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GOBIUS PRO
FUNCTIONAL DESCRIPTION

Gobius Sensor Technology AB
Ljungåsvägen 2, 302 91 Halmstad,
Sweden

Amendment history

Issue	Date	Author	Amendments
1.0	2020-05-03	A. Remar	First issue. Applicable for firmware revision 2.1.1

1 SCOPE

This document describes the operation of the Gobius Pro sensor and how it can be controlled via Bluetooth.

2 INTRODUCTION

The Gobius Pro sensor is uniqe because it measures the tank level through the outside of the tank.

The sensor is mounted on the tank wall at the height that the level shall be measued. The sensor can determine if the fluid level is above or below the sensor by measuring the stiffness of the tank wall. The stiffness changes when the fluid level passes the sensor.

For this to work, the sensor must know the stiffnes of the wall in the initial state when the tank is empty or full. This is done by the calibration procedure which must be performed once during installation of the sensor.(Or anytime afterwards). The measured stiffness value (LMS value) is saved in the sensors non-volatile memory and is used as a reference value for the subsquent measurements.

During operation, the sensor measures the tank level with a pre-set time interval which is also set by the user during the installation, but can be changed later.

The sensor has two outputs that can be connected to different type of indicators such as LEDs or lamps.

3 ABBREVIATIONS

LED Light Emitting Diode

LMS Least Mean Squared

RMS Root Mean Squared

mg milli-g (Acceleration, 1 g = 9.8 m/s^2)

4 HARDWARE DESCRIPTION

The Gobius Pro sensor consists of the following hardware depicted in Figure 1:

- A voltage converter with wide input voltage range.
- A microprocessor with integrated Bluetooth communication and a temperature sensor. The microprocessor has an on-chip non-volatile memory for storing the firmware and sensor configuration.
- A miniature chip antenna.
- An electrodynamic exciter.
- An accelerometer
- Two digital outputs that can activate low power lamps, LED indicators or low power relays.
- A separate non-volatile memory for storing the microprocessor firmware when performing over-the-air firmware upgrades.

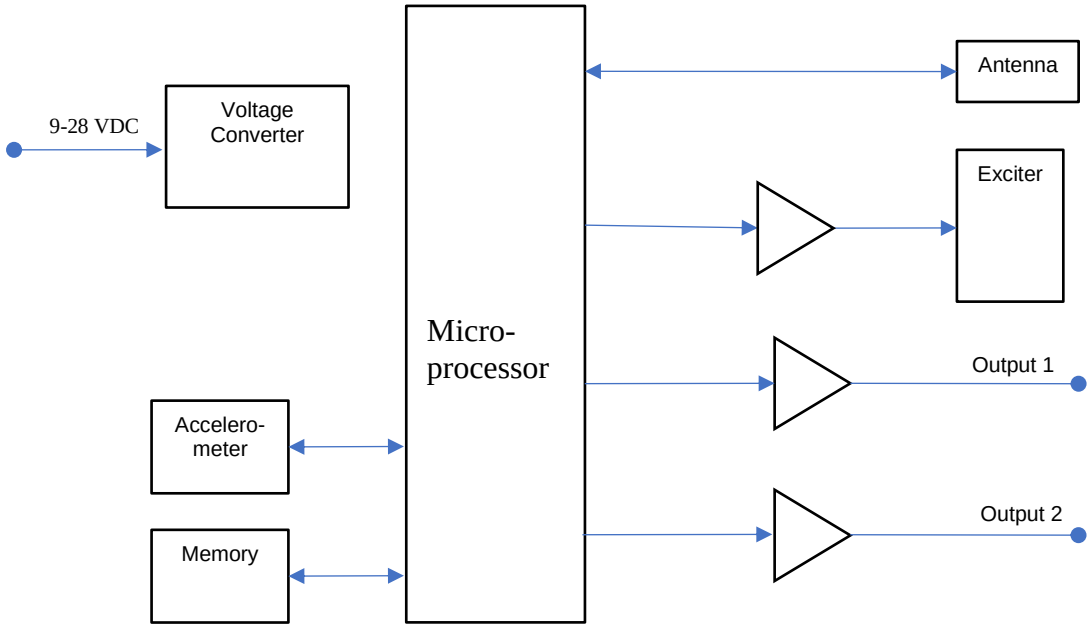

Figure 1: Gobius Pro sensor block diagram

5 ELECTRICAL DATA:

- Input voltage range: 9-28V DC
- Current consumption:
  - Idle: 10 mA max
  - Measuring (1 second duration): < 100 mA
- Digital outputs:
  - Maximum DC voltage: 30 V
  - Maximum DC current: 200 mA

6 FUNCTIONAL DESCRIPTION

6.1 Configuration Memory

Part of the internal non-volatile memory in the microprocessor is reserved for storing the configuration of the sensor. The configuration can be set to default values via a command.

