Electron

GRIDSCAN 5000

High-Precision Monitoring for Transformers with Continuous Measurement of Hydrogen, Humidity, Pressure, and Temperature

MODBUS Registry Map

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OPERATION

After plugging in the cable and turning on the power supply, the sensor performs a power-up sequence that can last up to 16 hours. The following operations are performed during the boot sequence:

- Connected system self-test
- Restoring non-volatile memory configuration settings
- Start measuring oil and hydrogen temperature
- The self-calibration sequence is performed to stabilize the sensor as needed (the sensor may show the initial value before the self-calibration is completed)

Before putting the sensor into operation, perform the following steps:

1. Connect the sensor to power for at least 5 minutes to recharge the supercapacitor, which may have discharged if the sensor has been out of power for several months.
2. Reset the date/time according to the steps in the
3. Turn the power off and on to eliminate any errors.

After a short power outage, approximate hydrogen readings will be reported by the sensor within 30 minutes of power being restored. In new installations and after long power outages, the sensor can take up to 16 hours to stabilize and report accurate hydrogen readings.

The Modbus 111, bit 15 status record will indicate ready when the first valid hydrogen measurement is available. After the boot sequence is complete, the measured and calculated values will be available in the Modbus records.

If an error is reported, turn off the 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 in technicalsupport@h2scan.com.

During normal operation, the sensor will measure oil temperature (approximately once per hour) to provide temperature-compensated dissolved gas readings. The unit will periodically undergo an internal self-calibration check (reference cycle). These are automatic activities that don't require any user interaction

The RS485 input is galvanically isolated within the GRIDSCAN 5000 to improve noise immunity in harsh electrical environments.

The GRIDSCAN 5000 does not include bias resistors for the data lines that may need to be added to the SCADA end of the cable. A 120-ohm termination resistor, between Data+ and Data- is installed on the GRIDSCAN 5000.

The following standard communication settings are used for the RS485, 2-wire, half-duplex connection.

- Baud Rate: 19,200

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- Data bits: 8
- Stop bits: 1 or 2
- Parity: None
- Flow Control: None

During normal operation, the measurements of the GRIDSCAN 5000 hydrogen sensor should be periodically surveyed for a measurement reading. The polling frequency can be from 1 second to several hours or days, depending on the user's requirements. Each read must include the following Modbus retention records.

- Status Log (111, 15 and 12 bits) – Bit 15 indicates that hydrogen measurement is available. Bit 12 indicates that there is an error.
- Error Status Records (112.113) – Indicates which error was detected. (These records are active when the 111 bit 12 record is high)
- PCB Temperature Logging (7) – Provides the internal temperature of the GRIDSCAN 5000. Note: Operating temperatures above 105°C may cause permanent damage.
- Oil Temperature Record (8) – Provides the temperature of the oil on the sensor. Please note that an oil temperature above 105°C is outside the calibration range. Oil temperature above 135°C can cause permanent damage.
- Hydrogen Records (0.1) – Provides the ppm values of hydrogen. Note: The word high

(0) must be read to allow the low value of the word (1) to be available.

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 oil temperature.

If the sensing element is damaged and inoperable, the GRIDSCAN 5000 will shut down the measurement system and continue responding to Modbus requests for error reports. This error will be reported through the 111 bit 12 log and then the details specified in the 112.113 logs. This type of error typically indicates a hardware failure that can only be repaired in H2scan. Power cycle the drive to attempt recovery. If the error condition is repeated, contact H2scan for technicalsupport@h2scan.com repair.

The Modbus protocol communicates over RS485 and supports RTU packets. The default Modbus ID of the GRIDSCAN 5000 is 1. The Modbus ID can be changed by writing to the 150 retention record.

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SUPPORTED FUNCTIONS CODE

Function code	Description
02 (02 hex)	Read discrete entries
03 (03 hex)	Read Retention Records
04 (04 hex)	Read Input Logs
06 (06 hex)	Write single record
16 (10 hex)	Write multiple records

Note: The maximum response time for the sensor is 10 seconds. Therefore, the master timeout should be set to 10,000 milliseconds or more.

