Vertical Gyro System
VG

Interface Control Document

Revision 1.4

CHANGE STATUS LOG			
DOCUMENT: Inertial Labs™ VG Interface Control Document			
REVISION	DATE	AFFECTED PARAGRAPHS	REMARKS
1.0	May.11, 2012	All	Released version.
1.1	Jan.21, 2013	3 5 6.2	1. Added specifications for VG.01.02 model. 2. Updated links on website for VG connectors. 3. Augmented Notes 1 and 2 under Table 6.6 for VG firmware since v.4.9.6.3.
1.2	Apr.02, 2013	3	Updated specifications for VG.01.02 model.
1.3	Oct.10, 2013	3	1. Document format updates. 2. Updated VG specifications.
1.4	Mar.06, 2014	3 6.2	1. Updated VG specifications. 2. Updated notes to Table 6.6.

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1. INTRODUCTION

1.1. Description of the System

The **Inertial Labs™ Vertical Gyro (VG)** is a high-performance strapdown system that determines the tilt angles (roll and pitch) and also freely integrated yaw angle for any object on which it is mounted. The Inertial Labs™ VG estimates tilt angles with high accuracy for both motionless and dynamic applications. Yaw is not related to the North, it is calculated only for control of the heading change during object rotation.

The Inertial Labs™ VG utilizes 3-axes each of precision MEMS gyroscopes and MEMS accelerometers to provide accurate pitch, roll and freely integrated yaw of the device under measure. Integration of gyroscopes' output provides high frequency, real-time measurement of the device rotation about all three rotational axes. Accelerometers measure absolute pitch and roll at VG initial alignment as well as ongoing corrections to gyroscopes during operation. Yaw angle is calculated as an integration of gyros signal.

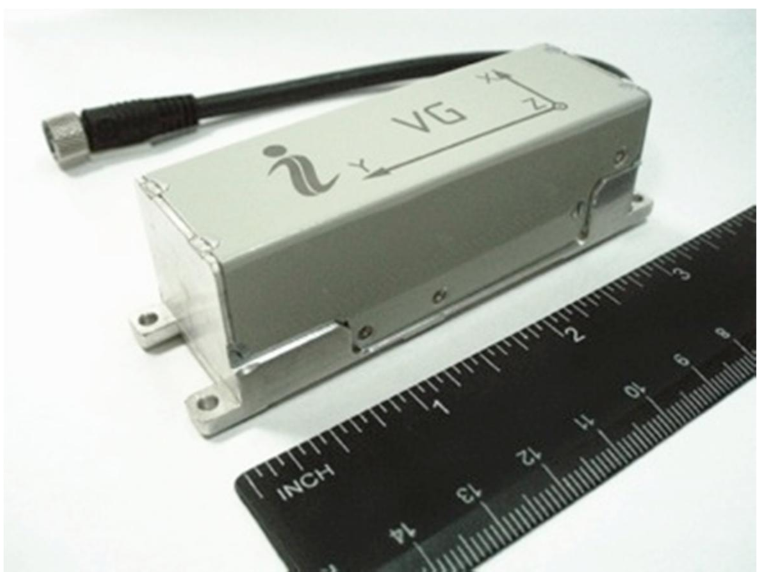

Fig.1.1. The Inertial Labs™ VG

Fig.1.2 shows the VG own coordinate system $Ox_oy_oz_o$. This coordinate system is body-fixed and defined as the calibrated sensors coordinate system. Non-orthogonality between the axes of the body-fixed coordinate system $Ox_oy_oz_o$ is an order of 0.01°.