6.2 State Diagram

The sensor firmware have the states listed in Table 1 with the possible state transitions shown in Figure 2.

Table 1: States

State	Description
Start-Up	First state after power-on. The hardware and firmware is initialized
Self-Test	The sensor performs a self-test. The next state is determined as follows: If an error is detected, the sensor will go to state Error. If no error, the sensor configuration is then checked: If no valid configuration, state Uninit is entered. If the configuration is valid but the sensor is not calibrated, state Uncalibrated is entered. If the configuration is valid and the sensor is calibrated, state Idle will be entered and an initial measurement will be performed.
Uninit	No valid configuration. An Init or Production Test command is required.
Uncalibrated	The sensor is not calibrated. A Calibration command is required.
Production Test	The production test is executing
Error	An error that prevents the sensor to perform measurements has been detected
Calibration	Sensor calibration is in progress
Measure	A measurement is in progress
Idle	The sensor is idle waiting for the point of time for the next measurement
Beep	A sound is played
HW-Test	The commanded hardware test is executing

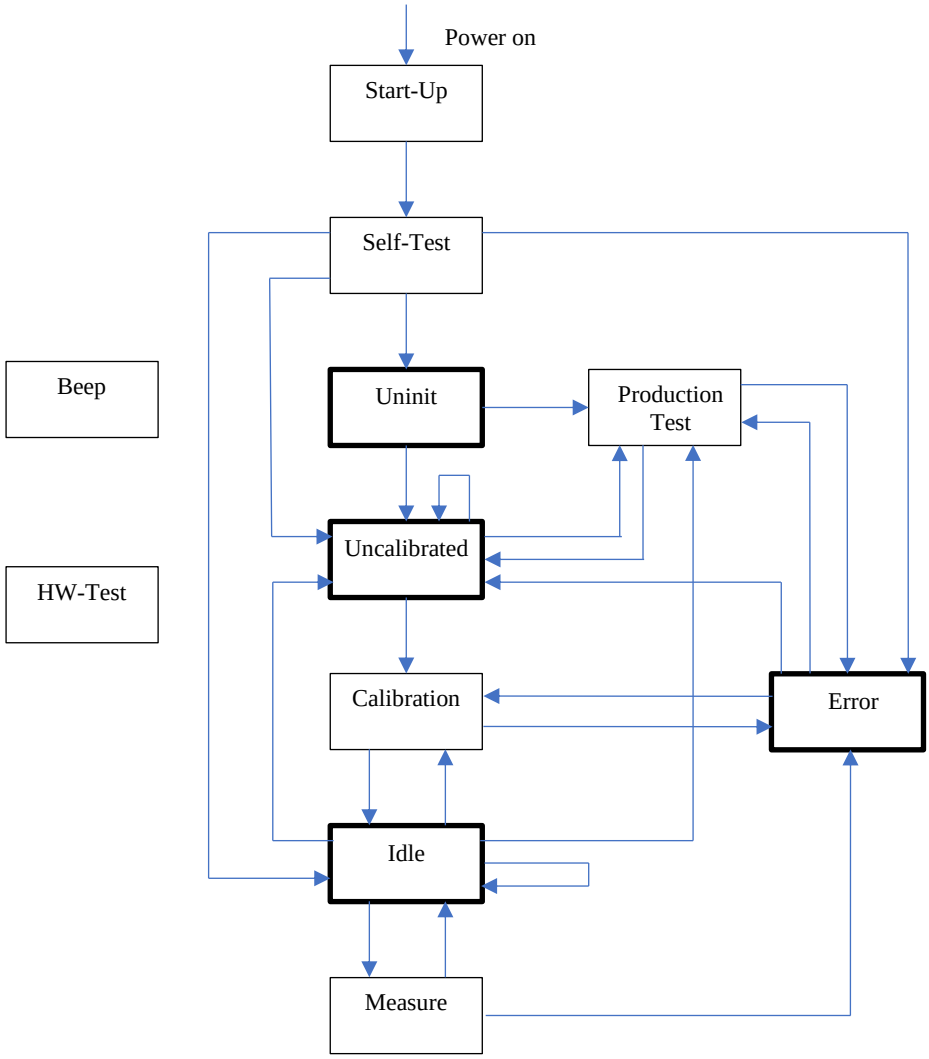

Figure 2: State Diagram

6.3 Commands

The command listed in Table 2 can be sent to the sensor. It is shown in the table in which state that each command is valid.