MODBUS READ RETENTION RECORD REQUEST

Byte	Modbus Parameter	Range	Meaning
1	Slave Address	1–247	**Unit ID address**
2	Function code	03	**Read the withholding record**
3	Home Address Hello	0x00–0xFF	**Holding the High-Byte Register**
4	Starting Address Lo	0x00–0xFF	**Holding the Low Byte Registry**
5	Number of Oi records	0	**Limited by the Modbus V1.1b specification**
6	Number of Lo Records	0–230	**Number of 16-bit Low Byte Records**
7	CRC Lo	0x00–0xFF	**CRC Byte Bass**
8	CRC Hi	0x00–0xFF	**CRC Byte High**

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MODBUS READ RETENTION LOG RESPONSE

Byte #	Modbus Parameter	Range	Meaning
1	Slave's Address	1–247	**Unit ID address**
2	Function code	03	**Returning Retention Records**
3	Byte Count	7–255	**Number of bytes of data returned = N**
4	1st Data Value Hello	0x00–0xFF	-
5	1st Value of Lo Data	0x00–0xFF	-
6	2 Hi Data Value	0x00–0xFF	-
7	2nd Value of Lo Data	0x00–0xFF	-
2N+4	CRC Lo	0x00–0xFF	**CRC Byte Bass**
2N+5	CRC Hi	0x00–0xFF	**CRC Byte High**

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

MODBUS WRITE ONE-TIME RETENTION RECORD REQUEST

Byte #	Modbus Parameter	Range	Meaning
1	Slave's Address	1–247	**Unit ID address**
2	Function code	06	**Write Retention Records**
3	Hi Byte Registration Address	0x00–0xFF	**High Byte Drive Registration Address**
4	Lo Byte Registration Address	0x00–0xFF	**Drive Registration Address Low Byte**
5	Hi Byte Data Value	0x00–0xFF	-
6	Lo Byte Data Value	0x00–0xFF	-
7	CRC Lo	0x00–0xFF	**CRC Byte Bass**
8	CRC Hi	0x00–0xFF	**CRC Byte High**

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ONE-TIME RETENTION RESPONSE MODBUS RECORDING

Byte #	Modbus Parameter	Range	Meaning
1	Slave's Address	1–247	**Unit ID address**
2	Function code	06	-
3	Hi Registration Address	0x00–0xFF	**Hi byte drive registration address**
4	Lo Registration Address	0x00–0xFF	**Lo byte drive registration address**
5	Hi Byte Data Value	0x00–0xFF	-
6	Lo Byte Data Value	0x00–0xFF	-
7	CRC Lo	0x00–0xFF	**CRC Byte Bass**
8	CRC Hi	0x00–0xFF	**CRC Byte High**

MODBUS WRITE MULTIPLE RETENTION LOG REQUEST

Byte #	Modbus Parameter	Range	Meaning
1	Slave's Address	1–247	**Unit ID address**
2	Function code	16	**Record Multiple Retention Record**
3	Home Address Hello	0x00–0xFF	**Holding the High-Byte Register**
4	Starting Address Lo	0x00–0xFF	**Holding the Low Byte Registry**
5	Number of Oi records	0	**Limited by the Modbus V1.1b specification**
6	Number of Lo Records	1-125	**Number of 16-bit Low Byte Records**
7	Byte Count	7–255	**N number of bytes of data to follow**
8	1st Data Value Hello	0x00–0xFF	-
9	1st Value of Lo Data	0x00–0xFF	-
10	2 Hi Data Value	0x00–0xFF	-
12	2nd Value of Lo Data	0x00–0xFF	-
2N+7	CRC Lo	0x00–0xFF	**CRC Byte Bass**
2N+8	CRC Hi	0x00–0xFF	**CRC Byte High**

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MODBUS WRITE MULTIPLE RETENTION RECORD RESPONSE

Byte #	Modbus Parameter	Range	Meaning
1	Slave's Address	1–247	**Unit ID address**
2	Function code	16	**Write multiple retention records**
3	Hi Registration Address	0x00–0xFF	**Hi byte drive registration address**
4	Lo Registration Address	0x00–0xFF	**Lo byte drive registration address**
5	# From Hi Written Records	0x00–0xFF	**Number of records recorded Hi byte**
6	# From written records Lo	0x00–0xFF	**Number of records written Lo byte**
7	CRC Lo	0x00–0xFF	**CRC Byte Bass**
8	CRC Hi	0x00–0xFF	**CRC Byte High**

MODBUS READ DISCRETE ENTRY RECORD REQUEST

Byte #	Modbus Parameter	Range	Meaning
1	Slave's Address	1–247	**Unit ID address**
2	Function code	02	**Read Discrete Entry Log**
3	Starting Address Hi	0x00–0xFF	**Data address of the first Hi Byte entry**
4	Starting Address Lo	0x00–0xFF	**Data address of the first entry Lo Byte**
5	Number of Hi entries	0	**Number of Requested Entries Hi Byte**
6	Number of Lo Entries	0–68	**Number of Requested Entries Lo Byte**
7	CRC Lo	0x00–0xFF	**CRC Byte Bass**
8	CRC Hi	0x00–0xFF	**CRC Byte High**

Note: The number of coils is limited to the number of coils supported. The supported data address range is 0 through 67.

