

# LPMS-USBAL

## Reference Manual

Version 1.2.7



© 2014 LP-RESEARCH

[www.lp-research.com](http://www.lp-research.com)

## I. INTRODUCTION

Welcome to the LP-RESEARCH Motion Sensor USB version with aluminum housing (LPMS-USBAL) User's Manual!

In this manual we will try to explain everything you need to know to set up the LPMS-USBAL hardware, install and use its software, as well as getting started with integrating the sensor within your own software project. We have put a lot of effort into making the LPMS-USBAL a great product, but we are always eager to improve and work on new developments. So, if you have any further question or have any comment regarding this manual please feel free to contact us anytime.

For more information on the LPMS-USBAL or other product series, please refer to the flyers, datasheets or user manuals, available from the LP-RESEARCH Inc. website at the following address: <http://www.lp-research.com>.

## II. TABLE OF CONTENTS

- I. INTRODUCTION.....2**
- II. TABLE OF CONTENTS .....3**
- III. REVISION HISTORY .....6**
- IV. DEVICE OVERVIEW .....7**
  - Measurement Output.....7
  - Technical Background .....7
  - Communication Methods.....8
  - Calibration .....8
  - Magnetic Field Distortion Compensation .....8
  - Application Areas .....8
- V. DEVICE SPECIFICATIONS .....9**
- VI. CONNECTOR CONFIGURATION.....10**
- VII. OPERATION ..... 11**
  - Powering Up and Operation Modes..... 11
  - Host Device Communication ..... 11
  - Data Acquisition ..... 12
    - Raw Sensor Data..... 12
    - Orientation Data..... 12
  - Filter Settings ..... 12
    - Filter Modes..... 13
    - Magnetometer Correction Setting ..... 14
    - Acceleration Compensation Setting..... 15
    - Gyroscope Threshold ..... 15
    - Gyroscope Auto-calibration Function ..... 16
    - Low Pass Filter Setting ..... 16
  - Trade-offs and Limitations..... 16
  - Calibration Methods ..... 17
    - Basic Gyroscope Calibration ..... 17

Advanced Gyroscope Calibration ..... 17

Magnetometer Calibration ..... 18

Accelerometer Calibration ..... 18

**VIII. COMMUNICATION PROTOCOL.....20**

    Establishing a Connection.....20

    Basic Protocol Introduction .....20

        GET Commands.....20

        SET Commands .....20

    LpBUS Protocol.....20

        Packet Format .....20

        Data Format in a Packet Data Field .....21

    Protocol Commands List.....22

        Acknowledged and Not-acknowledged Identifier .....22

        Firmware Update and In-Application-Programmer Upload Command.....23

        Configuration and Status Command .....23

        Mode Switching Command .....25

        Data Transmission Command.....26

        Register Value Save and Reset Command .....28

        Reference Setting and Offset Reset Command.....28

        Self-Test Command .....29

        IMU ID Setting Command.....29

        Gyroscope Settings Command.....29

        Accelerometer Settings Command.....31

        Magnetometer Settings Command.....32

        Filter Settings Command .....33

        CAN Bus Settings Command .....35

        Additional Settings.....36

**IX. OpenMAT.....40**

    Overview.....40

        Introduction.....40

        Application Installation.....40

    LpmsControl Software Operation.....41

        Overview.....41

        GUI Elements .....42

Device Discovery.....45

Connecting and Disconnecting a Device .....45

Sensor Parameter Adjustment.....45

Reset of Orientation and Reference Vectors .....46

How to Upload New Firmware.....47

The LpSensor Library.....47

Building Your Application .....47

Important Classes.....48

Example Code.....55

**X. MECHANICAL INFORMATION.....58**

### III. REVISION HISTORY

Date	Revision	Changes
01-Jan-2014	1.2.7	Initial release.

## IV. DEVICE OVERVIEW

### Measurement Output

The LP-RESEARCH Motion Sensor USB version with aluminum housing (LPMS-USBAL) is a wired inertial measurement unit. We designed the unit to be water proof so that it can be used in a wide range of industrial applications. The unit can measure orientation in 360 degrees about all three global axes. Measurements are taken digitally and transmitted to a data analysis system in the form of orientation quaternion or Euler angles. Whereas Euler angles are the traditional way of describing the orientation of an object, quaternion allow orientation measurement without encountering the so-called Gimbal's lock by using a four-element vector to express orientation around all axes without being limited by singularities. A more in-depth explanation of the quaternion output of the LPMS-USBAL will follow later on in this manual.

In addition, a pressure sensor is selectable on the LPMS-USBAL for some specific applications, such as GPS navigation enhancement, indoor and outdoor navigation, vertical velocity indication, etc.

### Technical Background

To measure the orientation of an object, the sensor internally uses three different sensing units. These units are micro-electro-mechanical system (MEMS) sensors that integrate complex mechanical and electronic capabilities on a miniaturized device. The units used in the LPMS-USBAL for orientation determination are a 3-axis gyroscope (detecting angular velocity), a 3-axis accelerometer (detecting the directing of the earth's gravity field) and a 3-axis magnetometer to measure the direction of the earth magnetic field. In principle orientation data about all three room axes can be determined by integrating the angular velocity data from the gyroscope. However through the integration step the error from the gyroscope measurements, although it might be very small, has an exponential influence on the calculation result. Therefore we correct the orientation data from the gyroscope with information from the accelerometer (roll and pitch angles) and magnetometer (yaw angle) to calculate orientation information of high accuracy and stability while guaranteeing fast sampling rates. We combine the orientation information from the three sensing units using a complementary filter in conjunction with an extended Kalman filter (EKF). The Kalman filter allows us to reduce the measurement error especially in case of regular movements (e.g. human gait analysis, vehicle vibration analysis etc.). Sampling rates of the sensor can be adjusted to up to 300 Hz internal measurement frequency.

## Communication Methods

Data can be transferred using a USB port. For communication protocols we rely on commonly used open standard protocols: a modified ModBus protocol (LpBUS)

## Calibration

For accurate operation the sensor needs to be calibrated. The calibration procedure includes the determination of the gyroscope data offset, gyroscope movement threshold, accelerometer misalignment, accelerometer offset, and magnetometer interference bias and gain. As the earth magnetic field can be distorted by metal or electromagnetic sources within the vicinity of the sensor, the re-calibration of the magnetic sensor and re-calculation of the magnetic reference vector of the sensor might be necessary when using the sensor in different location or under varying experiment environments. Later in this manual we will describe in detail the necessary calibration procedures and measures to be taken to guarantee the accuracy of the measurements taken by the sensor. We tried to automate the calibration procedures as far as possible inside the firmware of the sensor to make the usage as convenient as possible for the users.

## Magnetic Field Distortion Compensation

Additionally to the established method of compensating a distorted earth magnetic field by re-adjusting the magnetometer bias and gain, the LPMS-USBAL offers either completely switching off the magnetometer compensation of the gyroscope data or selectively switching the compensation modes between: dynamic, weak, medium and strong magnetometer correction, in places where an earth magnetic field outside the normal limits is being detected. We implemented a special algorithm that allows switching between operation with different modes of magnetometer compensation and without magnetometer compensation without any inconsistencies in the orientation detection. For further adjustment of the calibration parameters to the sensor environment a temperature sensor and pressure sensor have been optionally integrated on the LPMS-USBAL. Data from these indicators can be utilized by the user to correct raw data measurements from the LPMS-USBAL sub-sensors.

## Application Areas

The sensor can be effectively used in the field of virtual reality, navigation, robotics, or for measuring vehicle dynamics. If more than one sensor is used for a sensor network the motion of complex objects as necessary in cinematic motion capturing or animation movie production is possible.



## V. DEVICE SPECIFICATIONS

Please see the below table of the summary of sensor specification. Please refer to the section “X. MECHANICAL INFORMATION” for detail introduction of package layout.

Wired Interface	USB 2.0
Maximum baudrate	921.6kbit/s
Communication protocol	LpBUS
Size	40 x 34 x 17 mm
Weight	36 g
Orientation	360° about all axes
Resolution	< 0.05 °
Accuracy	< 2 °RMS (dynamic), < 0.5 °(static)
Accelerometer	3-axis, ±20 / ±40 / ±80 / ±160 m/s <sup>2</sup> 16 bits
Gyroscope	3-axis, ±250 / ±500 / ±2000 °/s, 16 bits
Magnetometer	3-axis, ±130 ~ ±810 uT, 16 bits
Pressure sensor	300 ~ 1100 hPa *
Data output format	Raw data / Euler angle / Quaternion
Sampling rate	0 ~ 300 Hz.
Latency	5ms
Power consumption	165 mW @ 5 V
Supply voltage (Vcc)	5 V DC
Connector	Micro USB, type B
Case material	Aluminum
Temperature range	- 40 ~ +80 °C
Software	C++ library for Windows, Java library for Android, LpmsControl utility software for Windows, Open Motion Analysis Toolkit (OpenMAT) for Windows

\*The pressure sensor is optional and can be added on LPMS-USBAL, which depends on the requirement from users. Please contact us for more information about this.

## VI. CONNECTOR CONFIGURATION

**Pin description:**

<b>Pin (USB port)</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Function</b>	<i>+5V</i>	<i>D-</i>	<i>D+</i>	<i>None</i>	<i>GND</i>

**Connector type:** Micro-USB type B female

## VII. OPERATION

### Powering Up and Operation Modes

The LPMS-USBAL sensor is switched on by connecting the sensor with a power source via the power lines of USB connector. There are 3 different modes for operation:

Mode	Description
<b>Command mode</b>	In command mode the functionality of the sensor is accessed command-by-command. Also data is transferred from the sensor to the user by a special command. This mode is suitable for making adjustments to the parameter settings of the sensor and synchronized data-transfer.
<b>Streaming mode (default)</b>	In streaming mode data is continuously sent from the sensor to the host. This mode is suitable for simple and high-speed data acquisition. Sensor parameters cannot be set in this mode. The data is sent out by LpBUS protocol.
<b>Sleep mode (reserved)</b>	Sleep mode is the power-saving state of the sensor. The sensor can be woken up by switching into streaming mode or command mode. In this mode no data can be read from the sensor.

Please see the table below for the available options depending on the user’s actions:

User action	Description
<b>Sensor power-on</b>	The sensor is now in LpBUS streaming mode and continuously sends data over the UART port using the LpBUS protocol.
<b>User sends data to sensor using LpBUS protocol</b>	Sensor is always waiting for “Goto command mode” instructions to switch to command mode over the USB port with LpBUS protocol. This is also the way the LpmsControl application communicates with the sensor.

### Host Device Communication

The USB interface of the LPMS-USBAL uses a serial-to-USB interface IC by the company FTDI. Drivers for this IC for all major operating systems can be downloaded from their website:

<http://www.ftdichip.com/FTDrivers.htm>. Generally there are two options for communicating with the FTDI chip.

1. By downloading a virtual com port driver (VCP): This driver allows you to see the LPMS-USBAL as COM port in your operating system. All communication is done using standard COM port access procedures. The default connection baudrate is 912.6Kbit/s, 8N1, hardware flow control.
2. By accessing the FTDI chip directly using a DLL library: FTDI offers a convenient library that allows users to communicate with their USB interface ICs.

## Data Acquisition

For data acquisition, all the communications with the device needs to be according to LpBUS protocol, which is introduced in section “*VIII. COMMUNICATION PROTOCOL*”.

### Raw Sensor Data

The LPMS-USBAL contains three MEMS sensors: A gyroscope, an accelerometer and a magnetometer. The raw data from all three of these sensors can be accessed by the host system based on LpBUS protocol. This data can be used to check if the current acquisition range of the sensors is sufficient and if the different sensors generate correct output. Users can also implement their own sensor fusion algorithms using the raw sensor data values. Sensor range and data sampling speed can be set by sending commands to the firmware. Details will be explained later on in this manual at section of “*VIII. COMMUNICATION PROTOCOL*”.

The LPMS-USBAL is calibrated by default, but it might be necessary to recalibrate the sensors if the measurement environment changes (e.g. different ambient electromagnetic field, strong temperature changes). Please refer to the following sections for a detailed introduction of sensor calibration methods.

### Orientation Data

The LPMS-USBAL has two orientation output formats: quaternion and Euler angle. As the Euler angle representation of orientation is subject to the Gimbal lock, we strongly recommend users to use the quaternion representation for the orientation calculation where possible.

## Filter Settings

Data from the three MEMS sensors is combined using an extended complementary Kalman filter (LP-Filter) to calculate the orientation data (orientation quaternion and Euler angles). To make the filter operate correctly, its measurement parameters need to be set in an appropriate way.