Table 2: List of commands

Command	Valid in state				Actions
	Uninit	Uncalibrated	Idle	Error	
Initialize	X	X	X	X	The sensor configuration is initialized to the default values (See Table 7). The sensor will be uncalibrated. The next state will be Uncalibrated.
Calibrate	-	X	X	X	A calibration is performed
Measure	-	-	X	-	A measurement is performed
Run Production Test	X	X	X	X	The production test will be performed
Beep	X	X	X	X	A sound is played for 5 seconds
Run Hardware Test	X	X	X	X	The hardware test will be performed
Restart Measurement Timer	-	-	X	-	The measurement timer is restarted
Set Safe Mode	-	X	X	X	Sets the sensor to Safe Mode. The password is saved in the configuration memory. The protection state is set to Unprotected.
Set Unsafe Mode	-	X	X	X	Sets the sensor to Unsafe Mode which is saved in the configuration memory. The protection state is set to Unprotected.
Write Info Data	-	X	X	X	The current contents of "Info 1", "Info 2" and "Info 3" are written to the configuration memory.
Set Advertise Mode Normal	-	X	X	X	Sets "Advertise Mode" to "Advertise Normal". The value is saved in the configuration memory.
Set Advertise Mode Off	-	X	X	X	Sets "Advertise Mode" to "Advertise Off". The value is saved in the configuration memory.
Erase Log Data	-	X	X	X	Erase the logging data in the external memory.
Start Logging	-	X	X	X	Starts the data logging. The value is saved in the configuration memory.
Stop Logging	-	X	X	X	Stops the data logging. The value is saved in the configuration memory.
Reset Log Read Pointer	-	X	X	X	Starts reading of the data logging memory. Initialized the log read pointer to the beginning of the data
Increment Log Read Pointer	-	X	X	X	Increments the log read pointer

6.4 Detailed Description

6.4.1 Supply Voltage Measurement

The supply voltage is measured each 10'th second.

6.4.2 Temperature Measurement

The temperature of the microprocessor is measured each 10'th second.

6.4.3 Power-on Timer

The power-on timer is updated each 10'th second.

6.4.4 The Production Test

To perform a production test, the sensor shall be placed horizontally on a foam pad and the digital outputs must be connected to the power supply through resistors, lamps or LED indicators. The following is tested:

1. The communication with the external memory
2. The exciter driver electronics
3. The accelerometer
4. The exciter with feedback through the accelerometer
5. The digital outputs
6. The configuration memory is tested and set to defaults.

6.4.5 Calibration

The calibration is performed as follows:

- The exciter power is determined by performing a number of measurements until the accelerometer signal (The RMS value) is above the threshold defined in "Factory Config" in Table 7.
- An error is reported if the accelerometer signal is too low or too high.
- A number of fluid level measurements are performed and the mean level is saved in the configuration memory. The calibration result can be read in "Calibration" in Table 7.
- The measurement is stored in the log if logging is enabled.
- The state of the digital outputs are updated.
- The measurement result is shown in "Measurement" in Table 7.

6.4.6 Measurement

A measurement is performed as follows:

- The background noise is measured.
- A fluid level measurement is performed.
- The state of the digital outputs are updated.
- The measurement is stored in the log if logging is enabled.
- The measurement result is shown in "Measurement" in Table 7.

6.4.7 The HW-Test

To perform a hardware test, the sensor may be located on a tank. The following is tested:

1. The communication with the external memory
2. The exciter driver electronics
3. The accelerometer
4. The exciter with feedback through the accelerometer

Note that test #4 may fail if the tank wall is too stiff.

6.4.8 Sensor Access Security

In order to prevent unauthorized write access to the sensor, a simple scheme with a password is implemented.

The sensor can be in two different modes with regards to security:

- Unsafe Mode
- Safe Mode

The current mode is stored in the configuration memory.

The sensor is initially in "Unsafe Mode". To switch to "Safe Mode", the user must first write a user-defined password to "Password" in Table 7 and then issue the command "Set Safe Mode".

Note: The password may not be 0.

In "Safe Mode", the sensor can be in two different states with regards to security:

- Protected State
- Unprotected State

In "Protected State", the GATT registers in Table 7 can be read but not written.

