GRIDSCAN 5000
Hydrogen Sensor

MODBUS MAP

H2scan
ADVANCED HYDROGEN SENSING

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IMPORTANT NOTICES

Read and understand this operating manual before installing or using the unit.
If this equipment is used in a manner not specified by H2scan, the protection provided by this equipment may be impaired.

LIMITATION OF LIABILITY - seller shall under no circumstances be liable for any incidental, consequential, special, punitive, or other damages, including, but not limited to, loss of business or profit, promotional or manufacturing expenses, injury to reputation, or loss of customer, based on any alleged negligence, breach of warranty, strict liability, breach of contract, or any other legal theory arising out of the use, misuse, purchase, sale or possession of its goods or its performance of this contract to the extent that such liability extends seller's obligations beyond the price paid by buyer to seller for the item on which such claim is based. Seller advises buyer to perform acceptable tests on all hardware prior to deployment and to perform maintenance as described in the seller's instruction guide. Under no circumstances shall the equipment provided hereunder be used in a manner where it is the sole protective system for facilities, equipment, and personnel safety; the equipment is intended for use in conjunction with other appropriate protective systems.

LIMITED WARRANTY

H2scan Limited Warranty: Each hydrogen instrument ("Product") will conform, as to all substantial operational features, to the Product specifications set forth in this Manual and will be free of defects which substantially affect such Product's performance for thirty-six (36) months from the ship date for such Product.

Must Provide Notice of Defect: If you believe a Product that you believe is defective, you must notify H2scan in writing, within ten (10) days of receipt of such Product, of your claim regarding any such defect.

Return Product to H2scan for Repair, Replacement or Credit: If the Product is found defective by H2scan, H2scan's sole obligation under this warranty is to either (i) repair the Product, (ii) replace the Product, or (iii) issue a credit for the purchase price for such Product, the remedy to be determined by H2scan on a case-by-case basis.

Voided Warranty: H2scan's 36 Month Limited Warranty is void for any of the following:

- The unit is opened, and the manufacturing seal is broken.
- Unauthorized repair work performed at the customer's location or conducted by anyone other than H2scan's factory trained technicians.
- Equipment or parts that have been tampered with, misused, neglected, mishandled, improperly adjusted, or modified in any way without the written consent of H2scan.
- Equipment or parts that have been damaged due to shipping, misuse, accidents, mishandling, neglect, or problems with electrical power sources.
- Repair work performed during the warranty period does not prolong the warranty period past the original period.
- System operation in incorrect or inappropriate environments.
- Usage that is not in accordance with system guidelines or an operator's failure to follow manual instructions.

LIMITATION OF WARRANTY: THE ABOVE IS A LIMITED WARRANTY AS IT IS THE ONLY WARRANTY MADE BY H2SCAN. H2SCAN MAKES NO OTHER WARRANTY EXPRESS OR IMPLIED AND EXPRESSLY EXCLUDES ALL WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. YOUR SOLE REMEDY HEREUNDER IS REPAIR OR REPLACEMENT OF THE PRODUCT OR A CREDIT FOR THE PURCHASE PRICE FOR SUCH PRODUCT, THE PARTICULAR REMEDY TO BE DETERMINED BY H2SCAN ON A CASE-BY-CASE BASIS. H2SCAN SHALL HAVE NO LIABILITY WITH RESPECT TO ITS OBLIGATIONS UNDER THIS AGREEMENT FOR CONSEQUENTIAL, EXEMPLARY, OR INCIDENTAL DAMAGES EVEN IF IT HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THE STATED EXPRESS WARRANTY IS IN LIEU OF ALL LIABILITIES OR OBLIGATIONS OF H2SCAN FOR DAMAGES ARISING OUT OF OR IN CONNECTION WITH THE DELIVERY, USE OR PERFORMANCE OF THE PRODUCTS.

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1 Operation

1.1 Startup

After connecting the cable and turning on the power supply, the sensor executes a startup sequence that can last up to 16 hours. The following operations are performed during the startup sequence:

- Power on system self-test
- Restore configuration settings from non-volatile memory
- Start measuring liquid temperature and hydrogen
- Autocalibration sequence is performed to stabilize sensor as needed (sensor may show initial value before autocalibration is complete)

Prior to placing the sensor in operation, please perform the following steps:

1. Connect the sensor to power for at least 5 minutes to recharge the super capacitor, which may have discharged if the sensor has been without power for several months.
2. Reset the date/time per the steps in section **7.2.16**.
3. Cycle the power to clear any errors.

After a short power interruption, the approximate hydrogen readings will be reported by the sensor within 30 minutes after power is restored. On new installations and after long power interruptions, the sensor can take up to 16 hours to stabilize and report accurate hydrogen readings.

The Modbus status register **111**, bit **15** will indicate **Ready** when the first valid hydrogen measurement is available. After the startup sequence completes, measured and calculated values will be available in the Modbus registers.

If an error is reported, turn off power to the sensor; check the electrical connections and power supply voltage before restoring power again. If the error condition persists, contact H2scan customer service for assistance at **technicalsupport@h2scan.com**.

