Inertial Measurement Unit

IMU-P

Interface Control Document

Revision 1.4

CHANGE STATUS LOG			
DOCUMENT: Inertial Labs™ IMU-P Interface Control Document			
REVISION	**DATE**	**AFFECTED PARAGRAPHS**	**REMARKS**
1.0	Mar.20, 2017	All	Released version.
1.1	Jul.17, 2017	5.2.2 5.3.1, Appendix 3 5	1. Corrected scale factors for gyros and accelerometers data for "IMU GA Data" format. 2. Corrected command code for IMU_ClbData and IMU_ADCdata commands. 3. Added Fig.1.2 with IMU-P axes 4. Added "IMU Orientation" output format.
1.2	Sep.21, 2017	All	General edits and corrections.
1.3	Oct.9, 2017	4.1	Added TOV description
1.4	Nov.21, 2017	5 5	1. Added 'IMU Platform Stabilization' output format. 2. Added g value to notes to Tables 5.4 – 5.8 with description of output data formats.

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1. INTRODUCTION

The **Inertial Labs™ Inertial Measurement Unit, IMU-P** is an Advanced MEMS sensors based, compact, self-contained strapdown inertial measurement system, that measures absolute orientation (heading, pitch, and roll angles), linear accelerations and angular rates with three-axis high-grade MEMS accelerometers and three-axis tactical grade MEMS gyroscopes. Angular rates and accelerations are determined with high accuracy for both motionless and dynamic applications.

All IMU-P sensors are precision-aligned across axes and calibrated over their operating temperature range.

Fig.1.1. The Inertial Labs™ IMU-P Coordinate System

Fig.1.1 shows the IMU-P and its own coordinate system, Oxyz. This coordinate system is body-fixed and defined as the calibrated sensors coordinate system.

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-P 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-P housing has two base surfaces A (bottom) and B (lateral), see Fig.3.1, that are designed for the IMU mounting during its run and testing.

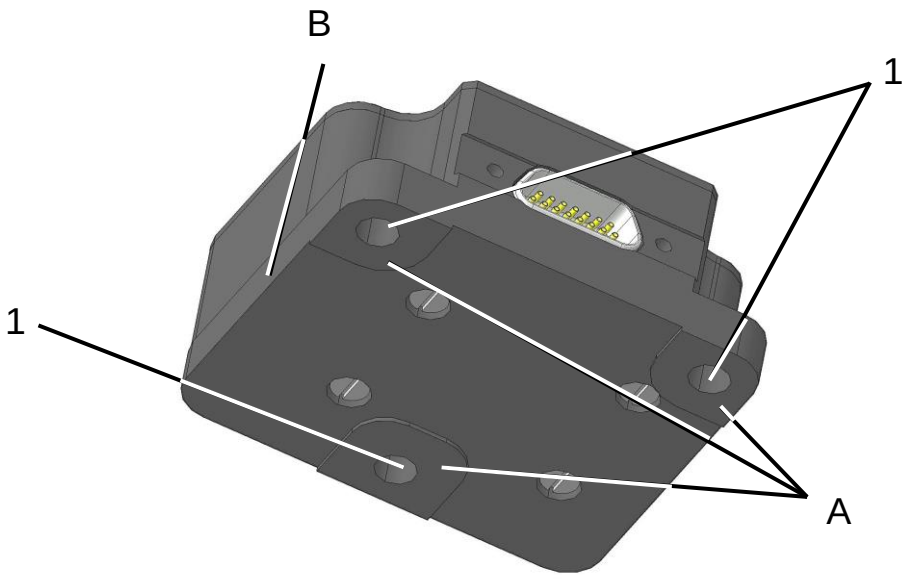


Fig.3.1. IMU-P mounting surfaces A, B and mounting holes 1

Salient parts of the base surface A have 3 holes ∅4.2 mm (see Fig.3.1, positions 1) which are designed for the IMU-P mounting. Lateral base surface B is designed for the IMU-P alignment during mounting.

The Inertial Labs™ IMU-P 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-P should be mounted on your system using 3 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-P. All dimensions are in millimetres.