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DISCRETE INPUT REGISTER RESPONSE READING MODBUS

Byte #	Modbus Parameter	Range	Meaning
1	Slave Address	1–247	**Unit ID address**
2	Function code	02	**Read Discrete Entry Log**
3	Byte Count	7–255	**Number of bytes of data to follow**
4	1st Byte of Data	0x00–0xFF	**Bit 0 of the first byte of data is the starting address of the on/off status; bit 7 is the on/off status of the Starting Address+7**
5	2nd Byte of Data	0x00–0xFF	**Bit 0 of the second byte of data is the on/off status Start address +8; bit 7 is the on/off status of the Starting Address+8+7**
N+4	CRC Lo	0x00–0xFF	**CRC Byte Bass**
N+5	CRC Hi	0x00–0xFF	**CRC Byte High**

Note: N is the number of bytes returned based on the number of reels requested. N = Number of Reels / 8 Bits Per Byte
If N%8 > 0, N = N + 1
The data value returns the on/off status of discrete entries. The first data address (Initial Address) is placed on 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 with zeros (towards the most significant bit).
For example: Request the on/off status of discrete entries starting at data address 0 through 18 (#10001 through 10019). The request will read 19 discrete entries, starting at address 10001. The number of bytes returned is: N = 19/8 = 2, 19%8=3 > 0; then N = 3. The unused bits in the 3rd (last) byte of data are filled with zeros (towards the most significant bit).

MODBUS READ ENTRY REGISTRATION REQUEST

Byte	Modbus Parameter	Range	Meaning
1	Slave Address	1 – 247	**Unit ID address**
2	Function code	04	**Read Entry Log**
3	Starting Address Hi	0x00 – 0xFF	**Hi Byte Retention Record**
4	Starting Address Lo	0x00 – 0xFF	**Holding Register Lo Byte**
5	Number of Oi records	0	**Number of 16-bit Hi Byte Records**
6	Number of Lo Records	1 – 15	**Number of 16-bit Lo Byte registers**
7	CRC Lo	0x00 – 0xFF	**CRC Byte Bass**
8	CRC Hi	0x00 – 0xFF	**CRC Byte High**
The number of read input records is limited to the number of records reported. The supported data address range is 0 through 14			

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MODBUS READ INPUT LOG RESPONSE

Byte #	Modbus Parameter	Range	Meaning
1	Slave Address	1 – 247	**Unit ID address**
2	Function code	04	**Read Entry Log**
3	Byte Count	2 – 30	**If No. of Records Requested = N Byte Count = 2N**
4	1st Data Value Hi	0x00 – 0xFF	
5	1st Value of Lo Data	0x00 – 0xFF	
6	2 Hi Data Value	0x00 – 0xFF	
7	2nd Value of Lo Data	0x00 – 0xFF	
…	…		
…	…		
2N+4	CRC Lo	0x00 – 0xFF	**CRC Byte Bass**
2N+5	CRC Hi	0x00 – 0xFF	**CRC Byte High**

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

EXCEPTION RESPONSE

In a normal communication 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. Abnormal communication between the two devices produces one of four possible events:

1. If the slave does not receive the query due to a communication error, no response is returned from the slave and the master device eventually processes a timeout condition for the query.
2. If the slave receives the query but detects a communication error (UART or CRC), no response is returned from the slave and the master device eventually processes a timeout condition for the query.
3. If the slave receives the query without a communication error and takes longer than the master's timeout setting, no response is returned from the slave. The master device eventually processes a timeout condition for the query. To avoid this condition, the master timeout should be set to longer than the maximum slave response time (10,000 milliseconds).
4. If the slave receives the query without a communication error, but cannot process it due to reading from or writing to a nonexistent 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. The first is the function code – byte 2. This code will have the higher-order bit set to one (that is, 0x83 for a read exception and 0x86 for a write exception). The second field of differentiation is the exception code – byte 3. In addition, the total length of the exception response is 5 bytes, instead of the normal message length.

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EXCEPTION RESPONSE PACKET

Byte	Modbus Parameter	Range	Meaning
1	Slave's Address	1 – 247	
2	Function code	0x83 or 0x86	**Read or write**
3	Exception Code	See the table below	
4	High CRC	0x00 – 0xFF	
5	CRC Bass	0x00 – 0xFF	

EXCEPTION RESPONSE CODES

Code	Name	Description
1	Illegal function code	**The function code received in the query is not an allowed action for the slave. This may be because the function code is only applicable to newer devices and has not been implemented on the selected drive. It can also indicate that the slave is in the wrong state to process such a request, for example.** **example because it is not configured and is being prompted to return registry values.**
2	Illegal data address	**The data address received in the query is not an allowed address for the slave. More specifically, the combination of the reference number and the length of the transfer 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 an initial registration address of 96 and a record quantity of 4, that request will work successfully (at least in terms of address) on records 96, 97, 98, 99. If a request is submitted with an initial registration address of 96 and a record quantity of 5, that request will fail with the Exception Code 0x02 "Illegal Data Address" as it attempts to operate on records 96, 97, 98, 99** **and 100, and there is no record with the address 100.**
3	Value of illegal data	**A value contained in the query data field is not an allowed value for slave. This indicates a flaw in the structure of the remainder of a complex request, such as the implicit length is incorrect. Specifically, it does NOT mean that a data item sent for storage in a record has a value outside the expectation of the application program, since the MODBUS protocol is unaware of the importance**
4	Slave device failure	**An unrecoverable error occurred while the slave was attempting to perform the requested action.**

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MODBUS COMMAND REGISTER SETTINGS

The Command Register definitions for the GRIDSCAN 5000 Hydrogen Sensor are identified in Table 17.