**Filter Modes**

First, the mode of the filter needs to be selected, which can be set by LpmsControl software or firmware commands. The following filter modes are available:

Filter mode	Description
<b>Gyroscope only</b>	Only the data from the gyroscope is used to calculate the orientation data output from the sensor. In this mode the orientation data can be calculated very quickly and with little noise. However, a strong drift of the acquired values can occur due to the inherent bias problem of gyroscope. This mode should therefore be only used for cases in which a frequent reset of the zero-angle position is allowed.
<b>Gyroscope + accelerometer (default mode)</b>	The orientation data that is calculated from the gyroscope is corrected by the accelerometer data based on quaternion representation. The accelerometer acquires accurate information about the roll and pitch orientation regarded with the earth gravity vector. The result of the correction is therefore orientation information that has very little error on the roll and pitch axis, the yaw axis however is still affected by the drift of the un-corrected gyroscope data.  This mode might be significant useful when there is a strong magnetic interference that can hardly be efficiently calibrated exiting around the sensor and only the roll and pitch information is interest to the users.
<b>Gyroscope + accelerometer + magnetometer</b>	Orientation data from the gyroscope that has been corrected by the accelerometer output as previously described is additionally modified by the direction of the earth magnetic field. This results in accurate orientation information for all three axes. This mode delivers good speed and accuracy for roll, pitch and yaw. In this mode, (un-calibrated) distortions of the earth magnetic will affect the accuracy of the orientation measurement.
<b>Accelerometer + magnetometer (Euler only)</b>	Orientation is directly calculated by the combination of the data from accelerometer and magnetometer using Euler representation. Therefore it has the singularity problem at certain orientations. Based on the information of gravity in the vertical frame and the geomagnetic field vector in horizontal frame, the roll, pitch and yaw angle can be achieved based on the readings from accelerometer and magnetometer. This mode is suitable for the application of small motion and limited magnetic distortion.
<b>Gyroscope +</b>	The orientation data that is calculated from the gyroscope is corrected by the

<b>accelerometer (Euler only)</b>	<p>accelerometer data based on Euler representation. Therefore it has the singularity problem at certain orientations. The accelerometer acquires accurate information about the roll and pitch orientation regarded with the earth gravity vector. The result of the correction is therefore orientation information that has very little error on the roll and pitch axis, the yaw axis however is still affected by the drift of the un-corrected gyroscope data.</p> <p>This mode might be significant useful when there is a strong magnetic interference that can hardly be efficiently calibrated exiting around the sensor and only the roll and pitch information is interest to the users.</p>
---------------------------------------	--

### Magnetometer Correction Setting

The amount by which the magnetometer corrects the orientation output of the sensor can be controlled by the magnetic correction settings. The following options are selectable through LpmsControl or directly through the firmware commands.

Parameter presets	Description
<b>Dynamic (default)</b>	The value “Dynamic” means the magnetic correction inside the filter is performed dynamically together with the acceleration data according to the variance of magnetic interference. This parameter set is suitable for the situation when the magnetic interference keeps changing.
<b>Weak</b>	The value “weak” means the magnetic correction inside the filter has little impact on the orientation output. Sensor orientation is calculated mainly from the acceleration / gyroscope data. This parameter set is suitable for situations when strong magnetic interference that cannot be compensated through calibration appear regularly.
<b>Medium</b>	With the “medium” correction setting the impact of the magnetometer readings is still relatively weak, but stronger than in “weak” mode. This mode should be suitable for environments with occasional irregular field distortions.
<b>Strong</b>	In this mode the magnetometer readings have a strong direct impact on the orientation output. It can be used in environments with a

	<p>calibrate-able constant field distortion or in “clean” fields (outside buildings with no metal parts or strong power sources in the vicinity of the sensor). Yaw orientation measurement in world coordinates will be most accurate in this mode.</p>
--	--

### Acceleration Compensation Setting

The amount by which the accelerometer corrects the orientation output of the sensor can be controlled by both linear acceleration and centripetal acceleration settings. The following options are selectable through LpmsControl or directly through the firmware commands.

#### Linear Acceleration Correction Settings

Parameter presets	Description
<b>Off</b>	There is no linear acceleration compensation for the sensor fusion in this mode. This parameter set is suitable for situations when there is no linear acceleration appears.
<b>Weak</b>	The value “weak” means the linear acceleration correction inside the filter has little dynamic impact on the orientation output. This parameter set is suitable for situations when linear acceleration appears regularly and slightly.
<b>Strong (default)</b>	The value “Strong” means the linear acceleration correction inside the filter has strong dynamic impact on the orientation output. This parameter set is suitable for situations when linear acceleration appears regularly and strongly.

#### Rotational Acceleration Correction Settings

Parameter presets	Description
<b>Disable</b>	There is no rotational acceleration compensation for the sensor fusion in this mode.
<b>Enable (default)</b>	There is dynamic rotational acceleration compensation for the sensor fusion in this mode.

### Gyroscope Threshold

The input from the gyroscope can be thresholded so that the sensor orientation data is only updated when the sensor is moved. This threshold is automatically determined during gyroscope calibration.

Parameter preset	Description
<b>Enable</b>	Switches gyroscope threshold on.
<b>Disable (default)</b>	Switches gyroscope threshold off.

### Gyroscope Auto-calibration Function

The selection of the following parameter values allows the users to enable or disable the gyroscope auto calibration function. In auto calibration mode the filter is automatically detects if the sensor is moving or not. If the sensor stays still for a certain time, the currently sampled gyroscope data will be used to re-calculate the gyroscope offset. This function is significant useful when the user is using the “Gyroscope only” filter mode, and most the time of the system stays still. Using this function will reduce the drift problem of the gyroscope.

Parameter preset	Description
<b>Enable (default)</b>	Switch gyroscope auto-calibration on.
<b>Disable</b>	Switch gyroscope auto-calibration off.

### Low Pass Filter Setting

The selection of the following parameter values allows the users to further implement a simple low pass filter for smoothing the output data after the sensor fusion algorithm. The low pass filter is based on the following formula:  $X_i = (1-a)*X_{i-1} + a*U_i$ , where  $a$  is the coefficient listed in the following table,  $U$  is the input.

Parameter preset	Description
<b>Off (default)</b>	No filter implemented.
<b>0.1</b>	$a = 0.1$
<b>0.05</b>	$a = 0.05$
<b>0.01</b>	$a = 0.01$
<b>0.005</b>	$a = 0.005$
<b>0.001</b>	$a = 0.001$

### Trade-offs and Limitations

Although we have put (and still do) a lot of effort into the design of the LPMS-USBAL, there are a few limitations of the sensor that need to be taken into account when using the device. The accuracy of the sensor is limited by the electronic noise level of the MEMS sensors used in the



LPMS-USBAL. Although the sensor data acquisition speeds for gyroscope, accelerometer and magnetometer are more than 500Hz, but the data output frequency of the whole system is limited to a certain frequency (up to 300Hz). The parameters of the filter that fuses the data from the gyroscope, magnetometer and accelerometer need to be adjusted well, in order to achieve measurements with maximum accuracy. Furthermore, in case the sensor is used in changing environments, the sensor occasionally might need to be re-calibrated. The greatest drawback of the measurement principle of the sensor certainly is its affectability by a deformed earth magnetic field (in the vicinity of hard / soft iron, electric motors etc.). In such situations the use of the filter mode and parameters of the filter must be well considered.

## Calibration Methods

### Basic Gyroscope Calibration

When the sensor is resting the output data of the gyroscope should be around zero. The raw data from the gyroscope sensor has a constant bias of a certain value. To determine this value please follow the following calibration procedure:

Step	Description
1	If it is not already switched on, power up the LPMS-USBAL device.
2	Put the sensor in a resting (non-moving) position.
3	Connect to the sensor.
4	Trigger the gyroscope calibration procedure either through a firmware command or using the “Calibrate gyroscope” function in LpmsControl software.
5	The gyroscope calibration will take around 30s. After that the gyroscope is calibrated, normal operation can be resumed.

Additionally to the gyroscope bias, the gyroscope threshold value will be adjusted during this calibration procedure. By default the use of the gyroscope threshold is disabled. It can be enabled by sending a firmware command or using the LpmsControl software. The gyro auto calibration function is enabled by default.

### Advanced Gyroscope Calibration

The gain and misalignment parameters of gyroscope can be further calibrated under the following instructions by expert users.

Step	Description
1	If it is not already switched on, power up the LPMS-USBAL device.

2	Put the sensor on a turntable which is placed horizontally.
3	Set the rotating rate of the turntable to 45rpm.
4	Trigger the gyroscope misalignment calibration procedure either through a firmware command or using the “Calibrate gyr. misalignment” function in LpmsControl software.
5	Following the guideline of pop out window, to set the x axis upwards, and start the turntable until the x axis calibration is finished
6	To set the y axis upwards, and start the turntable until the y axis calibration is finished
7	To set the z axis upwards, and start the turntable until the z axis calibration is finished
	After finishing the above procedures the gyroscope misalignment matrix and gain values will be re-calculated. This finishes the gyroscope advanced calibration.

### Magnetometer Calibration

During the magnetometer calibration procedure several parameters are to be determined: magnetometer bias and gain on the X, Y and Z-axis; length and direction of the geomagnetic field vector. In most environments the earth magnetic field is influenced by electromagnetic noise sources such as power lines, metal etc. As a result the magnetic field becomes de-centered and deformed. During the magnetometer calibration the amount of de-centering and deformed as well as the average length of the magnetic field vector is calculated. These parameters are tuned automatically using the calibration procedures in the LpmsControl software:

Step	Description
1	If it is not already switched on, power up the LPMS-USBAL device.
2	If it is not already connected, connect to the sensor.
3	Start the magnetometer calibration using the LpmsControl software.
4	Rotate the sensor around its yaw axis for 2~3 rotations.
5	Rotate the sensor around its pitch axis for 2~3 rotations.
6	Rotate the sensor around its roll axis for 2~3 rotations.
7	Rotate the sensor randomly to acquire data as much as possible from different directions.
8	The calibration procedure finished automatically after 30 seconds. After that the magnetometer has been calibrated.

### Accelerometer Calibration

The misalignment of the accelerometer relative to the casing of the LPMS-USBAL device is expressed by the so called misalignment matrix. Using the LpmsControl software this misalignment matrix can be calibrated by the user. In the mean time, the offsets of the accelerometer can be also evaluated. Whereas the usage of the LpmsControl software is explained in more detail in the “LpmsControl Software Operation” section, the calibration procedure consists of the following steps:

Step	Description
<b>1</b>	If it is not already switched on, power up the LPMS-USBAL device.
<b>2</b>	If it is not already connected, connect to the sensor.
<b>3</b>	Start the accelerometer misalignment calibration using the LpmsControl software. See “LpmsControl Software Operation” section.
<b>4</b>	Fix the sensor to a horizontal surface with the Z-axis pointing upwards.
<b>5</b>	Fix the sensor to a horizontal surface with the Z-axis pointing downwards.
<b>6</b>	Fix the sensor to a horizontal surface with the X-axis pointing upwards.
<b>7</b>	Fix the sensor to a horizontal surface with the X-axis pointing downwards.
<b>8</b>	Fix the sensor to a horizontal surface with the Y-axis pointing upwards.
<b>9</b>	Fix the sensor to a horizontal surface with the Y-axis pointing downwards.
<b>10</b>	After finishing the above procedures the accelerometer misalignment matrix and offset values will be re-calculated. This finishes the accelerometer calibration.

## VIII. COMMUNICATION PROTOCOL

### Establishing a Connection

After powering up the sensor by default continuously streams measurement data using the LpBUS protocol. For a short explanation of our LpBUS implementation please read further below. In this mode it is not necessary to send any commands to the sensor. The sensor will just send the measurement values non-stop over the USB port. Which values are sent, as well as the other measurement parameters can be set using the LpmControl application and then saved to the flash memory of the sensor. Please don't forget that the sensor needs to be powered down once after using LpmsControl to be returned into its default data streaming mode. Use this method, if you simply want to read data from the sensor.

### Basic Protocol Introduction

The communication packet has two basic command types, GET and SET, that are sent from a host (PC, mobile data logging unit etc.) to a client (LPMS-USBAL device). Later in this manual we will show a description of all supported commands to the sensor, their type, contained data etc.

#### GET Commands

Data from the client is read using GET requests. A GET request usually contains no data. The answer from the client to a GET request contains the requested data.

#### SET Commands

Data registers of the client are written using SET requests. A SET command from the host contains the data to be set. The answer from the client is an ACK command feedback for a successful write, or NACK command feedback for a failure to set the register occurred.

### LpBUS Protocol

#### Packet Format

All communication with the LPMS-USBAL works with a common protocol called LpBUS. The protocol is based on the industry standard MODBUS that we slightly adapted to be most suitable for our purpose. Each packet sent during the communication is based on this protocol, which is described in the following table:

Byte no.	Name	Description
0	Packet start (3Ah)	Mark of the beginning of a data packet.

<b>1</b>	OpenMAT ID byte 1	Contains the low byte of the OpenMAT ID of the sensor to be communicated with. The default value of this ID is 1. The host sends out a GET / SET request to a specific LPMS-USBAL sensor by using this ID, and the client answers to request also with the same ID. This ID can be adjusted by sending a SET command to the sensor firmware.
<b>2</b>	OpenMAT ID byte 2	High byte of the OpenMAT ID of the sensor.
<b>3</b>	Command no. byte 1	Contains the low byte of the command to be performed by the data transmission.
<b>4</b>	Command no. byte 2	High byte of the command number.
<b>5</b>	Packet data length byte 1	Contains the low byte of the packet data length to be transmitted in the packet data field.
<b>6</b>	Packet data length byte 2	High byte of the data length to be transmitted.
<b>x</b>	Packet data ( <i>n</i> bytes)	If data length <i>n</i> not equal to zero, $x = 6+1, 6+2 \dots 6+n$ . Otherwise $x = \text{none}$ . This data field contains the packet data to be transferred with the transmission if the data length not equals to zero, otherwise the data field is empty.
<b>7+n</b>	LRC byte 1	The low byte of LRC check-sum. To ensure the integrity of the transmitted data the LRC check-sum is used. It is calculated in the following way: LRC = sum(packet byte no. 1 to no. <i>x</i> ) The calculated LRC is usually compared with the LRC transmitted from the remote device. If the two LRCs are not equal, and error is reported.
<b>8+n</b>	LRC byte 2	High byte of LRC check-sum.
<b>9+n</b>	Termination byte 1	0Dh
<b>10+n</b>	Termination byte 2	0Ah

### Data Format in a Packet Data Field

Generally data is sent in little-endian format, low order byte first, high order byte last. Data in the data fields of a packet can be encoded in several ways, depending on the type of information to be transmitted. In the following we list the most common data types. Other command-specific data

types are explained in the command reference.