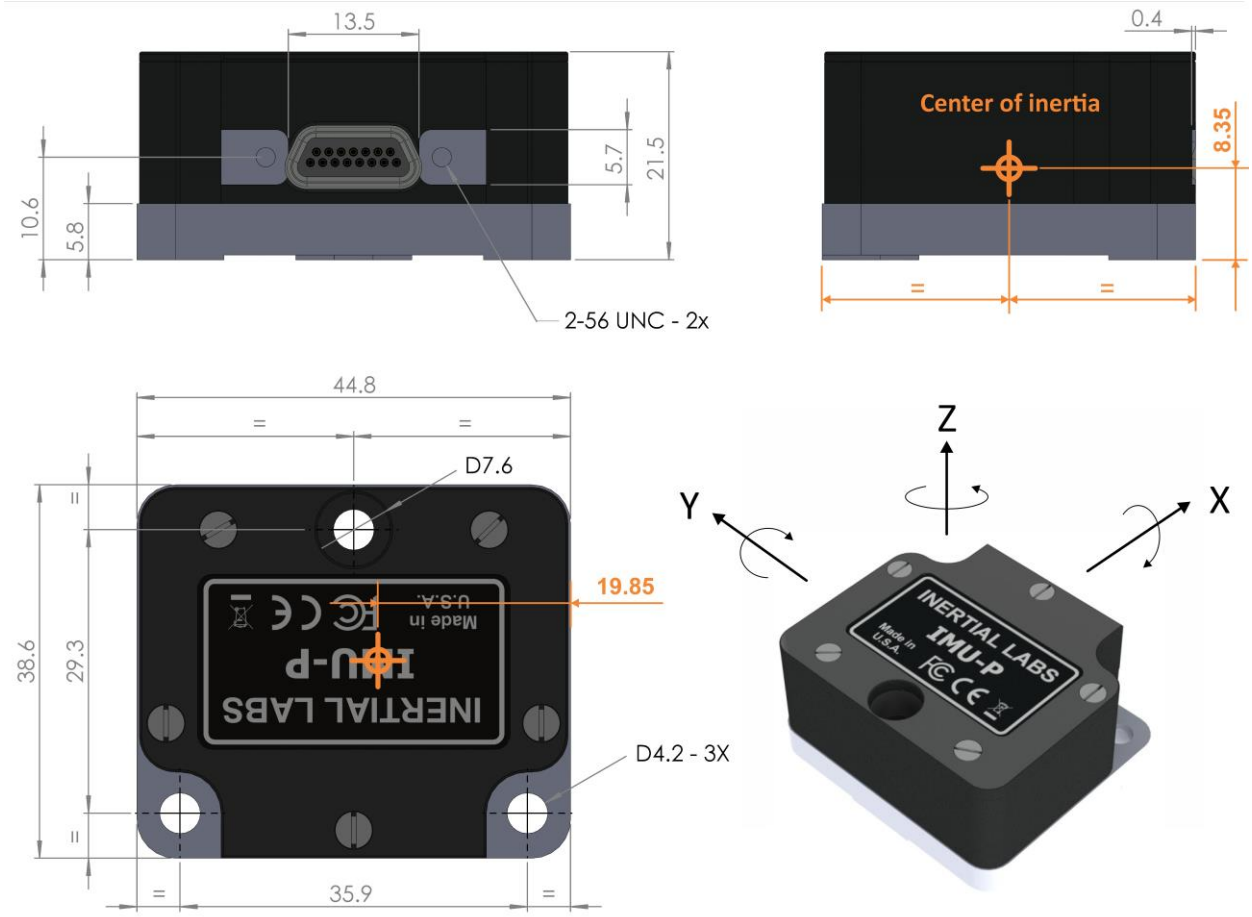


Fig.3.2. The Inertial Labs™ IMU-P outline drawing (all dimensions are in millimetres)

4. ELECTRICAL INTERFACE

The Inertial Labs™ IMU-P is equipped with a 15-pin micro D-subminiature female connector.

For electrical connection to the Inertial Labs™ IMU-P the host system should have a cable with a mating 15-pin micro D-sub male connector. Recommended part number for the 19" cable is M83513/03-B03N, and for the 3' cable - MDM-15PH006B-A174-F222 (both by ITT CANNON).

Fig.4.1 shows the Inertial Labs™IMU-P connector pinout. Table 5.1 contains the pin diagram of this connector.