During normal operation, the sensor will measure liquid temperature (approximately once per hour) to provide temperature-compensated dissolved gas readings. The unit will periodically go through an internal autocalibration check (reference cycle). These are automatic activities that do not require any user interaction (**Fig 6**)

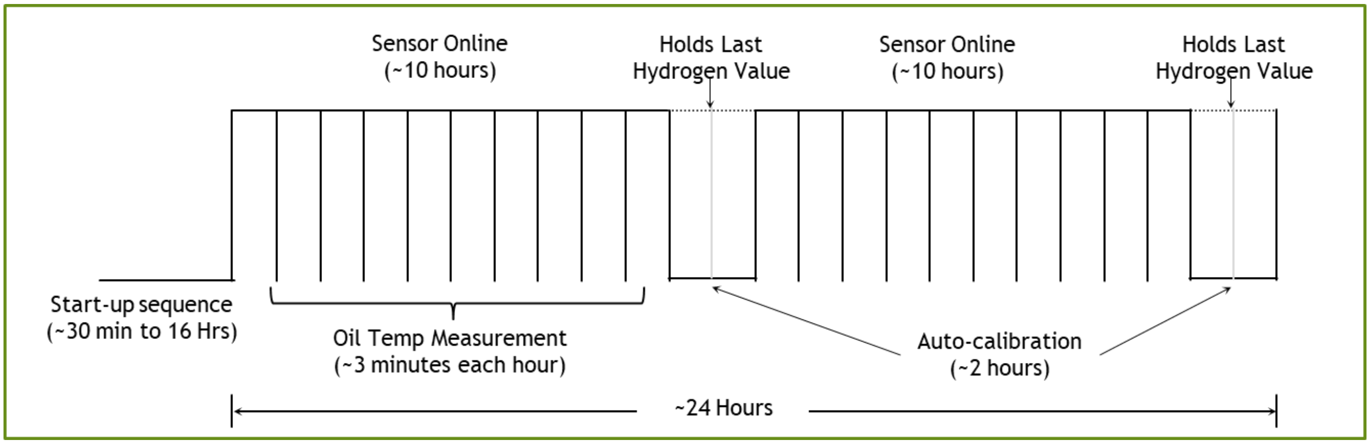

Figure 6: Normal Operation of GRIDSCAN 5000 Sensor

1.2 Monitoring

During normal operation, the GRIDSCAN 5000 Hydrogen Sensor measurements should be polled periodically for a measurement reading. The polling frequency can be from 1 second to several hours or days, depending on user requirements. Each reading should include the following Modbus holding registers.

- **Status Register** (**111**, bits **15** & **12**) – Bit 15 indicates that the hydrogen measurement is available. Bit 12 indicates that there is an error.
- **Error Status Registers** (**112,113**) – Indicates which error is detected. (These registers are active when register 111 bit 12 is high)
- **PCB Temperature Register** (**7**) – Provides the internal temperature of the GRIDSCAN 5000. **Note**: Operating temperatures above 105°C may cause permanent damage.
- **Liquid Temperature Register** (**8**) – Provides the liquid temperature at the sensor. Note that an liquid temperature above 105°C is outside the calibration range. Liquid temperature above 135°C may cause permanent damage.
- **Hydrogen Registers** (**0,1**) – Provides the Hydrogen ppm values. **Note**: The high word (0) must be read in order to enable the low word (1) value to be available.

1.3 Error/Exception Handling

The GRIDSCAN 5000 is designed for continuous operation and will automatically recover from intermittent problems due to insufficient power, excessive electrical noise, excessive internal PCB temperature, and excessive liquid temperature.

If the sensor element is damaged and inoperable, the GRIDSCAN 5000 will shut down the measurement system and continue responding to Modbus requests for error reporting. This error will be reported via register **111** bit **12** and then details specified in registers **112,113**. This type of error typically indicates a hardware fault that can only be repaired at H2scan. Power cycle the unit to attempt recovery. If the error condition repeats, contact H2scan for repair at **technicalsupport@h2scan.com**.

2 Modbus

The GRIDSCAN 5000 Hydrogen Sensor uses Modbus RTU to communicate with external equipment. Modbus RTU is a popular industrial interface supported by many products.

2.1 Communication Settings

Modbus protocol communicates over RS485 and supports RTU packets. The GRIDSCAN 5000's default Modbus ID is **1**. The Modbus ID can be changed by writing to holding register **150**.

2.2 Protocol

The following tables comprise the list of Modbus packets, values, registers, and register definitions. The supported Modbus Function Codes are shown in the table below:

Table 1: Supported Modbus Function Codes

Function Code	Description
02 (02 hex)	Read Discrete Inputs
03 (03 hex)	Read Holding Registers
04 (04 hex)	Read Input Registers
06 (06 hex)	Write Single Register
16 (10 hex)	Write Multiple Registers

The maximum response time for the sensor is 10 seconds. Therefore, the master's timeout should be set to 10,000 milliseconds or greater.

Table 2: Modbus Read Holding Register Request

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 Lo	0x00 – 0xFF	CRC Low Byte
8	CRC Hi	0x00 – 0xFF	CRC High Byte

Table 3: Modbus Read Holding Register Response

Byte #	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	03	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 Lo	0x00 – 0xFF	
6	2nd Data Value Hi	0x00 – 0xFF	
7	2nd Data Value Lo	0x00 – 0xFF	
…	…		
…	…		
2N+4	CRC Lo	0x00 – 0xFF	CRC Low Byte
2N+5	CRC Hi	0x00 – 0xFF	CRC High Byte
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 4: Modbus Write Single Holding Register Request

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 5: Modbus Write Single Holding Response

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 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 6: Modbus Write Multiple Holding Register Request