**32-bit integer values (LENGTH = 4 bytes)**

<b>Transmission order</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Integer word, byte number</b>	0 (LSB)	1	2	3 (MSB)

**32-bit integer 3-component vector (LENGTH = 12 bytes)**

<b>Transmission order</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Vector component 1, byte number</b>	0 (LSB)	1	2	3 (MSB)
<b>Transmission order</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>
<b>Vector component 2, byte number</b>	0 (LSB)	1	2	3 (MSB)
<b>Transmission order</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>
<b>Vector component 3, byte number</b>	0 (LSB)	1	2	3 (MSB)

**32-bit float value encoded as integer (LENGTH = 4 bytes)**

<b>Transmission order</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Integer-encoded float, byte number</b>	0 (LSB)	1	2	3 (MSB)

**32-bit float 3-component vector (LENGTH = 12 byte)**

<b>Transmission order</b>	<b>0</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Vector component 1, byte number</b>	0 (LSB)	1	2	3 (MSB)
<b>Transmission order</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>
<b>Vector component 2, byte number</b>	0 (LSB)	1	2	3 (MSB)
<b>Transmission order</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>
<b>Vector component 3, byte number</b>	0 (LSB)	1	2	3 (MSB)

## Protocol Commands List

If a user connects to LPMS-USBAL using LpBUS protocol, he can access the sensor functionality using the commands in the list below.

### Acknowledged and Not-acknowledged Identifier

<b>Command No. (decimal values)</b>	<b>Command description</b>
0	REPLY_ACK (acknowledged). Confirms a successful SET command.
1	REPLY_NACK (not-acknowledged) Reports an error during processing a SET

	command.
--	----------

**Firmware Update and In-Application-Programmer Upload Command**

2	<p>Start the firmware update process.</p> <p><b>IMPORTANT:</b> By not correctly uploading a firmware file the sensor might become in-operable. In normal cases please use the LpmsControl software to upload new firmware. Also please only use firmware packages that have been authorized by LP-RESEARCH.</p> <p><b>Packet data:</b> Firmware data</p> <p><b>Data format</b> Firmware binary file separated into 256 byte chunks for each update packet.</p> <p><b>Macro name:</b> UPDATE_FIRMWARE</p> <p><b>Response:</b> ACK (success) or NACK (error) for each transmitted packet.</p>
3	<p><b>“RESERVED”</b> This command is reserved by LP-RESEARCH.</p> <p>Start the in-application programmer (IAP) update process.</p> <p><b>Packet data:</b> IAP data</p> <p><b>Data format</b> IAP binary file separated into 256 byte chunks for each update packet.</p> <p><b>Macro name:</b> UPDATE_IAP</p> <p><b>Response:</b> ACK (success) or NACK (error) for each transmitted packet.</p>

**Configuration and Status Command**

4	<p>Get the current value of the configuration register of the sensor. The configuration word can ONLY be read. The different parameters are set by their respective SET commands. E.g. SET_TRANSMIT_DATA for defining which data is transmitted from the sensor.</p> <p><b>Packet data:</b> Configuration word. Each bit represents the state of one configuration parameter.</p> <p><b>Return format:</b> 32-bit integer</p> <table border="1" style="margin-left: 20px;"> <thead> <tr> <th style="text-align: center;">Bit</th> <th style="text-align: center;">Reported State / Parameter</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">0 - 2</td> <td>Stream frequency setting (see SET_STREAM_FREQ)</td> </tr> <tr> <td style="text-align: center;">3 - 8</td> <td>Reserved</td> </tr> <tr> <td style="text-align: center;">9</td> <td>Pressure data transmission enabled</td> </tr> </tbody> </table>	Bit	Reported State / Parameter	0 - 2	Stream frequency setting (see SET_STREAM_FREQ)	3 - 8	Reserved	9	Pressure data transmission enabled
Bit	Reported State / Parameter								
0 - 2	Stream frequency setting (see SET_STREAM_FREQ)								
3 - 8	Reserved								
9	Pressure data transmission enabled								

	<table border="1" data-bbox="632 264 1353 1348"> <tr><td><b>10</b></td><td>Magnetometer data transmission enabled</td></tr> <tr><td><b>11</b></td><td>Accelerometer data transmission enabled</td></tr> <tr><td><b>12</b></td><td>Gyroscope data transmission enabled</td></tr> <tr><td><b>13</b></td><td>Temperature output enabled</td></tr> <tr><td><b>14</b></td><td>Heave motion output enabled</td></tr> <tr><td><b>15</b></td><td>Reserved</td></tr> <tr><td><b>16</b></td><td>Angular velocity output enabled</td></tr> <tr><td><b>17</b></td><td>Euler angle data transmission enabled</td></tr> <tr><td><b>18</b></td><td>Quaternion orientation output enabled</td></tr> <tr><td><b>19</b></td><td>Output enabled</td></tr> <tr><td><b>20</b></td><td>Dynamic magnetometer correction enabled</td></tr> <tr><td><b>21</b></td><td>Linear acceleration output enabled</td></tr> <tr><td><b>22</b></td><td>Reserved</td></tr> <tr><td><b>23</b></td><td>Gyroscope threshold enabled</td></tr> <tr><td><b>24</b></td><td>Magnetometer compensation enabled</td></tr> <tr><td><b>25</b></td><td>Accelerometer compensation enabled</td></tr> <tr><td><b>26</b></td><td>Reserved</td></tr> <tr><td><b>27</b></td><td>Reserved</td></tr> <tr><td><b>28</b></td><td>Reserved</td></tr> <tr><td><b>29</b></td><td>Reserved</td></tr> <tr><td><b>30</b></td><td>Gyroscope auto-calibration enabled</td></tr> <tr><td><b>31</b></td><td>Reserved</td></tr> </table> <p><b>Macro name:</b> GET_CONFIG</p>	<b>10</b>	Magnetometer data transmission enabled	<b>11</b>	Accelerometer data transmission enabled	<b>12</b>	Gyroscope data transmission enabled	<b>13</b>	Temperature output enabled	<b>14</b>	Heave motion output enabled	<b>15</b>	Reserved	<b>16</b>	Angular velocity output enabled	<b>17</b>	Euler angle data transmission enabled	<b>18</b>	Quaternion orientation output enabled	<b>19</b>	Output enabled	<b>20</b>	Dynamic magnetometer correction enabled	<b>21</b>	Linear acceleration output enabled	<b>22</b>	Reserved	<b>23</b>	Gyroscope threshold enabled	<b>24</b>	Magnetometer compensation enabled	<b>25</b>	Accelerometer compensation enabled	<b>26</b>	Reserved	<b>27</b>	Reserved	<b>28</b>	Reserved	<b>29</b>	Reserved	<b>30</b>	Gyroscope auto-calibration enabled	<b>31</b>	Reserved
<b>10</b>	Magnetometer data transmission enabled																																												
<b>11</b>	Accelerometer data transmission enabled																																												
<b>12</b>	Gyroscope data transmission enabled																																												
<b>13</b>	Temperature output enabled																																												
<b>14</b>	Heave motion output enabled																																												
<b>15</b>	Reserved																																												
<b>16</b>	Angular velocity output enabled																																												
<b>17</b>	Euler angle data transmission enabled																																												
<b>18</b>	Quaternion orientation output enabled																																												
<b>19</b>	Output enabled																																												
<b>20</b>	Dynamic magnetometer correction enabled																																												
<b>21</b>	Linear acceleration output enabled																																												
<b>22</b>	Reserved																																												
<b>23</b>	Gyroscope threshold enabled																																												
<b>24</b>	Magnetometer compensation enabled																																												
<b>25</b>	Accelerometer compensation enabled																																												
<b>26</b>	Reserved																																												
<b>27</b>	Reserved																																												
<b>28</b>	Reserved																																												
<b>29</b>	Reserved																																												
<b>30</b>	Gyroscope auto-calibration enabled																																												
<b>31</b>	Reserved																																												
5	<p>Get the current value of the status register of the LPMS-USBAL device. The status word can ONLY be read.</p> <p><b>Packet data:</b> Status indicator. Each bit represents the state of one status parameter.</p> <p><b>Return format:</b> 32-bit integer</p> <table border="1" data-bbox="632 1702 1347 1993"> <thead> <tr> <th>Bit</th> <th>Indicated state</th> </tr> </thead> <tbody> <tr><td><b>0</b></td><td>COMMAND mode enabled</td></tr> <tr><td><b>1</b></td><td>STREAM mode enabled</td></tr> <tr><td><b>2</b></td><td>SLEEP mode enabled</td></tr> <tr><td><b>3</b></td><td>Gyroscope calibration on</td></tr> <tr><td><b>4</b></td><td>Reserved</td></tr> </tbody> </table>	Bit	Indicated state	<b>0</b>	COMMAND mode enabled	<b>1</b>	STREAM mode enabled	<b>2</b>	SLEEP mode enabled	<b>3</b>	Gyroscope calibration on	<b>4</b>	Reserved																																
Bit	Indicated state																																												
<b>0</b>	COMMAND mode enabled																																												
<b>1</b>	STREAM mode enabled																																												
<b>2</b>	SLEEP mode enabled																																												
<b>3</b>	Gyroscope calibration on																																												
<b>4</b>	Reserved																																												



	<b>5</b>	Gyroscope initialization failed
	<b>6</b>	Accelerometer initialization failed
	<b>7</b>	Magnetometer initialization failed
	<b>8</b>	Pressure sensor initialization failed
	<b>9</b>	Gyroscope unresponsive
	<b>10</b>	Accelerometer unresponsive
	<b>11</b>	Magnetometer unresponsive
	<b>12</b>	Flash write failed
	<b>13</b>	Reserved
	<b>14</b>	Set broadcast frequency failed
	<b>15-31</b>	reserved
<b>Macro name:</b>		GET_STATUS

**Mode Switching Command**

6	<p>Switch to command mode. In command mode the user can issue commands to the firmware to perform calibration, set parameters etc.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> GOTO_COMMAND_MODE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
7	<p>Switch to streaming mode. In this mode data is continuously streamed from the sensor, and all other commands cannot be performed until the sensor receives the GOTO_COMMAND_MODE command.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> GOTO_STREAM_MODE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
8	<p>Switch to sleep mode. The purpose of the sleep mode is to reduce the power consumption of the sensor. Once in sleep mode, no commands can be issued to the sensor until it is woken up by switching back into command mode or streaming mode.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> GOTO_SLEEP_MODE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>

**Data Transmission Command**

<p>9</p>	<p>Get the latest set of sensor data. The format of the sensor data depends on the transmission settings (SET_TRANSMIT_DATA). The currently set format can be retrieved with the sensor configuration word.</p> <p>IMPORTANT: In the current version of the firmware calibrated accelerometer data as well as calibrated magnetometer data will always be transmitted. As these values are necessary for the calibration of the sensor, they can at the moment not be switched off.</p> <p>This format is also used in streaming mode to continuously send data from the sensor to the host.</p> <p><b>Packet data:</b> Sensor data. The data always has the same order. Depending on the enabled transmission data, chunks are inserted or left out.</p> <p><b>Return format:</b> Raw sensor data chunk</p> <table border="1" data-bbox="632 840 1347 1765"> <thead> <tr> <th>Chunk number</th> <th>Data type</th> <th>Sensor data</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Float</td> <td>Timestamp (ms)</td> </tr> <tr> <td>2</td> <td>Float 3-vector</td> <td>Calibrated gyroscope data [deg/s]</td> </tr> <tr> <td>3</td> <td>Float 3-vector</td> <td>Calibrated accelerometer data [m/s<sup>2</sup>]</td> </tr> <tr> <td>4</td> <td>Float 3-vector</td> <td>Calibrated magnetometer data [μT]</td> </tr> <tr> <td>5</td> <td>Float 3-vector</td> <td>Angular velocity [deg/s]</td> </tr> <tr> <td>6</td> <td>Float 4-vector</td> <td>Orientation quaternion [normalized]</td> </tr> <tr> <td>7</td> <td>Float 3-vector</td> <td>Euler angle data [deg.]</td> </tr> <tr> <td>8</td> <td>Float 3-vector</td> <td>Linear acceleration data [m/s<sup>2</sup>]</td> </tr> <tr> <td>9</td> <td>Float</td> <td>Barometric pressure [mPa]</td> </tr> <tr> <td>10</td> <td>Float</td> <td>Heave motion [m] (if enabled)</td> </tr> </tbody> </table> <p><b>Macro name:</b> GET_SENSOR_DATA</p>	Chunk number	Data type	Sensor data	1	Float	Timestamp (ms)	2	Float 3-vector	Calibrated gyroscope data [deg/s]	3	Float 3-vector	Calibrated accelerometer data [m/s <sup>2</sup> ]	4	Float 3-vector	Calibrated magnetometer data [μT]	5	Float 3-vector	Angular velocity [deg/s]	6	Float 4-vector	Orientation quaternion [normalized]	7	Float 3-vector	Euler angle data [deg.]	8	Float 3-vector	Linear acceleration data [m/s <sup>2</sup> ]	9	Float	Barometric pressure [mPa]	10	Float	Heave motion [m] (if enabled)
Chunk number	Data type	Sensor data																																
1	Float	Timestamp (ms)																																
2	Float 3-vector	Calibrated gyroscope data [deg/s]																																
3	Float 3-vector	Calibrated accelerometer data [m/s <sup>2</sup> ]																																
4	Float 3-vector	Calibrated magnetometer data [μT]																																
5	Float 3-vector	Angular velocity [deg/s]																																
6	Float 4-vector	Orientation quaternion [normalized]																																
7	Float 3-vector	Euler angle data [deg.]																																
8	Float 3-vector	Linear acceleration data [m/s <sup>2</sup> ]																																
9	Float	Barometric pressure [mPa]																																
10	Float	Heave motion [m] (if enabled)																																
<p>10</p>	<p>Set the data that is transmitted from the sensor in streaming mode or when retrieving data through the GET_SENSOR_DATA command.</p> <p><b>Packet data:</b> Data selection indicator</p>																																	