In "Unprotected State", the user has full access to the register.

The current security mode and state can be read in "Status" in Table 7.

Table 3: Security Overview

Security Mode	**Security State**	**Register access**
Unsafe Mode	Not applicable	Full access
Safe Mode	Unprotected State	Full access
Safe Mode	Protected State	Only read access

To set the sensor in "Safe Mode":

1. Write the desired password to the "Password" register
2. Write command "Set Safe Mode"
3. The sensor will save the password in the configuration memory and set "Safe Mode" and "Unprotected State"
4. The user has full access to the registers.
5. When the user disconnects the Bluetooth communication, the sensor will enter "Protected State"

To get access to a sensor that is in "Safe Mode":

1. The sensor is initially in "Protected State"
2. Write the password to the "Password" register
3. The sensor switches to "Unprotected State"
4. The user has full access to the registers.

To set the sensor in "Unsafe Mode":

1. The sensor is initially in "Protected State"
2. Write the password to the "Password" register
3. The sensor switches to "Unprotected State"
4. Write the command "Set Unsafe Mode"

To set the sensor in "Unsafe Mode" if the password has been lost by the user:

1. Power off the sensor
2. Interconnect the two digital outputs (They must not be connected to anything else)
3. Power on the sensor.
4. The sensor will be in "Unprotected State"
5. Write the command "Set Unsafe Mode"

6.4.9 Storage of User-Defined Data in the Sensor

There are three data blocks ("Info 1", "Info 2" and "Info 3") for storing user-defined data. The data can be in arbitrary format and is not used by the sensor. The user must first store data in the register(s) and then issue the command "Write Info Data"

6.4.10 Automatic Turn-Off of Bluetooth Communication

The Bluetooth communication can be turned off if there is no communication. This is controlled by the "Advertise Mode" which can be in two states (Current mode can be read in "Status" in Table 7)

- In "Advertise Mode Normal", the sensor works normally.
- In "Advertise Mode Off", the Bluetooth communication is turned off after 20 minutes if there is no communication.

The sensor power must be cycled to restart the Bluetooth communication.

6.4.11 Configuration Change

A configuration change is handled by the sensor as described in Table 4.

Table 4: Configuration Change

Register update	**Sensor Action**
Factory Config	The new values are saved in the configuration memory.
User Config	The new values are saved in the configuration memory. Change of ”Output 1 mode” or ”Output 2 mode” have immediate effect. Change of ”Measurement interval” will restart the measurement timer.
On/Off	The new value is saved in the configuration memory.
Password"	No effect in "Unsafe Mode" In "Safe Mode", the "Unprotected State" will be set if the previously written password is correct.
Info	No action

6.4.12 The measurement timer

The timer that determines the point of time for the next measurement works as follows:

- The minimum time interval is 10 seconds.
- The timer can be restarted by the command "Restart Measurement Timer".
- The timer is restarted when the time interval in ”User Config” is changed.
- When the timer expires, the measurement is performed after a delay which can be configured in ”Measurement Delay” in ”User Config” in Table 7.

6.4.13 The Digital Outputs

The digital outputs can separately be configured to be:

- Inactive (Always off)
- Active (Always on)
- Active when the fluid level is below the sensor.
- Active when the fluid level is above the sensor.

6.4.14 Measurement Data Logging

Measurement and calibration data can be logged to an area in the external non-volatile memory. Up to 1024 blocks of data can be stored.

The following information is stored in each data block:

- Point of time (From power-on)
- Measurement value (LMS value)
- Background noise (RMS mg)
- Status: Calibration or normal measurement
- Status: If the fluid level is above or below the sensor.

Perform the following steps to start the logging:

1) Write the command "Erase Log Data"
2) Write the command "Start Logging"

Perform the following steps to read out the data:

1) Write the command "Stop Logging"
2) Write the command "Reset Log Read Pointer"
3) Read 4 data blocks
4) Write the command "Increment Log Read Pointer" to advance to next 4 blocks of data.
5) Repeat steps 3) and 4) until all data has been read.

