H2scan
Advanced Hydrogen Sensing

MODBUS REGISTER MAP

GRIDSCAN® 5000

Hydrogen Monitor

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IMPORTANT NOTICES

Read and understand the operation manual before installing or using the unit. If this equipment is used in a manner not specified by H2scan, the warranty may be void.

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 GRIDSCAN® 5000 Hydrogen Monitor ("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 36 months from the ship date for such Product.

Must Provide Notice of Defect: If you have a Product that you believe is defective, you must notify H2scan in writing, within the warranty period of your claim regarding any such defect.

Return Product to H2scan for Repair, Replacement or Credit: The customer is responsible for shipping and handling costs. 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. A valid RMA number must be assigned by H2scan and clearly marked on the package when the unit is returned.

Voided Warranty: H2scan's three-year Limited Warranty is void for any of the following:

- 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.

1. OPERATION

1.1 STARTUP

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

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

1.2 MODBUS COMMUNICATION SETTINGS

Modbus protocol communicates over RS-485 and supports RTU packets. To change the GRIDSCAN 5000 Modbus ID from the default 1, write to holding register **150**.

1.3 MONITORING

During normal operation, poll the GRIDSCAN 5000 Hydrogen Monitor measurements for a reading at a frequency of one second to several hours or days, depending on end user requirements. Include the Modbus holding registers listed in Table 1 in each reading.

Table 1: Holding Registers

Register	Purpose	Bit	Definition
111	Status	12,15	Bit 15 indicates the hydrogen measurement is available. Bit 12 indicates an error.
112	Error Status		These registers are active when register 111 bit 12 is high and indicate which error is detected.
113			
8	Liquid Temperature		Provides the liquid temperature at the monitor.
0	Hydrogen		Provides the hydrogen ppm values.*
1			

*The high word (0) must be read in order to make the low word (1) value available.

CAUTION

Operating temperatures above 105 °C may cause permanent damage.

NOTE: Liquid temperature above 105 °C is outside the calibration range.

CAUTION

Liquid temperature above 135 °C may cause permanent damage.

1.4 ERROR/EXCEPTION HANDLING

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

If the sensor element is damaged and inoperable, the GRIDSCAN 5000 shuts down the measurement system and continues responding to Modbus requests for error reporting via register **111** bit **12** with 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 persists, contact H2scan for repair at technicalsupport@h2scan.com.

2. MODBUS PROTOCOL

Tables 2–12 comprise the list of Modbus packets, values, registers, and register definitions.

Table 2: 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

Set the master's timeout to at least 10,000 milliseconds to accommodate the the monitor's 10-second maximum response time.

Table 3: 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 High Byte
4	Starting Address Lo	0x00–0xFF	Holding Register Low Byte
5	Number of registers Hi	0	Limited by Modbus spec V1.1b
6	Number of Registers Lo	0–230	Number of 16-bit registers Low Byte
7	CRC Lo	0x00–0xFF	CRC Low Byte
8	CRC Hi	0x00–0xFF	CRC High Byte

Table 4: 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

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

Table 5: 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 Byte	0x00–0xFF	Unit Register Address High 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

Table 6: 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	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 7: 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 High Byte
4	Starting Address Lo	0x00–0xFF	Holding Register Low Byte
5	Number of registers Hi	0	Limited by Modbus spec V1.1b
6	Number of Registers Lo	121–122, 125-129, 136–148, 150–152, 159-160, 175–178, 197, 201–230	Number of 16-bit registers Low 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 8: 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 9: 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	0–67	Number of inputs requested Lo Byte
7	CRC Lo	0x00–0xFF	CRC Low Byte
8	CRC Hi	0x00–0xFF	CRC High Byte

Table 10: 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 first 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 second 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

NOTE: 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 first Data Value Hi; the second data address is placed in Bit **1** of the first Data Value Hi**,** etc. The ninth 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).

EXAMPLE: Request the on/off status of discrete inputs starting at data address 0–18 (#10001–10019). The request reads 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 third (last) data byte are filled in with zeroes (toward the most significant bit).