Note: When reading records containing 32-bit or 64-bit integers, the user must first read the higher-order word, and then the lower-order word(s). Reading the high order word causes the low order word to be saved in a temporary location for the next read of the record. The second record is then automatically read from the temporary location by the firmware. Similarly, with one write, the high value is stored until the second value is received, at which point both values are written to the instrument.

COMMAND LOGGING LOCATIONS

Register	Parameter	Function	Type of data	Data range	Access
Measures					
0	Hydrogen, ppm H2	High word	32-bit binary	0 to 20,000,000	**R**
1		Low word			
2-6	**Reserved for future use**				
7	PCB Temperature, Celsius	x100 scale; 100 displacements (T=V/100-100)	16-bit binary	-100 to +200	**R**
8	Oil Temperature, Celsius	x100 scale; 100 displacements (T=V/100-100)	16-bit binary	-100 to +200	**R**
9-12	**Reserved for future use**				
13	Rate of Change, ppm H2 per day +20,000,000offset	High word	32-bit binary	-20,000,000 Towards +20,000,000	**R**
14		Low word			
15	Change rate, ppm H2 per week +20,000,000offset	High word	32-bit binary	-20,000,000 Towards +20,000,000	**R**
16		Low word			
17	Change Fee, ppm H2 per Month +20,000,000 Offset	High word	32-bit binary	-20,000,000 Towards +20,000,000	**R**
18		Low word			
19-30	**Reserved for future use**				

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Register	Parameter	Function	Type of data	Data range	Access
Information					
31-40	Model Number		ASCII Rope		**R**
41-50	Product Serial Number		ASCII Rope		**R**
51-60	Sensor Serial Number		ASCII Rope		**R**
61-70	Sensor Board Serial Number		ASCII Rope		**R**
71-80	**Reserved for future use**				
81	Date of manufacture	High Byte: Low Byte of the Month: Day	32-bit binary value		**R**
82		Year			
83	Factory calibration date	High Byte: Low Byte of the Month: Day	32-bit binary value		**R**
84		Year			
85-86	**Reserved for future use**				
87	Dissolved gas calibration date	High Byte: Low Byte of the Month: Day	32-bit binary value		**R**
88		Year			
89-98	Firmware revision		ASCII Rope		**R**
99-110	**Reserved for future use**				
Status/Error Information					
111	State	See section 7.2.3	16-bit binary flags	Table 11: Unit Status	**R**
112	Error status	See the section 7.2.8.2 High word	32-bit binary flags	Table 12: Error Status	**R**
113		Low word			
114-120	**Reserved for future use**				

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Register	Parameter	Function	Type of data	Data range	Access
Calibration functions					
121	DA Command		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 H2	High word	32-bit binary	0 to 1,000,000	**R/W**
127		Low word			
128	Calibration Date	High Byte: Low Byte of the Month: Day	32-bit binary value		**R/W**
129		Year			
130-135	**Reserved for future use**				
Configuration settings					
136-143	User-defined oil type name	See the section for user-defined oil type setting Window descriptions.	ASCII Rope		**R/W**
144	Ostwald slope, m		16-bit binary		**R/W**
145			16-bit binary		**R/W**
146	Ostwald displacement, b		16-bit binary		**R/W**
147			16-bit binary		**R/W**
148	Oil-type operations		16-bit binary	1 = open edit 2 = save close 3 = abort edit	**R/W**
149	**Reserved for future use**				

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Register	Parameter	Function	Type of data	Data range	Access
150	Set Unit ID		8-bit binary number	1 to 247	**R/W**
151	Mode of operation	Select between Field and Lab mode	16-bit binary	0 = Field 1 = Laboratory	**R/W**
152	Oil Type Selection	Select oil type	16-bit binary	0 = Mineral 1 = Silicone 2 = Nat Ester 3 = Ester Syn	**R/W**
153-158	**Reserved for future use**				
159	Parity, Stop Bit Selection	Select Parity, Stop Bits	16-bit binary	1 = 8N1 2 = 8N2 3 = 8E1 4 = 8E2 5 = 8O1 6 = 8O2	**R/W**
160	Baud Rate	Baud Rate Selection	8-bit binary no.	1 = 9600 2 = 14400 3 = 19200 4 = 38400 5 = 57600 6 = 115200	**R/W**
161-174	**Reserved for future use**				
Diagnostics					
175	Month / Year	Date and Time; Read Log 175 first; High Byte Order / low byte; Add 2000 to the year (64-bit)	16-bit binary		**R/W**
176	Hour / Day		16-bit binary		**R/W**
177	Second / Minute		16-bit binary		**R/W**
178	Millisecond		16-bit binary		**R/W**
179-200	**Reserved for future use**				