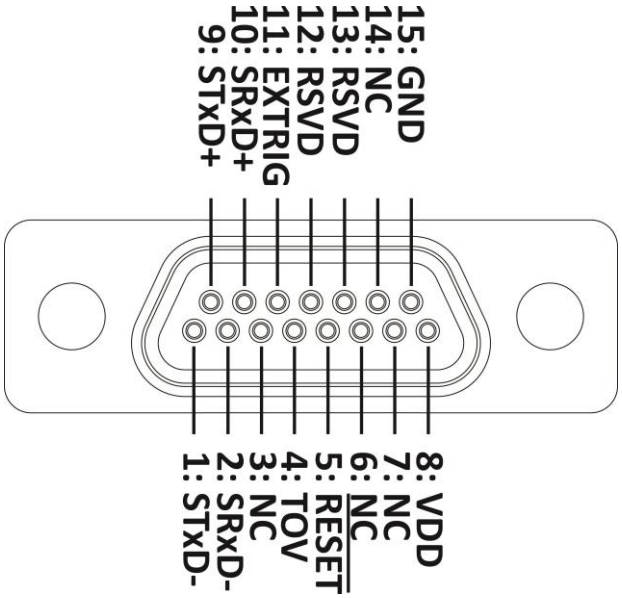


Fig.4.1. The Inertial Labs™ IMU-P connector pinout (mating side of the connector)

Table 4.1 Pin diagram of the Inertial Labs™ IMU-P connector

Pin	Name	Description
1	STxD-	RS422 inverted output
2	SRxD-	RS422 inverted input
3	NC	Do not connect
4	TOV (1)	Time of Validity output. Leave floating if not used. Open drain output pulled up to VDD via 10K.
5	RESET	Reset input. Leave floating if not used. Active low input, pulled up to VDD.
6	NC	Do not connect
7	NC	Do not connect
8	VDD	Power input
9	STxD+	RS422 non-inverted output
10	SRxD+	RS422 non-inverted input
11	EXTRIG (1)	External trigger input. Pulled up to VDD via 10K, leave floating if not used.
12	RSVD	Reserved for future use
13	RSVD	Reserved for future use
14	NC	Do not connect
15	GND	Supply and signal ground

Note (1) Please contact Inertial Labs about possibility of TOV and EXTRIG signals using in your IMU-P unit.

Table 4.2 Electrical specifications

Parameter	Conditions	Min	Typical	Max	Units
Input Supply		+5	+12V	+30V	Volts DC
Power		800	1100	1800	mW
Current	V_{DD} = +12V	160	90	60	mA

In order to operate with the Inertial Labs™ IMU it should be connected to a host system which provides both power and the command interface described in Section 5 below.

For testing purposes the Inertial Labs™ IMU can be connected to a PC with the supplied cable set as Fig.4.2 shows. At this, the AC/DC adapter, which receives the power from 100/240V 50/60Hz AC, can be used for powering the device.

