Inertial Measurement Unit

IMU

Interface Control Document

Revision 1.0

CHANGE STATUS LOG			
DOCUMENT: Inertial Labs™ AHRS Interface Control Document			
REVISION	DATE	AFFECTED PARAGRAPHS	REMARKS
1.0	Apr.25, 2016	All	Released version.

TABLE OF CONTENTS

1. Introduction 4
2. Scope and applicability 4
3. Mechanical interface 5
4. Electrical Interface 7
5. Software interface 10
5.1. Operational modes of the Inertial Labs™ IMU 12
5.2. Output Data Formats of the Inertial Labs™ IMU in the Operating Modes 12
5.2.1. The “IMU Calibrated Data” format 12
5.2.2. The “IMU Raw Data” format 14
5.2.3. The “NMEA Output” data format 15
5.3. Control of the Inertial Labs™ IMU 16
5.3.1. IMU_ClbData, IMU_RawData, IMU_NMEA commands 16
5.3.2. SetOnRequestMode command – getting IMU data on request (on demand) 18
5.3.3. Stop command 19
5.3.4. LoadIMUPar command 19
5.3.5. ReadIMUPar command 21
5.3.6. GetDevInfo command 22
5.4. The Unit Status Word definition 23
5.5. IMU automatic start 25
5.6. Change of the IMU COM port baud rate 26
5.7. Limitation of the IMU maximum output data rate 26
APPENDIX. Full list of the Inertial Labs™ IMU commands 28

1. INTRODUCTION

The **Inertial Labs™ Inertial Measurement Unit, IMU** is high-performance strapdown system that measures angular rates, linear accelerations and magnetic field in three orthogonal axes and also barometric pressure.

The Inertial Labs™ IMU includes three-axis MEMS angular rate sensors (gyros), three-axis MEMS accelerometers, three-axis MEMS magnetometers, piezo-resistive pressure sensor. All IMU sensors are precision-aligned across axes and calibrated in whole operating temperature range.

Fig.1.1. The Inertial Labs™ IMU

2. SCOPE AND APPLICABILITY

This Interface Control Document (ICD) provides details on mechanical mounting, the electrical connections, powering and software interface between the Inertial Labs™ IMU and host computer. This document is intended for all parties requiring such information, including engineers and researchers responsible for implementing the interface.

3. MECHANICAL INTERFACE

The Inertial Labs™ IMU housing has two base surfaces A and B (see Fig.3.1) that are designed for the IMU mounting during its run and testing.

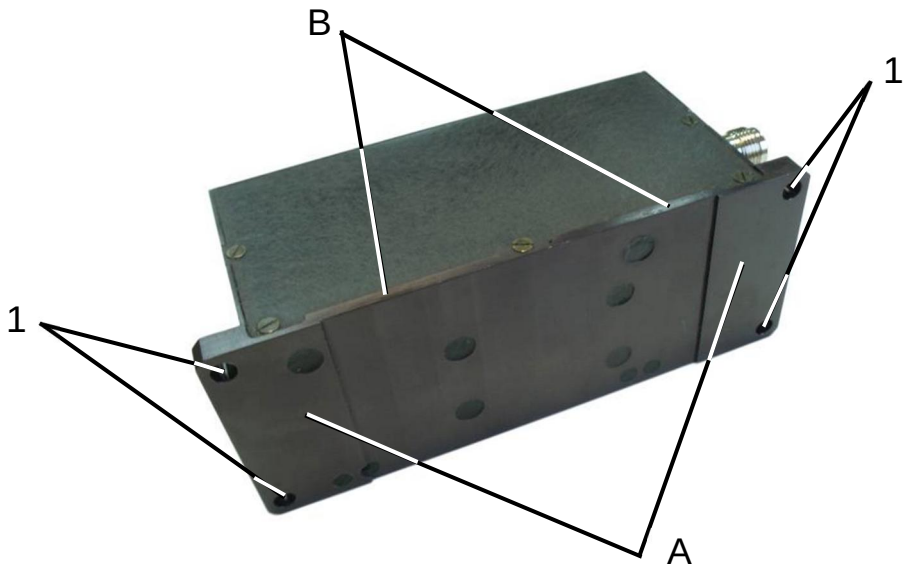

Fig.3.1. IMU mounting surfaces A, B and mounting holes 1, 2

Salient bottom base surface A has 4 holes ∅4.2 mm (see Fig.3.1, positions 1) which are designed for the IMU mounting. Lateral base surface B is designed for the IMU alignment during mounting.

The Inertial Labs™ IMU is factory calibrated with respect to the base surfaces A and B, thus it must be aligned within the host system (carrier object) with respect to these mounting surface, not the device edges.

The Inertial Labs™ IMU should be mounted on your system using 4 holes ∅4.2 mm (see Fig.3.1, positions 1).

Requirements to the mounting surface of the carrier object: flatness tolerance is 0.03 mm; undulation is Ra=1.25.

Fig.3.2 sows the outline drawings of the Inertial Labs™ IMU. All dimensions are in millimetres.