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Register	Parameter	Function	Type of data	Data range	Access
User Information					
201-210	Owner ID	You should start reading from a low address; Must write low and high addresses to save the string	ASCII Rope		**R/W**
211-220	Substation ID		ASCII Rope		**R/W**
221-230	Transformer ID		ASCII Rope		**R/W**
231-255	**Reserved for future use**				

HYDROGEN MEASUREMENT

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

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

HYDROGEN TRENDS

The GRIDSCAN 5000 calculates and maintains a daily, weekly, and monthly rate of change value.
An hourly trend is calculated at the end of each 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) hour values to give the amount of change over the past 24 hours.

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

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

A positive trend indicates an increase in hydrogen, a negative trend indicates a decreasing level of hydrogen. The rate of change is calculated as the change in hydrogen measured over time.
Note: Trend values are reset to zero after a power cycle.

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RATE CHANGE

Rate of change per day
The rate of change per day is reported in 13,14 records. The unsigned 32-bit integer value scales with an offset of 20,000,000 (0x0131 2D00), resulting in a signed 32-bit integer value in ppm H2 per day.
The daily trend is the average of the last 24-hour measurements.

Rate of Change per Week
The weekly rate of change is reported in the 15.16 records. The unsigned 32-bit integer value scales with an offset of 20,000,000 (0x0131 2D00), resulting in a signed 32-bit integer value in ppm H2 per day.
The weekly trend is the average of the last 7 daily measurements.

Rate of Change per Month
The monthly rate of change is reported in the 17.18 records. The unsigned 32-bit integer value scales with an offset of 20,000,000 (0x0131 2D00), resulting in a signed 32-bit integer value in ppm H2 per day.
The monthly trend is the average of the last 28 daily measurements.

Temperature measurement
The GRIDSCAN 5000 monitors the oil temperature and the internal temperature of electronic components. Temperature is reported as an unsigned 16-bit integer scaled in degrees Celsius. Dividing the integer value by 100 and subtracting 100 will give you the temperature measured to 2 decimal places.

PCB Temperature
The temperature of the PCB is reported in log 7. This is the internal temperature of the electronic casing, which should not exceed 105°C.
This is a good record to read during installation and communication testing because the value is always valid and changes frequently.

Oil temperature
The oil temperature is indicated in register 8. The sensor is calibrated for oil temperature up to 105°C; the accuracy of hydrogen measurement is unknown above this temperature; the sensor survives oil temperatures of up to 135°C. Zero is the default energy value for oil temperature.

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

Model Number
The model number is in records 31-40.

Product Serial Number
The product serial number is in records 41-50.

Sensor Serial Number

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The sensor serial number is in records 51-60.

Sensor Board Serial Number
The sensor board serial number is in records 61-70.

Firmware revision
The firmware revision is in records 89-98, using the format x:y:z; Example 3:7:A

- x is the main revision
- y is the minor revision
- z is the designator of the product

Date Stamp Format
Records 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

Date of manufacture
The original date of manufacture is in the records 81.82

Factory calibration date
The last factory calibration date is in the 83.84 records

Dissolved gas calibration date
The last DGA calibration date is at 87.88 records

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

Unit Status
The status information of the unit is maintained in the Modbus 111 registry. The bitmap for this status word is described below:

Bit #	Description
15	**Unit ready, hydrogen readings are valid**
14	**New measurement data available, automatic cleaning after reading the record**
13	**Unlisted bits are not used and can be either 0 or 1.**
12	**Error, indicates that an unrecoverable error has occurred, read Reg 112.113 for more information**
6-11	**Unlisted bits are not used and can be either 0 or 1.**
5-3	**Sensor A Status Information:** **001 – Hydrogen Measurement Cycle** **010 – Oil temperature measurement cycle 011 – Self-calibration cycle** **100 – Oil temperature too high**
0-2	**Unlisted bits are not used and can be either 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 – Oil temperature measurement cycle (decimal 16)
00x0 xxxx xx10 0xxx – Unit not ready – Oil temperature too high (decimal 32)
xxx1 xxxx xxxx xxxx – Unit Error – Error Bit 12 (Decimal 4,096)
10x0 xxxx xx01 0xxx – Unit ready – Oil temperature measurement cycle (decimal 32.784)
10x0 xxxx xx00 1xxx – Unit Ready – Hydrogen Measurement Cycle (decimal 32.776)
10x0 xxxx xx01 1xxx – Unit ready – Self-calibration cycle (decimal 32.792)
11x0 xxxx xx01 0xxx – Unit Ready – Oil 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 – Self-Calibration Cycle, New Data (Decimal 49.176)

