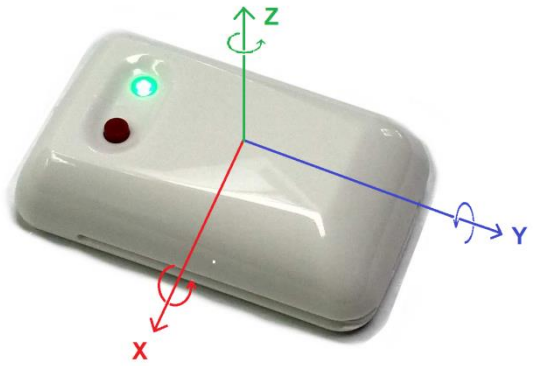
EXLs3

Miniature Wireless Inertial Measurement Unit



USER GUIDE

(FIRMWARE REV. 6.26)

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EXLs3

Miniature Wireless Inertial Measurement Unit

■ 1. GENERAL DESCRIPTION

The **EXLs3** is a miniaturized electronic device with the function of real-time *Inertial Measurement Unit* (IMU).

It features a complete MEMS sensor set, which is composed of a tri-axial **accelerometer**, **gyroscope** and **compass**, a 32-bit Cortex microprocessor for data processing and a Bluetooth radio to send real-time data.

The unit can be used for real-time motion measurement and transmission in particular in the medical field as a wearable device for biomechanical analysis, such as posture assessment, rehabilitation, gait monitoring, joints' functionality analysis, activity monitoring, etc.

The **Bluetooth**™ radio allows easy interfacing to a wide range of devices (PC, Tablets, Smartphones) without the need of additional hardware so that data can be transmitted wirelessly up to 10 meters.

The unit is also equipped with an embedded **1 GB flash drive** which allows data logging to CSV files and USB interface for file transfer.

The on board 32-bit CPU provide algorithms for **orientation** estimation with Kalman filtering in order to give high quality measurement.

The integrated rechargeable Litium battery allows continuous data acquisition and streaming up to 3 hours and can be recharged by means of a dedicated docking station.

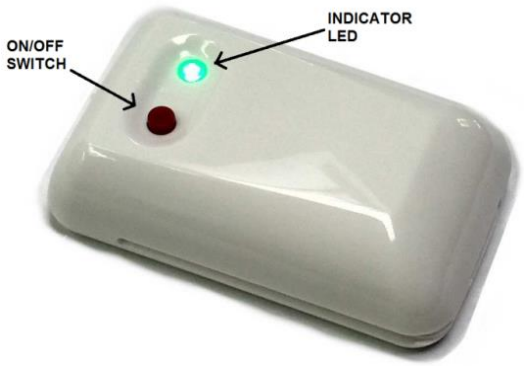
■ 2. FEATURES

- Module size 54 mm x 33 mm x 14 mm
- Module weight 22 g
- 32-bit MCU, Cortex-M3 @72 MHz
- 3-axis accelerometer with selectable full-scale range (±2 / ±4 / ±8 / ±16 g).
- 3-axis gyroscope with selectable full-scale range (±250 / ±500 / ±1000 / ±2000 dps)
- 3-axis magnetometer
- Orientation estimation with Kalman filtering and quaternion output.
- Sampling rate up to 200 Hz for raw data and 100 Hz for orientation data.
- Various data packet format available
- Bluetooth™ 2.1 class 1.
- Up to 7 nodes at the same time can stream data to the same host.
- 1GB Flash Memory (USB Mass Storage) for data storage
- Docking station with micro-USB connector for battery recharging and log-file downloading.
- Battery operating time 3h
- Firmware upgradable by means of bluetooth connection.

■ *3. HARDWARE OVERVIEW*

On the front side of the IMU the **ON/OFF button** and an **indicator LED** are located**.**
In order to *switch-on* the device**,** press *shortly* the button. The LED lights **green.**
To switch-off the IMU press and hold the button for two seconds, until the LED turns-off.

In addition, the IMU turns-off automatically after 10 minute of inactivity.
When the battery reaches a low voltage the LED starts **blinking red**.



On the back side 4 golden contacts are present in order to allow communication with the *docking station* for battery recharging and data download.

The **Docking-station** allows the sensor to be interfaced to a PC via USB cable, for *battery recharging* and data-log file transfer.
The IMU must be properly placed in the docking station as shown in the above picture.
For battery recharging is alternatively possible to connect the docking station to a standard 5V power supply equipped with micro-USB connector.
The current required to recharge the battery is 250 mA.

When the battery is being charged the EXLs3's indicator LED turns **red.**
When the battery is fully charged the LED turns **green.**

By connecting the docking-station to a PC it is possible to access the IMU's internal storage flash disk, in order to retrieve data-log files.