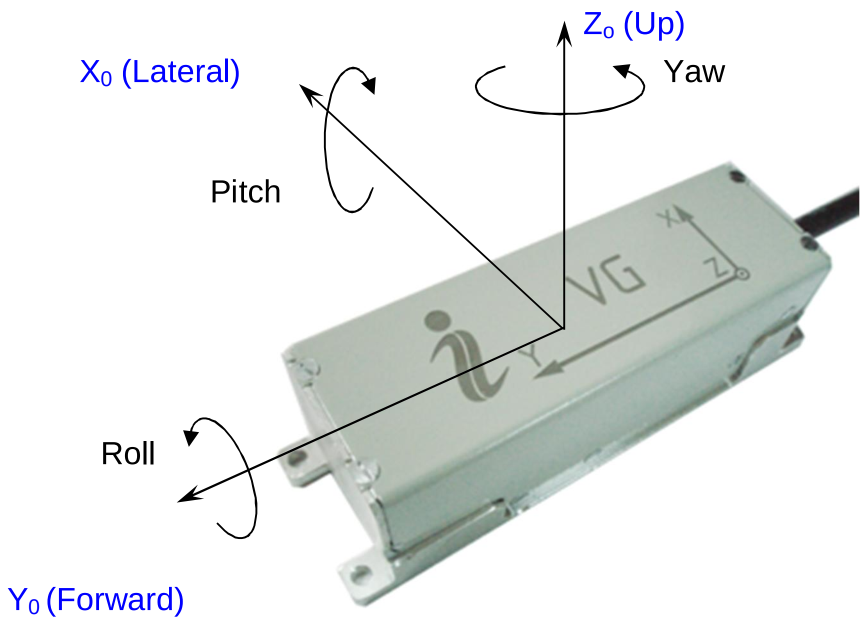

Fig.1.2. Coordinate system of the Inertial Labs™ VG

Measured angles are the standard Euler angles of rotation from the Earth-level frame (East-North-Up) to the body frame, yaw first, then pitch, and then roll.

Orientation angles, measured by the Inertial Labs™ VG, are not limited and are within common ranges:

- Yaw 0…360°;
- Pitch ±90°;
- Roll ±180°.

Also the Inertial Labs™ VG provided orientation calculation in quaternion form.

1.2. Principles of the Inertial Labs™ VG Operation

Fig.2.1 shows the operational diagram of the Inertial Labs™ VG.

The VG uses gyros to measure absolute angular rate of the carrier object, then its orientation angles (pitch, roll and yaw) are obtained by using special integration of gyros outputs.

Accelerometers are used to determine initial attitude of the VG and to correct gyros drift in the pitch and roll determination.