ERROR STATUS

Bit #	Hexadecimal value	Description
31	0x8000 0000	**Sensor – Heater failure**
30	0x4000 0000	**Sensor – Temperature Sensor Failure**
29	0x2000 0000	**Sensor – Hydrogen Sensor Failure**
9-28	0x1000 0000 - 0x0000 0200	**Unlisted bits are not used and can be either 0 or 1.**
8	0x0000 0100	**Battery Backup Error**
5-7	0x0000 0080 - 0x0000 0020	**Unlisted bits are not used and can be either 0 or 1.**
4	0x0000 0010	**PCB temperature higher than 105C.**
2-3	0x0000 0008- 0x0000 0004	**Unlisted bits are not used and can be either 0 or 1.**
1	0x0000 0002	**Mandatory data not available.**
0	0x0000 0001	**The configuration data is not valid.**

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ERROR RESPONSE

Recommended responses to these errors are:

- **Sensor failures** (heater, temperature, or hydrogen): Turn off the sensor, wait 5 minutes, turn on the sensor, and check the status after 15 minutes to determine if the error is persistent. Contact support@h2scan.com for more information about persistent sensor failures.
- **Battery Backup Error**: The internal rechargeable battery was discharged while the power was disconnected and will be recharged when the power is turned on. Setting the clock as described in section 7.2.16 will clear this error status. Cycle power will also eliminate this error. Contact support@h2scan.com if this error does not go away after power cycling.
- **PCB Temperature**: The internal temperature is too high and may affect the operation of the sensor and the accuracy of hydrogen measurement. Turn off for an hour and investigate the area around the sensor for high temperature or lack of airflow. Turn on the power and wait an hour to determine if the error is persistent. Contact support@h2scan.com for more information about persistent PCB temperature error.
- Mandatory data not available: indicates an error in the internal microcontroller, please contact support@h2scan.com for more information.
- Invalid configuration data: indicates an error in internal memory, please contact support@h2scan.com for more information.

DGA CALIBRATION

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

Note: Incorrect data entered for DGA calibration will impede the sensor's ability to measure and monitor.

COMMAND OF

The DA command (write to Modbus register 121) is the first step in making an adjustment to the GRIDSCAN 5000 hydrogen measurement based on the results of laboratory DGA tests. This command must be issued when an oil sample is taken so that 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.

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CAMANDO DB

The DB command (write to Modbus 122 register) is the second step in adjusting the GRIDSCAN 5000 hydrogen measurement based on the results of laboratory DGA tests. Note that a DA command must have been executed before a database is issued. The DB command uses data written to records 126-129, which must be written before writing to record 122. The date in the 128.129 logs must match the real-time internal clock to be accepted.
The recommended sequence of operations to run the DB command is:

1) Read records 175.176 for internal date
2) Write the date for records 128,129
3) Write DGA results in ppm H2 in records 126,127
4) Write to record 122

The new hydrogen measurement may differ from the DGA value due to changes since the oil sample was collected. The internal data of the last DA command is erased when the DB command completes. Writing to the Modbus 122 registry will take up to 10 seconds to respond.

DC COMMAND

The DC command (write to Modbus 125 register) allows the user to clear the DGA setting defined by a DB command.
Note: Wait at least 24 hours before issuing a DA command.

CALIBRATION GAS PPM H2

The actual hydrogen value in ppm is written to Modbus 126.127 records for use with the DB command. This value must be written before the database record is written.

CALIBRATION DATE

The calibration date (month, day, year) recorded in the Modbus 128.129 records must match the internal clock in real time for the database command to be accepted.

USER-DEFINED OIL TYPE SETTING

The 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 the programmed oil types or modify the fourth user-configurable oil type. The records in the Oil Type Configuration Window are used to read and modify the user-defined Oil Type configuration data structure. This includes Ostwald's name and values for tilt and offset.
Note: These values are a critical part of the hydrogen calculation. Incorrect values will impede the sensor's ability to measure and monitor.