	<p><b>Data format:</b> 32-bit integer. The flags to switch data chunks on (set the bit to 1) and off (set the bit to 0) are the same as in the configuration word (see SET_CONFIG).</p> <table border="1" data-bbox="592 409 1351 999"> <thead> <tr> <th>Bit</th> <th>Reported State / Parameter</th> </tr> </thead> <tbody> <tr> <td>9</td> <td>Pressure data transmission enabled</td> </tr> <tr> <td>10</td> <td>Magnetometer data transmission enabled</td> </tr> <tr> <td>11</td> <td>Accelerometer data transmission enabled</td> </tr> <tr> <td>12</td> <td>Gyroscope data transmission enabled</td> </tr> <tr> <td>13</td> <td>Temperature output enabled</td> </tr> <tr> <td>14</td> <td>Heave motion output enabled</td> </tr> <tr> <td>16</td> <td>Angular velocity output enabled</td> </tr> <tr> <td>17</td> <td>Euler angle data transmission enabled</td> </tr> <tr> <td>18</td> <td>Quaternion orientation output enabled</td> </tr> <tr> <td>19</td> <td>Altitude output enabled</td> </tr> <tr> <td>21</td> <td>Linear acceleration output enabled</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_TRANSMIT_DATA  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> Gyroscope, accelerometer, magnetometer and quaternion data.</p>	Bit	Reported State / Parameter	9	Pressure data transmission enabled	10	Magnetometer data transmission enabled	11	Accelerometer data transmission enabled	12	Gyroscope data transmission enabled	13	Temperature output enabled	14	Heave motion output enabled	16	Angular velocity output enabled	17	Euler angle data transmission enabled	18	Quaternion orientation output enabled	19	Altitude output enabled	21	Linear acceleration output enabled
Bit	Reported State / Parameter																								
9	Pressure data transmission enabled																								
10	Magnetometer data transmission enabled																								
11	Accelerometer data transmission enabled																								
12	Gyroscope data transmission enabled																								
13	Temperature output enabled																								
14	Heave motion output enabled																								
16	Angular velocity output enabled																								
17	Euler angle data transmission enabled																								
18	Quaternion orientation output enabled																								
19	Altitude output enabled																								
21	Linear acceleration output enabled																								
11	<p>Set the timing in which streaming data is sent to the host. Please note that high frequencies might be not practically applicable due to limitations of the communication interface. Check the current baudrate before setting this parameter.</p> <p><b>Packet data:</b> Update frequency identifier  <b>Format:</b> 32-bit integer</p> <table border="1" data-bbox="592 1413 1303 1856"> <thead> <tr> <th>Frequency (Hz)</th> <th>Identifier</th> </tr> </thead> <tbody> <tr> <td>5</td> <td>5</td> </tr> <tr> <td>10</td> <td>10</td> </tr> <tr> <td>30</td> <td>30</td> </tr> <tr> <td>50</td> <td>50</td> </tr> <tr> <td>100</td> <td>100</td> </tr> <tr> <td>200</td> <td>200</td> </tr> <tr> <td>300</td> <td>300</td> </tr> <tr> <td>500</td> <td>500</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_STREAM_FREQ  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> 100 Hz</p>	Frequency (Hz)	Identifier	5	5	10	10	30	30	50	50	100	100	200	200	300	300	500	500						
Frequency (Hz)	Identifier																								
5	5																								
10	10																								
30	30																								
50	50																								
100	100																								
200	200																								
300	300																								
500	500																								

12	<p>Get the current roll angle in radians.</p> <p><b>Packet data:</b> Roll angle</p> <p><b>Return format:</b> 32-bit integer coded float value.</p> <p><b>Macro name:</b> GET_ROLL</p>
13	<p>Get the current pitch angle in radians.</p> <p><b>Packet data:</b> Pitch angle</p> <p><b>Return format:</b> 32-bit integer coded float value.</p> <p><b>Macro name:</b> GET_PITCH</p>
14	<p>Get the current yaw angle in radians.</p> <p><b>Packet data:</b> Yaw angle</p> <p><b>Return format:</b> 32-bit integer coded float value.</p> <p><b>Macro name:</b> GET_YAW</p>

**Register Value Save and Reset Command**

15	<p>Write the currently set parameters to flash memory.</p> <p><b>Packet data:</b> None</p> <p><b>Macro name:</b> WRITE_REGISTERS</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
16	<p>Reset the LPMS parameters to factory default values. Please note that upon issuing this command your currently set parameters will be erased.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> RESTORE_FACTORY_VALUE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>

**Reference Setting and Offset Reset Command**

17	<p>Set the accelerometer and magnetometer reference vectors.</p> <p><b>Packet data:</b> None</p> <p><b>Macro name:</b> RESET_REFERENCE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
18	<p>Set the orientation offset (the value that is subtracted from the acquired orientation value</p>

	<p>after a measurement) to the currently measured orientation. This effectively resets the zero orientation of the sensor to the current orientation.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> SET_OFFSET</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
--	--

**Self-Test Command**

19	<p>Initiate the self-test. During the self test the sensor automatically rotates about the three room axes. To simulate realistic circumstances an artificial offset is applied to the magnetometer and the gyroscope values.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> SELF_TEST</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
----	---

**IMU ID Setting Command**

20	<p>Set the OpenMAT ID of the sensor.</p> <p><b>Packet data:</b> OpenMAT ID</p> <p><b>Data format:</b> 32-bit integer</p> <p><b>Macro name:</b> SET_IMU_ID</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 1</p>
21	<p>Get the ID (OpenMAT ID) of the device</p> <p><b>Packet data:</b> The ID of the IMU device</p> <p><b>Return format:</b> 32-bit integer</p> <p><b>Macro name:</b> GET_IMU_ID</p>

**Gyroscope Settings Command**

22	<p>Start the calibration procedure of the gyroscope sensor. Details of the gyroscope calibration procedure are described in the <i>Operation – Calibration Methods</i> section of this manual. The calibration takes about 5s.</p> <p><b>Packet data:</b> none</p> <p><b>Macro name:</b> START_GYR_CALIBRATION</p> <p><b>Response:</b> ACK (success) or NACK (error)</p>
23	<p>Enable or disable auto-calibration of the gyroscope.</p>

	<p><b>Packet data:</b> Gyroscope auto-calibration enable / disable identifier</p> <p><b>Format:</b> 32-bit integer</p> <table border="1" data-bbox="590 360 1110 510"> <thead> <tr> <th>State</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Disable</td> <td>0x00000000</td> </tr> <tr> <td>Enable</td> <td>0x00000001</td> </tr> </tbody> </table> <p><b>Macro name:</b> ENABLE_GYR_AUTOCAL</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> Disable</p>	State	Value	Disable	0x00000000	Enable	0x00000001		
State	Value								
Disable	0x00000000								
Enable	0x00000001								
24	<p>Enable or disable gyroscope threshold.</p> <p><b>Packet data:</b> Gyroscope threshold enable / disable identifier</p> <p><b>Format:</b> 32-bit integer</p> <table border="1" data-bbox="590 840 1110 990"> <thead> <tr> <th>State</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Disable</td> <td>0x00000000</td> </tr> <tr> <td>Enable</td> <td>0x00000001</td> </tr> </tbody> </table> <p><b>Macro name:</b> ENABLE_GYR_THRES</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> Disable</p>	State	Value	Disable	0x00000000	Enable	0x00000001		
State	Value								
Disable	0x00000000								
Enable	0x00000001								
25	<p>Set the current range of the gyroscope.</p> <p><b>Packet data:</b> Gyroscope range identifier</p> <p><b>Format:</b> 32-bit integer</p> <table border="1" data-bbox="590 1321 1303 1518"> <thead> <tr> <th>Range (deg/s)</th> <th>Identifier</th> </tr> </thead> <tbody> <tr> <td>250</td> <td>250</td> </tr> <tr> <td>500</td> <td>500</td> </tr> <tr> <td>2000</td> <td>2000</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_GYR_RANGE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 2000 deg/s</p>	Range (deg/s)	Identifier	250	250	500	500	2000	2000
Range (deg/s)	Identifier								
250	250								
500	500								
2000	2000								
26	<p>Get current gyroscope range.</p> <p><b>Packet data:</b> Gyroscope range indicator</p> <p><b>Return format:</b> 32-bit integer</p> <p><b>Macro name:</b> GET_GYR_RANGE</p>								

**Accelerometer Settings Command**

27	<p>Set the accelerometer bias.</p> <p><b>Packet data:</b> Accelerometer bias (X, Y, Z-axis)</p> <p><b>Format:</b> 32-bit integer encoded float 3-component vector</p> <p><b>Macro name:</b> SET_ACC_BIAS</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> (0.0, 0.0, 0.0)</p>										
28	<p>Get the current accelerometer bias vector.</p> <p><b>Packet data:</b> Accelerometer bias vector</p> <p><b>Return format:</b> 32-bit integer encoded float 3-component vector</p> <p><b>Macro name:</b> GET_ACC_BIAS</p>										
29	<p>Set the accelerometer alignment matrix.</p> <p><b>Packet data:</b> Alignment matrix</p> <p><b>Format:</b> 32-bit integer encoded float 3 x 3 matrix</p> <p><b>Macro name:</b> SET_ACC_ALIG</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 3x3 Identity matrix</p>										
30	<p>Get the current accelerometer alignment matrix.</p> <p><b>Packet data:</b> Accelerometer alignment matrix</p> <p><b>Return format:</b> 32-bit integer encoded float 3 x 3 matrix</p> <p><b>Macro name:</b> GET_ACC_ALIG</p>										
31	<p>Set the current range of the accelerometer.</p> <p><b>Packet data:</b> Accelerometer range identifier</p> <p><b>Format:</b> 32-bit integer</p> <table border="1" style="margin-left: 40px;"> <thead> <tr> <th>Range (g: 1 gravity)</th> <th>Identifier</th> </tr> </thead> <tbody> <tr> <td>2g</td> <td>2</td> </tr> <tr> <td>4g</td> <td>4</td> </tr> <tr> <td>8g</td> <td>8</td> </tr> <tr> <td>16g</td> <td>16</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_ACC_RANGE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 2g</p>	Range (g: 1 gravity)	Identifier	2g	2	4g	4	8g	8	16g	16
Range (g: 1 gravity)	Identifier										
2g	2										
4g	4										
8g	8										
16g	16										

32	<p>Get current accelerometer range.</p> <p><b>Packet data:</b> Accelerometer range indicator</p> <p><b>Return format:</b> 32-bit integer</p> <p><b>Macro name:</b> GET_ACC_RANGE</p>
----	--

**Magnetometer Settings Command**

33	<p>Set the current range of the magnetometer.</p> <p><b>Packet data:</b> Magnetometer range identifier</p> <p><b>Format:</b> 32-bit integer</p> <table border="1" style="margin-left: 40px;"> <thead> <tr> <th>Range</th> <th>Identifier</th> </tr> </thead> <tbody> <tr> <td>130 uT</td> <td>130</td> </tr> <tr> <td>190 uT</td> <td>190</td> </tr> <tr> <td>250 uT</td> <td>250</td> </tr> <tr> <td>400 uT</td> <td>400</td> </tr> <tr> <td>470 uT</td> <td>470</td> </tr> <tr> <td>560 uT</td> <td>560</td> </tr> <tr> <td>810 uT</td> <td>810</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_MAG_RANGE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 250 uT</p>	Range	Identifier	130 uT	130	190 uT	190	250 uT	250	400 uT	400	470 uT	470	560 uT	560	810 uT	810
Range	Identifier																
130 uT	130																
190 uT	190																
250 uT	250																
400 uT	400																
470 uT	470																
560 uT	560																
810 uT	810																
34	<p>Get current magnetometer range.</p> <p><b>Packet data:</b> Magnetometer range indicator (same as above)</p> <p><b>Return format:</b> 32-bit integer</p> <p><b>Macro name:</b> GET_MAG_RANGE</p>																
35	<p>Set the current hard iron offset vector.</p> <p><b>Packet data:</b> Hard iron offset values in uT</p> <p><b>Format:</b> 32-bit integer encoded 3-element float vector</p> <p><b>Macro name:</b> SET_HARD_IRON_OFFSET</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> (0.0, 0.0, 0.0)</p>																
36	<p>Get current hard iron offset vector.</p> <p><b>Packet data:</b> Hard iron offset values in uT</p> <p><b>Return format:</b> 32-bit integer encoded 3-element float vector</p>																



	<p><b>Macro name:</b> GET_HARD_IRON_OFFSET</p>
37	<p>Set the current soft iron matrix.</p> <p><b>Packet data:</b> Soft iron matrix values in uT</p> <p><b>Format:</b> 32-bit integer encoded 9-element (3x3) float matrix</p> <p><b>Macro name:</b> SET_SOFT_IRON_MATRIX</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> (1, 0, 0) (0, 1, 0) (0, 0, 1)</p>
38	<p>Get the current soft iron matrix.</p> <p><b>Packet data:</b> Soft iron matrix values in uT</p> <p><b>Return format:</b> 32-bit integer encoded 9-element (3x3) float matrix</p> <p><b>Macro name:</b> GET_SOFT_IRON_MATRIX</p>
39	<p>Set the current earth magnetic field strength estimate.</p> <p><b>Packet data:</b> Field estimate value in uT</p> <p><b>Format:</b> 32-bit integer encoded float</p> <p><b>Macro name:</b> SET_FIELD_ESTIMATE</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 50 uT</p>
40	<p>Get the current earth magnetic field strength estimate.</p> <p><b>Packet data:</b> Field estimate value in uT</p> <p><b>Return format:</b> 32-bit integer encoded float</p> <p><b>Macro name:</b> GET_FIELD_ESTIMATE</p>

**Filter Settings Command**

41	<p>Set the sensor filter mode.</p> <p><b>Packet data:</b> Mode identifier</p>
----	---