Byte #	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	16	Write Multiple 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	Byte Count	7 – 255	N number of data bytes to follow
8	1st Data Value Hi	0x00 – 0xFF	
9	1st Data Value Lo	0x00 – 0xFF	
10	2nd Data Value Hi	0x00 – 0xFF	
12	2nd Data Value Lo	0x00 – 0xFF	
…	…		
…	…		
2N+7	CRC Lo	0x00 – 0xFF	CRC Low Byte
2N+8	CRC Hi	0x00 – 0xFF	CRC High Byte

Table 7: Modbus Write Multiple Holding Register Response

Byte	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	16	Write Multiple 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	# Of Registers Written Hi	0x00 – 0xFF	Number of registers written Hi byte
6	# Of Registers Written Lo	0x00 – 0xFF	Number of registers written Lo byte
7	CRC Lo	0x00 – 0xFF	CRC Low Byte
8	CRC Hi	0x00 – 0xFF	CRC High Byte

Table 8: Modbus Read Discrete Input Register Request

Byte	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	02	Read Discrete Input Register
3	Starting Address Hi	0x00 – 0xFF	Data Address of the first input Hi Byte
4	Starting Address Lo	0x00 – 0xFF	Data Address of the first input Lo Byte
5	Number of Inputs Hi	0	Number of inputs requested Hi Byte
6	Number of Inputs Lo	1 – 68	Number of inputs requested Lo Byte
7	CRC Lo	0x00 – 0xFF	CRC Low Byte
8	CRC Hi	0x00 – 0xFF	CRC High Byte
Number of Coils is limited to the number of coils supported. Supported data address range is 0 to 67			

Table 9: Modbus Read Discrete Input Register Response

Byte #	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	02	Read Discrete Input Register
3	Byte Count	7 – 255	Number of data bytes to follow
4	1st Data Byte	0x00 – 0xFF	Bit 0 of 1st Data Byte is the on/off status Starting Address; bit 7 is the on/off status of Starting Address+7
5	2nd Data Byte	0x00 – 0xFF	Bit 0 of 2nd Data Byte is the on/off status Starting Address+8; bit 7 is the on/off status of Starting Address+8+7
…	…		
…	…		
N+4	CRC Lo	0x00 – 0xFF	CRC Low Byte
N+5	CRC Hi	0x00 – 0xFF	CRC High Byte

N is the number of bytes returned based on the number of coils requested.
N = Number of coils / 8 bits per byte
If N%8 > 0, N = N + 1
Data Value returns the on/off status of discrete inputs. The first data address (Starting Address) is placed in Bit 0 of the 1st Data Value Hi; the second data address is placed in Bit 1 of the 1st Data Value Hi, etc. The 9th data address is placed in Bit 0 of the 1st Data Value Lo.
The unused bits of the last Data Value Lo are filled in with zeroes (toward the most significant bit).
For example: Request the on/off status of discrete inputs starting at data address 0 to 18 (#10001 to 10019). The request will read 19 discrete inputs, starting at address 10001. The number of bytes returned is: N = 19/8 = 2, 19%8=3 > 0; so N=3. The unused bits in 3rd (last) data byte are filled in with zeroes (toward the most significant bit).

Table 10: Modbus Read Input Register Request

Byte	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	04	Read Input 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	Number of 16-bit registers Hi Byte
6	Number of Registers Lo	1 – 23	Number of 16-bit registers Lo Byte
7	CRC Lo	0x00 – 0xFF	CRC Low Byte
8	CRC Hi	0x00 – 0xFF	CRC High Byte

Number of Read Input Registers is limited to the number of registers reported.
Supported data address range is 0 to 22

Table 11: Modbus Read Input Register Response

Byte #	Modbus Parameter	Range	Meaning
1	Slave address	1 – 247	Unit ID Address
2	Function Code	04	Read Input Register
3	Byte Count	2 – 30	If number of registers requested=N Byte Count=2N
4	1st Data Value Hi	0x00 – 0xFF	
5	1st Data Value Lo	0x00 – 0xFF	
6	2nd Data Value Hi	0x00 – 0xFF	
7	2nd Data Value Lo	0x00 – 0xFF	
…	…		
…	…		
2N+4	CRC Lo	0x00 – 0xFF	CRC Low Byte
2N+5	CRC Hi	0x00 – 0xFF	CRC High Byte
2N is the number of bytes returned based on the number of registers requested. If N registers are requested, then 2N+5 bytes are returned.			

2.2.1 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 12: Exception Response

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 13: 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.

2.2.2 Modbus Holding Register Definitions

The Modbus Holding Register definitions for the GRIDSCAN 6000 Hydrogen Sensor are identified in Table 14.

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 word 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.

Table 14: Modbus Holding Register Descriptions

Register	Parameter	Function	Data Type	Data Range	Access
Measurements					
0	Hydrogen, ppm H2	High word	32-bit binary number	0 to 20,000,000	R
1		Low word			
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	Liquid 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	-20,000,000 to +20,000,000	R
14		Low word			
15	Rate of Change, ppm H_2 per Week +20,000,000 offset	High word	32-bit binary number	-20,000,000 to +20,000,000	R
16		Low word			
17	Rate of Change, ppm H_2 per Month +20,000,000 offset	High word	32-bit binary number	-20,000,000 to +20,000,000	R
18		Low word			
19-30	Reserved for future use				