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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 type of oil is:

1) Write record 148 with 0x0001 to open the user-configurable oil type for editing
2) Write records 136-143 with the name of the oil
3) Write 144,145 records with the Ostwald slant
4) Write 146.147 Records with the Ostwald Offset
5) Write record 148 with 0x0002 to save the values and close

USER-DEFINED OIL TYPE NAME

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

- A string length of 15 characters
- Ended in null with at least one bye of 0x00

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 · 1,000,000) + 1000
The Ostwald slope can then be determined or verified by reading the Data32 and converting the value with the following equation:
Date32 − 1000
m =
1,000,000

- Register 144, 16-bit high value of Data32 (0x0000)
- Register 145, Data32 16-bit low value (0x0445)

OSTWALD DISPLACEMENT, DISPLACEMENT (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 · 1,000,000) + 1000
The Ostwald Intercept can then be determined or verified by reading the Data32 and converting the value with the following equation:
Date32 − 1000
b =
1,000,000

- Register 146, 16-bit high value of Data32 (0x0000)
- Register 147, 16-bit low value of Data32 (0x9F23)

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OIL TYPE OPERATIONS

Recording to the 148 log is used to initiate operations to edit and save the user-defined oil type.

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

SET UNIT ID

The Modbus ID is reported or set in record 150. Reading this log is used to confirm that the selected ID is in use. Writing the desired ID in record 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, writing the desired ID to device 0 will transmit the ID to all connected GRIDSCAN 5000 devices.

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 so that that unit registers 150 on device ID 0.

For PC-based configuration, use www.BaseBlock.com's ComTest Pro for a Modbus controller. The device must be turned off and off for the new ID to take effect. It is recommended that each device be labeled with the new device ID.

A simple procedure for setting up multiple drives is as follows:

1) Disconnect all units from the RS485 cable
2) Connect the first unit to the RS485 cable
3) Use the Modbus controller to write a single hold logger (function 6) to register 150, device 0, with the desired ID for the connected unit
4) Wait up to 10 seconds for the Modbus response
5) Unplug this unit and connect the next one to the RS485 cable
6) Repeat steps 3, 4, and 5 until all units are set up
7) Connect all units to the RS485 cable and read log 150 from each of the configured devices

OIL TYPE SELECTION

The selection of the type of oil to be used by the GRIDSCAN 5000 is made by writing in the Modbus 152 register with the number corresponding to the desired type of oil in the table below.

Number	Oil Type	Description on Modbus map
0	Mineral oil	Mineral
1	Silicone oil	Silicone
2	Natural ester oil	Natural ester
3	Synthetic ester oil	Synthetic ester

Example: Write record 152 with a value of 0x0003 to select synthetic ester oil.

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STOP BIT, PARITY SELECTION

To select the desired parity and stop bits to be used in the RS485 communication port settings, write the corresponding number in the Modbus 159 register (the default selection is 1). Turn the GRIDSCAN 5000 off and on.

Number	Description
1	8-bit data, no parity, 1 stop bit
2	8-bit data, no parity, 2-bit stop
3	8-bit data, uniform parity, 1 stop bit
4	8-bit data, uniform parity, 2-bit stop
5	8-bit data, odd parity, 1 stop bit
6	8-bit data, odd parity, 2-bit stop

MODE OF OPERATION

The GRIDSCAN 5000 is shipped from the factory for normal field operation. If undergoing laboratory testing, the mode of operation must be changed by writing a 1 in record 151. The difference in operating modes is how often self-calibration is performed (every 12 hours in normal mode; every 4 hours in lab mode).

REAL-TIME CLOCK

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

Determine the correct start date and time (Month/Year, Time/Day, Sec/Min, Milliseconds (0)).

Convert each section of the date and time to hexadecimal, using the table below (or use a decimal to hexadecimal converter).
Hexadecimal Date/Time Table

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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										

Using ComTest Pro, write the date and time sections (now in hexadecimal) in the appropriate records, as shown below.
Record 175 - Record Month/Year 176 - Record Hour/Day 177 - Record Sec/Min 178 - Milliseconds (0)
Once the 178 log is recorded, the date and time are automatically saved.
To confirm the correct date and time, read logs 175-178.

USER INFORMATION

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 long, including null termination.

Owner ID
The owner's string is saved in listings 201 through 210.
Substation ID
The substation string is saved in listings 211 through 220.
Transformer ID
The transformer string is saved in records 231 through 230.

MODBUS 2 FUNCTION CODE, DISCRETE ENTRY REGISTER LOCATIONS

(Discrete entry records start at #10001).

Data Address	Description
0	Drive ready, hydrogen readings are valid (Drive Status, bit 15)
1	New measurement data available, automatic cleaning after record reading (Unit Status, Bit 14)
2	Error, indicates that an unrecoverable error has occurred (Drive Status, Bit 12)
3	Sensor Status Information A: Hydrogen Measurement Cycle (Unit Status, Bit 5-3, 001)
4	Sensor Status Information A: Oil Temperature Measurement Cycle (Unit Status, bit 5-3, 010)
5	Sensor Status Information A: Auto Calibration Cycle (Unit Status, Bit 5-3, 011)
6	Sensor Status Information A: Oil Temperature Too High (Unit Status, bit 5-3, 100)
7 - 15	0 (Spare)
16	Sensor – Heater Failure (Error Status, Bit 31)
17	Sensor – Temperature sensor failure (error status, bit 30)
18	Sensor – Temperature Sensor Failure (Error Status, 29 bit)
19	Battery Backup Error (Error Status, 8 Bit)
20	PCB temperature higher than 105C. (Error status, bit 4)
21	Mandatory data not available. (Error status, bit 1)
22	The configuration data is 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 – Oil Temperature
54	Valid – Oil 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 – Date of manufacture 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