	<p><b>Format:</b> 32-bit integer</p> <table border="1" data-bbox="593 313 1252 945"> <thead> <tr> <th>Mode</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Gyroscope only</td> <td>0x00000000</td> </tr> <tr> <td>Accelerometer + gyroscope</td> <td>0x00000001</td> </tr> <tr> <td>Accelerometer+ gyroscope+ magnetometer</td> <td>0x00000002</td> </tr> <tr> <td>Accelerometer + Magnetometer (Euler angle based filtering)</td> <td>0x00000003</td> </tr> <tr> <td>Accelerometer + Gyroscope (Euler angle-based filtering)</td> <td>0x00000004</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_FILTER_MODE  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> Accelerometer + gyroscope</p>	Mode	Value	Gyroscope only	0x00000000	Accelerometer + gyroscope	0x00000001	Accelerometer+ gyroscope+ magnetometer	0x00000002	Accelerometer + Magnetometer (Euler angle based filtering)	0x00000003	Accelerometer + Gyroscope (Euler angle-based filtering)	0x00000004
Mode	Value												
Gyroscope only	0x00000000												
Accelerometer + gyroscope	0x00000001												
Accelerometer+ gyroscope+ magnetometer	0x00000002												
Accelerometer + Magnetometer (Euler angle based filtering)	0x00000003												
Accelerometer + Gyroscope (Euler angle-based filtering)	0x00000004												
42	<p>Get the currently selected filter mode.</p> <p><b>Packet data:</b> Filter mode identifier  <b>Return format:</b> 32-bit integer</p> <table border="1" data-bbox="630 1272 1289 1615"> <thead> <tr> <th>Mode</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Gyroscope only</td> <td>0x00000000</td> </tr> <tr> <td>Accelerometer + gyroscope</td> <td>0x00000001</td> </tr> <tr> <td>Accelerometer + gyroscope + magnetometer</td> <td>0x00000002</td> </tr> </tbody> </table> <p><b>Macro name:</b> GET_FILTER_MODE</p>	Mode	Value	Gyroscope only	0x00000000	Accelerometer + gyroscope	0x00000001	Accelerometer + gyroscope + magnetometer	0x00000002				
Mode	Value												
Gyroscope only	0x00000000												
Accelerometer + gyroscope	0x00000001												
Accelerometer + gyroscope + magnetometer	0x00000002												
43	<p>Set one of the filter parameter presets.</p> <p><b>Packet data:</b> Magnetometer correction strength preset identifier  <b>Format:</b> 32-bit integer</p> <table border="1" data-bbox="593 1848 1252 1993"> <thead> <tr> <th>Preset</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Dynamic</td> <td>0x00000000</td> </tr> <tr> <td>Strong</td> <td>0x00000001</td> </tr> </tbody> </table>	Preset	Value	Dynamic	0x00000000	Strong	0x00000001						
Preset	Value												
Dynamic	0x00000000												
Strong	0x00000001												

	<table border="1"> <tr> <td>Medium</td> <td>0x00000002</td> </tr> <tr> <td>Weak</td> <td>0x00000003</td> </tr> </table> <p><b>Macro name:</b> SET_FILTER_PRESET  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> Dynamic</p>	Medium	0x00000002	Weak	0x00000003						
Medium	0x00000002										
Weak	0x00000003										
44	<p>Get the currently magnetometer correction strength preset</p> <p><b>Packet data:</b> Magnetometer correction strength preset identifier  <b>Return format:</b> 32-bit integer</p> <table border="1"> <thead> <tr> <th>Correction strength</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Dynamic</td> <td>0x00000000</td> </tr> <tr> <td>Strong</td> <td>0x00000001</td> </tr> <tr> <td>Medium</td> <td>0x00000002</td> </tr> <tr> <td>Weak</td> <td>0x00000003</td> </tr> </tbody> </table> <p><b>Macro name:</b> GET_FILTER_PRESET</p>	Correction strength	Value	Dynamic	0x00000000	Strong	0x00000001	Medium	0x00000002	Weak	0x00000003
Correction strength	Value										
Dynamic	0x00000000										
Strong	0x00000001										
Medium	0x00000002										
Weak	0x00000003										

**CAN Bus Settings Command**

45	SetCAN stream format.This command has been deprecated.																		
46	<p>Set the CAN baudrate</p> <p><b>Packet data:</b> CAN communication baudrate  <b>Format:</b> 32-bit integer</p> <table border="1"> <thead> <tr> <th>Correction strength</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>10Kbit/s</td> <td>0x00000000</td> </tr> <tr> <td>20Kbit/s</td> <td>0x00000008</td> </tr> <tr> <td>50Kbit/s</td> <td>0x00000010</td> </tr> <tr> <td>125Kbit/s</td> <td>0x00000018</td> </tr> <tr> <td>250Kbit/s</td> <td>0x00000020</td> </tr> <tr> <td>500Kbit/s</td> <td>0x00000028</td> </tr> <tr> <td>800Kbit/s</td> <td>0x00000030</td> </tr> <tr> <td>1Mbit/s</td> <td>0x00000038</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_CAN_BAUDRATE  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> 1Mbit/s</p>	Correction strength	Value	10Kbit/s	0x00000000	20Kbit/s	0x00000008	50Kbit/s	0x00000010	125Kbit/s	0x00000018	250Kbit/s	0x00000020	500Kbit/s	0x00000028	800Kbit/s	0x00000030	1Mbit/s	0x00000038
Correction strength	Value																		
10Kbit/s	0x00000000																		
20Kbit/s	0x00000008																		
50Kbit/s	0x00000010																		
125Kbit/s	0x00000018																		
250Kbit/s	0x00000020																		
500Kbit/s	0x00000028																		
800Kbit/s	0x00000030																		
1Mbit/s	0x00000038																		

**Additional Settings**

47	Get the currently firmware version.
48	<p>Set gyroscope alignment bias</p> <p><b>Packet data:</b> Gyroscope alignment bias</p> <p><b>Format:</b> Float 3-vector</p> <p><b>Macro name:</b> SET_GYR_ALIGN_BIAS</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 1Mbit/s</p>
49	<p>Get gyroscope alignment bias</p> <p><b>Packet data:</b> Gyroscope alignment bias</p> <p><b>Return format:</b> Float 3-vector</p> <p><b>Macro name:</b> GET_GYR_ALIGN_BIAS</p>
50	<p>Set gyroscope alignment matrix</p> <p><b>Packet data:</b> Gyroscope alignment matrix</p> <p><b>Format:</b> Float 3x3 matrix</p> <p><b>Macro name:</b> SET_GYR_ALIGN_MATRIX</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> (1, 0, 0) (0, 1, 0) (0, 0, 1)</p>
51	<p>Get gyroscope alignment matrix</p> <p><b>Packet data:</b> Gyroscope alignment matrix</p> <p><b>Return format:</b> Float 3x3 matrix</p> <p><b>Macro name:</b> GET_GYR_ALIGN_MATRIX</p>
52	Reserved
53	Reserved
54	Reserved
55	Reserved
56	Reserved
57	Reserved
58	Reserved
59	Reserved
60	<p>Set raw data low-pass</p> <p><b>Packet data:</b> Low pass strength (1.0 is weakest / disabled)</p> <p><b>Format:</b> Float</p> <p><b>Macro name:</b> SET_RAW_DATA_LP</p>

	<p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> 1.0</p>																																
61	<p>Get raw data low-pass</p> <p><b>Packet data:</b> Low pass strength (1.0 is weakest / disabled)</p> <p><b>Return format:</b> Float</p> <p><b>Macro name:</b> GET_RAW_DATA_LP</p>																																
62	<p>Set CANOpen mapping</p> <p><b>Packet data:</b> CANOpen mapping</p> <p><b>Format:</b> The mapping data consists of 8 integer words. Each of these words represents the assignment of half a CANOpen transmission object / message (TPDO) to specific sensor data. In more detail:</p> <table border="1" data-bbox="632 936 1305 1525"> <thead> <tr> <th>Message name</th> <th>Position in configuration mapping message</th> </tr> </thead> <tbody> <tr> <td>TPDO 1 (msg. 0x180, bytes 0-3)</td> <td>0</td> </tr> <tr> <td>TPDO 1 (msg. 0x180, bytes 5-7)</td> <td>1</td> </tr> <tr> <td>TPDO 2 (msg. 0x280, bytes 0-3)</td> <td>2</td> </tr> <tr> <td>TPDO 2 (msg. 0x280, bytes 5-7)</td> <td>3</td> </tr> <tr> <td>TPDO 3 (msg. 0x380, bytes 0-3)</td> <td>4</td> </tr> <tr> <td>TPDO 3 (msg. 0x380, bytes 5-7)</td> <td>5</td> </tr> <tr> <td>TPDO 4 (msg. 0x480, bytes 0-3)</td> <td>6</td> </tr> <tr> <td>TPDO 4 (msg. 0x480, bytes 5-7)</td> <td>7</td> </tr> </tbody> </table> <p>Assignments work according to the following table:</p> <table border="1" data-bbox="632 1621 1305 1962"> <thead> <tr> <th>Sensor data</th> <th>Assignment index</th> </tr> </thead> <tbody> <tr> <td>Angular velocity X</td> <td>0</td> </tr> <tr> <td>Angular velocity Y</td> <td>1</td> </tr> <tr> <td>Angular velocity Z</td> <td>2</td> </tr> <tr> <td>Euler angle X</td> <td>3</td> </tr> <tr> <td>Euler angle Y</td> <td>4</td> </tr> <tr> <td>Euler angle Z</td> <td>5</td> </tr> </tbody> </table>	Message name	Position in configuration mapping message	TPDO 1 (msg. 0x180, bytes 0-3)	0	TPDO 1 (msg. 0x180, bytes 5-7)	1	TPDO 2 (msg. 0x280, bytes 0-3)	2	TPDO 2 (msg. 0x280, bytes 5-7)	3	TPDO 3 (msg. 0x380, bytes 0-3)	4	TPDO 3 (msg. 0x380, bytes 5-7)	5	TPDO 4 (msg. 0x480, bytes 0-3)	6	TPDO 4 (msg. 0x480, bytes 5-7)	7	Sensor data	Assignment index	Angular velocity X	0	Angular velocity Y	1	Angular velocity Z	2	Euler angle X	3	Euler angle Y	4	Euler angle Z	5
Message name	Position in configuration mapping message																																
TPDO 1 (msg. 0x180, bytes 0-3)	0																																
TPDO 1 (msg. 0x180, bytes 5-7)	1																																
TPDO 2 (msg. 0x280, bytes 0-3)	2																																
TPDO 2 (msg. 0x280, bytes 5-7)	3																																
TPDO 3 (msg. 0x380, bytes 0-3)	4																																
TPDO 3 (msg. 0x380, bytes 5-7)	5																																
TPDO 4 (msg. 0x480, bytes 0-3)	6																																
TPDO 4 (msg. 0x480, bytes 5-7)	7																																
Sensor data	Assignment index																																
Angular velocity X	0																																
Angular velocity Y	1																																
Angular velocity Z	2																																
Euler angle X	3																																
Euler angle Y	4																																
Euler angle Z	5																																

	<table border="1"> <tr><td>Lin. acceleration X</td><td>6</td></tr> <tr><td>Lin. acceleration Y</td><td>7</td></tr> <tr><td>Lin. acceleration Z</td><td>8</td></tr> <tr><td>Magnetometer X</td><td>9</td></tr> <tr><td>Magnetometer Y</td><td>10</td></tr> <tr><td>Magnetometer Z</td><td>11</td></tr> <tr><td>Quaternion W</td><td>12</td></tr> <tr><td>Quaternion X</td><td>13</td></tr> <tr><td>Quaternion Y</td><td>14</td></tr> <tr><td>Quaternion Z</td><td>15</td></tr> <tr><td>Accelerometer X</td><td>16</td></tr> <tr><td>Accelerometer Y</td><td>17</td></tr> <tr><td>Accelerometer Z</td><td>18</td></tr> </table> <p><b>Macro name:</b> SET_CAN_MAPPING  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> 0x00000007 00000006 00000005 00000004  00000003 00000002 00000001 00000000</p>	Lin. acceleration X	6	Lin. acceleration Y	7	Lin. acceleration Z	8	Magnetometer X	9	Magnetometer Y	10	Magnetometer Z	11	Quaternion W	12	Quaternion X	13	Quaternion Y	14	Quaternion Z	15	Accelerometer X	16	Accelerometer Y	17	Accelerometer Z	18
Lin. acceleration X	6																										
Lin. acceleration Y	7																										
Lin. acceleration Z	8																										
Magnetometer X	9																										
Magnetometer Y	10																										
Magnetometer Z	11																										
Quaternion W	12																										
Quaternion X	13																										
Quaternion Y	14																										
Quaternion Z	15																										
Accelerometer X	16																										
Accelerometer Y	17																										
Accelerometer Z	18																										
63	<p>Get CANOpen mapping</p> <p><b>Packet data:</b> CANOpen mapping  <b>Return format:</b> See command 62  <b>Macro name:</b> GET_CAN_MAPPING</p>																										
64	<p>Set CANOpen heartbeat frequency</p> <p><b>Packet data:</b> CANOpen heartbeat frequency  <b>Format:</b> Integer. In detail:</p> <table border="1"> <thead> <tr> <th>Heartbeat frequency</th> <th>Identifier</th> </tr> </thead> <tbody> <tr> <td>5Hz</td> <td>0x00000000</td> </tr> <tr> <td>1Hz</td> <td>0x00000001</td> </tr> <tr> <td>0.5Hz</td> <td>0x00000002</td> </tr> <tr> <td>0.2Hz</td> <td>0x00000003</td> </tr> <tr> <td>0.1Hz</td> <td>0x00000004</td> </tr> </tbody> </table> <p><b>Macro name:</b> SET_CAN_HEARTBEAT  <b>Response:</b> ACK (success) or NACK (error)  <b>Default value:</b> 0x00000000</p>	Heartbeat frequency	Identifier	5Hz	0x00000000	1Hz	0x00000001	0.5Hz	0x00000002	0.2Hz	0x00000003	0.1Hz	0x00000004														
Heartbeat frequency	Identifier																										
5Hz	0x00000000																										
1Hz	0x00000001																										
0.5Hz	0x00000002																										
0.2Hz	0x00000003																										
0.1Hz	0x00000004																										

65	<p>Get CAN heartbeat</p> <p><b>Packet data:</b> CANOpen heartbeat frequency</p> <p><b>Return format:</b> See command 64</p> <p><b>Macro name:</b> GET_CAN_HEARTBEAT</p>
66	<p>Reset sensor data timestamp to 0</p> <p><b>Packet data:</b> none</p> <p><b>Format:</b> none</p> <p><b>Macro name:</b> RESET_TIMESTAMP</p> <p><b>Response:</b> ACK (success) or NACK (error)</p> <p><b>Default value:</b> none</p>

## IX. OpenMAT

### Overview

#### Introduction

OpenMAT is the software package delivered with a LPMS device. The package contains the basic hardware device drivers for the sensors, a C++ library to easily access the functionality of the IMUs and also a network interface (OpenMAT network) that allows applications to communicate with each other to exchange sensor information. OpenMAT consists of the following components:

1. **LpSensor library:** OpenMAT applications above are based on the LpSensor library. This library contains classes that allow easy access to the functionality of the LPMS devices. Contained classes and their most important methods as well as usage examples are described further on in this chapter.
2. **LpmsControl application:** This application is used to control the basic LPMS device functionality. It can be used to connect to multiple sensors, adjust parameters and record sample data. Data is graphically represented as line graphs or as a 3D cube that changes orientation according to the data received from a sensor.  
  