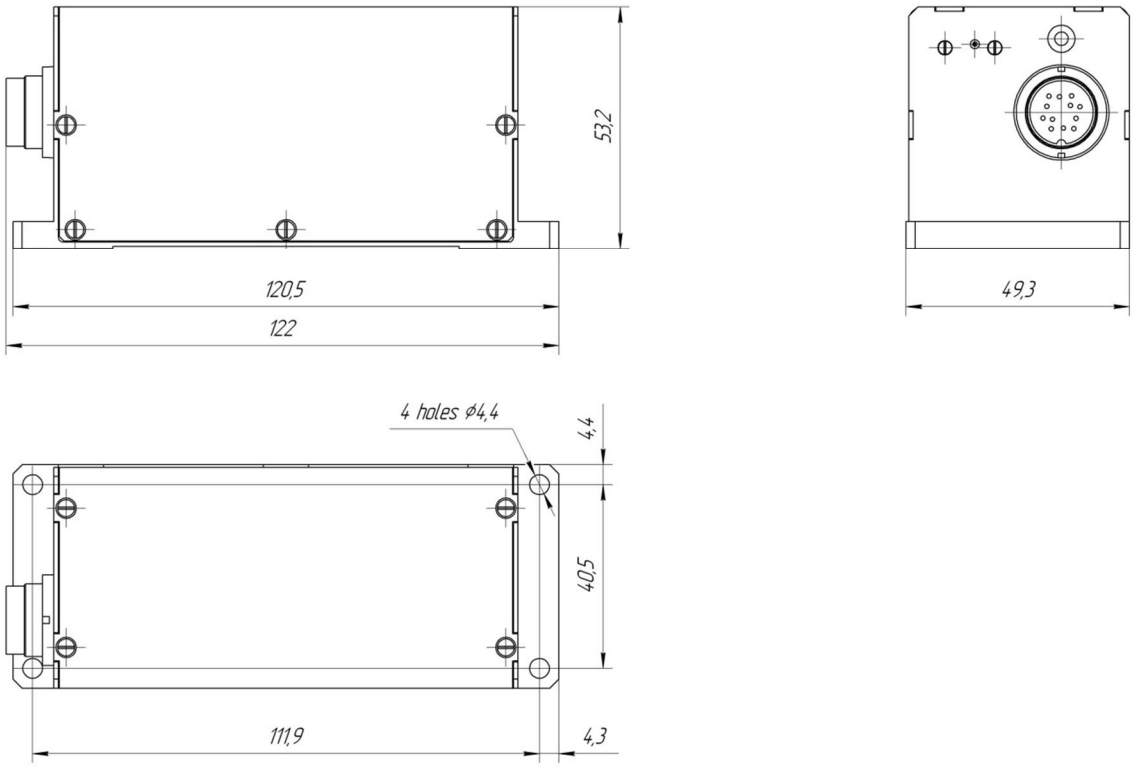

Fig.3.2. The Inertial Labs™ IMU outline drawing (all dimensions are in millimetres)

4. ELECTRICAL INTERFACE

The Inertial Labs™ IMU has the Binder Series 723 male 12 pin connector, part # 09 0131 80 12, https://www.binder-usa.com/products/partsdetail/86929

For electrical connection to the Inertial Labs™ IMU the host system should have a cable with mating connector – Binder Series or 423, 425 or 723 female 12 pin connector (or cordset), part # 09 0130 70 12, # 99 5130 40 12, # 79 6130 20 12.

Fig.4.1 shows the Inertial Labs™ IMU connector pinout. Table 5.1 contains pin diagram of this connector and appropriate color of wires in cable with mating Binder Series 425 Female plug, part # 79 6130 20 12.

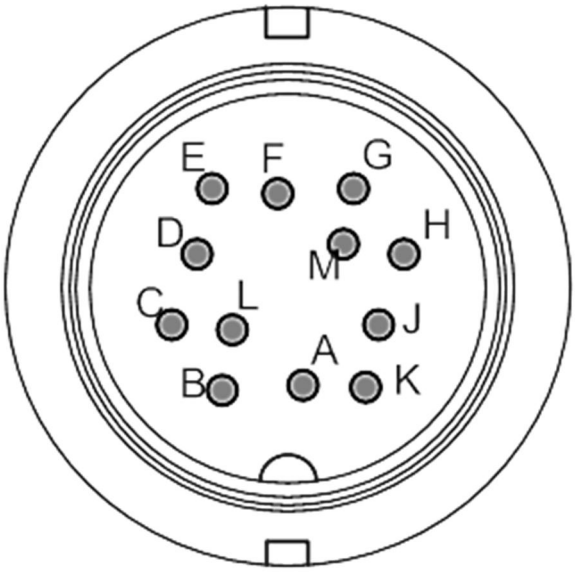

Fig.4.1. The Inertial Labs™ IMU connector pinout (mating side of the connector)

Table 4.1 Pin diagram of the Inertial Labs™ IMU connector

Pin	Wire color	Signal
A	White	RS422 – A
B	Brown	RS422 – B
C	Green	RS422 – Y
D	Yellow	RS422 – Z
E	Grey	**Power**
F	Pink	**Ground**
G	Blue	**RS232 – RX**
H	Red	**RS232 – TX**
J	Black	PPS
K	Violet	GPIO
L	Grey/pink	Do not connect
M	Red/blue	Do not connect

Notes: 1. Do not connect anything to pins #L or #M that are connected to IMU PCB for firmware updates.
2. RS-232 is the default interface. In this case pins #A to #D are not used.

Table 4.2 Electrical specifications

Parameter	Conditions	Min	Typical	Max	Units
Input Supply		+9	+12V	+36V	Volts DC
Power		1.35	1.40	1.50	W
Current	V_{DD} = +12V	100	115	125	mA

At the Inertial Labs™ IMU operations it should be connected to the host system which provides command interface described in the section 5 and the IMU powering.

For tests, the Inertial Labs™ IMU can be connected to PC by cable set as Fig.4.2 shows. At this, for the Inertial Labs™ IMU powering the AC/DC adapter can be used which receives the power from the 100…240V 50…60Hz AC power source. This AC/DC adapter is provided by the Inertial Labs and is included in the delivery set.