6.4.15 Error Handling

The following errors can be reported:

Table 5: General Errors (Bit masks)

Error	Occasion	Possible causes	Recommended User Action	Code
No error	-	-	-	0x00
Hardware error. See Table 6 for details	Self test, Production Test or HW Test	-	-	0x01
Too low sensor signal in relation to the configured minimum value in "Factory Config"	Calibration	• The sensor is faulty. • The tank wall is too thick or the sensor is located near a tank corner.	• Replace the sensor • Check the sensor location	0x08
Too high sensor signal in relation to the configured maximum value in "Factory Config"	Calibration	• The sensor is faulty. • The sensor is not affixed properly to the tank wall	• Replace the sensor • Re-mount the sensor	0x10
Reserved	-	-	-	0x02 0x04 0x20 0x40 0x80

Table 6: Hardware Errors (Bit masks)

Error	Occasion	Code
No error		0x00
Accelerometer error	Self-test, HW-Test, Production Test	0x01
Exciter driver error	Self-test, HW-Test, Production Test	0x02
Exciter driver error	Self-test, HW-Test, Production Test	0x04
Exciter error	Self-test, HW-Test, Production Test	0x08
Output 1 error	Production Test	0x10
Output 2 error	Production Test	0x20
Internal non-volatile memory error		0x40
External non-volatile memory error	Self-test, HW-Test, Production Test	0x80

7 BLUETOOTH PROTOCOL

Bluretooth version 5.1

7.1 Generic Attribute Profile (GATT)

7.1.1 GATT Device Information 0x180A

UUID	Description	Value
0x2A23	System ID	N/A, not used
0x2A24	Model Number String	"Gobius Pro"
0x2A25	Serial Number String	N/A, not used
0x2A26	Firmware Revision String	"2.1.1"
0x2A27	Hardware Revision String	"4E"
0x2A28	Software Revision String	"2.1.1"
0x2A29	Manufacturer Name String	"Gobius Sensor Tech"
0x2A50	PnP ID	N/A, not used

7.1.2 GATT Generic Access 0x1800

UUID	Description	Value
0x2A00	Device Name	"Gobius Pro"
0x2A01	Appearance	N/A, write only
0x2A04	Peripheral Preferred Connection Parameters	0x50 00 A0 00 00 00 E8 03 0x0050 = Minimum Connection Interval * 1.25 ms 0x00A0 = Maximum Connection Interval * 1.25 ms 0x0000 = Slave latency 0x03E8 = Connection Supervision Timeout Multiplier
0x2AA6	Central Address Resolution	0x01 = Address resolution is supported
0x2AC9	Resolvable Private Address	0x00 = Only Resolvable Private Addresses will be used as local addresses after bonding

7.1.3 GATT Generic Attribute 0x1801

UUID	Description	Value
-	-	-

7.1.4 GATT Custom Service

Data is organized as "big endian"

Table 7: GATT protocol

UUID	User Description	R/ W	Byte offset	Size [bytes]	Description	Default value
0xFFF1	Factory Config	R/W	--	10		
			0	2	Lower Accelerometer Limit (unit: mg RMS): Unsigned integer 16 bits	50
			2	2	Upper Accelerometer Limit (unit: mg RMS): Unsigned integer 16 bits	1000
			4	2	Desired accelerometer level (unit: mg RMS) when calibrating with an empty tank: Unsigned integer 16 bits	300
			6	2	Desired accelerometer level (unit: mg RMS) when calibrating with a full tank: Unsigned integer 16 bits	175
			8	1	Threshold in % when calibrated with an empty tank: Unsigned integer 8 bits	70
			9	1	Threshold in % when calibrated with a full tank: Unsigned integer 8 bits	140
0xFFF2	"User Config"	R/W	--	9		
			0	1	Calibration mode: 0x00 = Calibrate with empty tank 0x01 = Calibrate with full tank	0x00
			1	1	Output 1 mode: 0x00 = No activation 0x01 = Always activated 0x02 = Activate output when level is below sensor 0x03 = Activate output when level is above sensor	0x00
			2	1	Output 2 mode: 0x00 = No activation 0x01 = Always activated 0x02 = Activate output when level is below sensor 0x03 = Activate output when level is above sensor	0x00
			3	4	Measurement interval [s]: Integer (Minimum 10 s)	300
			7	2	Measurement delay [s]: Integer	0