PLEASE NOTE: LpmsControl is also used to do updates of the LPMS firmware. We will explain further details below. IMPORTANT: We recommend the users to use the high performance mode of a PC in order to guarantee the LpmsControl application performance.
3. **OpenMAT server:** The OpenMAT server manages the communication of applications on the OpenMAT network. Please contact LP-Research for examples of how to use the OpenMAT network.

OpenMAT is available as binary release and as source code release. If you would like to use the included applications as is, please use the binary release. This is suggested as the easiest way to start as it allows you to test the functionality of your sensor.

We also offer a source code release that allows you to re-compile or modify the code. In case you would like to include OpenMAT with your own applications it is recommended to take a look at the source code release.

#### Application Installation

Please follow the steps below to install the OpenMAT binary release. The binary release also includes the OpenMAT API pre-compiled for Windows 32-bit.



1. When you purchase one of our sensors the latest version of the library at the time is also contained on the included CD. Please be aware that development on OpenMAT is ongoing and therefore the version on the CD might become outdated. Therefore please check on our website for updates.
2. Start OpenMAT-x.x.x-Setup.exe (x.x.x being the latest version number).
3. Follow the displayed installation instructions.
4. Switch the LPMS device on.
5. Start LpmsControl from the OpenMAT entry in the start menu.
6. Check if your device is listed in the 'Discovered devices' list.
7. Mark the device you would like to connect to by clicking on it in the list and push the connect button.
8. After a few seconds you should be seeing data being streamed from your sensor.

## LpmsControl Software Operation

### Overview

The LpmsControl application allows users to control various aspects of the LPMS-USBAL sensor that can be used to:

- List all LPMS devices that are discovered in the system.
- Adjust the sensor parameters (sensor range etc.).
- Reset orientation and reference vectors.
- Initiate gyroscope and magnetometer calibration.
- Adjust the accelerometer misalignment matrix.
- Display the acquired data in real-time either as line graphs or a 3D cube.
- Record data from the sensors to a CSV data file.
- Upload new firmware and in-application-programming software to the sensor.

As LpmsControl is part of the open-source OpenMAT package its source code is available and can be modified by the user. Most parts of the code are documented, so that a user can also use parts of LpmsControl to write their own sensor control code.

## GUI Elements

### Application window

The screenshot shows the LPMS Control application window. At the top is the **Menu Bar** with options: Connect, Measurement, Calibration, OpenMAT, View, Expert. To the right is the **Tool Bar** with icons for connection, zoom, and data. The main interface is divided into a left sidebar for device configuration and a right area for data visualization. The sidebar includes sections for 'Connected devices' (showing status like 'OK' and 'started'), 'ID / Sampling rate', 'Range' (GYR, ACC, MAG), 'Filter', and 'CANopen'. The visualization area contains three stacked plots: 'Accelerometer' (top), 'Gyroscope (Gmag / a)' (middle), and 'Magnetometer (GUT)' (bottom). Each plot shows three data series (X, Y, Z) over 120 samples. Callouts point to the Menu Bar, Tool Bar, and the three plots.

### Menu Bar

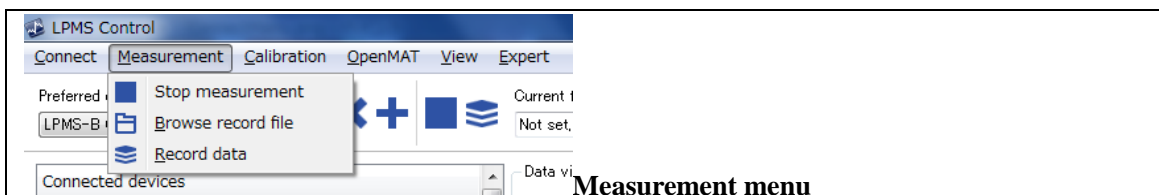
This close-up shows the **Connect menu** from the LPMS Control application. The menu items are: Connect (lightning bolt icon), Disconnect (X icon), Add / remove sensor (+ icon), and Exit program (power icon). The menu is currently open over the 'Connect' button in the application's tool bar.

**Connect** - Connects to sensor selected in 'Preferred devices' list.

**Disconnect** - Disconnects sensor currently selected in the 'Connected devices' list.

**Add / remove sensor** - add new discovered sensor from the "Discovered devices" list to "Preferred devices" list, or remove the currently selected sensor from "Preferred devices" list.

**Exit program** - Exits the application.

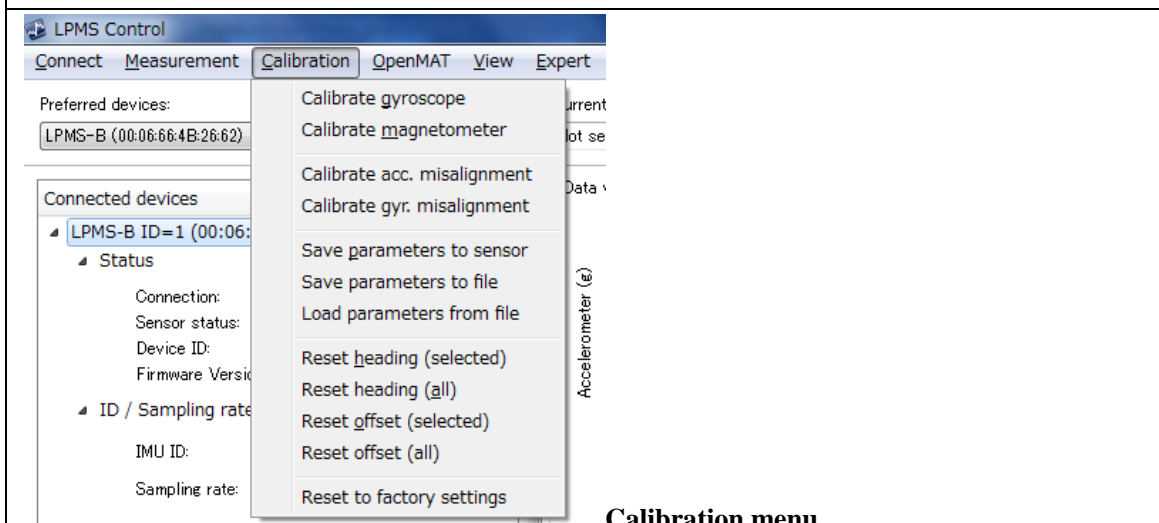


**Measurement menu**

**Stop measurement** - Starts or stops a measurement (depending if measurement is already in progress or not).

**Browse record file**– locates or create a csv format file for saving the recorded data.

**Record data** - Starts or stops data recording (depending if recording is already in progress or not).



**Calibration menu**

**Calibrate gyroscope** – Starts the gyroscope calibration (users should follow the instructions introduced in section “*Calibration Methods*”)

**Calibrate magnetometer** – Starts the magnetic calibration (users should follow the instructions introduced in section “*Calibration Methods*”). **IMPORTANT:** Euler angle transmission must be turned on for the magnetometer calibration to succeed.

**Calibrate acc. misalignment**– Starts the accelerometer calibration. (users should follow the instructions introduced in section “*Calibration Methods*”).

**Calibrate gyr. misalignment**– reserved by LP-RESEARCH.

**Save parameters to sensor** – Saves the current parameter settings and calibration results into the sensor flash.

**Save parameters to file** – Saves the current parameter settings and calibration results into a .txt file in your local host system.

**Load parameters from file** – Loads the previously saved calibration results in a local txt file into the sensor flash.

**Reset heading (selected)**– Sets the magnetometer and accelerometer reference of the LP-Filter of the currently selected sensor in the “*Connected devices*” list to the current measured magnetic

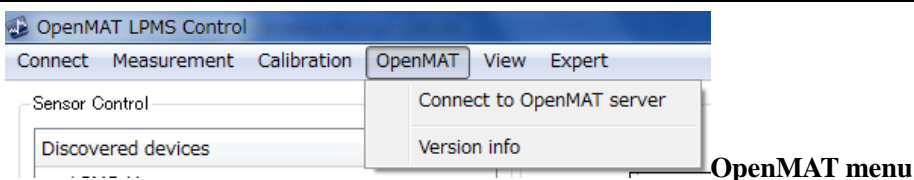
and acceleration vector. This function should be used after calibrating the magnetometer.

**Reset heading (all)**– Sets the magnetometer and accelerometer reference of the LP-Filter of all the sensors in the “Connected devices” list to the current measured magnetic and acceleration vector. This function should be used after calibrating the magnetometer.

**Reset offset (selected)** - Resets the current orientation of the selected sensor in the “Connected devices” list as zero-orientation. Further rotations will be the difference rotation between the zero-orientation and the currently measured orientation.

**Reset offset (all)** - Resets the current orientation of all the sensors in the “Connected devices” list as zero-orientation. Further rotations will be the difference rotation between the zero-orientation and the currently measured orientation.

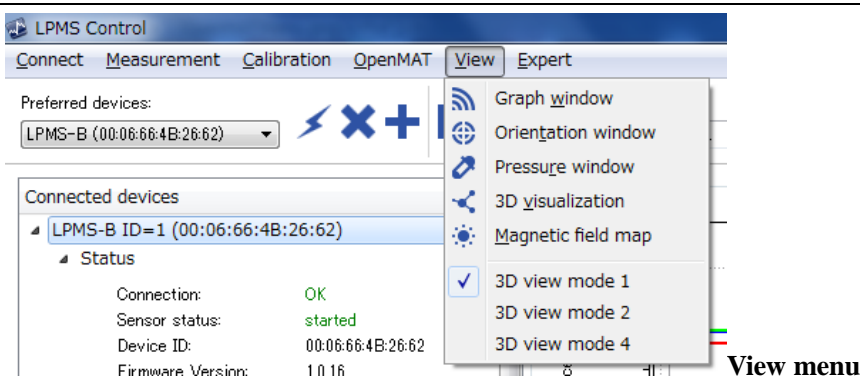
**Reset to factory settings** – Recovers the settings of all the connected sensors to the factory default values.



**OpenMAT menu**

**Connect to OpenMAT server** - This is used for human model simulator. The human model simulator allows the construction of 3D models with links and joints that can be associated with orientation sensors on the OpenMAT network. Momentarily this application is still in an experimental state. PLEASE NOTE: This function is reserved by LP-RESEARCH.

**Version info** – Version information of the LpmsControl software.



**View menu**

**Graph window**- Switches the middle graph window to show the raw sensor data.

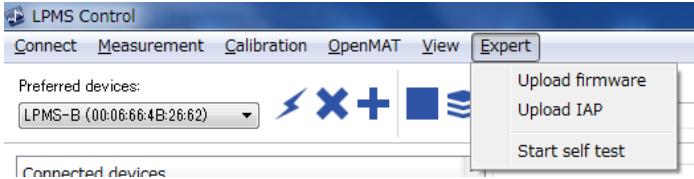
**Orientation window** – Switches the middle graph window to show the orientation data.

**Pressure window** - Switches the middle graph window to show the pressure data.

**3D visualization** - Switches the middle graph window to 3D cube view.

**Magnetic field map** – Switches the middle graph window to magnetic field map view.

- 3D view mode 1** - Switches the middle graph window to 1 window for one sensor 3D visualization.
- 3D view mode 2** - Switches the middle graph window to 2 windows for 2 sensors 3D visualization.
- 3D view mode 4** - Switches the middle graph window to 4 windows for 4 sensors 3D visualization.



**Expert menu**

- Upload firmware** - Starts firmware upload. **IMPORTANT:** Only upload authorized firmware that you received from LP-RESEARCH. Uploading a wrong firmware file can make the sensor in-operable.
- Upload IAP**- Uploads a new in-application programmer. **PLAESNOTE:** This is reserved by LP-RESEARCH and should not be used by user.
- Start self test**- Starts a self test for checking the basic functionalities of the sensor.

### Device Discovery

Discovery can be re-started by clicking on the “Scan devices” button. If the LPMS-USBAL device cannot be discovered by the initial discovering, please try to push the “Scan devices” button and search again.