Register	Parameter	Function	Data Type	Data Range	Access
Information					
31-40	Model Number		ASCII String	Maximum string length is 19. Must be NULL terminated.	R
41-50	Product Serial Number		ASCII String	Maximum string length is 19. Must be NULL terminated.	R
51-60	Sensor Serial Number		ASCII String	Maximum string length is 19. Must be NULL terminated.	R
61-70	Sensor Board Serial Number		ASCII String	Maximum string length is 19. Must be NULL terminated.	R
71-80	Reserved for future use				
81	Manufacturing Date	high byte: Month low byte: Day	32-bit binary value		R
82		Year			
83	Factory Calibration Date	high byte: Month low byte: Day	32-bit binary value		R
84		Year			
85-86	Reserved for future use				
87	Dissolved Gas Calibration Date	high byte: Month low byte: Day	32-bit binary value		R
88		Year			
89-98	Firmware Revision		ASCII String	Maximum string length is 19. Must be NULL terminated.	R
99-110	Reserved for future use				
Status/Error Information					

Register	Parameter	Function	Data Type	Data Range	Access
111	Status	Refer to section 2.2.3	16-bit binary flags	Table 11: Unit Status	R
112	Error Status	Refer to section 2.2.8.2 High word	32-bit binary flags	Table 12: Error Status	R
113		Low word			
114-120	Reserved for future use				

<table>
<tr><th>Register</th><th>Parameter</th><th>Function</th><th>Data Type</th><th>Data Range</th><th>Access</th></tr>
<tr><th colspan="6">Calibration Functions</th></tr>
<tr><td>121</td><td>DA command</td><td></td><td>None</td><td></td><td>R/W</td></tr>
<tr><td>122</td><td>DB command</td><td>Write reg 126-129 first</td><td>None</td><td></td><td>R/W</td></tr>
<tr><td>123-124</td><td colspan="5">Reserved for future use</td></tr>
<tr><td>125</td><td>DC command</td><td>clear DGA calibration</td><td>None</td><td></td><td>R/W</td></tr>
<tr><td>126</td><td rowspan="2">Calibration Gas, ppm H2</td><td>High word</td><td rowspan="2">32-bit binary number</td><td rowspan="2">0 to 1,000,000</td><td rowspan="2">R/W</td></tr>
<tr><td>127</td><td>Low word</td></tr>
<tr><td>128</td><td rowspan="2">Calibration Date</td><td>high byte: Month
low byte: Day</td><td rowspan="2">32-bit binary value</td><td rowspan="2"></td><td rowspan="2">R/W</td></tr>
<tr><td>129</td><td>Year</td></tr>
<tr><td>130-135</td><td colspan="5">Reserved for future use</td></tr>
<tr><th colspan="6">Configuration Settings</th></tr>
<tr><td>136-143</td><td>User-define Liquid Type name</td><td rowspan="3">Refer to section 2.2.10 for User-define Liquid type Configuration Window descriptions.</td><td>ASCII String</td><td>Maximum string length is 15. Must be NULL terminated.</td><td>R/W</td></tr>
<tr><td>144</td><td rowspan="2">Ostwald Slope, m</td><td>16-bit binary number</td><td></td><td>R/W</td></tr>
<tr><td>145</td><td>16-bit binary number</td><td></td><td>R/W</td></tr>
<tr><td>146</td><td rowspan="2">Ostwald Offset, b</td><td rowspan="3"></td><td>16-bit binary number</td><td></td><td>R/W</td></tr>
<tr><td>147</td><td>16-bit binary number</td><td></td><td>R/W</td></tr>
<tr><td>148</td><td>Liquid Type Operations</td><td>16-bit binary number</td><td>1 = open edit
2= close save
3 = abort edit</td><td>R/W</td></tr>
<tr><td>149</td><td colspan="5">Reserved for future use</td></tr>
</table>

Register	Parameter	Function	Data Type	Data Range	Access
150	Set Unit ID		8-bit binary number	1 to 247	R/W
151	Operating Mode	Select between Field and Lab mode	16-bit binary number	0 = Field 1 = Lab	R/W
152	Liquid Type Selection	Select Liquid Type	16-bit binary number	0 = Mineral 1 = Silicone 2 = Nat Ester 3 = Syn Ester	R/W
153-158~~7~~	Reserved for future use				
159	Parity, Stop Bits Selection	Select Parity, Stop Bits	16-bit binary number	1 = 8N1 2 = 8N2 3 = 8E1 4 = 8E2 5 = 8O1 6 = 8O2	R/W
160	Baud Rate	Baud Rate Selection	8-bit binary number	1 = 9600 2 = 14400 3 = 19200 4 = 38400 5 = 57600 6 = 115200	R/W
161-174	Reserved for future use				

Register	Parameter	Function	Data Type	Data Range	Access
Diagnostics					
175	Month / Year	Date & Time; read register 175 first; order high-byte / low-byte; add 2000 to year (64-bit)	16-bit binary number		R/W
176	Hour / Day		16-bit binary number		R/W
177	Second / Minute		16-bit binary number		R/W
178	Millisecond		16-bit binary number		R/W
179-196	Reserved for future use				
197	Soft Reset	Reset the unit	16-bit binary number		R/W
198-200	Reserved for future use				
User Information					
201-210	Owner ID	Must start reading from low address; Must write low and high addresses to save string	ASCII String	Maximum string length is 19. Must be NULL terminated.	R/W
211-220	Substation ID		ASCII String	Maximum string length is 19. Must be NULL terminated.	R/W
221-230	Transformer ID		ASCII String	Maximum string length is 19. Must be NULL terminated.	R/W
231-255	Reserved for future use				

2.2.3 Hydrogen Measurement

GRIDSCAN 5000 reports the most recent hydrogen measurement in registers **0-1**. The 32-bit unsigned integer value is not scaled and reports the integer value of hydrogen in ppm H2.