UUID	User Description	R/W	Byte offset	Size [bytes]	Description	Default value
0xFFF3	"On/Off"	R/W	--	1		
			0	1	0x00 = Automatic measurement is off 0x01 = Automatic measurement is on	0x01
0xFFF4	"Command"	W	--	1		
			0	1	Command: 'b' (0x62, 98_{10}) = Beep 'c' (0x63, 99_{10}) = Calibrate 'i' (0x69, 105_{10}) = Initialize 'm' (0x6D, 109_{10}) = Measure 'p' (0x70, 112_{10}) = Run Production Test 'r' (0x72), 114_{10}) = Restart Measurement Timer 't' (0x74, 116_{10}) = Run Hardware Test 's' (0x73, 115_{10}) = Set Safe Mode 'u' (0x75, 117_{10}) = Set Unsafe Mode 'w' (0x77, 119_{10}) = Write Info Data 'n' (0x61), 97_{10}) = Set Advertise Mode Normal 'o' (0x6F), 111_{10}) = Set Advertise Mode Off 'e '(0x65, 101_{10}) = Erase Log Data 'x' (0x78, 120_{10}) = Start Logging 'y' (0x79, 121_{10}) = Stop Logging 'z' (0x7A, 122_{10}) = Reset Log Read Pointer 'j' (0x6A, 106_{10}) = Increment Log Read Pointer	--
0xFFF5	"Status"	R	--	14		
			0	1	State: 0x00 = Start-up 0x01 = Self-test 0x02 = Uninit 0x03 = Uncalibrated 0x04 = Calibration 0x05 = Idle 0x06 = Measure 0x07 = Error 0x08 = Production Test 0x09 = Beep 0x0A = HW-Test	N/A
			1	4	Time since power-on [s]	0
			5	1	General error code: See Table 5	0x00
			6	1	Hardware error code: See Table 6	0x00
			7	1	0 = Unsafe mode 1 = Safe mode	0
			8	1	0 = Unprotected 1 = Protected	0
			9	1	0 = Advertise Mode Normal 1 = Advertise Mode Off	0
			10	1	Log status bit-field 0x01 = Logging is on 0x02 = Log is full 0x04 = Log memory error	0
			11	1	Processor temperature: -128 to +127 °C	0

UUID	User Description	R/ W	Byte offset	Size [bytes]	Description	Default value
			12	2	Supply voltage [mV]	0
0xFFF6	Measurement	R	--	13		
			0	1	0x00 = Level is invalid (Not calibrated) 0x01 = Level is below sensor 0x02 = Level is above sensor	0
			1	4	Measurement LMS value	0
			5	4	Background noise level (unit mg)	0
			9	4	Time since measurement [s]	0
0xFFF7	Calibration	R	--	8		
			0	1	Calibration status: 0x00 = uncalibrated 0x01 = calibrated with empty tank 0x02 = calibrated with full tank	0x00
			1	4	Calibration LMS value (Integer)	0
			5	1	Calibration power 0-100 %	0
			6	2	Calibration RMS level (unit mg)	0
0xFFF8	"Password"	W	--	4		
			0	4	Password Unsigned integer 32 bits	N/A
0xFFF9	"Info 1"	R/W	--	20		
			0	20	Data "Info" part 1. ASCII or binary data.	0x20, 0x20, ...
0xFFFA	"Info 2"	R/W	--	20		
			0	20	Data "Info" part 2. ASCII or binary data.	0x20, 0x20, ...
0xFFFB	"Info 3"	R/W	--	20		
			0	20	Data "Info" part31. ASCII or binary data.	0x20, 0x20, ...
0xFFFC	"Logdata 1"	R	--	20		
			0	2	Number of log blocks 0..1024	0
			2	1	(Block 0) Status bit field: 0x00 = Block is empty 0x01 = Level is below sensor or 0x02 = Level is above sensor 0x04 = Calibration or 0x08 = Measurement	0
			3	2	(Block 0) Time stamp [s/10]	0
			5	4	(Block 0) Measurement LMS value	0
			9	2	(Block 0) Background noise RMS [mg]	0
			11	1	(Block 1) Status bit field:	0
			12	2	(Block 1) Time stamp [s/10]	0
			14	4	(Block 1) Measurement LMS value	0
			18	2	(Block 1) Background noise RMS [mg]	0

UUID	User Description	R/ W	Byte offset	Size [bytes]	Description	Default value
0xFFFD	"Logdata 2"	R	--	20		
			0	2	Log block index 0..1023	0
			2	1	(Block 2) Status bit field:	0
			3	2	(Block 2) Time stamp [s/10]	0
			5	4	(Block 2) Measurement LMS value	0
			9	2	(Block 2) Background noise RMS [mg]	0
			11	1	(Block 3) Status bit field:	0
			12	2	(Block 3) Time stamp [s/10]	0
			14	4	(Block 3) Measurement LMS value	0
			18	2	(Block 3) Background noise RMS [mg]	0