error usually occurs when using a USB dongle without line biasing

4. To confirm that the new address has been successfully programmed on the unit, try to read the oil temperature register using the new programmed address.

Change the following:

- Slave ID: 2 (The address you have configured on your unit)
- Starting Register: 9 (Oil temperature register address)

Click Read, above Write button, to view the current temperature.

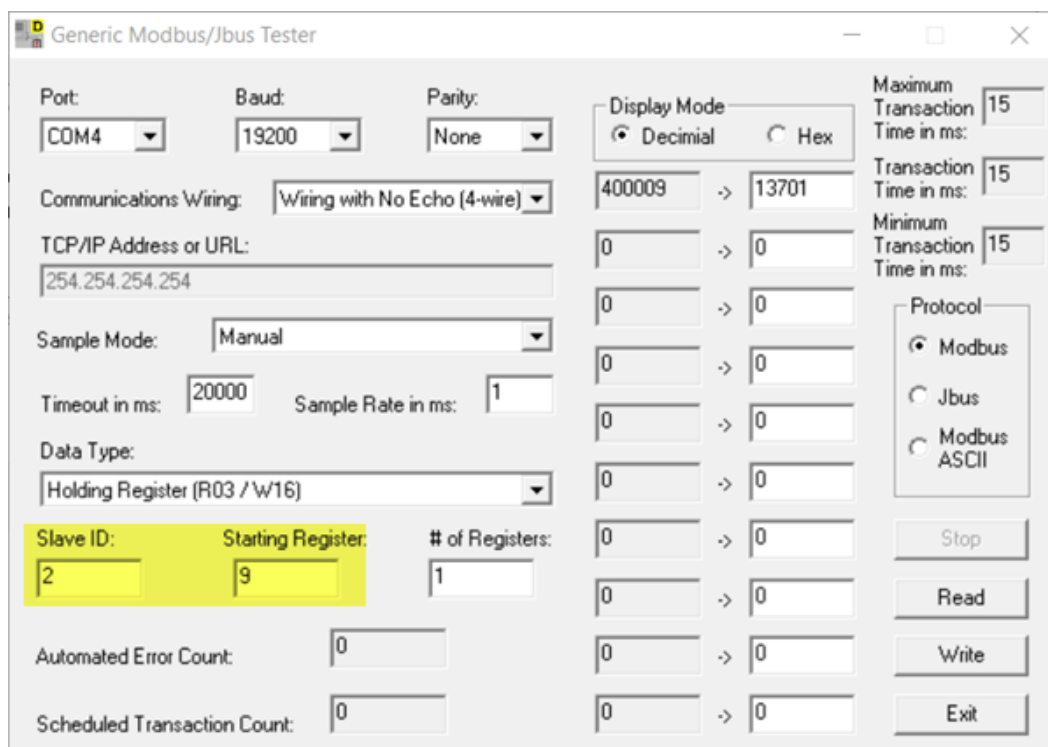


Figure 9 Configuration to Read Oil Temperature Register from H1 Address 2

Upon successful reading, the temperature count is shown in the field next to the box containing the oil temperature address.

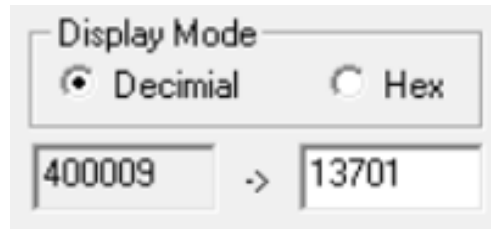


Figure 10 Raw Temperature Value

Use the following equation to convert the counts to engineering units:

$$\text{Temperature} = (\text{Counts}/100) - 100;$$

The counts in this example is 13701, therefore the temperature is:

$$\text{Temperature} = (13701/100) - 100 = 37.01\text{ }^{\circ}\text{C}$$

By successfully reading the oil temperature using the new Modbus address we have proved that the address writing was also successful and therefore your H1 is ready to be deployed in the field.