Read the device status in register 111 bit 15 to determine if the device is ready. The hydrogen value is zero until the ready bit is set.

2.2.4 Hydrogen Trend

GRIDSCAN 5000 calculates and maintains a daily, weekly, and monthly rate of change value.

An hourly trend is calculated at the end of every hour of operation. The value is the difference in hydrogen measured between the first and second hour. This difference is stored in a circular buffer of twenty-four (24) hourly values.

The daily trend is calculated as the average of the twenty-four (24) hourly values to give the amount of change over the last 24 hours.

The weekly trend is calculated as the average of the most recent seven (7) daily values to give the amount of change over the last seven (7) days.

The monthly trend is calculated as the average of the most recent twenty-eight (28) daily values to give the amount of change over the last twenty-eight (28) days.

A positive trend indicates increasing hydrogen, a negative trend indicates a decreasing level of hydrogen. The rate of change is calculated as the change of hydrogen measured over time.

The trend values are reset to zero after a power cycle.

2.2.4.1 Rate of Change per Day

Rate of Change per Day is reported in registers **13,14**. The unsigned 32-bit integer value is scaled with an offset of 20,000,000 (0x0131 2D00), resulting in a signed 32-bit integer value in ppm H_2 per day.

The daily trend is the average of the last 24hourly measurements.

2.2.4.2 Rate of Change per Week

Rate of Change per week is reported in registers **15,16**. The unsigned 32-bit integer value is scaled with an offset of 20,000,000 (0x0131 2D00), resulting in a signed 32-bit integer value in ppm H_2 per day.

The weekly trend is the average of the last 7 daily measurements.

2.2.4.3 Rate of Change per Month

Rate of Change per month is reported in registers **17,18**. The unsigned 32-bit integer value is scaled with an offset of 20,000,000 (0x0131 2D00), resulting in a signed 32-bit integer value in ppm H_2 per day.

The monthly trend is the average of the last 28 daily measurements.

2.2.5 Temperature Measurement

GRIDSCAN 5000 monitors liquid temperature and internal electronics temperature. The temperature is reported as a scaled16-bit unsigned integer in degrees Celsius. Dividing the integer value by 100 and subtracting 100 will provide the measured temperature with 2 decimal places.

2.2.5.1 PCB Temperature

PCB temperature is reported in register **7**. This is the internal temperature of the electronics enclosure, which must not exceed 105°C.

This is a good register to read during installation and communication testing because the value is always valid and frequently changes.

2.2.5.2 Liquid Temperature

Liquid temperature is reported in register **8**. The sensor is calibrated for liquid temperature up to 105°C; accuracy of the hydrogen measurement is unknown above this temperature; the sensor survives liquid temperatures up to 135°C.

Zero is the power on default value for Liquid Temperature.

2.2.6 ASCII Strings

GRIDSCAN 5000 information is available as ASCII strings terminated with a zero byte (0x00). Each string can be up to 19 characters long with 2 characters per Modbus register. Use the read holding register function and read ten registers, each byte is an ASCII character.

2.2.6.1 Model Number

The model number is in registers **31-40**.

2.2.6.2 Product Serial Number

The product serial number is in registers **41-50**.

2.2.6.3 Sensor Serial Number

The sensor serial number is in registers **51-60**.

2.2.6.4 Sensor Board Serial Number

The sensor board serial Number is in registers **61-70**.

2.2.6.5 Firmware Revision

The firmware revision is in registers **89-98**, using format x:y:z; example 3:7:A

- x is the major revision
- y is the minor revision
- z is the product designator

2.2.7 Date Register Format

Registers that report a date value are encoded as follows.

- High word, high byte is the Month
- High word, low byte is the Day
- Low word is the Year

2.2.7.1 Manufacturing Date

Original manufacturing date is in registers **81,82**

2.2.7.2 Factory Calibration Date

Last factory calibration date is in registers **83,84**

2.2.7.3 Dissolved Gas Calibration Date

Last DGA calibration date is in registers **87,88**

2.2.8 Status and Error Information

GRIDSCAN 5000 provides status and error information for the user to determine if it is operating normally.

2.2.8.1 Unit Status

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

Table 15: Unit Status

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

For example: If x = 0

00x0 xxxx xx00 1xxx – Unit not Ready – Hydrogen measurement cycle (**decimal 8**)
00x0 xxxx xx01 0xxx – Unit not Ready – Liquid temperature measurement cycle (**decimal 16**)
00x0 xxxx xx10 0xxx – Unit not Ready – Liquid temperature too high (**decimal 32**)
xxx1 xxxx xxxx xxxx – Unit Error – Error Bit 12 (**decimal 4,096**)
10x0 xxxx xx01 0xxx – Unit Ready – Liquid temperature measurement cycle (**decimal 32,784**)
10x0 xxxx xx00 1xxx – Unit Ready – Hydrogen measurement cycle (**decimal 32,776**)
10x0 xxxx xx01 1xxx – Unit Ready – Autocalibration cycle (**decimal 32,792**)
11x0 xxxx xx01 0xxx – Unit Ready – Liquid temperature cycle, new data (**decimal 49,168**)
11x0 xxxx xx00 1xxx – Unit Ready – Hydrogen measurement, new data (**decimal 49,160**)
11x0 xxxx xx01 1xxx – Unit Ready – Autocalibration cycle, new data (**decimal 49,176**)

2.2.8.2 Error Status

When the error flag (bit **12**) of the Unit Status register **111** is set, the 32-bit register **112,113** has more information about what is causing the error. The bit map is shown below for error description.