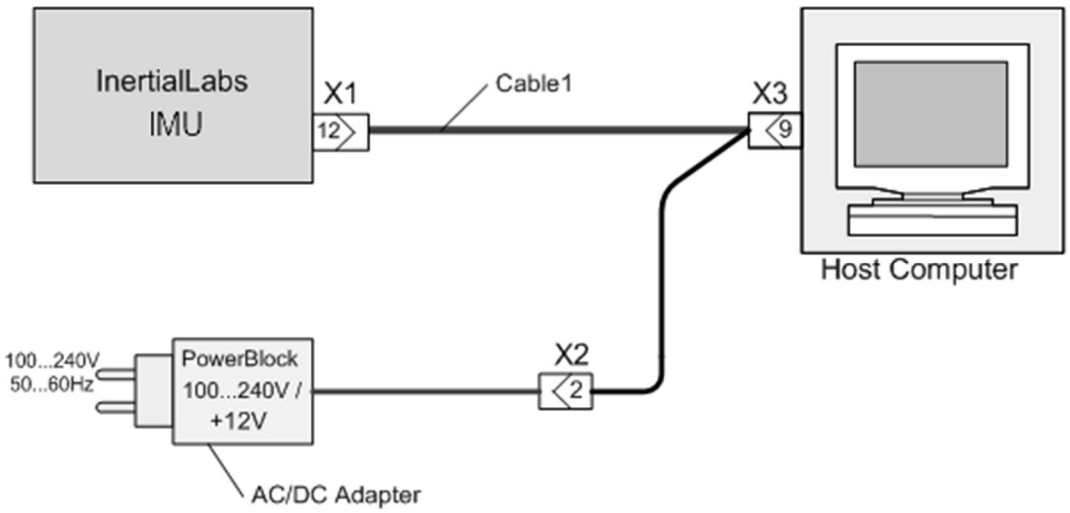

Fig.4.2. The diagram of electric connection of the Inertial Labs™ IMU to host computer (PC)

The delivery set for the IMU electrical connection to PC is provided by the Inertial Labs and includes:

- interface cable 1 for the Inertial Labs™ IMU connection to the COM-port of PC or another device, with branch wires for the Inertial Labs™ IMU DC powering;
- COM-to-USB converter for connection of the IMU to PC through the USB port;
- AC/DC adapter.

Also Inertial Labs IMU Demo software is included in the delivery set for quick evaluation of the Inertial Labs™ IMU.

Fig.4.3 shows the diagram of the interface cable 1 for the Inertial Labs™ IMU connections to the COM-port of host computer and to the DC power source.

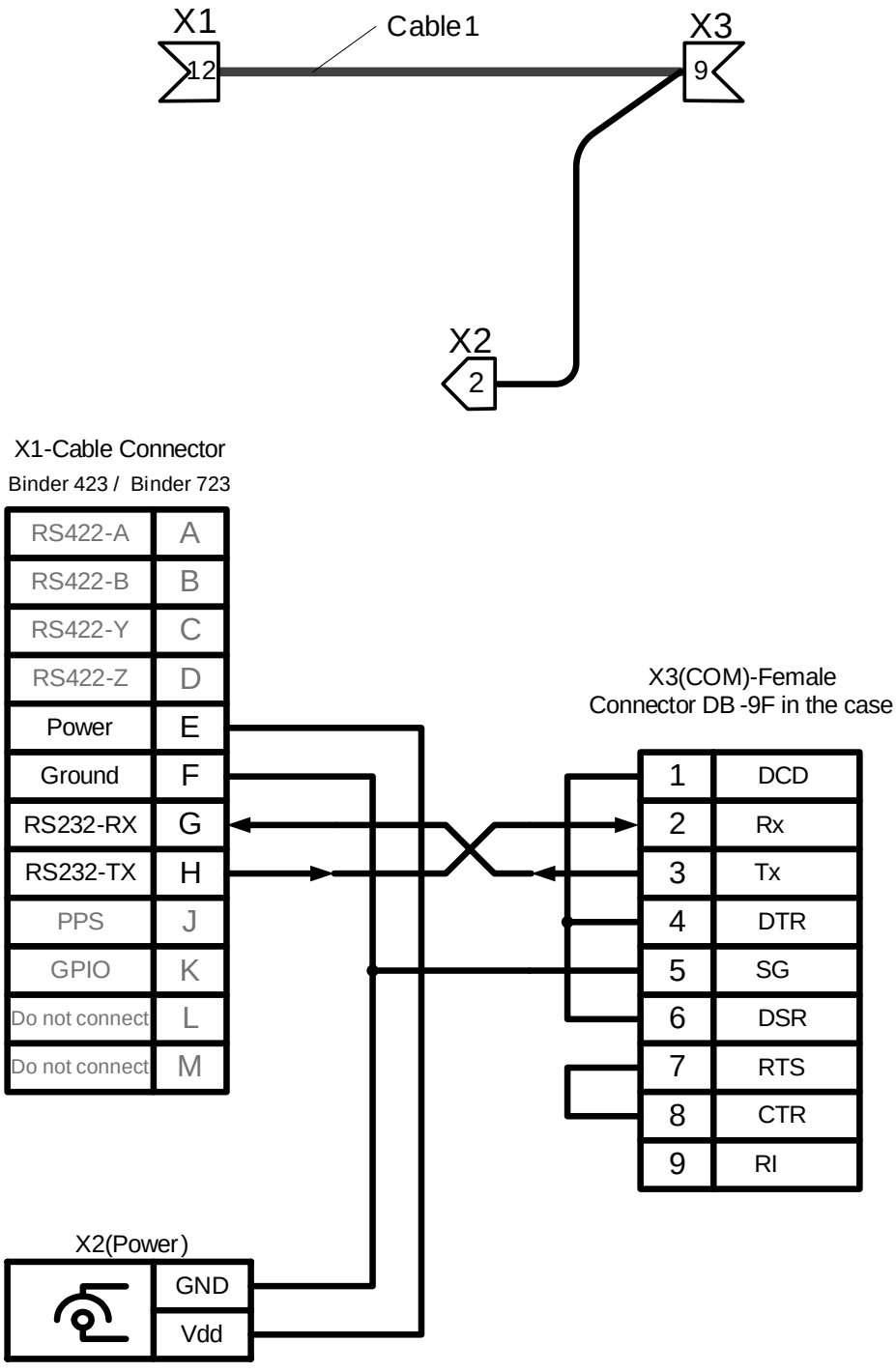

Fig.4.3. The diagram of the interface cable 1 for the Inertial Labs™ IMU connections to the COM-port of host computer and to the AC/DC adapter

5. SOFTWARE INTERFACE

After power connection the primary initialization of the Inertial Labs™ IMU microprocessor takes place and then the main program starts. The time of the device pretreatment is not more than 1 second. Then the program operates in the mode of commands waiting. The IMU indicator lights red.