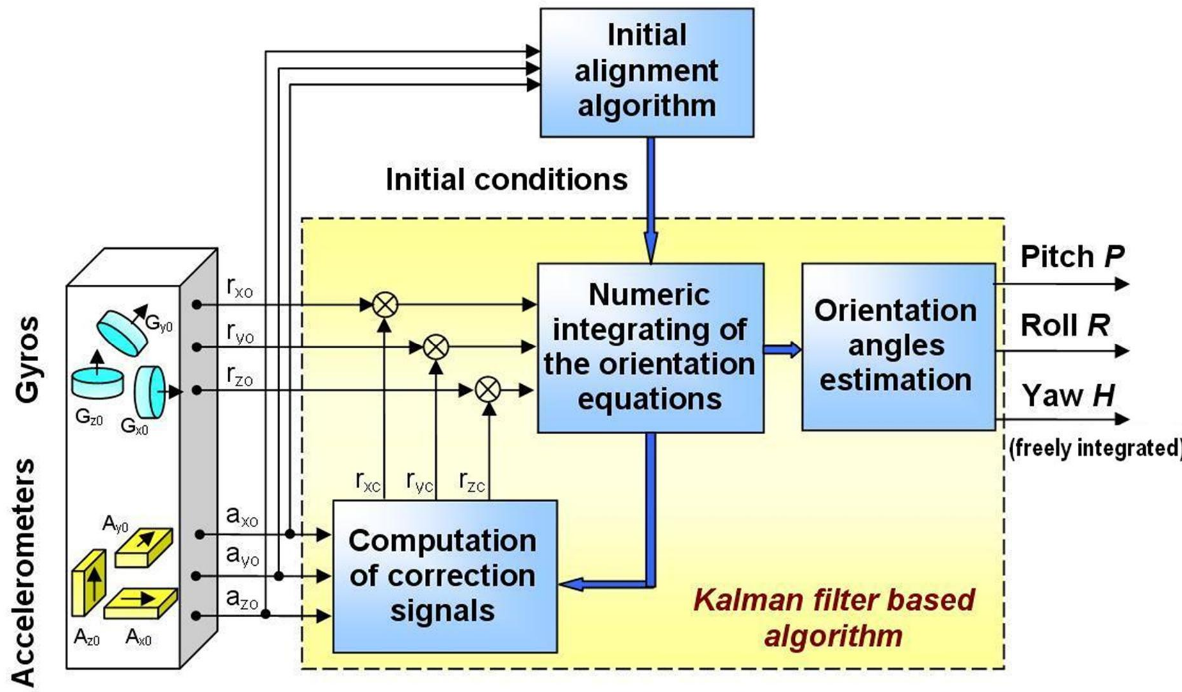

Fig.2.1. Operational Diagram of the Inertial Labs™ VG

The base of the VG algorithm is robust Kalman filter which is used for estimation of the gyros bias drift and for calculation of stabilized yaw, pitch and roll angles. The Kalman filter automatically adjusts for changing dynamic conditions without any external user input.

After start the Inertial Labs™ VG it requires about 60 seconds for initial alignment process. At this initial orientation angles are determined as initial conditions for integration of gyros outputs. Also gyros drift is estimated using Kalman filter for next compensation. <u>Therefore don't move the VG</u> during initial alignment process. If this requirement is not met then large errors may be occurred in orientation angles determination.

2. SCOPE AND APPLICABILITY

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

3. SPECIFICATIONS

Table 3.1. Inertial Labs™ VG specifications

Parameter	Units	Vertical Gyro models and part numbers	
		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Output signals		Euler angles; Quaternion; Accelerations; Angular rates; Delta Theta and Delta Velocity	
Update rate	Hz	1 … 100 (user settable)	
Start-up time	sec	< 1	
Full Accuracy Data (Warm-up Time) (1)	sec	30	
Attitude		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Range: Pitch, Roll	deg	±90, ±180	
Angular Resolution	deg	0.01	
Static Accuracy in whole Temperature Range	deg	0.1	0.2
Dynamic Accuracy (2)	deg RMS	0.3	0.5
Noise (@100 Hz)	deg RMS	0.02	0.02
Angular Rate		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Gyroscopes measurement range (3)	deg/s	±300	±300
In-run Bias Stability at Constant Temperature	deg/s RMS	0.02	0.02
Scale Factor Accuracy	%	0.1	0.1
Gyroscopes noise	deg/sec√Hz	0.035	0.035
Axis misalignment	mrad	0.15	0.15
Resolution	deg/sec	0.01	0.01
Bandwidth	Hz	50	50
Linear Acceleration		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Accelerometers measurement range	g	±2	±6
In-run Bias Stability at Constant Temperature	mg RMS	0.05	0.1
Bias Stability in whole Temperature Range	mg RMS	1	2
Bias turn-on, turn-on repeatability	mg RMS	0.1	0.1
Scale Factor Accuracy	%	0.1	0.1
Accelerometers noise	mg√Hz	0.04	0.09
Axis misalignment	mrad	0.15	0.15
Resolution	mg	0.1	0.2
Bandwidth	Hz	50	50
Environment		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Operating temperature	deg C	-40 to +70	
Storage temperature	deg C	-50 to +85	
Non-operating vibration (4)	g, Hz	10-50Hz, 0.15mm/55-500Hz 2.0g	
Non-operating shock (5)	g, ms	50g, 11ms, half sine wave	
MTBF	hours	55500	
Electrical		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Supply voltage	V DC	+5.5 to +6.5	
Current draw in readiness mode Current draw in sleep mode	mA mA	65 15	65 15
Connector	-	6-Pin Binder 718 series, female	
Digital Interface	-	RS-232 and USB (external converter)	
Output data format	-	Binary or NMEA 0183 ASCII characters	
Physical		VG-G300-A2-TGA-C1-V1.1	VG-G300-A6-TGA-C1-V1.1
Size	mm	90 × 27 × 26	
Weight	gram	65	

VG Specifications notes:

(1) including time of initial alignment, it may be decreased on request
(2) dynamic accuracy may depend on type of motion
(3) VG modification with ±1,000 deg/sec gyro measurement range is also available
(4) MIL-STD 810F. Method 514.5. Procedure I
(5) MIL-STD 810F. Method 516.5. Procedure I

4. MECHANICAL INTERFACE

The Inertial Labs™ VG housing has two base surfaces A and B (see Fig.4.1) that are designed for the VG mounting during its run and testing.