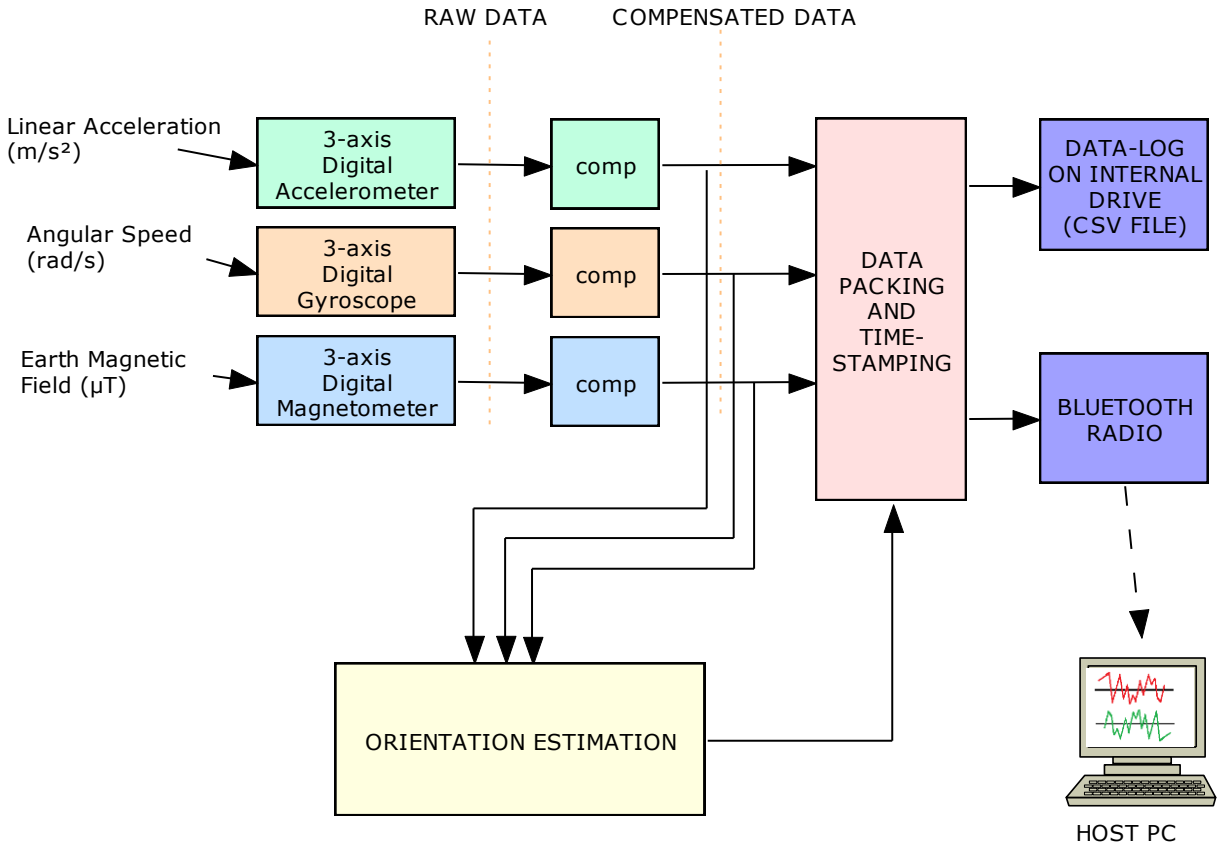
The **Multiple Docking-Station** allows more units to be recharged at the same time. It also acts as USB *hub* which allows more units to be seen as multiple distinct flash disks where log files can be found.
The multiple docking-station must be used with the provided **Power Supply Adapter**, otherwise neither battery recharging nor USB hub will work.

The IMU is provided with a special **holder** which allows easy fixing to a Velcro-strap or similar.
The IMU must be placed as shown in the following picture, by sliding it in the holder gently until the body hooks in the retainer, making sure the holder's lateral rails fit in the respective sensor's slots.

In case of *gait analysis* the holder can be used to hook the IMU *to shoes-laces*, as shown in the following picture.

■ 4. INTERNAL BLOCK DIAGRAM

The following picture shows in a simplified form the internal logic of the EXLs3 unit.



The task of the unit is to **measure** in real-time the linear **acceleration** and the **angular velocity** at which the unit itself is subjected (inertial measurements).
The unit can at the same time measure the magnitude of the surrounding **magnetic field**.

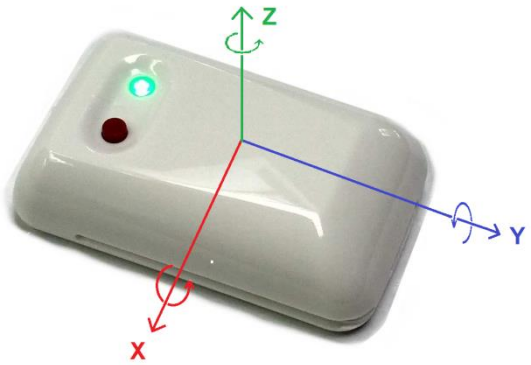
All measurements are performed by *tri-axial* sensors, so both *magnitude* and *vector direction* are acquired.

After the *compensation* of sensor's raw data (i.e. offset and gain error removal), data and are processed in order to calculate the *orientation* of the unit related to a earth reference frame in real-time.

Compensated inertial data together with *Orientation* data are packed and sent wirelessly to the host PC a the desired *sampling rate*.
The produced stream can also be saved in the internal flash drive, as standard CSV file, in order to be retrieved afterwards via USB connection for off-line post-processing and/or analysis.

■ *5. REFERENCE SYSTEM*

All raw inertial measurements (**linear accelerations**, **angular velocity** and **earth magnetic field** provided by the unit are referred to the reference system shown below (*body frame*).



The orientation of the unit in the space is referred to an earth-bound frame where:

X is pointing **NORTH**
Y is pointing **WEST**
Z is pointing **UPWARDS**

The orientation of the sensor is given by a *quaternion* (*q0,q1,q2,q3*) representing the *rotation* of the unit's *body frame* with respect to the *earth frame*.

Thus when the X axis of the sensor is pointing NORTH and Y axis is pointing WEST the output is the *Identity Quaternion* (1,0,0,0).

■ 6. MEASUREMENT UNITS

Main data returned in real-time by the EXLs3 to the host system are:

Acceleration	(AccX, AccX, AccZ)
Angular Velocity	(GyrX, GyrY, GyrZ)
Magnetic Field	(MagX, MagY, MagZ)
Orientation	(Q0, Q1, Q2, Q3)

For the Acceleration and the Angular Velocity you can chose among several *full-scale ranges* in order to best fit the specific application requirement.

All data are sent in **binary** form, so they require conversion to be expressed in standard measurement units.

ACCELERATION

$$a\ [m/sec^2] = Ka \frac{Acc}{32768}$$

SELECTED FULL-SCALE RANGE	Ka
±2 g	2 x g (19.613 m/sec^2)
±4 g	4 x g (39.227 m/sec^2)
±8 g	8 x g (78.45 m/sec^2)
±16 g	16 x g (156.91 m/sec^2)

This formula must be applied to each component (*AccX*, *AccY* and *AccZ*) of the acceleration.

ANGULAR VELOCITY

$$\omega[degree/sec] = Kg \frac{Gyr}{32768}$$

SELECTED FULL-SCALE RANGE	Kg
±250 dps	250 dps
±500 dps	500 dps
±1000 dps	1000 dps
±2000 dps	2000 dps

This formula must be applied to each component (*GyrX*, *GyrY* and *GyrZ*) of the angular velocity.

MAGNETIC FIELD

$$B[uT] = Km\ Mag$$

FULL-SCALE RANGE	Km
±1200 dps	0.007629 uT

This formula must be applied to each component (*MagX*, *MagY* and *MagZ*) of the angular velocity.

ORIENTATION

The orientation of the EXLs3 in the space is represented by a *unit quaternion* (q_0, q_1 , q_2, q_3) representing the *rotation* of the unit's *body frame* with respect to the *earth frame*.