If the auto start option is enabled the IMU starts operation automatically after power on (see section 5.5 for more details). The IMU indicator lights green.

The commands are transmitted through the serial port according to the protocol RS-232 with baud rate 115200 bps (default settings).

Table 5.1. COM-port parameters

COM-port parameters	
Baud rate	115200
Data bits	8
Parity	none
Stop bits	1

Notes

1. Other baud rate then 115200 bps can be set for IMU, see section "5.6. Change of the IMU COM port baud rate" for details.
2. The Inertial Labs™ IMU with RS-422, RS-485, CAN 2.0 interfaces are also available.

All commands and messages to/from the Inertial Labs™ IMU have the byte structure shown in the Table 5.2. Exception is done for the IMU output in the NMEA text format (see section 5.2.3).

Table 5.2. Byte structure for all commands and messages to / from the IMU

Byte number	0	1	2	3	4, 5	6..(n-1)	n, (n+1)
Parameter	Header 0	Header 1	Message type	IMU data identifier	Message length	Payload	Check sum
Length	1 byte	1 byte	1 byte	1 byte	1 word	Variable	1 word
Note	0xAA	0x55		In IMU messages	Equal to n		

In the Table 5.2 and in all other there is denoted:
word = unsigned 2 byte integer;
sword = signed 2 byte integer.

Message type is equal to:
0 – for commands;
1 – for transferring data.
All the IMU outputs are data, therefore they have Message type = 1.

IMU data identifier is used in IMU output data only. This byte is equal to code of the command from the host system which requested this IMU message. See all commands code in "APPENDIX A. Full list of the Inertial Labs™ IMU commands".

Note byte #3 in the block of the initial alignment data is equal to set output data rate (see Table 5.11). In all other messages and commands byte #3 in the Table 5.2 is zero.

The Message length is the number of bytes in the message without header.

The Check sum is the arithmetical sum of bytes 2…(n–1) (all bytes without header). In the check sum the low byte is transmitted first (see Table 5.3).

Table 5.3. Format of the check sum transmitting

byte0	byte1
low byte	high byte

Important note
The low byte is transmitted by first in all data denoted as word, sword, float.

5.1. Operational modes of the Inertial Labs™ IMU

The Inertial Labs™ IMU can operate in the three modes:

1. **Idle** mode. All sensors and electronics are powered. The IMU microprocessor waits any command from the host computer to start operate in one of the next modes. In the idle mode the indicator of IMU lights red.

2. **Continuous** operating mode. In this mode the IMU operates in the endless loop, providing the continuous output of measured data according to chosen output data format (see section 5.2). Data rate is set by user from 1 Hz to 200 Hz. In the Continuous operating mode indicator of the IMU lights green.

3. "**On Request**" operating mode. It is close to the Continuous operating mode, but the IMU sends only one data block after each Request command issued from host computer. In this mode indicator of the IMU lights green.

5.2. Output Data Formats of the Inertial Labs™ IMU in the Operating Modes

The next output data formats are available in the "Continuous" and "On Request" operating modes:

- IMU Calibrated Data;
- IMU Raw Data;
- NMEA Output.

5.2.1. The "IMU Calibrated Data" format

This is default data format. It provides the IMU output in the form of:

- calibrated outputs of the 9 sensors (gyros, accelerometers, magnetometers) that give information about current angular rate, linear acceleration of the IMU and components of outer magnetic field;
- calibrated data from pressure sensor – pressure and barometric altitude.

Structure of the IMU data blocks at the "IMU Calibrated Data" data format corresponds to the Table 5.2 with payload shown in the Table 5.4.

Table 5.4. The message payload at IMU Calibrated Data format

Byte number	0 – 5	6 – 11	12 – 17	18 – 19	20 – 21	22 – 23	24 – 25	26 – 27	28 – 29
Parameter	GyroX, GyroY, GyroZ	AccX, AccY, AccZ	MagX, MagY, MagZ	Pressure	Reserved	Reserved	USW	Vinp	Temper
Length	3× 2 byte sword	3× 2 byte sword	3× 2 byte sword	2 byte word	2 byte sword	2 byte sword	2 byte word	2 byte word	2 byte sword
Note	Angular rates, deg/s *KG	Accele-rations,g* KA	Magne-tic fields, nT/10	Pa/2				Supply voltage, VDC* 100	Temperature, ºC*10

Notes

1. Values of KG, KA are scale factors depending on gyro and accelerometer range:

Gyro range, deg/sec	250 or 300	500	1000	2000
KG	100	50	20	10

Accelerometer range, g	2	6	8	10	18
KA	10000	5000	4000	2000	1000

2. USW is unit status word (see section 5.4 for details).
3. Vinp is input voltage of the IMU.
4. Temper is averaged temperature in 3 accelerometers.
5. The low byte is transmitted by first.

More correctly gyros, accelerometers, magnetometers output are integrated angular rate, linear acceleration (specific force), magnetic field increments. In the IMU output these increments are divided by time step of data output so they may be interpreted as average angular rates, linear acceleration and magnetic field for cycle of data output. On the other hand, incremental sensor data are good for the IMU using in inertial systems – they are Delta Theta and Delta Velocity divided by time step of data output.

Maximum data rate for the IMU output at the "IMU Calibrated Data" format is limited to 200 Hz at standard COM-port baud rate 115200 bps. See Table 5.15 for maximum data rate at other baud rates.

5.2.2. The "IMU Raw Data" format

This format is near the same as the "IMU Calibrated Data" format but all sensors data are in original ADC codes (raw data). Usually the "IMU Raw Data" format is used by the IMU developers for full control of calculations in the IMU microprocessor. Also this format can be used by user at any troubles to get full data from the IMU for next sending them to developers.

Structure of the IMU data blocks at the "IMU Raw Data" data format corresponds to the Table 5.2 with payload shown in the Table 5.5.