**IMPORTANT:** After you plug-in the LPMS-USBAL to your PC, it takes a few seconds until Windows will correctly recognize the device. During that period the device might not be discoverable by the LpmsControl application.

### Connecting and Disconnecting a Device

To connect a LPMS-USBAL sensor click on the corresponding item in the “Preferred devices” list and click the “Connect” button. The sensor should now become listed in the “Connected devices” list. While establishing the connection, the ‘Connection status’ indicator shows ‘connecting...’. Once a connection has been successfully established, the connection status will change to ‘connected’. The sensor will start measuring automatically after connecting. Should the connection procedure fail for some reason, ‘failed’ will be displayed. If a successful connection is interrupted the connection status will change to ‘connection interrupted’.

### Sensor Parameter Adjustment

Sensor parameters can be adjusted using the item in the connected sensors list that corresponds to the target device. Using the drop down lists the following parameters can be set:

- **IMU ID:** The device OpenMAT ID.

- **Sampling rate:** System sampling frequency
- **GYR range:** Gyroscope measurement range
- **ACC range:** Accelerometer measurement range
- **MAG range:** Magnetometer measurement range
- **Filter mode:** The filter mode setting (see also the previous section “*Filter Settings*”)
- **Mag. correction:** The magnetic correction setting (see also the previous section “*Filter Settings*”)
- **Linear acc cor.:** The linear acceleration correction setting (see also the previous section “*Filter Settings*”)
- **Rotational acc cor.:** The linear rotational correction setting (see also the previous section “*Filter Settings*”)
- **Gyr. threshold:** To enable or disable the gyroscope threshold function (see also the previous section “*Filter Settings*”)
- **Gyr. autocalibration:** To enable or disable the gyroscope auto calibration function (see also the previous section “*Filter Settings*”)
- **Low-pass filter:** To set up the coefficient of the low pass filter (see also the previous section “*Filter Settings*”)
- **CAN baudrate:** Selects the baudrate used for CAN bus communication.
- **CANopen heartbeat:** Selects the frequency with which the CANOpen heartbeat is transmitted from the sensor.
- **TPDO 0 – 4 data setting:** Selects the data to be transmitted via the CANOpen TPDOs. Angular velocity, orientation in Euler angles, orientation quaternion, linear acceleration and raw accelerometer and magnetometer data can be sent.
- **Selected data:** check the data types you want to acquire.

Parameter adjustments are normally only persistent until the sensor is switched off. You can permanently save the newly adjusted parameters to the LPMS flash memory by selecting “Save parameters to sensor” in the “Calibration” menu of LpmsControl.

### Reset of Orientation and Reference Vectors

The offset of the orientation measured by the sensor can be set to the currently acquired orientation by clicking on the “Reset offset” functions of LpmsControl. The newly reported orientation data will be the orientation difference between this zero-orientation and the un-adjusted (raw) orientation measurement.

The accelerometer and magnetometer reference vector is reset by clicking on the “Reset heading” function of LpmsControl. Before resetting the heading reference, PLEASE DO complete the

magnetic calibration. While initiating the heading reference reset, point the y axis of the sensor roughly in north direction and hold the x-y plane of the sensor parallel to the ground.

**IMPORTANT:** The adjustment of the heading reference vectors is very important for accurate orientation measurements. The sensor will be delivered to you in a pre-calibrated state. However, as the direction of the earth magnetic field slightly varies at different place, it might be necessary to reset the reference. To save the new heading reference after a successful reset, select “Save parameters to sensor” function of LpmsControl. Normally the setting of the heading reference vectors when done accurately only needs to be done once.

### How to Upload New Firmware

**IMPORTANT:** Please follow the following steps carefully when you are updating the sensor firmware. Any mistake operation might result in a failure of firmware update and disable sensor functionality.

1. Start your current LpmsControl software.
2. Connect to the sensor you would like to update.
3. Choose the “Save parameters to file” function from the calibration menu of LpmsControl to save the current sensor calibration results into a .txt file in your local host system.
4. Select “Upload firmware” function in the “Expert” menu.
5. Click OK and select the new firmware file. Be careful that you select the right file which should be named as LpmsUSBALFirmwareX.X.X.bin by LP-RESEARCH.
6. Wait for the upload process to finish. It should take around 30 seconds. At around 15s the green LED on the sensor should begin to blink rapidly.
7. Disconnect from the sensor and exit LpmsControl.
8. Now install the new LpmsControl application. The previous LpmsControl application does not need to be un-installed.
9. Start LpmsControl and connect to your sensor.
10. Choose the “Load parameters fromfile” function from the calibration menu of LpmsControl to recover the previous sensor calibration results.
11. Choose the “Save parameters tosensor” function from the calibration menu of LpmsControl to save the previous sensor calibration results into sensor flash.
12. The whole procedure is done. Make sure everything works as expected. If there is anything unexpected, please contact LP-RESEARCH by Email: [info@lp-research.com](mailto:info@lp-research.com).

## The LpSensor Library

### Building Your Application

The LpSensor library contains classes that allow a user to integrate LPMS devices into their own

applications. The library is a Windows 32-bit C++ library for MS Visual C++ (express) 2010. Should you require a binary for the library for other operating systems or 64-bit applications, please contact LP-RESEARCH. Compiling applications that use the LpSensor library requires the following components:

Header files (usually in C:/OpenMAT/include)

<b>LpmsSensorManagerI.h</b>	Contains the interface for the LpmsSensorManager class.
<b>LpmsSensorI.h</b>	Contains the interface for the LpmsSensor class
<b>ImuData.h</b>	Structure for containing output data from a LPMS device
<b>LpmsDefinitions.h</b>	Macro definitions for accessing LPMS
<b>DeviceListItem.h</b>	Contains the class definition for an element of a LPMS device list

LIB files (usually in C:/OpenMAT/lib/x86)

<b>LpSensorD.lib</b>	LpSensor library (Debug version)
<b>LpSensor.lib</b>	LpSensor library (Release version)

DLL files (usually in C:/OpenMAT/lib/x86)

<b>LpSensorD.dll</b>	LpSensor library (Debug version)
<b>LpSensor.dll</b>	LpSensor library (Release version)

**PCANBasic.dll** PeakCAN library DLL for CAN interface communication. This file is only needed, if you use a PeakCAN interface to communicate with LPMS-CU.

**ftd2xx.dll** The FTDI library to communicate with an LPMS over USB.

To compile the application please do the following:

1. Include LpmsSensorManagerI.h before you access any LpSensor classes.
2. Add LpSensor.lib (or LpSensorD.lib if you are compiling in debug mode) to the list of linked libraries for your application.
3. Make sure that you set a path to LpSensor.dll / LpSensorD.dll, PCANBasic.dll and ftd2xx.dll reside so that the runtime file of your application can access them.

## Important Classes

### SensorManager

The sensor manager class wraps a number of LpmsSensor instances into one class, handles device discovery and device polling. For user applications the following methods are most commonly used. Please refer to the interface file SensorManagerI.h for more information.



IMPORTANT: An instance of `LpmsSensor` is returned by the static function `LpmsSensorManagerFactory()`. See the example listing in the next section for more information how to initialize a `LpmsSensorManager` object.

<b>Method name</b>	<b>SensorManager (void)</b>
<b>Parameters</b>	none
<b>Returns</b>	SensorManager object
<b>Description</b>	Constructor of a SensorManager object.

<b>Method name</b>	<b>LpSensor* addSensor(int mode, string deviceId)</b>								
<b>Parameters</b>	<p><b>mode</b> The device type to be connected. The following device types are available:</p> <table border="1" data-bbox="671 893 1350 1093"> <thead> <tr> <th>Macro</th> <th>Device type</th> </tr> </thead> <tbody> <tr> <td>DEVICE_LPMS_B</td> <td>LPMS-B</td> </tr> <tr> <td>DEVICE_LPMS_C</td> <td>LPMS-CU (CAN mode)</td> </tr> <tr> <td>DEVICE_LPMS_U</td> <td>LPMS-CU (USB mode)</td> </tr> </tbody> </table> <p><b>deviceId</b> Device ID of the LPMS device. The ID is equal to the OpenMAT ID (initially set to 1, user definable).</p>	Macro	Device type	DEVICE_LPMS_B	LPMS-B	DEVICE_LPMS_C	LPMS-CU (CAN mode)	DEVICE_LPMS_U	LPMS-CU (USB mode)
Macro	Device type								
DEVICE_LPMS_B	LPMS-B								
DEVICE_LPMS_C	LPMS-CU (CAN mode)								
DEVICE_LPMS_U	LPMS-CU (USB mode)								
<b>Returns</b>	Pointer to LpSensor object.								
<b>Description</b>	Adds a sensor device to the list of devices administered by the SensorManager object.								
<b>Method name</b>	<b>void removeSensor(LpSensor *sensor)</b>								
<b>Parameters</b>	<b>sensor</b> Pointer to LpSensor object that is to be removed from the list of sensors. The call to <code>removeSensor</code> frees the memory associated with the LpSensor object.								
<b>Returns</b>	none								
<b>Description</b>	Removes a device from the list of currently administered sensors.								

<b>Method name</b>	<b>void listDevices(std::vector&lt;DeviceListItem&gt; *v)</b>
<b>Parameters</b>	<b>*v</b> Pointer to a vector containing DeviceListItem objects with information about LPMS devices that have been discovered by the method.
<b>Returns</b>	None
<b>Description</b>	Lists all connected LPMS devices. The device discovery runs in a

	seperate thread.For Bluetooth devices should take several seconds to be added to the devicelist. CAN bus and USB devices should be added after around 1s.
--	---

**LpmsSensor**

This is a class to access the specific functions and parameters of an LPMS. The most commonly used methods are listed below. Please refer to the interface file LpmSensorI.h for more information.

<b>Method name</b>	<b>void run(void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Starts the data acquisition procedure.

<b>Method name</b>	<b>void pause(void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Pauses the data acquisition procedure.

<b>Method name</b>	<b>int getSensorStatus(void)</b>	
<b>Parameters</b>	None	
<b>Returns</b>	Sensor state identifier:	
	<b>Macro</b>	<b>Sensor state</b>
	SENSOR_STATUS_PAUSED	Sensor is currently paused.
	SENSOR_STATUS_RUNNING	Sensor is currently acquiring data.
	SENSOR_STATUS_CALIBRATING	Sensor is currently calibrating.
	SENSOR_STATUS_ERROR	Sensor has detected an error.
	SENSOR_STATUS_UPLOADING	Sensor is currently receiving new firmware data.
<b>Description</b>	Retrieves the current sensor status.	

<b>Method name</b>	<b>int getConnectionStatus(void)</b>
<b>Parameters</b>	None

<b>Returns</b>	Connection status identifier:	
	Macro	Sensor state
	SENSOR_CONNECTION_CONNECTED	Sensor is connected.
	SENSOR_CONNECTION_CONNECTING	Connection is currently being established.
	SENSOR_CONNECTION_FAILED	Attempt to connect has failed.
	SENSOR_CONNECTION_INTERRUPTED	Connection has been interrupted.
<b>Description</b>	Retrieves the current connection status.	

<b>Method name</b>	<b>void startResetReference (void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Resets the current accelerometer and magnetometer reference. Please see the ‘Operation’ chapter for details on the reference vector adjustment procedure.

<b>Method name</b>	<b>void startCalibrateGyro (void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Starts the calibration of the sensor gyroscope.

<b>Method name</b>	<b>void startCalibrateMag (void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Starts the calibration of the LPMS magnetometer.

<b>Method name</b>	<b>CalibrationData* getConfigurationData (void)</b>
<b>Parameters</b>	None
<b>Returns</b>	Pointer to CalibrationData object.
<b>Description</b>	Retrieves the CalibrationData structure containing the configuration parameters of the connected LPMS.

<b>Method name</b>	<b>bool setConfigurationPrm (int parameterIndex, int</b>
--------------------	--

parameter)																															
<b>Parameters</b>	<p><b>parameterIndex</b>            The parameter to be adjusted.</p> <p><b>parameter</b>                    The new parameter value.</p> <p>Supported parameterIndex identifiers:</p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>PRM_OPENMAT_ID</td> <td>Sets the current OpenMAT ID.</td> </tr> <tr> <td>PRM_FILTER_MODE</td> <td>Sets the current filter mode.</td> </tr> <tr> <td>PRM_PARAMETER_SET</td> <td>Changes the current filter preset.</td> </tr> <tr> <td>PRM_GYR_THRESHOLD_ENABLE</td> <td>Enables / disables the gyroscope threshold.</td> </tr> <tr> <td>PRM_MAG_RANGE</td> <td>Modifies the current magnetometer sensor range.</td> </tr> <tr> <td>PRM_ACC_RANGE</td> <td>Modifies the current accelerometer sensor range.</td> </tr> <tr> <td>PRM_GYR_RANGE</td> <td>Modifies the current gyroscope range.</td> </tr> </tbody> </table> <p>Supported parameter identifiers for each parameter index:</p> <p><b>PRM_OPENMAT_ID</b> Integer ID number between 1 and 255.</p> <p><b>PRM_FILTER_MODE</b></p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>FM_GYRO_ONLY</td> <td>Only gyroscope</td> </tr> <tr> <td>FM_GYRO_ACC</td> <td>Gyroscope + accelerometer</td> </tr> <tr> <td>FM_GYRO_ACC_MAG_NS</td> <td>Gyroscope + accelerometer + magnetometer</td> </tr> </tbody> </table> <p><b>PRM_PARAMETER_SET</b></p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>LPMS_FILTER_PRM_SET_1</td> <td>Magnetometer correction “dynamic” setting.</td> </tr> <tr> <td>LPMS_FILTER_PRM_SET_2</td> <td>Strong</td> </tr> </tbody> </table>	Macro	Description	PRM_OPENMAT_ID	Sets the current OpenMAT ID.	PRM_FILTER_MODE	Sets the current filter mode.	PRM_PARAMETER_SET	Changes the current filter preset.	PRM_GYR_THRESHOLD_ENABLE	Enables / disables the gyroscope threshold.	PRM_MAG_RANGE	Modifies the current magnetometer sensor range.	PRM_ACC_RANGE	Modifies the current accelerometer sensor range.	PRM_GYR_RANGE	Modifies the current gyroscope range.	Macro	Description	FM_GYRO_ONLY	Only gyroscope	FM_GYRO_ACC	Gyroscope + accelerometer	FM_GYRO_ACC_MAG_NS	Gyroscope + accelerometer + magnetometer	Macro	Description	LPMS_FILTER_PRM_SET_1	Magnetometer correction “dynamic” setting.	LPMS_FILTER_PRM_SET_2	Strong
	Macro	Description																													
	PRM_OPENMAT_ID	Sets the current OpenMAT ID.																													
	PRM_FILTER_MODE	Sets the current filter mode.																													
	PRM_PARAMETER_SET	Changes the current filter preset.																													
	PRM_GYR_THRESHOLD_ENABLE	Enables / disables the gyroscope threshold.																													
	PRM_MAG_RANGE	Modifies the current magnetometer sensor range.																													
	PRM_ACC_RANGE	Modifies the current accelerometer sensor range.																													
	PRM_GYR_RANGE	Modifies the current gyroscope range.																													
	Macro	Description																													
FM_GYRO_ONLY	Only gyroscope																														
FM_GYRO_ACC	Gyroscope + accelerometer																														
FM_GYRO_ACC_MAG_NS	Gyroscope + accelerometer + magnetometer																														
Macro	Description																														
LPMS_FILTER_PRM_SET_1	Magnetometer correction “dynamic” setting.																														
LPMS_FILTER_PRM_SET_2	Strong																														