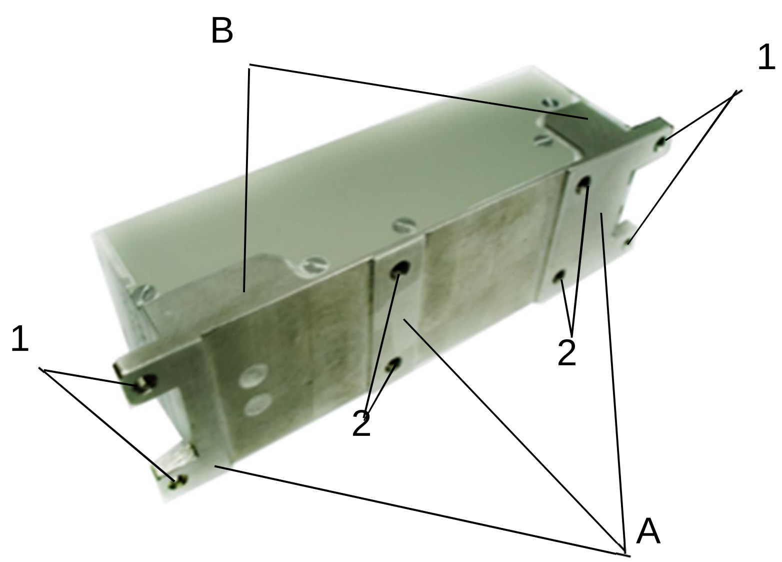

Fig.4.1. The Inertial Labs™ VG mounting surfaces A, B and mounting holes 1, 2

Salient bottom base surface A has 4 holes ∅2.6 mm on 4 lugs (see Fig.4.1, positions 1) and 4 threaded holes M3x6 mm (see Fig.4.1, positions 2) which are designed for the VG mounting. Lateral base surface B is designed for the VG alignment during mounting. The Inertial Labs™ VG 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.

When mounting Inertial Labs™ VG on your system, please pay attention to orientation of input axes X", "Y", "Z" marked on the cover of the VG (see Fig.1.2). During the ordinary operation on the carrier object the VG is set on the surface A with the axis Y directed to the nose of the object.

Also the Inertial Labs™ VG can be mounted on the object in any known position (up to upside-down, upright etc.) relative to the object axes. Such mounting doesn't change right determination of the object orientation if angles of the VG mounting are correctly stored in the VG nonvolatile memory. See Appendix A. Variants of the Inertial Labs™ VG mounting relative to carrier object axes.

To obtain accurate attitude, please remember that mounting is very important and mounting error can cause attitude errors. When Inertial Labs™ VG mounting please align it on two base surfaces A, B relative your system axes.