The quaternion's components returned by the EXLs3 are normalized so that the ***unity*** is represented by the value **16384**. So the following formula should be applied:

$$q_n = \frac{Q_n}{16384} \qquad n = 0,1,2 \text{ and } 3$$

The rotation of the *body-frame* is identified by an *axis of rotation A* and an *angle of rotation α* around that axis:

$q_0 = cos(\alpha / 2)$
$q_1 = A_x \ sin(\alpha / 2)$
$q_2 = A_y \ sin(\alpha / 2)$
$q_3 = A_z \ sin(\alpha / 2)$

EXAMPLES:

A rotation of +90 degrees around the Z axis (0,0,1) results:

$q_0 = cos(90 / 2) = 0.7071$
$q_1 = 0 \ sin(90 / 2) = 0$
$q_2 = 0 \ sin(90 / 2) = 0$
$q_3 = 1 \ sin(90 / 2) = 0.7071$

A rotation of -90 degrees around the Y axis (0,1,0) results:

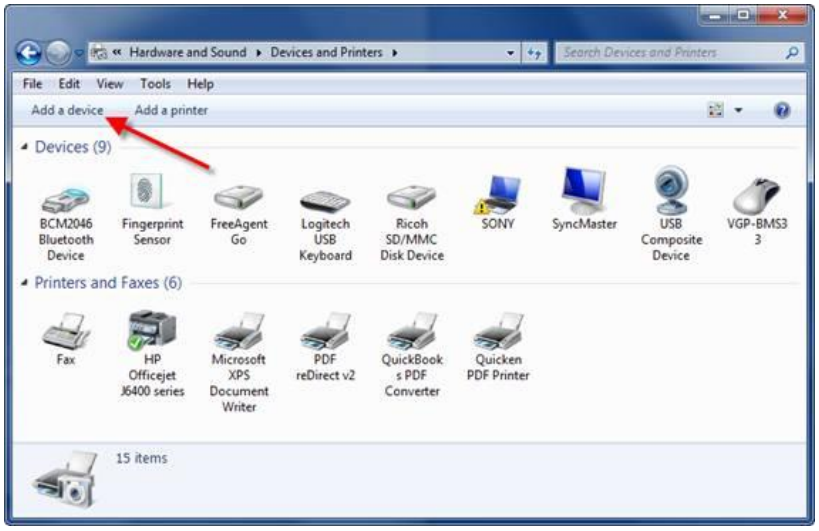
$q_0 = cos(-90 / 2) = 0.7071$
$q_1 = 0 \ sin(-90 / 2) = 0$
$q_2 = 1 \ sin(-90 / 2) = -0.7071$
$q_3 = 0 \ sin-(90 / 2) = 0$

The *Identity Quaternion (1,0,0,0)* indicates the unit's body frame (X-Y-Z) is aligned with the North-West-Up earth-frame.

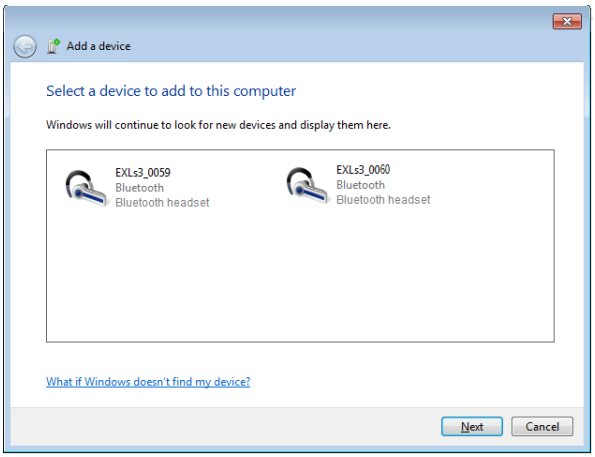
■ *7. BLUETOOTH SETUP*

The communication with the unit is done via bluetooth SPP connection, so you should have a **Bluetooth 2.1** internal card or USB Bluetooth **dongle** properly installed on your host machine.

After, you must *pair* each EXLs3 with the host by going to *View Devices and Printers (under Windows 7)* and clicking on *Add a device*. Note your EXLs3 device(s) must be switched-on in order to be discoverable by the host.



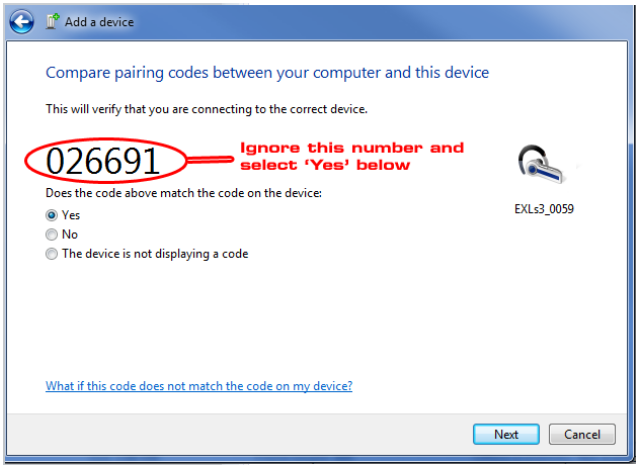
After a few seconds (up to 15) you should se a list of the available EXLs3 devices and you can select the one you want to pair.



After a few seconds (up to 15) you should se a list of the available EXLs3 devices and you can select the one you want to pair.

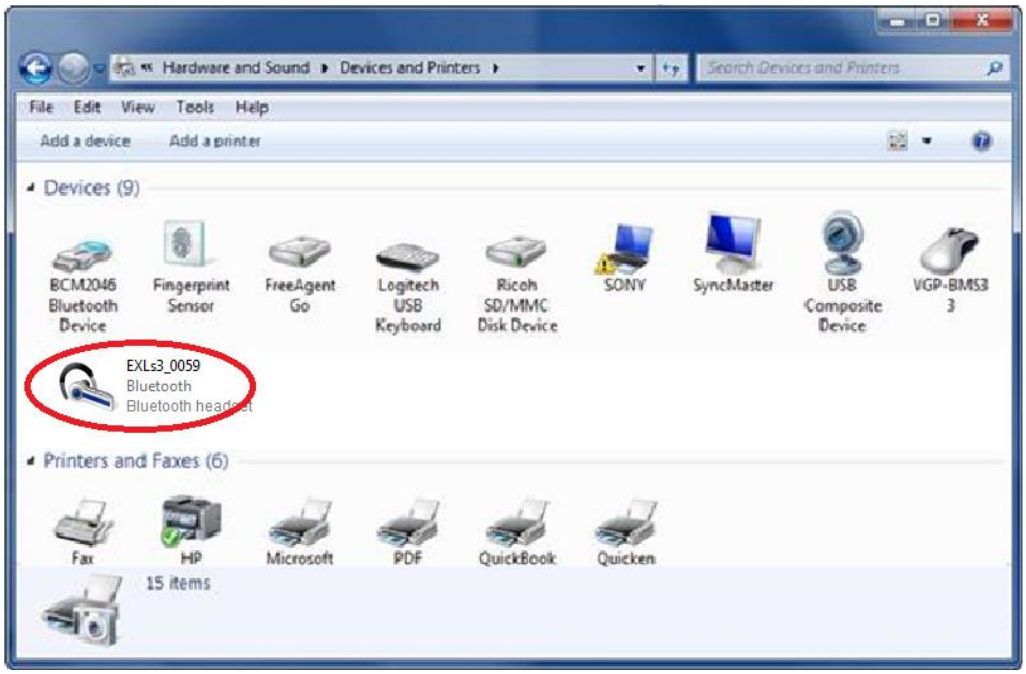
Note: for FW rev 6.26+ the EXLs3 is seen as generic Bluetooth device instead of bluetooth headset