Table 11: 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 High Byte
4	Starting Address Lo	0x00–0xFF	Holding Register Low Byte
5	Number of registers Hi	0	Number of 16-bit registers Hi Byte
6	Number of Registers Lo	0–14	Number of 16-bit registers Lo Byte
7	CRC Lo	0x00–0xFF	CRC Low Byte
8	CRC Hi	0x00–0xFF	CRC High Byte

NOTE: Number of Read Input Registers is limited to the number of registers reported.

Supported data address range is 0–22.

Table 12: 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

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

2.1 EXCEPTION RESPONSE

Normally, after receiving a query from the master, the slave device processes the request and returns a response to the master. An abnormal communication between the two devices produces one of four possible events.

1. The slave does not receive the query due to a communications error and does not return a response. The master device eventually processes a timeout condition for the query.
2. The slave receives the query, but detects a communication error (UART or CRC) and does not return a response. The master device eventually processes a timeout condition for the query.
3. The slave receives the query without a communications error, but takes longer than the master's timeout setting, and does not return a response. The master device eventually processes a timeout condition for the query. To prevent this condition, set the master timeout longer than the slave's maximum response time (10,000 milliseconds).
4. 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. 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.

1. Function code – byte **2**. The high-order bit is set to a one (i.e., 0x83 for a read exception and 0x86 for a write exception).
2. Exception code – byte **3**. The total exception response length is five bytes rather than normal message length.

Table 13: 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 14	
4	CRC High	0x00–0xFF	
5	CRC Low	0x00–0xFF	

Table 14: Exception Response Codes

Code	Name	Reasons for Error
1	Illegal Function Code	1. The function code may only apply to newer devices and was not implemented in the unit selected. 2. The slave is in the wrong state to process a request of this type, e.g., it cannot return register values because it is not configured.
2	Illegal Data Address	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 as 99. If a request is submitted with a starting register address of 96 and a quantity of four registers, this request will successfully operate (address-wise at least) on registers 96–99. If a request is submitted with a starting register address of 96 and a quantity of five registers, this request will fail with Exception Code 0x02 “Illegal Data Address” since it attempts to operate on registers 96–100, the latter of which does not exist.
3	Illegal Data Value	A fault is in the structure of the remainder of a complex request, e.g., the implied length is incorrect. This code 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 MODBUS HOLDING REGISTER DEFINITIONS

The Modbus Holding Register definitions for the GRIDSCAN 5000 Hydrogen Monitor are identified in Table 15.

NOTE: When reading registers containing 32- or 64-bit integers, read the high-order word first, followed by the lower-order word(s). Reading the high-order word saves the low-order word in a temporary location for the next register read. The firmware automatically reads the second register from the temporary location. 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 15: Modbus Holding Register Descriptions

Register	Parameter	Function	Data Type	Data Range	Access
Measurements					
0	Hydrogen, ppm H_2	High word	32-bit binary number	0–20,000,000	R
1		Low word			
2–7	Reserved for future use				
8	Liquid temperature, Celsius	x100 scale; 100 offset (T=V/100-100)	16-bit binary number	-100–+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–+20,000,000	R
14		Low word			

Register	Parameter	Function	Data Type	Data Range	Access
15	Rate of change, ppm H_2 per week +20,000,000 offset	High word	32-bit binary number	-20,000,000–+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–+20,000,000	R
18		Low word			
19–30	Reserved for future use				
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
61–80	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					
111	Status	Refer to 2.8.1	16-bit binary flags	Table 17: Unit Status	R

Register	Parameter	Function	Data Type	Data Range	Access
112	Error status	Refer to 2.8.2 High word	32-bit binary flags	Table 18: Error Status	R
113		Low word			
114–120	Reserved for future use				
Calibration Functions					
121	DA command	Refer to 2.9	None		R/W
122	DB command	Write reg 126–129 first	None		R/W
123–124	Reserved for future use				
125	DC command	Clear DGA calibration	None		R/W
126	Calibration gas, ppm H_2	High word	32-bit binary number	0–1,000,000	R/W
127		Low word			
128	Calibration date	High byte: Month Low byte: Day	32-bit binary value		R/W
129		Year			
130–135	Reserved for future use				
Configuration Settings					
136–143	User-defined liquid type name	Refer to 2.10 for configuration window descriptions	ASCII String	Maximum string length is 15. Must be NULL terminated.	R/W
144	Ostwald slope, m		32-bit binary number		R/W
145					
146	Ostwald offset, b		32-bit binary number		R/W
147					
148	Liquid type operations		16-bit binary number	1 = Open edit 2= Close save 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	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	Reserved for future use				