	<table border="1"> <tr> <td>LPMS_FILTER_PRM_SET_3</td> <td>Medium</td> </tr> <tr> <td>LPMS_FILTER_PRM_SET_4</td> <td>Weak</td> </tr> </table>	LPMS_FILTER_PRM_SET_3	Medium	LPMS_FILTER_PRM_SET_4	Weak												
LPMS_FILTER_PRM_SET_3	Medium																
LPMS_FILTER_PRM_SET_4	Weak																
	<p><b>PRM_GYR_THRESHOLD_ENABLE</b></p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>IMU_GYR_THRESH_DISABLE</td> <td>Enable gyr. threshold</td> </tr> <tr> <td>IMU_GYR_THRESH_ENABLE</td> <td>Disable gyr. threshold</td> </tr> </tbody> </table>	Macro	Description	IMU_GYR_THRESH_DISABLE	Enable gyr. threshold	IMU_GYR_THRESH_ENABLE	Disable gyr. threshold										
Macro	Description																
IMU_GYR_THRESH_DISABLE	Enable gyr. threshold																
IMU_GYR_THRESH_ENABLE	Disable gyr. threshold																
	<p><b>PRM_GYR_RANGE</b></p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>GYR_RANGE_250DPS</td> <td>Gyr. Range = 250 deg./s</td> </tr> <tr> <td>GYR_RANGE_500DPS</td> <td>Gyr. Range = 500 deg./s</td> </tr> <tr> <td>GYR_RANGE_2000DPS</td> <td>Gyr. Range = 2000 deg./s</td> </tr> </tbody> </table>	Macro	Description	GYR_RANGE_250DPS	Gyr. Range = 250 deg./s	GYR_RANGE_500DPS	Gyr. Range = 500 deg./s	GYR_RANGE_2000DPS	Gyr. Range = 2000 deg./s								
Macro	Description																
GYR_RANGE_250DPS	Gyr. Range = 250 deg./s																
GYR_RANGE_500DPS	Gyr. Range = 500 deg./s																
GYR_RANGE_2000DPS	Gyr. Range = 2000 deg./s																
	<p><b>PRM_ACC_RANGE</b></p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>ACC_RANGE_2G</td> <td>Acc. range = 2g</td> </tr> <tr> <td>ACC_RANGE_4G</td> <td>Acc. range = 4g</td> </tr> <tr> <td>ACC_RANGE_8G</td> <td>Acc. range = 8g</td> </tr> <tr> <td>ACC_RANGE_16G</td> <td>Acc. range = 16g</td> </tr> </tbody> </table>	Macro	Description	ACC_RANGE_2G	Acc. range = 2g	ACC_RANGE_4G	Acc. range = 4g	ACC_RANGE_8G	Acc. range = 8g	ACC_RANGE_16G	Acc. range = 16g						
Macro	Description																
ACC_RANGE_2G	Acc. range = 2g																
ACC_RANGE_4G	Acc. range = 4g																
ACC_RANGE_8G	Acc. range = 8g																
ACC_RANGE_16G	Acc. range = 16g																
	<p><b>PRM_MAG_RANGE</b></p> <table border="1"> <thead> <tr> <th>Macro</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>MAG_RANGE_130UT</td> <td>Mag. range = 130uT</td> </tr> <tr> <td>MAG_RANGE_190UT</td> <td>Mag. range = 190uT</td> </tr> <tr> <td>MAG_RANGE_250UT</td> <td>Mag. range = 250uT</td> </tr> <tr> <td>MAG_RANGE_400UT</td> <td>Mag. range = 400uT</td> </tr> <tr> <td>MAG_RANGE_470UT</td> <td>Mag. range = 470uT</td> </tr> <tr> <td>MAG_RANGE_560UT</td> <td>Mag. range = 560uT</td> </tr> <tr> <td>MAG_RANGE_810UT</td> <td>Mag. range = 810uT</td> </tr> </tbody> </table>	Macro	Description	MAG_RANGE_130UT	Mag. range = 130uT	MAG_RANGE_190UT	Mag. range = 190uT	MAG_RANGE_250UT	Mag. range = 250uT	MAG_RANGE_400UT	Mag. range = 400uT	MAG_RANGE_470UT	Mag. range = 470uT	MAG_RANGE_560UT	Mag. range = 560uT	MAG_RANGE_810UT	Mag. range = 810uT
Macro	Description																
MAG_RANGE_130UT	Mag. range = 130uT																
MAG_RANGE_190UT	Mag. range = 190uT																
MAG_RANGE_250UT	Mag. range = 250uT																
MAG_RANGE_400UT	Mag. range = 400uT																
MAG_RANGE_470UT	Mag. range = 470uT																
MAG_RANGE_560UT	Mag. range = 560uT																
MAG_RANGE_810UT	Mag. range = 810uT																
<b>Returns</b>	None																
<b>Description</b>	Sets a configuration parameter.																
<b>Method name</b>	<code>bool getConfigurationPrm(int parameterIndex, int *parameter)</code>																

<b>Parameters</b>	<p><b>parameterIndex</b>      The parameter to be adjusted.</p> <p><b>parameter</b>              Pointer to the retrieved parameter value.</p> <p>See setConfigurationPrm method for an explanation of supported parameter indices and parameters.</p>
<b>Returns</b>	None
<b>Description</b>	Retrieves a configuration parameter.

<b>Method name</b>	<b>void resetOrientation(void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Resets the orientation offset of the sensor.

<b>Method name</b>	<b>void saveCalibrationData(void)</b>
<b>Parameters</b>	None
<b>Returns</b>	None
<b>Description</b>	Starts saving the current parameter settings to the sensor flash memory.

<b>Method name</b>	<b>virtual void getCalibratedSensorData(float g[3], float a[3], float b[3])</b>
<b>Parameters</b>	<p><b>g[0..2]</b>      Calibrated gyroscope data (x, y, z-axis).</p> <p><b>a[0..2]</b>      Calibrated accelerometer data (x, y, z-axis).</p> <p><b>b[0..2]</b>      Calibrated magnetometer data (x, y, z-axis).</p>
<b>Returns</b>	None
<b>Description</b>	Retrieves calibrated sensor data (gyroscope, accelerometer, magnetometer).

<b>Method name</b>	<b>virtual void getQuaternion(float q[4])</b>
<b>Parameters</b>	<b>q[0..3]</b> Orientation quaternion (qw, qx, qy, qz)
<b>Returns</b>	None
<b>Description</b>	Retrieves the 3d orientation quaternion.

<b>Method name</b>	<b>virtual void getEulerAngle(float r[3])</b>
<b>Parameters</b>	<b>r[0..2]</b> Euler angle vector (around x, y, z-axis)
<b>Returns</b>	None
<b>Description</b>	Retrieves the currently measured 3d Euler angles.

<b>Method name</b>	<b>virtual void getRotationMatrix(float M[3][3])</b>
<b>Parameters</b>	<b>M[0..2][0..2]</b> Rotations matrix (row i=0..2, column j=0..2)
<b>Returns</b>	None
<b>Description</b>	Retrieves the current rotation matrix.

### Example Code

#### Connecting to the an LPMS-CU device

1	<code>#include "LpmsSensorI.h"</code>
2	<code>#include "LpmsSensorManagerI.h"</code>
3	
4	<code>main()</code>
5	<code>{</code>
6	<code>    // Get a LpmsSensorManager instance</code>
7	<code>    LpmsSensorManagerI* manager = SensorManagerFactory();</code>
8	
9	<code>    // Connect to LPMS-CU sensor with address A123456</code>
10	<code>    LpmsSensorI* lpms = manager-&gt;addSensor(DEVICE_LPMS_U, "A123456");</code>
11	
12	<code>    while(1) {</code>
13	<code>        float q[4];</code>
14	
15	<code>        // Read quaternion data</code>
16	<code>        lpms-&gt;getQuaternion(q);</code>
17	
18	<code>        // Do something with the data</code>
19	<code>        // ..</code>
20	<code>    }</code>
21	
22	<code>    // After doing the work, remove the initialized sensor</code>
23	<code>    sm-&gt;removeSensor(lpms);</code>
24	
25	<code>    // Delete LpmsSensorManager object</code>
26	<code>    delete manager;</code>
27	<code>}</code>

**Setting and Retrieval of Sensor Parameters**

1	<code>/* Setting a sensor parameter. */</code>
2	<code>lpmsDevice-&gt;setParameter(PRM_ACC_RANGE, LPMS_ACC_RANGE_8G);</code>
3	
4	<code>/* Retrieving a sensor parameter. */</code>
5	<code>int p;</code>
6	<code>lpmsDevice-&gt;setParameter(PRM_ACC_RANGE, &amp;p);</code>

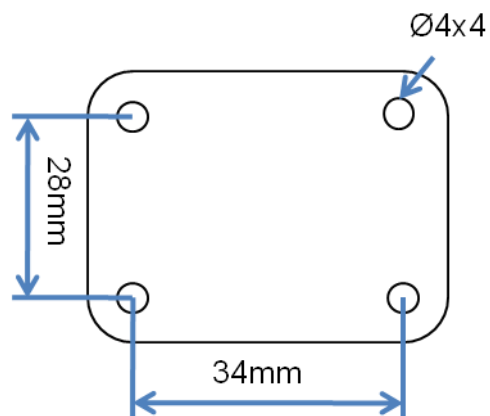
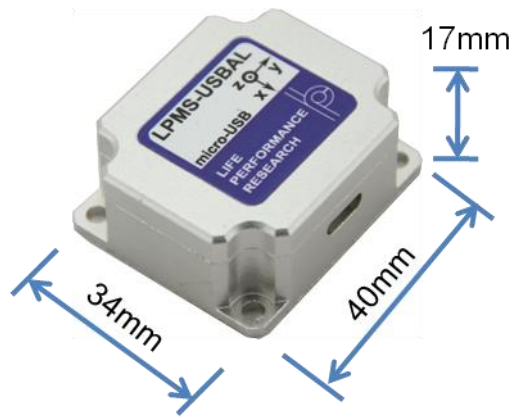
**Sensor and Connection Status Inquiry**

1	<code>/* Retrieves current sensor status */</code>
2	<code>int status = getSensorStatus();</code>
3	
4	<code>switch (status) {</code>
5	<code>case SENSOR_STATUS_RUNNING:</code>
6	<code>    std::cout &lt;&lt; "Sensor is running." &lt;&lt;std::endl;</code>
7	<code>break;</code>
8	
9	<code>case SENSOR_STATUS_PAUSED:</code>
10	<code>    std::cout &lt;&lt; "Sensor is paused." &lt;&lt;std::endl;</code>
11	<code>break;</code>
12	<code>}</code>
13	
14	<code>status = lpmsDevice-&gt;getConnectionStatus();</code>
15	
16	<code>switch (status) {</code>
17	<code>case SENSOR_CONNECTION_CONNECTING:</code>
18	<code>    std::cout &lt;&lt; "Sensor is currently connecting." &lt;&lt;std::endl;</code>
19	<code>break;</code>
20	
21	<code>case SENSOR_CONNECTION_CONNECTED:</code>
22	<code>    std::cout &lt;&lt; "Sensor is connected." &lt;&lt;std::endl;</code>
23	<code>break;</code>
24	<code>}</code>



In case you have any further questions regarding the programming interface please contact LP-RESEARCH directly.

## X. MECHANICAL INFORMATION



**Please Read Carefully:**

Information in this document is provided solely in connection with LP-RESEARCH products. LP-RESEARCH reserves the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All LP-RESEARCH products are sold pursuant to LP-RESEARCH's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the LP-RESEARCH products and services described herein, and LP-RESEARCH assumes no liability whatsoever relating to the choice, selection or use of the LP-RESEARCH products and services described herein.

**UNLESS OTHERWISE SET FORTH IN LP-RESEARCH'S TERMS AND CONDITIONS OF SALE LP-RESEARCH DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF LP-RESEARCH PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.**

**LP-RESEARCH PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. LP-RESEARCH PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.**

© 2014LP-RESEARCH - All rights reserved

Japan – China – Germany – Korea – Egypt

[www.lp-research.com](http://www.lp-research.com)