When the following window appear, just ignore the shown code and press *Next.*

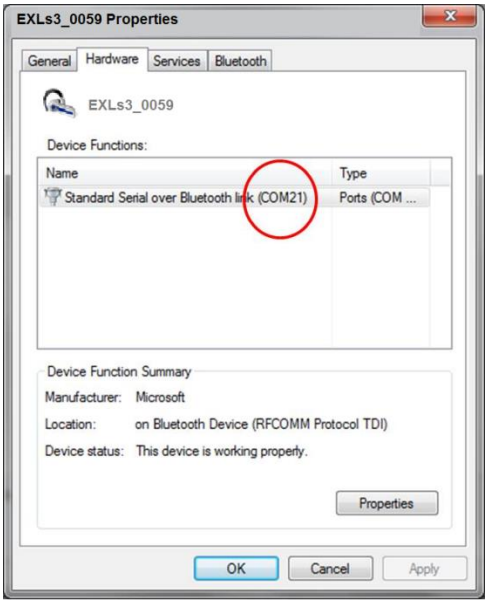


The driver installation starts automatically. During this process you should see at the bottom-right of your screen a notification of new COM port installation.
Ignore possible message of driver installation error, depending on the extra profiles supported by your bluetooth dongle).

At the end of the process you should have the EXLs3 device added in the *Devices and Printers* group:



By double-clicking the EXLs3 device on the window you can access the associated *Properties*.



In the *Hardware* tab, you must take note of the COM number (in the case above COM12) associated with the *Standard Serial over Bluettoth Link* function.

The identified COM port is the interface your host system will use to communicate with the EXLs3 device.

8. COMUNICATION PROTOCOL

The commands used to interact with the device are based on datagrams sent by the host device via the *serial port profile* over Bluetooth. They are in general constituted of an *opcode* (1 byte) followed by variable number of *parameters* (n bytes) and 1 byte *checksum*, calculated as sum modulo-256 of the previous n+1 bytes.

Byte0	Byte1 .. byte N	Byte (N + 1)
OPCODE	**PARAMETERS**	**CHECKSUM**

If the command is properly recognized by EXLs3 it responds with an **ACK** byte (**0x01**).
In case of error it respond with **NACK** byte (**0x00**)

8.1. Basic Commands

START_STREAM (0x3D)

Use this command to start real-time streaming of sampled and processed data to the controlling PC.

Byte 0	Byte1
0x3D	**0x3D**

The sensor starts sending to the host the data sampled in real-time with the format shown in the paragraph *Packet Data Types.*

STOP_STREAM

Use this command to stop real-time streaming.

Byte 0	Byte1
0x3A	**0x3A**

The sensor responds with an acknowledge

Byte0
0x01

8.2. Packet Data Types

When in streaming mode, the EXLs3 unit can send different type of packets, depending on the value of the **PACKET_TYPE** parameter (see in the registers description paragraph).

AGMOB_Type (Accelerometer, Gyroscope, Magnetometer, Orientation, vBattery)

This is the most generic packet format, which includes all possible information at the same time.

With this packet, the EXLs3 units sends the real-time, the **acceleration**, the **angular velocity** and the **magnetic field**, as well as the estimated **orientation** of the unit.

Together are also packed the value of the EXLs3's **battery voltage** and a progressive **packet counter**.

The actual values of *acceleration*, *angular velocity*, *magnetic field* and *orientation* can be calculated with the formulas described in paragraph *Measurement Units*.

Byte0	Byte1	Byte2..Byte3	Byte4 .. Byte9	Byte10 .. Byte15	Byte16 .. Byte21	Byte22 .. Byte29	Byte30 .. Byte31	Byte32
0x20	PKT_TYPE	PKT_CNT	ACC_DATA	GYR_DATA	MAG_DATA	ORIENT_DATA	V_BATT	CHKSUM

PKT_TYPE= 0x9F packet header which identify the *type* of packet.

PKT_COUNT: progressive packet number ranging from 0 to 10000

Byte2	Byte3
PKT_CNT _L	PKT_CNT _H

ACC_DATA : *acceleration* data sub-packed as following:

Byte4	Byte5	Byte6	Byte7	Byte8	Byte9
AccX_L	AccX_H	AccY_L	AccY_H	AccZ_L	AccZ_H

AccX_H : AccX_L : *X component* of the acceleration (16-bit, 2-complement)
AccY_H : AccY_L : *Y component* of the acceleration (16-bit, 2-complement)
AccZ_H : AccZ_L : *Z component* of the acceleration (16-bit, 2-complement)

GYR_DATA: *angular velocity* data packed as following:

Byte10	Byte11	Byte12	Byte13	Byte14	Byte15
GyrX_L	GyrX_H	GyrY_L	GyrY_H	GyrZ_L	GyrZ_H

GyrX_H : GyrX_L : *X component* of the angular rate (16-bit, 2-complement)
GyrY_H : GyrY_L : *Y component* of the angular rate (16-bit, 2-complement)
GyrZ_H : GyrZ_L : *Z component* of the angular rate (16-bit, 2-complement)

MAG_DATA: *magnetic field* data packed as following:

Byte16	Byte17	Byte18	Byte19	Byte20	Byte21
MagX_L	MagX_H	MagY_L	MagY_H	MagZ_L	MagZ_H