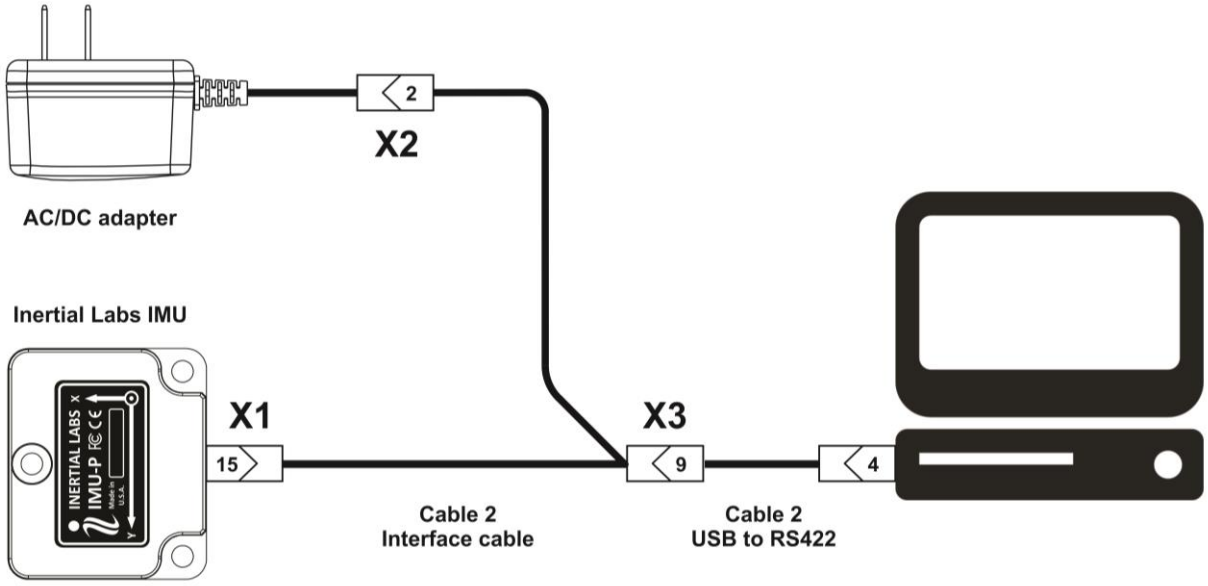


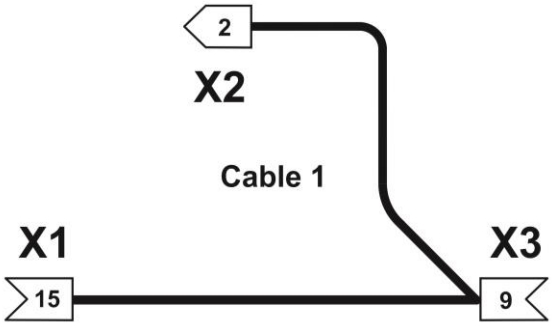
Fig.4.2. Electric connection of the Inertial Labs™ IMU-P to host computer (PC)

The delivery set for the IMU electrical connection to PC is provided with shipment and includes:

- one interface cable(cable 1) for the IMU connection to a host system equipped with an RS422 interface, with branch wires for the Inertial Labs™ IMU DC powering;
- one RS422-to-USB converter (cable 2) for connection of the IMU to PC through the USB port;
- one DB9-DB9 6 feet long cable (optional), to use as extension between the main cable and RS422-to-USB converter;
- AC/DC 12V power adapter.

Also Inertial Labs IMU Demo software is included in the delivery set for quick evaluation of the Inertial Labs™IMU, as well as the set of drivers for RS422-to-USB converter.

Fig.4.3 shows the diagram of the interface cable for the Inertial Labs™IMU connection to the RS422 adapter and then to the USB port of a host computer and to the DC power source.



X1: M83513/03-B03N by ITT CANNON

X1 pin	COLOR	FUNCTION
1	Black	422-Z
2	Brown	422-B
3	Red	NC
4	Orange	TOV
5	Yellow	RESET
6	Green	NC
7	Blue	NC
8	Violet	VINPUT
9	Grey	422-Y
10	White	422-A
11	Black	EXTRIG
12	Brown	232-RX
13	Red	232-TX
14	Orange	NC
15	Yellow	GND

X3: DB9 female

X3 pin	FUNCTION
1	422-B
2	422-A
3	422-Y
4	422-Z
5	GND
6	NC
7	NC
8	NC
9	NC

X2: Barrel power connector

VDD	
GND	

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

4.1. TOV description

The Inertial Labs IMU provides the Time of Validity (TOV) output. The appropriate pin of the IMU-P main connector provides the TOV signal (see Table 4.1 and Table 4.3).

The main purpose of the TOV signal is providing means to signal when data is ready and is being transmitted. The TOV falling edge occurs synchronous to the sample rate. The raising edge occurs after the last bit of the data has been transmitted (see Fig. 4.4).