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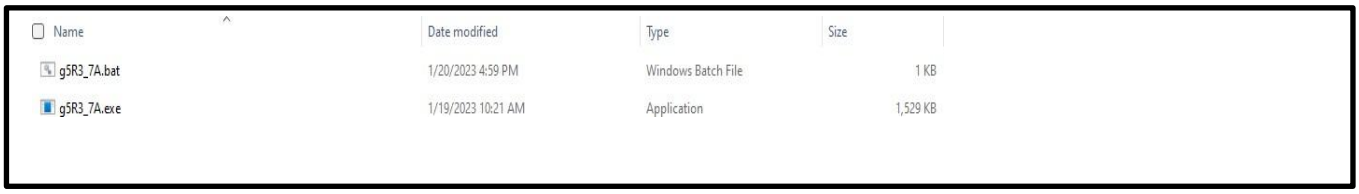
FIRMWARE UPDATE

The firmware of the GRIDSCAN 5000 hydrogen sensor can be updated in the field. Instructions and PC software will be provided by H2scan as needed.
Copy the firmware update files to a directory on your PC. (NOTE: The latest firmware available will be made available)

- g5R3_7A.exe – Sensor firmware binary file
- g5R3_7A.bat – batch file

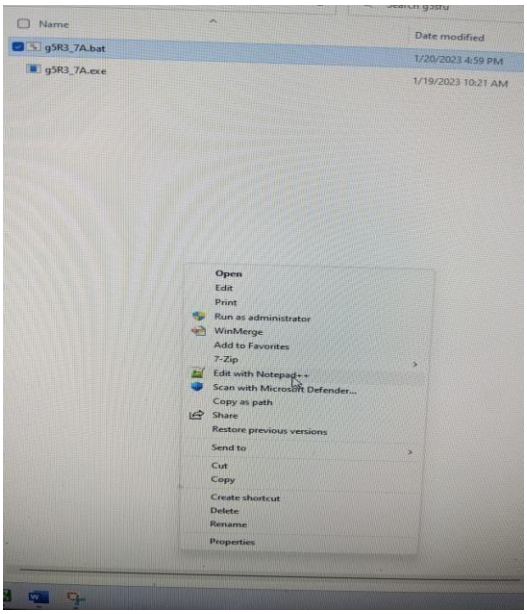
7-Step Procedure to Update Firmware:

1) Copy the files below to your local directory.



If the files are sent via "WeTransfer", unzip the three files. If necessary, you can download a free Zip file tool in https://www.7-zip.org/.

2) Connect the GRIDSCAN 5000 to your PC using a USB to RS485 adapter.
3) Right-click g5R3_7A.bat and select Edit.



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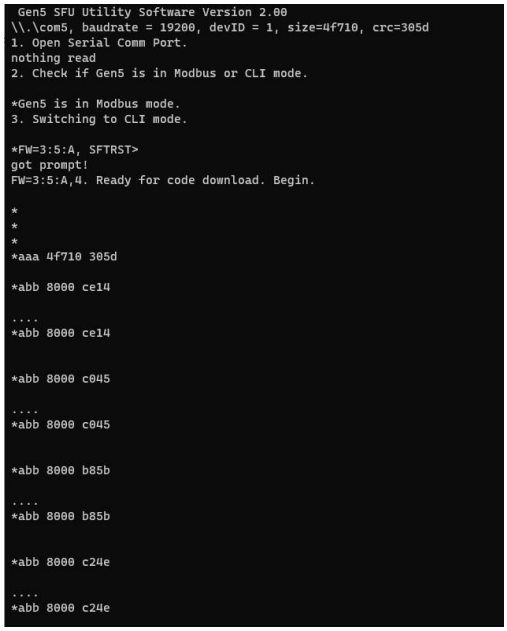
4) You will see the port information below. Update the com port, device address, and baud rate you are using to connect to the GRIDSCAN 5000. Save the file.

Transport = comX > Changing the COM port being used
Device Address = 1 > the default address is 1
Device baud rate = 19200 > The default baud rate is 19200

```
1  g5R3_7A.exe com5 1 19200
2  pause
3
```

5) Double-click g5R3_7A.bat. You will see the following information as the firmware is being updated.



6) The update process is complete when you see the window below.

7) Press any key to close the app.
8) To complete the process, turn the GRIDSCAN 5000 off and on.

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