MagX_H : MagX_L : *X component* of the magnetic field (16-bit, 2-complement)
MagY_H : MagY_L : *Y component* of the magnetic field (16-bit, 2-complement)
MagZ_H : MagZ_L : *Z component* of the magnetic field (16-bit, 2-complement)

ORIENT_DATA: *orientation* data packed as following:

Byte22	Byte23	Byte24	Byte25	Byte26	Byte27	Byte28	Byte29
Q0_L	Q0_H	Q1_L	Q1_H	Q2_L	Q2_H	Q3_H	Q3_H

Q0_H : Q0_L : *Q0 component* of the normalized quaternion (16-bit, , 2-complement)
Q1_H : Q1_L : *Q1 component* of the normalized quaternion (16-bit, , 2-complement)
Q2_H : Q2_L : *Q2 component* of the normalized quaternion (16-bit, , 2-complement)
Q3_H : Q3_L : *Q3 component* of the normalized quaternion (16-bit, , 2-complement)

V_BAT: *battery voltage* (in mV) data packed as following:

Byte30	Byte31
Vbat_L	Vbat_H

CHKSUM: sum modulo-256 of all previous bytes:

Byte32
CHKSUM

AGMB_Type (Accelerometer, Gyroscope, Magnetometer, vBattery)

Byte0	Byte1	Byte2..Byte3	Byte4 .. Byte9	Byte10 .. Byte15	Byte16 .. Byte21	Byte22 .. Byte23	Byte24
0x20	PKT_TYPE	PKT_CNT	ACC_DATA	GYR_DATA	MAG_DATA	V_BATT	CHKSUM

PKT_HEAD = 0x97 : packet header which identify the *type* of packet

Remaining data fields are coded the same of AGMOB packet

O_Type (Orientation)

Byte0	Byte1	Byte2..Byte3	Byte4 .. Byte11	Byte12
0x20	PKT_TYPE	PKT_CNT	ORIENT_DATA	CHKSUM

PKT_HEAD = 0x88: packet header which identify the *type* of packet

Remaining data fields are coded the same of AGMOB packet

IMPORTANT:
Other customizable packet type can be chosen by setting **PACKET_TYPE** register properly (see the *configuration register* paragraph).
Every bit in the PACKET_TYPE register enable/disable a different measurement.
However, the field sequence in the packet is always derived from the generic AGMOB type by suppressing the unused field.
For instance, the packet type **AO** has the following coding:

Byte0	Byte1	Byte2..Byte3	Byte4 .. Byte9	Byte10 .. Byte17	Byte18
0x20	PKT_TYPE	PKT_CNT	ACC_DATA	ORIENT_DATA	CHKSUM

RAW _Type

Raw data are values as read from the MEMS sensing elements, before any preprocessing and compensation take place. This packet format can be useful for advanced users to operate directly on *native* data in order to perform specific calibration algorithms.

Byte 0	Byte 1	Byte2	Byte3 .. Byte8	Byte9 .. Byte14	Byte15 .. Byte20	Byte21
0x20	0x0A	PKT_COUNT	ACC_DATA	GYR_DATA	MAG_DATA	CHECKSUM

PKT_HEAD: packet header which identify the *type* of packet

Byte0	Byte1
0x20	0x0A

PKT_COUNT: progressive packet number ranging from 0 to 255

Byte2
PKT_CNT

ACC_DATA : *acceleration* data sub-packed as following:

Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
AccX_L	AccX_H	AccY_L	AccY_H	AccZ_L	AccZ_H

AccX_H : AccX_L : *X component* of the acceleration (16-bit, 2-complement)
AccY_H : AccY_L : *Y component* of the acceleration (16-bit, 2-complement)
AccZ_H : AccZ_L : *Z component* of the acceleration (16-bit, 2-complement)

GYR_DATA: *angular velocity* data packed as following:

Byte9	Byte10	Byte11	Byte12	Byte13	Byte14
GyrX_L	GyrX_H	GyrY_L	GyrY_H	GyrZ_L	GyrZ_H

GyrX_H : GyrX_L : *X component* of the angular rate (16-bit, 2-complement)
GyrY_H : GyrY_L : *Y component* of the angular rate (16-bit, 2-complement)
GyrZ_H : GyrZ_L : *Z component* of the angular rate (16-bit, 2-complement)

MAG_DATA: *magnetic field* data packed as following:

Byte15	Byte16	Byte17	Byte18	Byte19	Byte20
MagX_L	MagX_H	MagY_L	MagY_H	MagZ_L	MagZ_H

MagX_H : MagX_L : *X component* of the magnetic field (16-bit, 2-complement)
MagY_H : MagY_L : *Y component* of the magnetic field (16-bit, 2-complement)
MagZ_H : MagZ_L : *Z component* of the magnetic field (16-bit, 2-complement)

CHKSUM: sum modulo-256 of all previous bytes:

Byte21
CHKSUM

8.3. Configuration Commands

The EXLs3's configuration parameters (sampling frequency, full-scale ranges, etc.) are mapped into a *register file*, where each *parameter* has a specific *address*.
The user can modify each parameter in order to adapt the operation of the EXLs3 to the specific requirement of the user's application.
The access to the *register file* is performed by **READ_PARAMETER** and **WRITE_PARAMETER** commands described further.

8.4. Configuration Registers

ADDRESS	PARAMETER NAME	LENGTH (bytes)	TYPE	DESCRIPTION
0x02	SW_RELEASE	16	String	info about the device's SW (read only)
0x12	HW_RELEASE	16	String	info about the device's HW (read only)
0x22	BT_NAME	16	string	Bluetooth name maximum 15 characters max plus *null* char ('/0') (WARNING: changing this parameter will require entering the *Bootloader Mode* in order to take effect)
0x34	ACC_FS	1	u8	Full-scale range of the *Accelerometer* **0x00** = ±2 g **0x01** = ±4 g **0x02** = ±8 g **0x03** = ±16 g
0x35	GYRO_FS	1	u8	Full-scale range of the *Gyroscope* **0x00** = ±250 dps **0x01** = ±500 dps **0x02** = ±1000 dps **0x03** = ±2000 dps
0x36	IMU_DLPF	1	u8	Internal sensor low-pass filter (reserved)
0x37	IMU_SRD	1	u8	Internal sensor divider (reserved)
0x38	PACKET_TYPE	1	u8	Output Packet type. By setting the value of this register it is possible to indicate the information transported by the data packet when streaming or logging. The following coding is used: **1 0 0 B O M G A** where each bit indicates if a specific measurement is enabled B = Battery voltage O = Orientation M= Magnetometer G = Gyroscope A = Accelerometer For example if packet_type = **0x9F** (hexadecimal) all the measurements are output (AGMOB type packet). **0x9F** = AGMOB **0x97** = AGMB **0x81** = A **0x91** = AB **0x8F** = AGMO …. **0x00** = RAW packet type
0x4E	ORIENT_ALG	1	u8	Selects the algorithm to compute the orientation **0x00** = eCompass (only the accelerometer and the compass are used) **0x01** = Gyro (only the Gyroscope Integration is used) **0x02** = Kalman Filtering (data fusion between Accelerometer, Compass and Gyroscope is used)