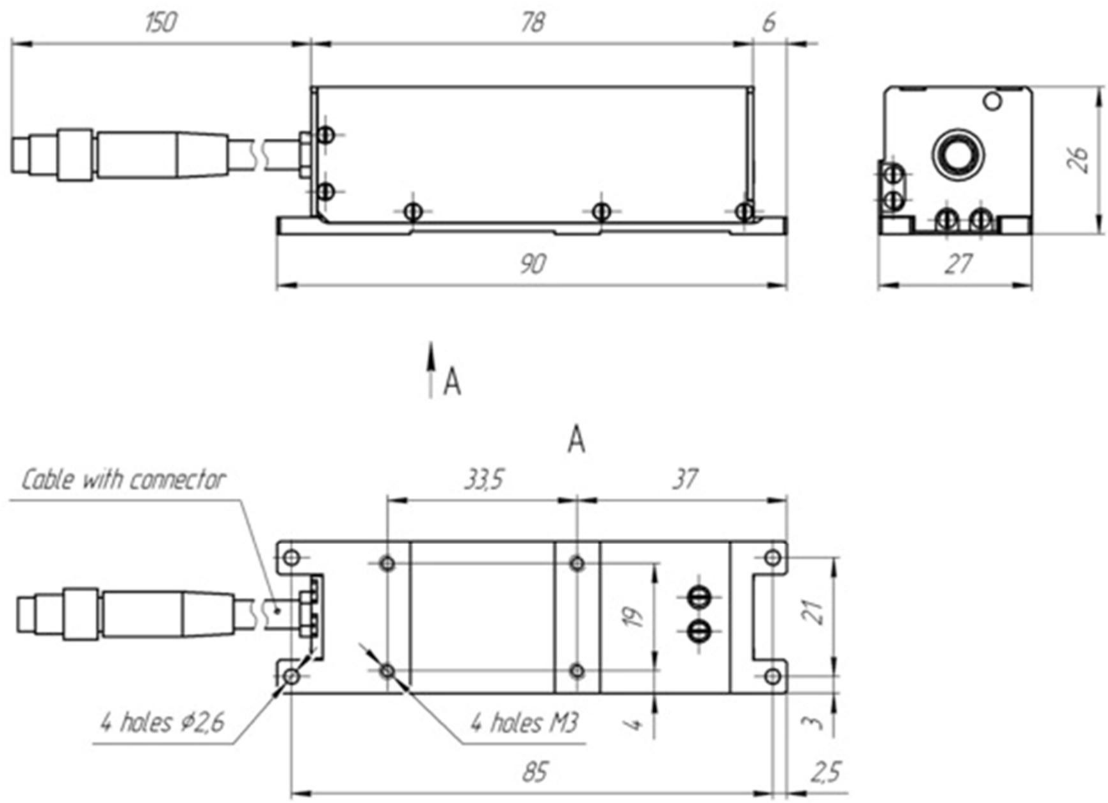

Fig.4.2. The Inertial Labs™ VG outline drawing
(all dimensions are in millimeters)

There are two variants of the Inertial Labs™ VG mounting on your system:
1) Use 4 holes ∅2.6 mm on 4 lugs (see Fig.4.1, positions 1).
2) Use 4 threaded holes M3x6 mm on the bottom of VG (see Fig.4.1, positions 2).

Note: *It is recommended to use holes in lugs for the VG mounting because of threaded holes in the aluminum case of the VG can be damaged at multiple mounting/dismounting procedures.*

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

5. ELECTRICAL INTERFACE

The Inertial Labs™ VG has the Binder Series 718 female 6 pin connector (cordset), part # 79-3464-52-06
(see http://www.binder-usa.com/?ACT=36&entry_id=89904).

For electrical connection of the Inertial Labs™ VG to the host system, the Binder Series 718 male 6 pin connector (cordset), part # 79-3465-52-06 or part # 79-3465-55-06 should be used
(see http://www.binder-usa.com/?ACT=36&entry_id=89902),
or Binder Series 768 male 6 pin connectors, part #
09-3423-00-06; 09-3463-00-06;
09-3423-81-06; 09-3463-81-06;
09-3423-86-06; 09-3463-86-06.

Fig.5.1 shows the Inertial Labs™ VG connector pinout. Pin color fits to wire color in mating cordset.

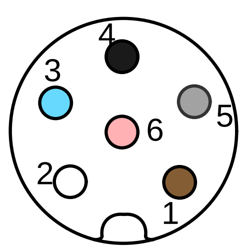

Fig.5.1. The Inertial Labs™ VG connector pinout
(mating side of the connector)

Table 5.1 Pin diagram of the Inertial Labs^{TM} VG connector

Pin	Signal
1	Do not connect
2	Tx-RS232
3	Rx-RS232
4	GND
5	V_{DD}
6	Do not connect

Note. Do not connect anything to pins #1 and #6 that are connected to VG PCB for firmware updates.

Table 5.2 Electrical specifications

Parameter	Conditions	Min	Typical	Max	Units
Input Supply		+5.5V	+6V	+6.5V	Volts DC
Current	V_{DD} = +6V	15	65	70	mA
Power	V_{DD} = +6V	90	390	420	mW

At the Inertial Labs^{TM} VG operations, it is connected to the host system that provides command interface described in the section 6 and the VG powering.

For tests, the Inertial Labs^{TM} VG can be connected to PC by wire as Fig.5.2 shows. At this, for the Inertial Labs^{TM} VG 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.