Table 5.5. The message payload at IMU Raw Data format

Byte number	0 – 5	6 – 11	12 – 17	18 – 19	20 – 21	22 – 23	24 – 25	26 – 27	28 – 29
Parameter	UgyroX, UgyroY, UgyroZ	UaccX, UaccY, UaccZ	UmagX, UmagY, UmagZ	UP	UT	Reserved	USW	Vdd	Utermo
Length	3× 2 byte sword	3× 2 byte sword	3× 2 byte sword	2 byte word	2 byte word	2 byte sword	2 byte word	2 byte word	2 byte sword
Note	Raw gyros data	Raw accelerometers data	Raw magnetometers data	Raw pressure data	Raw pressure temperature data			Combi-ned voltage	Temperature in each sensor

Notes

1. USW is unit status word (see section 5.4 for details).
2. The following data are recorded in the field «Vdd» sequentially:
   - the IMU input voltage, Vinp, VDC*100;
   - stabilized voltage supplied to the IMU sensors, Vdd, VDC*1000;
3. In the «Utermo» field ADC codes are recorded sequentially from 7 temperature sensors inside gyros, accelerometers and magnetometers.
4. UP and UT are raw data from the pressure sensor – pressure and temperature.
5. The low byte is transmitted by first.

Maximum data rate for the IMU output in the "IMU Raw Data" format is limited to 200 Hz at standard COM-port baud rate 115200 bps. See Table 5.15 for maximum data rate at other baud rates.

5.2.3. The "NMEA Output" data format

At the "NMEA Output" the IMU data are transmitted in the form of sentences with printable ASCII characters like the NMEA 0183 format. Each sentence starts with a "$" sign and ends with <CR><LF> (carriage return 0xD and line feed 0xA symbols). All data fields are separated by commas. The general form of the "NMEA Output" sentence is the next

$PGAM, GGGG.xx, GGGG.yy, GGGG.zz, AA.xxxx, AA.yyyy, AA.zzzz, MXXXXXX, MYYYYYY, MZZZZZZ, PPPPPP, tttttttt,TTT.t,VV.v,SSSS*CC<CR><LF>

where PGAM is identifier and other fields are listed in the Table 5.6.

Table 5.6.The IMU message in NMEA format

Field	Parameter	*Note*
GGGG.xx	GyroX	deg/s
GGGG.yy	GyroY	deg/s
GGGG.zz	GyroZ	deg/s
AA.xxxx	AccX	g
AA.yyyy	AccY	g
AA.zzzz	AccZ	g
MXXXXXX	MagX	nT
MYYYYYY	MagY	nT
MZZZZZZ	MagZ	nT
PPPPPP	Pressure	Pa
tttttttt	Timestamp	ms
TTT.t	Temperature	ºC
VV.v	Vinp	VDC
SSSS	USW	hex written with ASCII
CC	Check sum	

Notes

1. USW is unit status word (see section 5.4 for details).
2. Timestamp is time in milliseconds from the beginning of IMU start.
3. Temperature is averaged value for 3 accelerometers.
4. Vinp is input voltage of the IMU.
5. Check sum consists of a "*" and two hex digits representing XOR of all characters between, but not including "$" and "*".

Maximum data rate for the IMU output at the "NMEA Output" data format is limited to 90 Hz at standard COM-port baud rate 115200 bps. See Table 5.15 for maximum data rate at other baud rates.

5.3. Control of the Inertial Labs™ IMU

After power connection the IMU is in the idle mode. Red light of the LED indicator near the connector signifies the readiness of the Inertial Labs™ IMU to receive commands from the host computer. When the IMU switches from idle to any operation mode, the light indicator changes its color from red to green.

The next commands are used to control the IMU:

- IMU_ClbData;
- IMU_RawData;
- IMU_NMEA;
- SetOnRequestMode;
- Stop;
- ReadIMUPar;
- LoadIMUPar;
- GetDevInfo;
- GetBIT.

All these commands have the byte structure shown in the Table 5.2. Payload for all commands has length 1 byte and contains code of the command. See Appendix A for exact structure of these commands.

5.3.1. IMU_ClbData, IMU_RawData, IMU_NMEA commands

Commands IMU_ClbData, IMU_RawData, IMU_NMEA are used to start the Inertial Labs™ IMU in the "Continuous" operating mode with appropriate variant of output data format as Table 5.7 shows.

Table 5.7. IMU control commands and appropriate output data format

Command	Code	Output data format
IMU_ClbData	0x8C	IMU Calibrated Data
IMU_RawData	0x8D	IMU Raw Data
IMU_NMEA	0x8E	IMU NMEA

All these commands have the byte structure shown in the Table 5.2. Payload for all commands has length 1 byte and contains code of the command listed in the Table 5.7.

In order to identify to the host system that IMU received one of these commands, the IMU answers back immediately on this command. The IMU calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 5.2 where payload is the calculated check sum (1 word). This

check sum should be equal to the check sum in the message that was sent to the IMU.

After receiving of any from IMU_ClbData, IMU_RawData, IMU_NMEA commands the IMU performs quick initial alignment procedure during which it calculates initial values of angular rates, linear accelerations and magnetic field components. Then the IMU gives out message with block of the initial alignment data (see Table 5.8, Table 5.9) and goes to the "Continuous" operating mode.

Notes:

1. It is possible to use initial alignment procedure to estimate gyros biases for their next automatic compensation. Set nonzero initial alignment time (see section 5.3.4. LoadIMUPar command) during which gyros biases should be estimated as averaged gyros data. But don't move the IMU during such initial alignment otherwise some wrong residual biases may be present in output gyros data.
2. In the IMU with firmware version before 2.2.0.3 the initial alignment procedure is obligatory even if zero initial alignment time is set.