0x50	SAMPLE_RATE	1	u8	Selects the frequency of packets (samples) sent to the host **0x00** = 200 Hz (100 Hz if a packet with *orientation* is chosen) **0x01** = 100 Hz **0x02** = 50 Hz **0x03** = 33.33 Hz **0x04** = 25 Hz **0x05** = 20 Hz **0x06** = 16.67 Hz **0x07** = 12.5 Hz **0x08** = 10 Hz **0x09** = 5 Hz **0x0A** = 300 Hz (No magnetometer data, 100 Hz if a packet with *orientation* is chosen)
0x51	STREAM_LOG	1	U8	Select the Stream and or Log Mode when START command is issued **0x00** = Stream packets via bluetooth **0x01 =** Log packets on file in the EXLs3's internal flash disk **0x02** = Stream & Log packets
0x52	SWRFD	1	U8	*Start When Removed From Dock* mode **0x00** = data streaming and/or logging begins immediately after START command has been sent **0x01** = data streaming and/or logging begins immediately after START command has been sent only if the EXLs3 is not powered by the docking station, otherwise it waits the dock's power supply being removed before starting streaming/logging. When the EXLs3 is put back in the docking station and the power supply is restored, it *stops* streaming/logging This behavior can be used to synchronize the start/stop time of several sensors. **0x02** = continuous data logging when the EXLs3 is not powered by the docking station, without start/stop commands. In this operating mode no Bluetooth connection is required.
0x53	WAKEUP_MODE	1	U8	*Only available on EXLs3 with vibration sensor. It configure the device's wake-up mode **0x10** = BUTTON: the device switches-on by pressing the button **0x20**= VIBRO_FAST: the device switches-on with vibration (High sensitivity). **0x21**= VIBRO_MED: the device switches-on with vibration (Medium sensitivity). **0x22**= VIBRO_SLOW: the device switches-on with vibration (Low sensitivity). **0x30**= BUTTON + VIBRO_FAST: the device switches-on with vibration (High sensitivity) or by button. **0x31**= BUTTON+VIBRO_MED: the device switches-on with vibration (Medium sensitivity) or by button. **0x32**= BUTTON + VIBRO_SLOW: the device switches-on with vibration (Low sensitivity) or by button.

8.5. Configuration Parameter Access

The access to the *register file* is performed by a generic **READ_PARAMETER** and **WRITE_PARAMETER** commands, which also allow readings or writings of a sequence of multiple *consecutive parameters*.

READ_PARAMETERS

Use this command to read one or more parameters from the sensors. Parameters are mapped in a buffer as described in the related paragraph. The command lets the user read **N** bytes starting from **Add_H:Add_L**

Byte0	Byte1	Byte2	Byte3	Byte4
0x65	**N**	**Add_L**	**Add_H**	**CHKSUM**

The sensor responds with a packet containing the **N** bytes required of the parameter buffer

Byte0	Byte1		Byte(N-1)	ByteN
Data0	**Data1**	**…**	**Data(N-1)**	**CHKSUM**

This command is only accepted if the sensor is not in streaming mode

WRITE_PARAMETERS

Use this command to write one or more parameters to the sensor.

Byte0	Byte1	Byte2	Byte3	Byte4 .. Byte(4+N-1)	Byte(4+N)
0x64	**N**	**Add_L**	**Add_H**	**Buffer_data …**	**CHKSUM**

The sensor responds with an acknowledge:

Byte0
0x01

This command is only accepted if the sensor is not in sampling/streaming mode. The parameters change takes effect from the following sampling/streaming command. New parameters are stored in volatile memory so they are lost when the device is switched-off. To save permanently the current parameters use SAVE_PARAMETERS command.

SAVE_PARAMETERS

Use this command to save in non-volatile memory the current set of parameters, so that it will be retained also after switching the EXLs3 off.

Byte0	Byte1
0x66	**0x66**

The sensor responds with an acknowledge

Byte0
0x01

This command is only accepted if the sensor is not in streaming mode

EXAMPLES OF CONFIGURATION COMMANDS:

Set **SAMPLE_RATE** at **100 Hz**

➔ **WriteParameter** command **1 byte**, at address **0x50**, value = **0x01**

OpCode	Nbyte	AddL	AddH	Value	CHKSUM
0x64	0x01	0x50	0x00	0x01	0xB6

Set **SAMPLE_RATE** at **200 Hz**

➔ **WriteParameter** command **1 byte**, at address **0x50**, value = **0x00**

OpCode	Nbyte	AddL	AddH	Value	CHKSUM
0x64	0x01	0x50	0x00	0x00	0xB5

Set **PACKET_TYPE** at **ORIENT_Type**

➔ **WriteParameter** command **1 byte**, at address **0x38**, value = **0x02**

OpCode	Nbyte	AddL	AddH	Value	CHKSUM
0x64	0x01	0x38	0x00	0x02	0x9F

Set **ACC_FS** at **±16 g**

➔ **WriteParameter** command **1 byte**, at address **0x34**, value = **0x03**

OpCode	Nbyte	AddL	AddH	Value	CHKSUM
0x64	0x01	0x34	0x00	0x03	0x9C

Read **SW_RELEASE**

➔ **ReadParameter** command **16 byte**, at address **0x02**

OpCode	Nbyte	AddL	AddH	CHKSUM
0x65	0x0F	0x02	0x00	0x76

The EXLs3 responds with a stream similar to this:

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8	Byte9	Byte10	Byte11	Byte12	Byte13	Byte14	Byte15	Byte16
'S'	'W'	'='	'6'	'.'	'0'	'9'	' '	' '	' '	' '	' '	' '	' '	' '	0x00	Checksum

8.6. Real Time Clock configuration

The EXLs3 device is equipped with a Real Time Clock which allow time keeping for proper file creation and time stamping.
It is possible to read/write the RTC register by using the following commands.