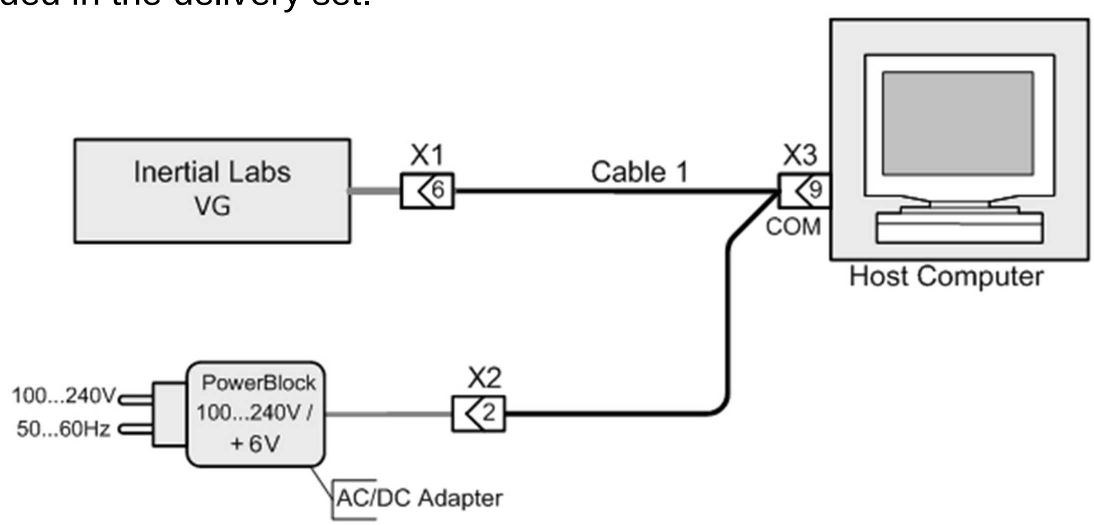

Fig.5.2. The diagram of electric connection of the Inertial Labs^{TM} VG to host computer

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

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

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

Fig.5.3 shows the diagram of the interface cable 1 for the Inertial Labs™ VG connections to the COM-port of host computer and to the DC power source.