Table 5.8. Byte structure of the block of initial alignment data

Byte number	0	1	2	3	4, 5	6..55	56, 57
Parameter	Header 0	Header 1	Message type	Output data rate (Hz)	Message length	Payload	Check sum
Length	1 byte	1 byte	1 byte	1 byte	1 word	50 bytes	1 word
Note	0xAA	0x55	0x01	hexadecimal value	0x38 0x00	see Table 5.12	

Table 5.9. Structure of the payload of the block of initial alignment data

Byte	**Parameter**	**Format**	**Length**	***Note***
0-11	Gyros bias	**float**	**3*4**	3 numbers in ADC codes
12-23	Average acceleration	**float**	**3*4**	3 numbers in ADC codes
24-35	Average magn. field	**float**	**3*4**	3 numbers in ADC codes
36-47	Reserved	**float**	**3*4**	Is used in other Inertial Labs™ products
48-49	USW (see section 5.4)	**word**	**2**	0 – successful initial alignment; ≠0 – unsuccessful

In the "Continuous" operating mode set by any of command IMU_ClbData, IMU_RawData, IMU_NMEA the program in the IMU microprocessor

operates in the endless loop, providing the process of sensors raw data reading and calculation of calibrated output data.

At the **IMU_ClbData, IMU_RawData** commands output data blocks have binary structure according to chosen variant of output data in messages described in the Table 5.2. The message payload depends on chosen variant of output data (see Tables 5.4 – 5.5).

At the **IMU_NMEA** command output data blocks are transmitted in the form of sentences with printable ASCII characters as section 5.2.3 describes.

The update rate of data blocks can be set by the user in range (1...200) Hz, but maximum data rate depends on chosen output data format and COM port baud rate (see Table 5.16).

5.3.2. SetOnRequestMode command – getting IMU data on request (on demand)

The command SetOnRequestMode is used to start the Inertial Labs™ IMU operation in the "On Request" (on demand) operating mode. This command has the byte structure shown in the Table 5.2 where payload is one byte equal to 0xC1.

In order to identify to the host system that IMU received this command, the IMU answers back immediately on this command. The IMU calculates the check sum of the message (without its header and check sum) and returns it for a checking. Byte structure of this message is shown in the Table 5.2 where payload is the calculated check sum (1 word). This check sum should be equal to the check sum in the message that was sent to the IMU.

After receiving of the SetOnRequestMode command the IMU performs quick initial alignment procedure during which it calculates initial values of angular rates, linear accelerations and magnetic field components. Then the IMU gives out message with block of the initial alignment data (see Table 5.8, Table 5.9) and goes to the "On Request" operating mode.

Notes:

1. It is possible to use initial alignment procedure to estimate gyros biases for their next automatic compensation. Set nonzero initial alignment time (see section 5.3.4. LoadIMUPar command) during which gyros biases should be estimated as averaged

gyros data. But don't move the IMU during such initial alignment otherwise some wrong residual biases may be present in output gyros data.
2. In the IMU with firmware version before 2.2.0.3 the initial alignment procedure is obligatory even if zero initial alignment time is set.

In the "On Request" operating mode the IMU sends only one data block after each request. To get this data block send one of above described commands IMU_ClbData, IMU_RawData, IMU_NMEA (see section 5.3.1).

If one of the **IMU_ClbData, IMU_RawData** commands is used for request then output data block has binary structure described in the Table 5.2 with payload depending on chosen variant of output data format (see matching Table 5.10 and detailed Tables 5.4 – 5.5).

If the **IMU_NMEA** command is used for request then output data block contains printable ASCII characters as section 5.2.3 describes.

5.3.3. Stop command

At receiving the Stop command (code 0xFE in the "Payload" field) the IMU stops work in an operating mode and goes to the idle mode. The IMU LED indicator changes its color to red. The IMU is ready to receive any command from the host computer.

Important Note: Before using all other commands please send the **Stop** command to the IMU to switch device into the idle mode. Be sure that the IMU's light indicator is red before sending of any other commands.

5.3.4. LoadIMUPar command

The LoadIMUPar command (code 0x40 in the "Payload" field) is used to load the block of the IMU parameters (which are available for changing by user) into the IMU nonvolatile memory. After sending the LoadIMUPar command, the block of the IMU parameters must be send to the IMU in the message shown in the Table 5.2 with payload shown in the Table 5.10. This message should be sent without pause after sending the LoadIMUPar command.

Table 5.10. Payload of the message following after the LoadIMUPar command (block of parameters for loading to the IMU)

Byte	Parameter	Format	Length	*Note*	*Available in IMU*
0-1	Data rate	**word**	**2**	Hz	✓
2-3	Initial alignment time	**word**	**2**	seconds	✓
4-7	Magnetic declination, Mdec	**longint**	**4**	degrees*100, if Mdec > 360 then IMU calculates it	These parameters are used in other Inertial Labs™ products. Do not change these parameters.
8-11	Latitude	**longint**	**4**	degrees*1e7	
12-15	Longitude	**longint**	**4**	degrees*1e7	
16-19	Altitude	**longint**	**4**	meters*100	
20	Date (Year from 2000)	**byte**	**1**	0 to 255	
21	Date (Month)	**byte**	**1**	1 to 12	
22	Date (Day)	**byte**	**1**	1 to 31	
23-24	Alignment angle A1	**sword**	**2**	Angles of IMU mounting on the carrier object, degrees*100	
25-26	Alignment angle A2	**sword**	**2**		
27-28	Alignment angle A3	**sword**	**2**		
29-30	IMU mount, right	**sword**	**2**	IMU mounting lever relative to the center of the object gravity, m*100	
31-32	IMU mount, forward	**sword**	**2**		
33-34	IMU mount, up	**sword**	**2**		
35-36	Reserved	**sword**	**2**	Must be all zeros	
37-38	Reserved	**sword**	**2**		
39-40	Reserved	**sword**	**2**		
41	Barometric altitude mode, h_bar_mode	**byte**	**1**	0 = Absolute 1 = At known initial value 2 = Heave	
42	Cutoff frequency for Heave HP filter	**byte**	**1**	Hz*100	
43	Cutoff frequency for Heave LP filter	**byte**	**1**	Hz*10, must be not less than cutoff frequency for Heave HP filter, or zero	
44-45	Target position, right	**sword**	**2**	Target position relative to the IMU for Heave calculation, lever, m*100	
46-47	Target position, forward	**sword**	**2**		
48-49	Target position, up	**sword**	**2**		
50-57	IMU device name	**char**	**8**	**only read**, change is ignored	✓
58	Baro_enabled	**byte**	**1**	0 = disabled; 1 = enabled	✓
59	Reserved	**byte**	**1**		

The IMU calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 5.2 where payload is the calculated check sum (2 bytes).