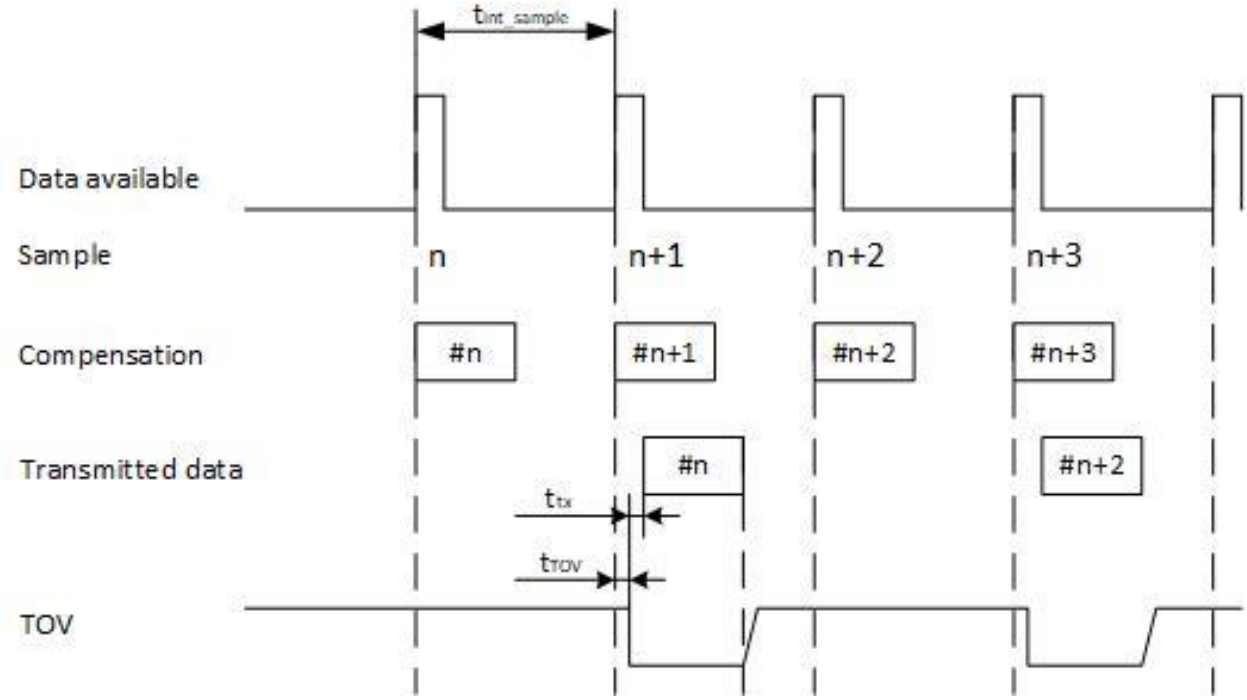


Fig.4.4 TOV signal

5. SOFTWARE INTERFACE

After power connection the primary initialization of the Inertial Labs™IMU-P 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.

If the auto start option is enabled the IMU-P starts operation automatically after power on (see section 5.5 for more details).

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

Table5.1. COM-port parameters

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

Note
Other baud rate then 115200 bps can be set for IMU-P, see section "5.6. Change of the IMU-P COM port baud rate" for details.

All commands and messages to/from the Inertial Labs™IMU-P have the byte structure shown in the Table 5.2. Exception is done for the IMU-P output in the NMEA text format (see section 5.2.4).

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

Byte number	0	1	2	3	4, 5	6..(n-1)	n, (n+1)
Parameter	Header 0	Header 1	Message type	IMU-P 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-P outputs are data, therefore they have Message type = 1.

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

Note byte #3 in the block of the initial alignment data is equal to set output data rate (see Table 5.14). 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-P

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

1. **Idle** mode. All sensors and electronics are powered. The IMU-P microprocessor waits any command from the host computer to start operating in Continuous or On Request modes.

2. **Continuous** operating mode. In this mode the IMU-P 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 800 Hz.

3. "**On Request**" operating mode. It is close to the Continuous operating mode, but the IMU-P sends only one data block after each Request command issued from host computer.

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

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

- IMU Calibrated Data;
- IMU GA Data;
- IMU ADC Data;
- IMU Orientation;
- IMU NMEA.

These data formats are common for all models of the Inertial Labs IMU units (IMU-B, IMU-E, IMU-P).

5.2.1. The "IMU Calibrated Data" format

This data format provides the IMU-P calibrated outputs of the gyros and accelerometers that give information about current angular rate and linear acceleration of the IMU-P.

Structure of the IMU-P 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* 4000	Magne-tic fields, nT/10	Pa/2				Supply voltage, VDC* 100	Temperature, ºC*10

Notes

1. KG is scale factor which value depends on gyro range:

Gyro range, deg/sec	120	240	450	950
KG	200	100	50	20

1. g = 9.8106 m/s^2.
2. MagX, MagY, MagZ parameters are zero (not measured in IMU-P).
3. Pressure is zero (not measured in IMU-P).
4. Vinp parameter is zero (not measured in IMU-P).
5. USW is unit status word (see section 5.4 for details).
6. The low byte is transmitted by first.

Maximum data rate for the IMU-P output at the "IMU Calibrated Data" format is 800 Hz but it is limited by set baud rate of COM-port. See Table 5.17 for maximum data rate at different baud rates.

5.2.2. The "IMU GA Data" format

The IMU GA Data format provides the IMU-P calibrated output of gyrosand accelerometers with high resolution that give information about current angular rate and linear acceleration of the IMU-P.

Structure of the IMU-P data blocks at the "IMU GA 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 GA Data format

Byte number	0 – 11	12 – 23	24 – 25	26 – 27	28 – 29	30 – 31
Parameter	GyroX, GyroY, GyroZ	AccX, AccY, AccZ	Reserved	USW	Vinp	Temper
Length	3×4 byte integer	3×4 byte integer	2 byte word	2 byte word	2 byte word	2 byte sword
Note	Angular rates, deg/s *1e5	Accelerations,g* 1e6			Supply voltage, VDC* 100	Temperature, ºC*10

Notes

1. g = 9.8106 m/s^2.
2. USW is unit status word (see section 5.4 for details).
3. Vinp parameter is zero (not measured in IMU-P).
4. The low byte is transmitted by first.