Table 16: 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
9-28	0x1000 0000 - 0x0000 0200	Unlisted bits are not used and may be 0 or 1.
8	0x0000 0100	RTC date and time not valid
5-7	0x0000 0080 - 0x0000 0020	Unlisted bits are not used and may be 0 or 1.
4	0x0000 0010	PCB Temperature greater than 105C.
2-3	0x0000 0008- 0x0000 0004	Unlisted bits are not used and may be 0 or 1.
1	0x0000 0002	Required data not available.
0	0x0000 0001	Configuration data not valid.

2.2.8.3 Error Response

Recommended response to these errors are:

- **Sensor faults** (heater, temperature, or hydrogen): power off the sensor, wait 5 minutes, power on the sensor, and check status after 15 minutes to determine if error is persistent. Contact support@h2scan.com for more information about persistent sensor faults.
- **RTC date and time not valid**: the internal rechargeable battery was drained while power was disconnected and will recharge when power is turned on. Setting the clock as described in section 2.2.16 will clear this error status. Cycling power will also clear this error. Contact support@h2scan.com if this error does not clear after power cycling.
- **PCB temperature**: the internal temperature is too hot and may impact operation of the sensor and accuracy of the hydrogen measurement. Power off for an hour and investigate area around the sensor for high temperature or lack of air flow. Turn power on and wait an hour to determine if error is persistent. Contact support@h2scan.com for more information about persistent PCB temperature error.
- **Required data not available**: indicates an error in internal microcontroller, contact support@h2scan.com for more information.
- **Configuration data not valid**: indicates an error in the internal memory, contact support@h2scan.com for more information.

2.2.9 DGA Calibration

The reported hydrogen from the GRIDSCAN 5000 can be adjusted to match a laboratory DGA test result using a two-command sequence. The first command (DA) is issued when a liquid sample is taken for analysis. The second command (DB) is issued after the liquid sample is analyzed. The sensor uses the DGA reported hydrogen value and internal data saved during the DA command to calculate a correction factor used in all future hydrogen measurements.

Incorrect data entered for the DGA calibration will impede the measurement and monitoring capability of the sensor.

2.2.9.1 DA command

The DA command (write to Modbus register **121**) is the first step in making an adjustment to the GRIDSCAN 5000 hydrogen measurement based on laboratory DGA test results. This command should be issued when a liquid sample is taken so that certain internal values are saved to be used when the DGA results are entered later.

Do not issue the DA command less than 24 hours after installation or since the last DC command.

2.2.9.2 DB command

The DB command (write to Modbus register **122**) is the second step in adjusting the GRIDSCAN 5000 hydrogen measurement based on laboratory DGA test results. Note that a DA command must have been executed prior to issuing a DB. The DB command uses data written in registers **126-129,** which must be written before writing to register **122**. The date in registers **128,129** must match the internal real time clock to be accepted. Recommended sequence of operations to execute the DB command is:

1) Read registers **175,176** to get the internal date
2) Write the date to registers **128,129**
3) Write the DGA results in ppm H_2 to registers **126,127**
4) Write to register **122**

The new hydrogen measurement may be different than the DGA value due to changes since the sample was taken.

Internal data from last DA command is erased when the DB command is completed.

Writing to Modbus register **122** will take up to 10 seconds to respond.

2.2.9.3 DC command

The DC command (write to Modbus register **125**) allows the user to clear the DGA adjustment set by a DB command.

Wait at least 24 hours before issuing a DA command.

2.2.9.4 Calibration Gas, ppm H2

The actual hydrogen value in ppm is written to Modbus registers **126,127** for use with the DB command. This value must be written before the DB register is written.

2.2.9.5 Calibration Date

The calibration date (month, day, year) written to Modbus registers **128,129** must match the internal real time clock for the DB command to be accepted.

2.2.10 User-Defined Liquid Type Configuration

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

These values are a critical part of the hydrogen calculation. Incorrect values will impede the measurement and monitoring capability of the sensor.

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

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

1) Write register **148** with 0x0001 to open the user-configurable liquid type for edit
2) Write registers **136-143** with the name of the liquid
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

2.2.10.1 User-defined Liquid Type name

The name of the user-defined liquid 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 Synthetic Ester.

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

2.2.10.2 Ostwald Slope, Slope (m)

The default value is m=0.000093, corresponding to the Data32 value of 1093 (0x0000,0x0445) for Synthetic Ester. This is calculated using a scale factor of 1,000,000 and an offset of +1,000 as shown in the following equation:

$$Data32 = (m \cdot 1{,}000{,}000) + 1000$$

The Ostwald Slope can then be determined or verified by reading Data32 and converting the value with the following equation:

$$m = \frac{Data32 - 1000}{1{,}000{,}000}$$

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

2.2.10.3 Ostwald Offset, Offset (b)

The default value is b=0.039739, corresponding to the Data32 value of 40,739 (0x0000, 0x9F23) for Synthetic Ester. This is calculated using a scale factor of 1,000,000 and an offset of +1,000 as shown in the following equation:

$$Data32 = (b \cdot 1{,}000{,}000) + 1000$$

The Ostwald Intercept can then be determined or verified by reading Data32 and converting the value with the following equation:

$$b = \frac{Data32 - 1000}{1{,}000{,}000}$$

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

2.2.10.4 Liquid Type Operations

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

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

2.2.11 Set Unit ID

The Modbus ID is reported or set in register **150**. Reading this register is used to confirm that the selected ID is in use. Writing desired ID to register 150 will set the unit to the specified ID. The device ID can range from 1 to 247 or as limited by the Modbus master. Note that if the current device ID is unknown, perform a single write to Function Code 107 with the appropriate serial connection settings. This can be done to one GRIDSCAN 5000 device at a time. The unit connected will send a response back identifying its device ID.