Notes:

1. The most easy and sure way to change above parameters is using the Inertial Labs™ IMU Demo Program.

2. Before using **LoadIMUPar** command it is necessary to use **ReadIMUPar** command (see below) to read parameters from the IMU at first. After that user can change some parameters listed in the Table 5.10, and to send back all block of parameters to the Inertial Labs™ IMU.

5.3.5. ReadIMUPar command

The ReadIMUPar command (code 0x41 in the "Payload" field, see the Table 5.2) is used to read block of the Inertial Labs™ IMU parameters (60 bytes) from the IMU nonvolatile memory.

After receiving ReadIMUPar command, the IMU sends out the message with structure according to the Table 5.2 and payload shown in the Table 5.11.

Table 5.11. Payload of the IMU answer on the ReadIMUPar command (block of parameters read from the IMU)

Byte	Parameter	Format	Length	*Note*	*Available in IMU*
0-1	Data rate	**word**	**2**	Hz	✓
2-3	Initial alignment time	**word**	**2**	seconds	✓
4-7	Magnetic declination	**longint**	**4**	degrees*100	These parameters are used in other Inertial Labs™ products
8-11	Latitude	**longint**	**4**	degrees*1e7	
12-15	Longitude	**longint**	**4**	degrees*1e7	
16-19	Altitude	**longint**	**4**	meters*100	
20	Date (Year from 2000)	**byte**	**1**	0 to 255	
21	Date (Month)	**byte**	**1**	1 to 12	
22	Date (Day)	**byte**	**1**	1 to 31	
23-24	Alignment angle A1	**sword**	**2**	Angles of IMU mounting on the carrier object, degrees*100	
25-26	Alignment angle A2	**sword**	**2**		
27-28	Alignment angle A3	**sword**	**2**		
29-30	IMU mount, right	**sword**	**2**	IMU mounting lever relative to the center of the object gravity, m*100	
31-32	IMU mount, forward	**sword**	**2**		
33-34	IMU mount, up	**sword**	**2**		
35-36	Reserved	**sword**	**2**		
37-38	Reserved	**sword**	**2**		
39-40	Reserved	**sword**	**2**		
41	Barometric altitude mode, h_bar_mode	**byte**	**1**	0 = Absolute 1 = At known initial value 2 = Heave	
42	Cutoff frequency	**byte**	**1**	Hz*100	

	for Heave HP filter				
43	Cutoff frequency for Heave LP filter	**byte**	**1**	Hz*10	
44-45	Target position, right	**sword**	**2**	Target position relative to the IMU for Heave calculation, lever, m*100	
46-47	Target position, forward	**sword**	**2**		
48-49	Target position, up	**sword**	**2**		
50-57	IMU device name	**char**	**8**		✓
58	Baro_enabled	**byte**	**1**	0 = disabled; 1 = enabled	✓
59	Reserved	**byte**	**1**		

See Notes to the section 5.3.4. LoadIMUPar command.

5.3.6. GetDevInfo command

The GetDevInfo command (code 0x12 in the "Payload" field) is used to get detailed information about devices installed in the IMU:
1) IMU processor;
2) IMU serial number;
3) Pressure sensor.

As answer the IMU sends out the message with structure according to the Table 5.2 and payload shown in the Table 5.12.

Table 5.12. Payload of the IMU answer on the GetDevInfo command

Byte	Parameter	Format	Length	*Note*	*Available in IMU*
0-7	ID_sn	**char**	**8**	Integrated device s/n	✓
8-47	ID_fw	**char**	**40**	Integrated device firmware version	✓
48	Press_Sens	**byte**	**1**	Pressure sensor: 1= present, 0 = absent	✓
49	IMU_type	**byte**	**1**	IMU type	✓
50-57	IMU_sn	**char**	**8**	IMU s/n	✓
58-97	IMU_fw	**char**	**40**	IMU firmware version	✓
98-113	GNSS_model	**char**	**16**	GNSS receiver model	
114-129	GNSS_sn	**char**	**16**	GNSS receiver product s/n	
130-	GNSS_hw	**char**	**16**	GNSS receiver	

145				hardware version	
146-161	GNSS_fw	**char**	**16**	GNSS receiver firmware version	
162-163	GPS_week	**word**	**2**	GPS reference week number	
164	GNSS_data_rate	**byte**	**1**	GNSS receiver max data rate, Hz	
165	Reserved	**byte**	**1**	Reserved	

5.4. The Unit Status Word definition

The Unit Status Word (USW) provides the IMU state information. The low byte (bits 0-7) of USW indicates failure of the IMU. If this byte is 0, the IMU operates correctly, if it is not 0, see the Table 5.13 for type of failure. The high byte (bits 8-15) contains a warning or is informative for the user. Status of each bit of the USW warning byte is specified in the Table 5.13 and Table 5.14.