SET_CLOCK

Use this command to set the **time** and **date** value in the RTC.

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
0x6E	**YY**	**MM**	**DD**	**HH**	**mm**	**SS**	**CHKSUM**

YY = Year [0..99] MM = Month [1..12] DD = Day [1..31]
HH = Hour [0..23] Mm = Minute [0..59] SS = second [0.59]

The sensor responds with an acknowledge:

Byte0
0x01

This command is only accepted if the sensor is not in sampling/streaming mode.

GET_CLOCK

Use this command to GET the **data** and **time** from RTC:

Byte0	Byte1
0x6F	**0x6F**

The sensor responds with:

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6
YY	**MM**	**DD**	**HH**	**mm**	**SS**	**CHKSUM**

YY = Year [0..99] MM = Month [1..12] DD = Day [1..31]
HH = Hour [0..23] Mm = Minute [0..59] SS = second [0.59]

This command is only accepted if the sensor is not in sampling/streaming mode.

8.7. Other commands

POWER_OFF

Use this command to switch-off the device.

Byte0	Byte1	Byte2	Byte3	Byte4
0x32	0x32	0x32	0x32	CHKSUM

The sensor responds with an acknowledge, right before switching-off.

Byte0
0x01

This command is only accepted if the sensor is not in sampling/streaming mode.

RESTORE_PARAMETERS

Use this command to restore all settings to the default values.

Byte0	Byte1
0x67	0x67

The sensor responds with an acknowledge.

Byte0
0x01

This command is only accepted if the sensor is not in sampling/streaming mode.

NOTE: This command does not reset the *calibration parameters*

START_BOOTLOADER

Use this command to start the *bootloader* at the next device's switching-on.

Byte0	Byte1	Byte2	Byte4
0x80	0xBA	0xBA	CHKSUM

The device responds with an acknowledge..

Byte0
0x01

This command is only accepted if the sensor is not in sampling/streaming mode.
NOTE: This command is only supported by devices with **bootloader v.1.05** and above.

Appendix A. Firmware Update

The EXLs3 unit is equipped with a *bootloader*, which employs the Bluetooth connection to upload a new firmware on the device.
The firmware must be provided as a binary file (.bin) and should be transmitted to the device via a *serial terminal emulator* which support **Y-modem** data transfer (e.g *TeraTerm* or *HyperTerminal*).

The *bootloader mode* can be entered when turning on the device be holding pressed the switch-on button for 5 seconds, until the red led starts blinking.
At this point the device is in the bootloader mode and will stay here until it receives further instructions. A button press will exit the bootloader mode and normally initialize the device.

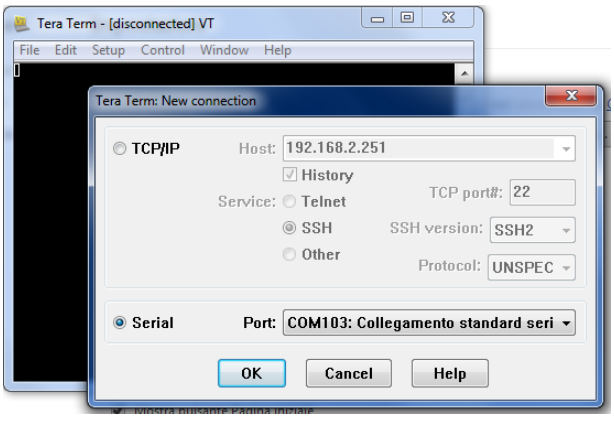
When in the bootloader mode, the device waits the connection from the terminal emulator.

The following instructions apply to *Teraterm* terminal emulator, but can be used with any similar program. We are also assuming that the user already paired the device with the PC, thus having a COM port corresponding to the device.

WARNING! This operation should be done with care and at your own risk.
Be sure that the binary file you are going to load to the EXLs3 unit is provided by EXEL only.
If the firmware file is not correct your device can be damaged permanently.
Be sure that the battery is fully charged before starting the updating procedure, as a the interruption of the process, for any reason, can damage your EXLs3 unit.

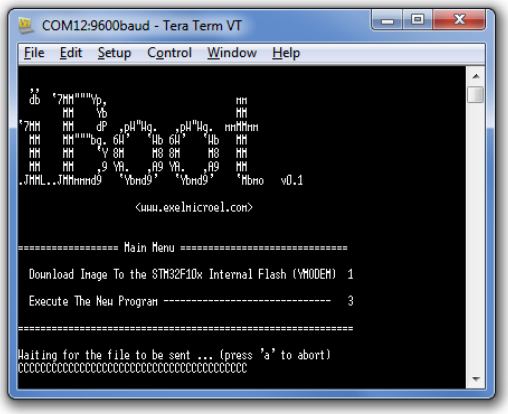
To upload a new firmware the user must:

1. Put the device in BOOTLOADER mode (red LED blinking)
2. Start *Teraterm* on the host PC
3. Connect to the EXLs3 unit by selecting in the ***File / New connection*** menu the COM port associated with the EXLs3 unit



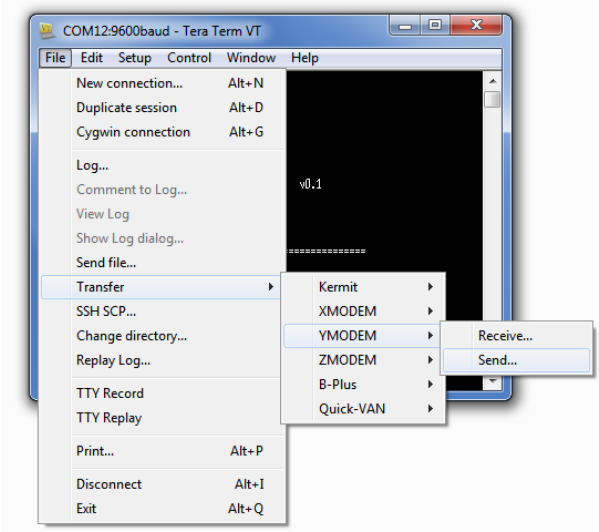
Note: The following points 4. and 5. are not required from the bootloader version >1.04

4. Once the communication channel is open press on the PC's keyboard the keys **SHIFT + A**, the following *bootloader* splash screen is shown:

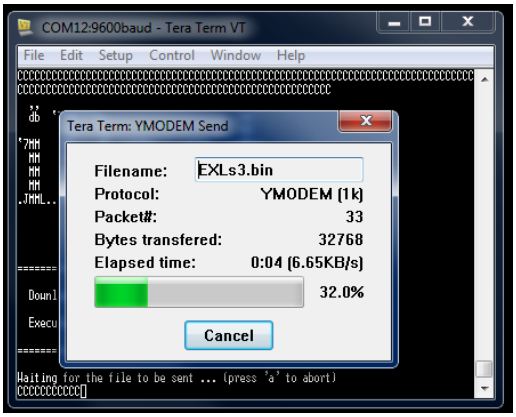


5. Press on the keyboard the key **"1"**.
   The *bootloader* starts showing a continuous sequence of **"C"** and wait the file to be uploaded.