Maximum data rate for the IMU-P output in the "IMU GAData" format is 800 Hz but it is limited by set baud rate of COM-port. See Table 5.17 for maximum data rate at different baud rate.

5.2.3. The "IMU ADC Data" format

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

Structure of the IMU-P data blocks at the "IMU ADC Data" data format corresponds to the Table 5.2 with payload shown in the Table 5.6.

Table 5.6. The message payload at IMU ADC 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	Gyros data, ADC code	Accelerometers data, ADC code	Magnetometers data, ADC code	Pressure data, ADC code	Pressure temperature data, ADC code			Combi-ned voltage	Temperature, ADC code

Notes

1. g = 9.8106 m/s^2.
2. USW is unit status word (see section 5.4 for details).
3. MagX, MagY, MagZ parameters are zero (not measured in IMU-P).
4. Vdd parameter is zero (not measured in IMU-P).
5. UP and UT parameters are zero (not measured in IMU-P).
6. The low byte is transmitted by first.

Maximum data rate for the IMU-P output in the "IMU ADC Data" formats 800 Hz but it is limited by set baud rate of COM-port. See Table 5.17 for maximum data rate at different baud rate.

5.2.4. The "IMU NMEA" data format

At the "IMU NMEA" the IMU-P 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 5.7.

Table 5.7.The IMU-P 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. g = 9.8106 m/s^2.
2. USW is unit status word (see section 5.4 for details).
3. MagX, MagY, MagZ parameters are zero (not measured in IMU-P).
4. Timestamp is time in milliseconds from the beginning of IMU-P start.
5. Vinp parameter is zero (not measured in IMU-P).
6. 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-P output at the “IMU Calibrated Data” format is 800 Hz but it is limited by set baud rate of COM-port. See Table 5.17 for maximum data rate at different baud rates.

5.2.5. The “IMU Orientation” data format

At “IMU Orientation” format IMU-P outputs also orientation in addition to sensors data.

Structure of the IMU-P data blocks at the “IMU Orientation” data format corresponds to the Table 5.2 with payload shown in the Table 5.8.

Table 5.8. The message payload at IMU Orientation data format

Byte number	0 – 1	2 – 3	4 – 5	6 – 11	12 – 17	18 – 23	24–27	28 – 29	30 – 31	32 – 33
Parameter	Yaw	Pitch	Roll	GyroX, GyroY, GyroZ	AccX, AccY, AccZ	MagX, MagY, MagZ	Reserved	USW	Vinp	Temper
Length	2 byte word	2 byte sword	2 byte sword	3× 2 byte sword	3× 2 byte sword	3× 2 byte sword	4 bytes integer	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Angular rates, deg/s *KG	Accele-rations,g *4000	Magnetic fields, nT/10			Supply voltage, VDC* 100	Temperature, ºC*10

Notes

1. KG is scale factor which value depends on gyro range:

Gyro range, deg/sec	120	240	450	950
KG	200	100	50	20

2. g = 9.8106 m/s^2.
3. MagX, MagY, MagZ parameters are zero (not measured in IMU-P).
4. Vinp parameter is zero (not measured in IMU-P).
5. USW is unit status word (see section 5.4 for details).
6. The low byte is transmitted by first.

Maximum data rate for the IMU-P output at the "IMU Calibrated Data" format is 800 Hz but it is limited by set baud rate of COM-port. See Table 5.17 for maximum data rate at different baud rates.

5.2.6. The "IMU Platform Stabilization" data format

At "IMU Platform Stabilization" format IMU-P outputs orientation and gyro data.

Structure of the IMU-P data blocks at the "IMU Platform Stabilization" data format corresponds to the Table 5.2 with payload shown in the Table 5.9.

Table 5.9. The message payload at IMU Platform Stabilization data format

Byte number	0 – 11	12 – 13	14 – 15	16 – 17	18 – 19	20 – 21
Parameter	GyroX, GyroY, GyroZ	Yaw	Pitch	Roll	Temper	USW
Length	3×4 byte integer	2 byte word	2 byte sword	2 byte sword	2 byte sword	2 byte word
Note	Angular rates, deg/s *1e5	Orientation angles, deg*100			Temperature, ºC*10	

Notes

1. USW is unit status word (see section 5.4 for details).
2. The low byte is transmitted by first.

Maximum data rate for the IMU-P output at the "IMU Calibrated Data" format is 800 Hz but it is limited by set baud rate of COM-port. See Table 5.17 for maximum data rate at different baud rates.