Register	Parameter	Function	Data Type	Data Range	Access
159	Parity, stop bits selection	Refer to 2.13 Select parity, stop bits	16-bit binary number	1 = 8N1 (default) 2 = 8N2 3 = 8E1 4 = 8E2 5 = 8O1 6 = 8O2	R/W
160	Baud rate	Refer to 2.14 Baud rate selection	8-bit binary number	1 = 9600 2 = 14400 3 = 19200 (default) 4 = 38400 5 = 57600 6 = 115200	R/W
161–174	Reserved for future use				
Diagnostics					
175	Month / Year	Refer to 2.16 Date and 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	Refer to 2.18 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				

2.3 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 H_2.

NOTE: 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.

2.4 HYDROGEN TREND

GRIDSCAN 5000 calculates and maintains a daily, weekly, and monthly rate of change. The unsigned 32-bit integer value of each 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.

Table 16: Hydrogen Trends

Rate of change	Reporting registers	Trend
Per Day	13,14	Average of the last 24 hourly measurements.
Per Week	15,16	Average of the last seven daily measurements.
Per Month	17,18	Average of the last 28 daily measurements.

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

2.5 TEMPERATURE MEASUREMENT

GRIDSCAN 5000 monitors and reports liquid temperature as a scaled 16-bit unsigned integer in degrees Celsius. Dividing the integer value by 100 and subtracting 100 will provide the measured temperature to two decimal places.

Liquid temperature is reported in register **8** with power-on default value of zero. The monitor is calibrated for liquid temperature up to 105 °C, above which accuracy of the hydrogen measurement is unknown. The monitor survives liquid temperatures up to 135 °C.

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 two characters per Modbus register. Use the read holding register function and read ten registers; each byte is an ASCII character.

- Model number: Registers **31–40**
- Product Serial Number: Registers **41–50**
- Sensor Serial Number: Registers **51–60**
- Firmware Revision: Registers **89–98**
  - Format x:y:z
    - x is the major revision
    - y is the minor revision
    - z is the product designator

2.7 DATE REGISTER FORMAT

Registers that report a date value are encoded as follows.

- Month: High word, high byte
- Day: High word, low byte
- Year: Low word

2.7.1 Manufacturing Date

- Original manufacturing date: Registers **81,82**
- Last factory calibration date: Registers **83,84**
- Last dissolved gas calibration date: Registers **87,88**

2.8 STATUS AND ERROR INFORMATION

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

2.8.1 Unit Status

Unit status information is maintained in Modbus register **111**.

Table 17: 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	Unrecoverable error occurred, read registers 112,113 for more information.
6–11	Unlisted bits are not used and may be 0 or 1.
5–3	Monitor A state information: 001 – Hydrogen measurement cycle 010 – Liquid temperature measurement cycle 011 – Auto-calibration cycle 100 – Liquid temperature too high
0–2	Unlisted bits are not used and may be 0 or 1.

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 – Auto-calibration 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 – Auto-calibration cycle, new data (decimal 49,176)

2.8.2 Error Status

When the error flag (bit **12**) of the Unit Status register **111** is set, refer to the 32-bit register **112,113** for more information about the error cause.

Table 18: Error Status

Bit #	Hex Value	Description	Response
31	0x8000 0000	Monitor: Heater fault	Power off the monitor, wait five minutes, power on the monitor, and check status after 15 minutes to determine if error persists.
30	0x4000 0000	Monitor: Temperature sensor fault	
29	0x2000 0000	Monitor: 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	The internal rechargeable battery was drained while power was disconnected and will recharge when power is turned on. Set the clock per 2.16 or cycle power to clear the error status.
5–7	0x0000 0080–0x0000 0020	Unlisted bits are not used and may be 0 or 1	
4	0x0000 0010	Over temperature error	Power off for an hour and investigate area around the monitor for high temperature or lack of air flow. Turn power on and wait an hour to determine if error persists.
3	0x0000 0008	Error detected due to memory access, invalid configuration, or sample error.	Contact support@h2scan.com for more information about this error.
0-2	0x0000 0004 -0x0000 0001	Unlisted bits are not used and may be 0 or 1	

If faults are persistent or errors do not clear after power cycling, contact support@h2scan.com.