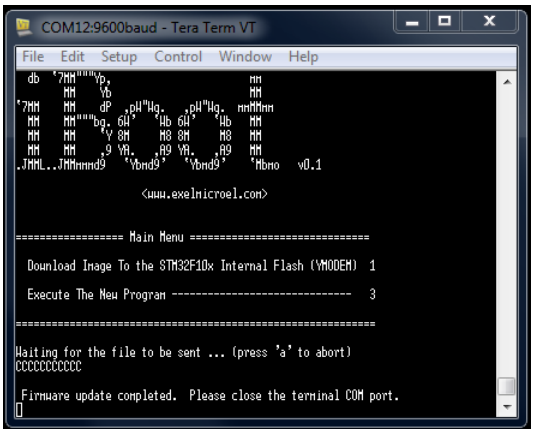
6. Select the file to send (**EXLs3_xxxx.bin**) to the EXLs3 unit by choosing ***File / Transfer / Ymodem / Send*** option.
   WARNING: only select trusted binary files provided by EXEL, otherwise you can damage your product permanently.



7. The file transfer take place



8. When the process is completed you can close the communication port by pressing ***File / Disconnect***



9. After the firmware transfer the EXLs3 unit should exit bootloader mode and the LED should turn **green**.

10. It is advised you *switch-off* and then *switch-on* the EXLs3 unit before using it.

LEGACY FUNCTIONS

The following configuration parameters and packet format have been kept for compatibility with the initial implementation.
It is advised not to use them anymore, and use newer packet formats

CONFIGURATION PARAMETERS

ADDRESS	PARAMETER NAME	LENGTH (bytes)	TYPE	DESCRIPTION
0x38	PACKET_TYPE	1	u8	**0x01** = CALIB_Type (Calibrated data) **0x02** = ORIENT_Type (Quaternions)
0x4F	SEND_BATT	1	u8	**0:** **-** **1**: Battery Voltage is sent periodically with a dedicated packet

PACKETS FORMAT

CALIB_Type (Accelerometer, Gyroscope, Magnetometer)

Byte 0	Byte 1	Byte2	Byte3 .. Byte8	Byte9 .. Byte14	Byte15 .. Byte20	Byte21
0x20	PKT_ID	Pkt_count	ACC_DATA	GYR_DATA	MAG_DATA	CHECKSUM_XOR

- **Packet Header:** the first packet byte is always **0x20**
- **PKT_ID:** the identifier for the packet type. For the calibrated data packet it's **0x0B**
- **PKT_COUNT:** progressive packet number ranging from 0 to 255
- **CHECKSUM_XOR:** calculated as XOR of previous Bytes
- **ACC_DATA :** *acceleration* data sub-packed as following:

Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
AccX_L	AccX_H	AccY_L	AccY_H	AccZ_L	AccZ_H

AccX_H : AccX_L : *X component* of the acceleration (2-complement)
AccY_H : AccY_L : *Y component* of the acceleration (2-complement)
AccZ_H : AccZ_L : *Z component* of the acceleration (2-complement)

- **GYR_DATA:** *angular rate* data packed as following:

Byte9	Byte10	Byte11	Byte12	Byte13	Byte14
GyrX_L	GyrX_H	GyrY_L	GyrY_H	GyrZ_L	GyrZ_H

GyrX_H : GyrX_L : *X component* of the angular rate (2-complement)
GyrY_H : GyrY_L : *Y component* of the angular rate (2-complement)
GyrZ_H : GyrZ_L : *Z component* of the angular rate (2-complement)

- **MAG_DATA:** *magnetic field* data packed as following:

Byte15	Byte16	Byte17	Byte18	Byte19	Byte20
MagX_L	MagX_H	MagY_L	MagY_H	MagZ_L	MagZ_H

MagX_H : MagX_L : *X component* of the magnetic field (2-complement)
MagY_H : MagY_L : *Y component* of the magnetic field (2-complement)
MagZ_H : MagZ_L : *Z component* of the magnetic field (2-complement)

ORIENT_Type (quaternion)

When this packet type is chosen, the node samples the sensors, applies the internally stored calibration and computes the orientation of the device using one of the available algorithms. The orientation is represented in quaternion form and represents the orientation of the device with respect to a local earth fixed frame. The node's body reference frame is the one illustrated in Figure 1, and the earth default reference frame has x pointing north, y pointing west and z pointing upwards (NWU – North-West-Up). An alternative reference frame can be chosen (NED – North-Est-Down).

Byte 0	Byte 1	Byte2	Byte3 .. Byte6	Byte7 .. Byte10	Byte11 .. Byte14	Byte15 .. Byte18	Byte19
0x20	PKT_ID	Pkt_count	q0	q1	q2	q3	CHECKSUM_XOR

- **Packet Header:** the first packet byte is always **0x20**
- **PKT_ID:** the identifier for the packet type. For the orientation data packet it's **0x0C**
- **PKT_COUNT:** progressive packet number ranging from 0 to 255
- **q0 – q3:** the orientation of the device expressed in quaternion form. Each one of the components is a 32-bit floating point number in the IEEE 754 standard. The four bytes are organized as follows:

Byte3	Byte4	Byte5	Byte6
Byte 0	Byte 1	Byte 2	Byte 3

IMPORTANT: The CHECKSUM is calculated as XOR of previous Bytes

VBATT (Battery Voltage)

This packet reports the battery voltage in mV.
It is sent periodically (typically every 5 seconds) if SEND_BATTERY (address 0x4F) is set to 1.

Byte 0	Byte 1	Byte2	Byte3	Byte4 .. Byte14	Byte15
0x20	0xBA	Vbatt_L	Vbatt_H	0	CHECKSUM_XOR

IMPORTANT: The CHECKSUM is calculated as XOR of previous Bytes