Preparing multiple units to share a common RS485 bus is accomplished by connecting one unit at a time to a Modbus controller and writing the desired ID for that unit to register 150 at the default device ID

For PC-based configuration, use ComTest Pro from www.BaseBlock.com for a Modbus controller. A power cycle is not necessary for the new ID to take effect. It is recommended that each device is labeled with the new device ID.

A simple procedure to configure multiple units is as follows:

1) Disconnect all units from the RS485 cable
2) Connect first unit to the RS485 cable
3) Use Modbus Controller to write a single holding register (function 6) to register **150**, with the desired ID for the connected unit
4) Wait up to 10 seconds for the Modbus response
5) Disconnect this unit and connect the next one to the RS485 cable
6) Repeat steps 3, 4, and 5 until all units are configured
7) Attach all units to the RS485 cable and read register **150** from each of the configured devices

2.2.12 Liquid Type Selection

Selecting which liquid type for GRIDSCAN 5000 to use is accomplished by writing to Modbus register **152** with the number corresponding to the desired liquid type from the table below.

Table 17: Liquid Type

Number	Liquid Type	Description in Modbus Map
0	Mineral Oil	Mineral
1	Silicone Oil	Silicone
2	Natural Ester Oil	Natural Ester
3	Synthetic Ester Oil	Synthetic Ester

Example: write register **152** with a value of 0x0003 to select synthetic ester oil.

2.2.13 Stop Bit, Parity Selection

To select the desired parity and stop bits to use in the RS485 communication port settings, write the corresponding number to Modbus register **159** (default selection is **1**). Write the appropriate baud rate setting to Write Holding Register **160** to apply the new uart settings without a need for a power-cycle.

Table 18: Data bits, Parity, Stop bits

Number	Description
1	8-bit data, No Parity, 1 Stop bit
2	8-bit data, No Parity, 2 Stop bits
3	8-bit data, Even Parity, 1 Stop bit
4	8-bit data, Even Parity, 2 Stop bits
5	8-bit data, Odd Parity, 1 Stop bit
6	8-bit data, Odd Parity, 2 Stop bits

2.2.14 Baud Rate

The GRIDSCAN 5000 RS485 baud rate can be modified from the default 19200 baud by writing to Modbus register **160** with the number corresponding to the desired value in the table below. A write to Modbus Holding Register **160** will reinitialize the UART with the new settings.

Table 19: Baud Rate

Number	Description
1	9600 baud
2	14400 baud
3	19200 baud
4	38400 baud
5	57600 baud
6	115200 baud

2.2.15 Operating Mode

The GRIDSCAN 5000 is shipped from the factory for normal Field operation. **If it will be subjected to Laboratory testing, then the operating mode should be changed by writing a 1 to register 151.** The difference in operating modes is the frequency that the autocalibration is performed (every 12 hours in normal mode; every 4 hours in laboratory mode).

2.2.16 Real time Clock

The GRIDSCAN 5000 has an internal real-time clock with backup power provided by a super capacitor. Depending on temperature, the backup power will last a few months in storage. During installation or after long periods of no power to the GRIDSCAN 5000, the real time clock should be set to the current date and time.