5.3. Control of the Inertial Labs™ IMU-P

After power connection the IMU-P is in the idle mode.

The next commands are used to control the IMU-P:

- IMU_ClbData;
- IMU_GAdata;
- IMU_ADCdata;
- IMU_Orientation;
- IMU_PStabilization;
- 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_GAdata, IMU_ADCdata, IMU_Orientation, IMU_PStabilization, IMU_NMEA commands

Commands IMU_ClbData, IMU_GAdata, IMU_ADCdata, IMU_Orientation, IMU_PStabilization, IMU_NMEA are used to start the Inertial Labs™IMU-P

in the “Continuous” operating mode with appropriate variant of output data format as Table 5.10 shows.

Table 5.10. IMU-P control commands and appropriate output data format

Command	Code	Output data format
IMU_ClbData	0x8D	IMU Calibrated Data
IMU_GAdata	0x8F	IMU GA Data
IMU_ADCdata	0x8C	IMU ADC Data
IMU_Orientation	0x33	IMU Orientation
IMU_PStabilization	0x92	IMU Platform Stabilization
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 5.10.

In order to identify to the host system that IMU-P received one of these commands, the IMU-P answers back immediately on this command. The IMU-P 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-P.

After receiving of any from IMU_ClbData, IMU_ADCdata, IMU_GAdata, IMU_Orientation, IMU_PStabilization, IMU_NMEA commands the IMU-P performs quick initial alignment procedure during which it calculates initial values of angular rates and linear accelerations. Then the IMU-P gives out message with block of the initial alignment data (see Table 5.11, Table 5.12) 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. for LoadIMUPar command) during which gyros biases should be estimated as averaged gyros data. But don’t move the IMU-P during such initial alignment otherwise some wrong residual biases may be present in output gyros data.

2. In the IMU-P with firmware version before 2.2.0.3 the initial alignment procedure is obligatory even if zero initial alignment time is set.

Table 5.11. 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 5.15	

Table 5.12. 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_ADCdata, IMU_GAdata, IMU_Orientation, IMU_PStabilization, IMU_NMEA the program in the IMU-P 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_ADCdata, IMU_GAdata, IMU_Orientation, IMU_PStabilization** 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 – 5.6).

At the **IMU_NMEA** command output data blocks are transmitted in the form of sentences with printable ASCII characters as section 5.2.4 describes.

The update rate of data blocks can be set by the user in range (1...800)Hz, but maximum data rate depends on chosen output data format and COM port baud rate (see Table 5.17).

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

The command SetOnRequestMode is used to start the Inertial Labs™IMU-P 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-P received this command, the IMU-P answers back immediately on this command. The IMU-P 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-P.

After receiving of the SetOnRequestMode command the IMU-P performs quick initial alignment procedure during which it calculates initial values of angular rates and linear accelerations. Then the IMU-P gives out message with block of the initial alignment data (see Table 5.11, Table 5.12)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-P during such initial alignment otherwise some wrong residual biases may be present in output gyros data.

2. In theIMU-P 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-P sends only one data block after each request. To get this data block send one of above described commands IMU_ClbData, IMU_ADCdata, IMU_GAdata, IMU_Orientation, IMU_PStabilization, IMU_NMEA (see section 5.3.1).

If one of the **IMU_ClbData, IMU_ADCdata, IMU_GAdata, IMU_Orientation, IMU_PStabilization** 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 5.13 and detailed Tables 5.4 – 5.6).

If the **IMU_NMEA** command is used for request then output data block contains printable ASCII characters as section5.2.4 describes.

5.3.3. Stop command

At receiving the Stop command (code 0xFE in the "Payload" field) the IMU-P stops work in an operating mode and goes to the idle mode. The IMU-P 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-P to switch device into the idle mode.

5.3.4. LoadIMUPar command

The LoadIMUPar command (code 0x40 in the "Payload" field) is used to load the block of the IMU-P parameters (which are available for changing by user) into the IMU-P nonvolatile memory. After sending the LoadIMUPar command, the block of the IMU-P parameters must be send to the IMU-P in the message shown in the Table 5.2 with payload shown in the Table 5.13. This message should be sent without pause after sending the LoadIMUPar command.

Table 5.13. Payload of the message following after the LoadIMUPar command (block of parameters for loading to the IMU-P)

Byte	Parameter	Format	Length	*Note*	*Available in IMU-P*
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-P 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-P at first. After that user can change some parameters listed in the Table 5.13, and to send back all block of parameters to the Inertial Labs™ IMU-P.