2.9 DGA CALIBRATION

Adjust hydrogen reported from the GRIDSCAN 5000 to match a laboratory DGA test result with a two-command sequence.

1. Issue the DA command (write to register **121**) when an oil sample is taken for analysis so certain internal values are saved to be used when the DGA results are entered later.

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

2. Issue the DB command (write to register **122**) after the oil sample is analyzed, using the following sequence of operations:
   - Read registers **175** and **176** to get the internal date.
   - Write the date to registers **128** and **129**.
   - Write the DGA results in ppm H_2 to registers **126** and **127**.
   - Write to register **122**, which will take up to 10 seconds to respond.

NOTE: A DA command must have been executed prior to issuing a DB. The DB command uses actual hydrogen value in ppm written to registers 126 and 127, which must be written before writing to register 122. The calibration date (month, day, year) written to registers 128 and 129 must match the internal real-time clock to be accepted.

The monitor 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.

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

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

3. To clear the DGA adjustment set by a DB command, use the DC command (write to register **125**).

NOTE: Wait at least 24 hours before issuing a DA command.

2.10 USER-DEFINED LIQUID TYPE CONFIGURATION

GRIDSCAN 5000 can operate in a variety of liquid types and comes configured for four popular types: Mineral, Silicone, Natural Ester, and Synthetic Ester. Select one of the programmed liquid types or modify the fourth, user-configurable liquid type, and program the name and Ostwald values for slope and offset using the Liquid Type Configuration Window registers.

CAUTION

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

EXAMPLE: Programming the Ostwald values for Synthetic Ester m=0.000093, b=0.039739 are used in the following instructions.

Sequence of operations to program a new liquid type.

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.

2.10.1 User-Defined Liquid Type Name

Access the user-defined liquid type name in registers **136–143**. Read these registers to return the current value and write with a null terminated string to modify the name.

- Default value is “Synthetic Ester\0” for Synthetic Ester
- A string length 15 characters
- Null-terminated with at least one bye of 0x00

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, is calculated using a scale factor of 1,000,000 and an offset of +1,000 as shown in the following equation:

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

Determine or verify the Ostwald Slope by reading Data32 and converting the value with the following equation:

$$m = Data32 - 1{,}000 / 1{,}000{,}000$$

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

2.10.3 Ostwald Offset, Offset (b)

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

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

Determine or verify the Ostwald Intercept by reading Data32 and converting the value with the following equation:

$$b = Data32 - 1{,}000 / 1{,}000{,}000$$

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

2.10.4 Liquid Type Operations

Write to register 148 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.

2.11 SET UNIT ID

Read register **150** to confirm the selected Modbus ID is in use. Write to register **150** to set the unit to the specified ID. The device ID can range from 1–247 or as limited by the Modbus master.

If the current device ID is unknown, perform a single write to Function Code 107 with the appropriate serial connection settings — one GRIDSCAN 5000 device at a time. The connected unit will return a response identifying its device ID.

Prepare multiple units to share a common RS-485 bus 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 1.

For PC-based configuration, use ComTest Pro for a Modbus controller. A power cycle is not necessary for the new ID to take effect. Label each device with the new device ID.

2.11.1 Configure Multiple Units

1. Disconnect all units from the RS-485 cable.
2. Connect first unit to the RS-485 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 RS-485 cable.
6. Repeat steps 3, 4, and 5 until all units are configured.
7. Attach all units to the RS-485 cable and read register **150** from each of the configured devices.

2.12 LIQUID TYPE SELECTION

Select which liquid type for GRIDSCAN 5000 to use by writing to Modbus register **152** with the number corresponding to the desired liquid type from Table 19.

Table 19: 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.