2.2.16.1 Determine the correct starting date and time (Month/Year, Hour/Day, Sec/Min, Milliseconds (0)).

2.2.16.2 Convert each section of the date and time to hex, using the table below (or use a decimal-to-hex-converter).

Table 20: Date/Time Hex Table

Month	Hex	Year	Hex	Hour	Hex	Day	Hex	Seconds	Hex	Seconds	Hex	Minutes	Hex	Minutes	Hex	Milliseconds	Hex
Jan (01)	1	22	16	1	1	1	1	1	1	31	1F	1	1	31	1F	0	0
Feb (02)	2	23	17	2	2	2	2	2	2	32	20	2	2	32	20		
Mar (03)	3	24	18	3	3	3	3	3	3	33	21	3	3	33	21		
Apr (04)	4	25	19	4	4	4	4	4	4	34	22	4	4	34	22		
May (05)	5	26	1A	5	5	5	5	5	5	35	23	5	5	35	23		
Jun (06)	6	27	1B	6	6	6	6	6	6	36	24	6	6	36	24		
Jul (07)	7	28	1C	7	7	7	7	7	7	37	25	7	7	37	25		
Aug (08)	8	29	1D	8	8	8	8	8	8	38	26	8	8	38	26		
Sep (09)	9	30	1E	9	9	9	9	9	9	39	27	9	9	39	27		
Oct (10)	A	31	1F	10	A	10	A	10	A	40	28	10	A	40	28		
Nov (11)	B	32	20	11	B	11	B	11	B	41	29	11	B	41	29		
Dec (12)	C	33	21	12	C	12	C	12	C	42	2A	12	C	42	2A		
		34	22	13	D	13	D	13	D	43	2B	13	D	43	2B		
		35	23	14	E	14	E	14	E	44	2C	14	E	44	2C		
		36	24	15	F	15	F	15	F	45	2D	15	F	45	2D		
		37	25	16	10	16	10	16	10	46	2E	16	10	46	2E		
		38	26	17	11	17	11	17	11	47	2F	17	11	47	2F		
		39	27	18	12	18	12	18	12	48	30	18	12	48	30		
		40	28	19	13	19	13	19	13	49	31	19	13	49	31		
		41	29	20	14	20	14	20	14	50	32	20	14	50	32		
		42	2A	21	15	21	15	21	15	51	33	21	15	51	33		
		43	2B	22	16	22	16	22	16	52	34	22	16	52	34		
		44	2C	23	17	23	17	23	17	53	35	23	17	53	35		
		45	2D	24	18	24	18	24	18	54	36	24	18	54	36		
		46	2E			25	19	25	19	55	37	25	19	55	37		
		47	2F			26	1A	26	1A	56	38	26	1A	56	38		
		48	30			27	1B	27	1B	57	39	27	1B	57	39		
		49	31			28	1C	28	1C	58	3A	28	1C	58	3A		
		50	32			29	1D	29	1D	59	3B	29	1D	59	3B		
						30	1E	30	1E	60	3C	30	1E	60	3C		
						31	1F										

2.2.16.3 Using ComTest Pro, write the date and time sections (now in hex) to the proper registers, as shown below.

Register **175** – Month/Year
Register **176** – Hour/Day
Register **177** – Sec/Min
Register **178** – Milliseconds (0)

2.2.16.4 After register **178** is written, the date and time is automatically saved.

2.2.16.5 To confirm the correct date and time, read registers 175-178.

2.2.17 Software Reset (Holding Register **197**)

Perform a read operation to obtain a 16-bit value.

Perform a write operation with the 16-bit value obtained from the read operation. If the data matches, a software reset is issued. Modbus communications may resume after approximately 10 seconds.

2.2.18 User Information

The GRIDSCAN 5000 provides three ASCII strings that the user can program to indicate the owner, substation, and transformer that the sensor is monitoring. Each string can be up to 20 characters including null termination.

2.2.18.1 Owner ID

The owner string is saved in registers **201** through **210**.

2.2.18.2 Substation ID

The substation string is saved in registers **211** through **220**.

2.2.18.3 Transformer ID

The transformer string is saved in registers **231** through **230**.

Table 21: Modbus Function Code 2, Discrete Input Register Locations
(Discrete Input Registers start at #10001)

Data Address	Description
0	Unit Ready, hydrogen readings are valid (Unit Status, Bit 15)
1	New measurement data available, auto clear after register read (Unit Status, Bit 14)
2	Error, indicates an unrecoverable error occurred (Unit Status, Bit 12)
3	Sensor A state Information: Hydrogen measurement cycle (Unit Status, Bit 5-3, 001)
4	Sensor A state Information: Liquid temperature measurement cycle (Unit Status, Bit 5-3, 010)
5	Sensor A state Information: Auto calibration cycle (Unit Status, Bit 5-3, 011)
6	Sensor A state Information: Liquid temperature too high (Unit Status, Bit 5-3, 100)
7 - 15	0 (Spare)
16	Sensor – Heater fault (Error Status, Bit 31)
17	Sensor – Temperature Sensor Fault (Error Status, Bit 30)
18	Sensor – Temperature Sensor Fault (Error Status, Bit 29)
19	RTC date and time not valid. (Error Status, Bit 8)
20	PCB Temperature greater than 105C. (Error Status, Bit 4)
21	Required data not available. (Error Status, Bit 1)
22	Configuration data not valid. (Error Status, Bit 0)
23 - 47	0 (Spare)
48	Valid – H2
49	Valid – Rate of Change, daily
50	Valid – Rate of Change, weekly
51	Valid – Rate of Change, monthly
52	Valid – PCB Temperature
53	Valid – Liquid Temperature
54	Valid – Liquid Type Selection
55	Valid – DGA Date string
56	Valid – Model Number string
57	Valid – Product Serial Number string
58	Valid – Sensor A Serial Number string
59	Valid – Sensor B Serial Number string
60	Valid – Sensor Board Serial Number string
61	Valid – Manufacturing Date string
62	Valid – Factory Calibration Date string
63	Valid – Firmware Revision Number string
64	Valid – Owner ID string
65	Valid – Substation ID string
66	Valid – Transformer ID string
67	Valid – User Defined OT Name string

Table 22: Modbus Function Code 4, Read Input Register Locations
(Read Input Registers start at #30001)

Data Address	Description	Data Type
0	Unit Status	16-Bit number
1	Error Status High word	32-Bit number
2	Error Status Low word	
3	H2 Value High word	floating point number
4	H2 Value Low word	
5	Rate of Change, daily High word	floating point number
6	Rate of Change, daily Low word	
7	Rate of Change, weekly High word	floating point number
8	Rate of Change, weekly Low word	
9	Rate of Change, monthly High word	floating point number
10	Rate of Change, monthly Low word	
11	PCB Temperature High word	floating point number
12	PCB Temperature Low word	
13	Liquid Temperature High word	floating point number
14	Liquid Temperature Low word	

QUESTIONS?
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