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-P parameters (60 bytes) from the IMU-P nonvolatile memory. After receiving ReadIMUPar command, the IMU-P sends out the message with structure according to the Table 5.2 and payload shown in the Table 5.14.

Table 5.14. Payload of the IMU-P answer on the ReadIMUPar command (block of parameters read from the IMU-P)

Byte	Parameter	Format	Length	*Note*	*Available in IMU-P*
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 for Heave HP filter	**byte**	**1**	Hz*100	
43	Cutoff frequency	**byte**	**1**	Hz*10	

	for Heave LP filter				
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-P:
1)IMU-P processor;
2)IMU-P serial number;
3)Pressure sensor.

As answer the IMU-P sends out the message with structure according to the Table 5.2 and payload shown in the Table 5.15.

Table 5.15. Payload of the IMU-P answer on theGetDevInfo command

Byte	Parameter	Format	Length	*Note*	*Available in IMU-P*
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**	IMUs/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	
130-145	GNSS_hw	**char**	**16**	GNSS receiver hardware version	
146-161	GNSS_fw	**char**	**16**	GNSS receiver firmware version	
162-	GPS_week	**word**	**2**	GPS reference week	

163				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-P state information. The low byte (bits 0-7) of USW indicates failure of the IMU-P. If this byte is 0, the IMU-P operates correctly, if it is not 0, see the Table 5.16 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 5.16.

Table 5.16. 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	Reserved	–
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 max 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	Reserved	–

5.5. IMU-P automatic start

The Inertial Labs™IMU-P 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-P 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-P Demo Program User's Manual, section "9.2. IMU-P automatic start" for details.

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

- The primary initialization of the IMU-P microprocessor that takes not more than 1 second.
- The IMU-P automatically starts operation from sending out the message AA 55 01 00 08 00 00 00 09 00 (in hexadecimal format) that indicates IMU-Patarted without any external command.
- Then the IMU-P performs quick initial alignment procedure during which it calculates initial values of angular rates and linear accelerations. Then the IMU-P gives out message with block of the initial alignment data (see Table 5.11, Table 5.12) and starts data output according to the chosen data format.

To stop the IMU-P please send the Stop command (see section 5.3.3). After receiving the Stop command the IMU-P stops data calculation and goes to the idle mode. The IMU-P 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-P averages

gyros data to estimate gyros biases for their next automatic compensation. In such case don't move the IMU-P during the initial alignment procedure otherwise some wrong residual biases may be present in output gyros data.
2. In the IMU-P 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-P COM port baud rate

The default baud rate for IMU-P COM port is set to 115200 bps (maximum for the standard COM-port). The IMU-P supports different baud rates: 9600, 14400, 19200, 38400, 57600, 115200, 230400, 460800bps.See IMU-P Demo Program User's Manual, section "4.2.1. 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-P maximum output data rate

When setting of the output data rate for the IMU-P unit using LoadIMUPar command (see section 5.3.4) or using the Inertial Labs™IMU-P 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:

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

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 5.17 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-P data is limited by 800 Hz.

Table 5.17. IMU-P 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	30+8	20	40	90	**270**	550	800
IMU ADC Data	30+8	20	40	90	**270**	550	800
IMU GA Data	32+8	20	40	80	**260**	520	800
IMU Orientation	34+8	20	40	80	**240**	490	800
IMU Platform Stabilization	22+8	20	50	110	**340**	690	800
IMU NMEA	115	7	10	30	**90**	180	360

Note IMU-P unit controls correctness of the data rate setting. If user sets data rate which exceeds limit shown in Table 5.17, then its value is corrected. True data rate is given out in the byte #3 of IMU-P message after completing of the initial alignment procedure (see Table 5.11).

APPENDIX.
Full list of the Inertial Labs™ IMU-P commands

All the IMU-P 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-P commands with exact structure

Command name	Code	Exact structure (hex)
Commands for Inertial Labs™ IMU-P control		
IMU_ClbData	0x8D	AA 55 00 00 07 00 8D 94 00
IMU_GAdata	0x8F	AA 55 00 00 07 00 8F 96 00
IMU_ADCdata	0x8C	AA 55 00 00 07 00 8C 93 00
IMU_Orientation	0x33	AA 55 00 00 07 00 33 3A 00
IMU_PStabilization	0x92	AA 55 00 00 07 00 92 99 00
IMU_NMEA	0x8E	AA 55 00 00 07 00 8E 95 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