2.13 STOP BIT, PARITY SELECTION

Select the desired parity and stop bits to use in the RS-485 communication port settings by writing the corresponding number to 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 20: Data Bits, Parity, Stop Bits

Number	Data	Parity	Stop bits
1	8-bit	None	1
2	8-bit	None	2
3	8-bit	Even	1
4	8-bit	Even	2
5	8-bit	Odd	1
6	8-bit	Odd	2

2.14 BAUD RATE

Modify the GRIDSCAN 5000 RS-485 baud rate from the default 19200 baud by writing to Modbus register **160** with the number corresponding to the desired value in Table 21. Write to Modbus holding register **160** to reinitialize the UART with the new settings.

Table 21: Baud Rate

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

2.15 OPERATING MODE

The GRIDSCAN 5000 is shipped from the factory for normal field operation. If it will be subjected to laboratory testing, change the operating mode by writing 1 to register **151**. The operating modes differ in auto-calibration frequency: every 12 hours in normal mode, every four hours in laboratory mode.

2.16 REAL-TIME CLOCK

The GRIDSCAN 5000 has an internal real-time clock with backup power provided by a supercapacitor. 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, set the real-time clock to the current date and time.

1. Determine the correct starting date and time (Month/Year, Hour/Day, Sec/Min, Milliseconds (0)).
2. Convert each section of the date and time to hex, using Table 22 (or use a decimal-to-hex-converter).

Table 22: Date/Time Hex Table

Hex	Month	Year	Hour	Day	Seconds	Minutes	Milliseconds
1	Jan (01)		1	1	1	1	
2	Feb (02)		2	2	2	2	
3	Mar (03)		3	3	3	3	
4	Apr (04)		4	4	4	4	
5	May (05)		5	5	5	5	
6	June (06)		6	6	6	6	
7	Jul (07)		7	7	7	7	
8	Aug (08)		8	8	8	8	
9	Sep (09)		9	9	9	9	
A	Oct (10)		10	10	10	10	
B	Nov (11)		11	11	11	11	
C	Dec (12)		12	12	12	12	
D			13	13	13	13	
E			14	14	14	14	
F			15	15	15	15	
10			16	16	16	16	
11			17	17	17	17	
12			18	18	18	18	
13			19	19	19	19	
14			20	20	20	20	
15			21	21	21	21	
16		22	22	22	22	22	
17		23	23	23	23	23	
18		24	24=0	24	24	24	
19		25		25	25	25	
1A		26		26	26	26	
1B		27		27	27	27	
1C		28		28	28	28	
1D		29		29	29	29	
1E		30		30	30	30	
1F		31		31	31	31	
20		32			32	32	
21		33			33	33	
22		34			34	34	
23		35			35	35	
24		36			36	36	

Hex	Month	Year	Hour	Day	Seconds	Minutes	Milliseconds
25		37			37	37	
26		38			38	38	
27		39			39	39	
28		40			40	40	
29		41			41	41	
2A		42			42	42	
2B		43			43	43	
2C		44			44	44	
2D		45			45	45	
2E		46			46	46	
2F		47			47	47	
30		48			48	48	
31		49			49	49	
32		50			50	50	
33					51	51	
34					52	52	
35					53	53	
36					54	54	
37					55	55	
38					56	56	
39					57	57	
3A					58	58	
3B					59	59	
3C					60	60	
0							0

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)
4. After register **178** is written, the date and time are automatically saved.
5. Confirm the correct date and time by reading registers **175–178**.

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.

2.18 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.

- Owner ID: Registers **201–210**
- Substation ID: Registers **211–220**
- Transformer ID: Registers **221–230**

Table 23: Modbus Function Code 2, Discrete Input Register Locations

NOTE: 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	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	Over temperature error (Error Status, Bit 4)
21	Internal error (Error Status, Bit 3)
22–47	0 (Spare)
48	Valid – H_2
49	Valid – Rate of Change, daily
50	Valid – Rate of Change, weekly
51	Valid – Rate of Change, monthly
52	Reserved
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	Reserved

Data Address	Description
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 24: Modbus Function Code 4, Read Input Register Locations

NOTE: 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	H_2 value high word	Floating point number
4	H_2 value low word	
5	Rate of change, daily high word	
6	Rate of change, daily low word	
7	Rate of change, weekly high word	
8	Rate of change, weekly low word	
9	Rate of change, monthly high word	
10	Rate of change, monthly low word	
11–12	Reserved	
13	Liquid temperature high word	
14	Liquid temperature low word	