Table 5.13. The Unit Status Word description

	Bit	Parameter	Description
Low (failure) byte	0	Initial Alignment	0 – Successful initial alignment 1 – Unsuccessful initial alignment due to IMU moving or large changing of outer magnetic field
	1	IMU Parameters	0 – Parameters are correct 1 – Parameters are incorrect
	2	Gyroscope Unit	0 – No failure 1 – Failure detected
	3	Accelerometer Unit	0 – No failure 1 – Failure detected
	4	Magnetometer Unit	0 – No failure 1 – Failure detected
	5	Electronics	0 – No failure 1 – Failure detected
	6	Software	0 – No failure 1 – Failure detected
	7	IMU mode	See the Table 5.22
High (warning) byte	8	Incorrect Power Supply	0 – Supply voltage is not less than minimum level 1 – Low supply voltage detected
	9		0 – Supply voltage is not higher than maximum level 1 – High supply voltage detected

	10	Angular Rate Exceeding Detect	0 – X-angular rate is within the range 1 – X-angular rate is outrange
	11		0 – Y-angular rate is within the range 1 – Y-angular rate is outrange
	12		0 – Z-angular rate is within the range 1 – Z-angular rate is outrange
	13	Large Magnetic Field Detect	0 – Total magnetic field is within the normal range 1 – Total magnetic field limit is exceeded
	14	Environmental Temperature	0 – Temperature is within the operating range 1 – Temperature is out of the operating range
	15	IMU mode	See the Table 5.22

The IMU indicates its current mode of operation in the bits 7 and 15 as the Table 5.14 shows.

Table 5.14. Indication of the IMU current operational modes

USW bits		**IMU mode**
Bit #7	**Bit #15**	
0	0	Readiness
1	1	Sleep (this is in the last data block sent by the IMU before it went to Sleep mode)

5.5. IMU automatic start

The Inertial Labs™ IMU auto start allows start of its operation and data output after power on without any command from the host computer. It is possible to choose desirable output data format for auto start (see section 5.2).

The auto start option can be enabled or disabled using the IMU Demo Program, in the "Options / Device options" menu. There is drop-down list "Auto start" where auto start with desirable output data format can be chosen. See IMU Demo Program User's Manual, section "9.2. IMU automatic start" for details.

If the auto start option is enabled then after the IMU power on the next operations take place:

- The primary initialization of the IMU microprocessor that takes not more than 1 second. The IMU LED indicator lights yellow.
- The IMU automatically starts operation from sending out the message AA 55 01 00 08 00 00 00 09 00 (in hexadecimal format) that indicates IMU atarted without any external command. The IMU LED indicator changes color to green.
- Then the IMU performs quick initial alignment procedure during which it calculates initial values of angular rates, linear accelerations and magnetic field components. Then the IMU gives out message with block of the initial alignment data (see Table 5.8, Table 5.9) and starts data output according to the chosen data format. The IMU LED indicator lights green.

To stop the IMU please send the Stop command (see section 5.3.3). After receiving the Stop command the IMU stops data calculation and goes to the idle mode. The IMU LED indicator changes its color to red. The IMU is ready to receive any command from the host computer.

Notes:

1. If nonzero initial alignment time was set then during this time the IMU averages gyros data to estimate gyros biases for their next automatic compensation. In such case don't move the IMU during the initial alignment procedure otherwise some wrong residual biases may be present in output gyros data.
2. In the IMU with firmware version before 2.2.0.3 the initial alignment procedure is obligatory even if zero initial alignment time is set.

5.6. Change of the IMU COM port baud rate

The default baud rate for IMU COM port is set to 115200 bps (maximum for the standard COM-port). The IMU supports different baud rates: 4800, 9600, 14400, 19200, 38400, 57600, 115200, 230400, 460800 bps. See IMU Demo Program User's Manual, section "4.2.3. Change of the COM port baud rate" for details.

Note the same baud rate must be set for COM port of the host computer.

5.7. Limitation of the IMU maximum output data rate

When setting of the output data rate for the IMU unit using LoadIMUPar command (see section 5.3.4) or using the Inertial Labs™ IMU Demo Program it is essential to ensure the chosen baud rate is capable of handling the data throughput with desirable data rate. The maximum data rate (Hz) can be calculated using the baud rate and data package length:

$$\text{max\_data\_rate} = \frac{\text{COM\_baud\_rate}}{\text{bits\_per\_byte} * \text{package\_length}}, \qquad (5.1)$$

where COM_baud_rate is COM port baud rate (bits/s); bits_per_byte = 11 bits per one transferred byte of data; package_length for binary data = payload length plus 8 bytes of overhead. See Table 5.4, Table 5.5 for payload length of binary output data formats. The package_length of the text output data format correspond to its structure shown in Table 5.6.

Below Table 5.15 contains data package length for each output data format and also maximum data rate calculated using formula (5.1), with some spare. Note the maximum measurement rate of IMU data is limited by 200 Hz.

Table 5.15. IMU maximum data rate for different output data formats

Output data format	Data package length, bytes	COM-port baud rate, bps					
		9600	19200	38400	**115200**	230400	460800
		Maximum data rate, Hz					
IMU Calibrated Data	38+8	10	40	90	**200**	200	200
IMU Raw Data	38+8	10	40	90	**200**	200	200
IMU NMEA	115	3	10	30	**90**	180	200

Note IMU unit controls correctness of the data rate setting. If user sets data rate which exceeds limit shown in Table 5.15, then its value is corrected. True data rate is given out in the byte #3 of IMU message after completing of the initial alignment procedure (see Table 5.8).

APPENDIX.
Full list of the Inertial Labs™ IMU commands

All the IMU commands have the byte structure shown in the Table 5.2. Payload for all commands has length 1 byte and contains code of the command. Below Table A.1 lists all commands with their exact structure in hexadecimal numbers.

Table A.1. List of the IMU commands with exact structure

Command name	Code	Exact structure (hex)
Commands for Inertial Labs™ IMU control		
IMU_ClbData	0x8C	AA 55 00 00 07 00 8C 93 00
IMU_RawData	0x8D	AA 55 00 00 07 00 8D 94 00
IMU_NMEA	0x8E	AA 55 00 00 07 00 8F 96 00
SetOnRequestMode	0xC1	AA 55 00 00 07 00 C1 C8 00
Stop	0xFE	AA 55 00 00 07 00 FE 05 01
LoadIMUPar	0x40	AA 55 00 00 07 00 40 47 00
ReadIMUPar	0x41	AA 55 00 00 07 00 41 48 00
GetDevInfo	0x12	AA 55 00 00 07 00 12 19 00