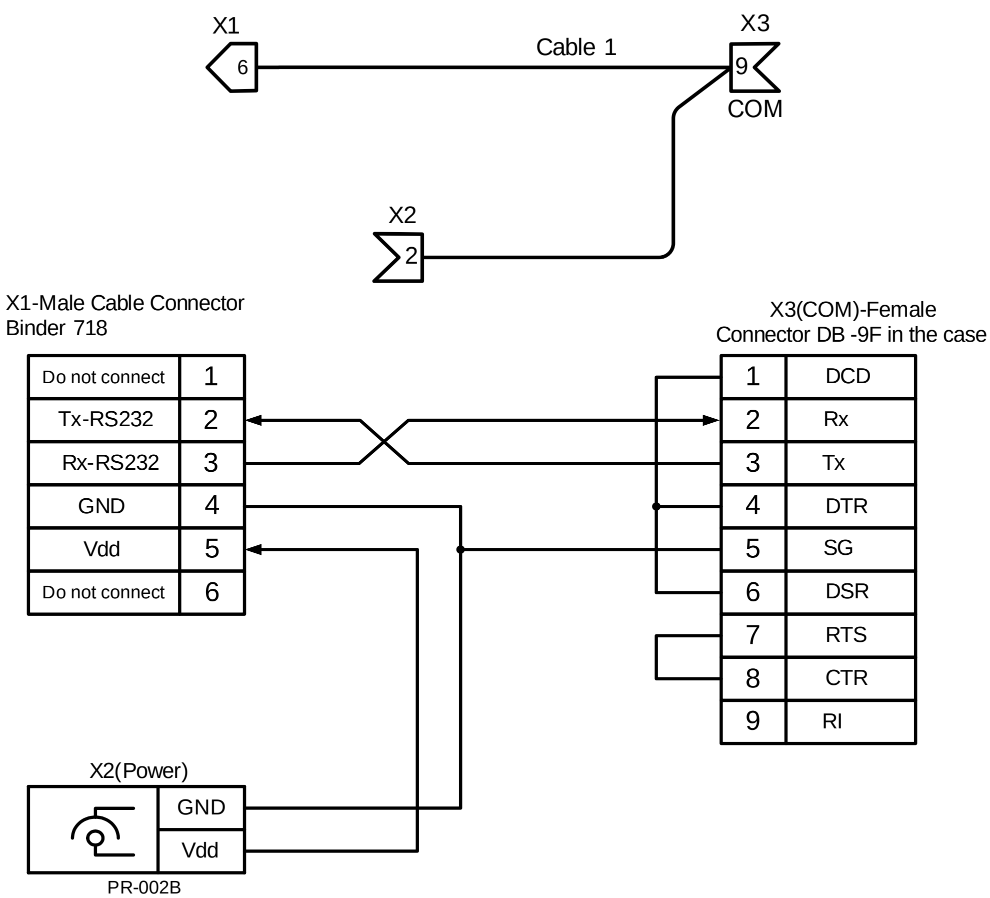

Fig.5.3. The diagram of the interface cable 1 for the Inertial Labs™ VG connections to the COM-port of host computer and to the AC/DC adapter

6. SOFTWARE INTERFACE

After power connection the primary initialization of the Inertial Labs™ VG microprocessor takes place and the main program starts working. The time of the device pretreatment is not more 1 second. The program works in the waiting mode of the commands.

The commands are transmitted through the serial port according to the protocol RS232.

Table 6.1. COM-port parameters

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

All commands and messages to / from the Inertial Labs™ VG have the byte structure shown in the Table 6.2. Exception is done for the VG output in the NMEA text format (see section 6.2).

Table 6.2. Byte structure for all commands and messages to / from the VG

Byte number	0	1	2	3	4 – 5	6 – n	(n+1) – (n+2)
Parameter	Header 0	Header 1	Message type	Reser-ved	Message length	Payload	Check sum
Length	1 byte	1 byte	1 byte	1 byte	1 word	Variable	1 word
Note	0xAA	0x55			Equal to n		

Message type is equal to:
0 – for commands;
1 – for transferring data.

All the VG outputs are data, therefore they have Message type = 1.

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

The Check sum is the arithmetical sum of bytes 2…n (all bytes without Header). In the check sum the low byte is transmitted first (see Table 6.3).

Table 6.3. Format of the check sum transmitting

byte0	byte1
low byte	high byte

In the Table 6.2 and in all other there is denoted:
word = unsigned 2 byte integer;
sword = signed 2 byte integer.

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

6.1. Operational modes of the Inertial Labs™ VG

The Inertial Labs™ VG can operate in the five modes:

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

2. **Continuous** operating mode. In this mode the VG operates in the endless loop, providing the continuous output of calculated orientation angles and some other data according to chosen output data format (see section 6.2). Data rate is set by user from 1 Hz to 100 Hz. In the Continuous operating mode the VG's indicator lights green.

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

4. "**Sleep**" low-power mode with the minimal power consumption of the VG. All sensors are switched off, processor core and part of periphery are switched off. No outputs are from the VG, only its microprocessor waits command from the host computer to exit from the Sleep mode. In the Sleep mode the VG's indicator lamp is off.

6.2. Output Data Formats of the Inertial Labs™ VG in the Operating Modes

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

- Full Output Data;
- Quaternion of Orientation;
- Orientation + Sensor Outputs;
- NMEA Output

The default is “**Orientation + Sensor Outputs**” data format. It provides the VG output in the form of 3 orientation angles (relative yaw, pitch and roll) and calibrated outputs of the 6 sensors (gyros, accelerometers) that give information about current angular rate and linear acceleration of the VG along the VG measurement axes (see Fig.1.2).

More correctly, these 6 sensors output are integrated angular rate and linear acceleration (specific force). In the VG output these increments are divided by time step of data output so they may be interpreted as average angular rates, linear acceleration of data output. On the other hand, incremental sensor data are good for the VG using as IMU (inertial measurement unit).

The “**Quaternion of Orientation**” data format gives quaternion presentation of an object orientation in addition to 3 orientation angles.

Usually the “**Full Output Data**” format is used by the VG developers for full control of calculations in the VG microprocessor. Also this format can be used by user at any troubles to get full data from the VG for next sending them to developers.

Structure of the VG output in above output data formats corresponds to the Table 6.2 where payload depends on chosen output data format. Below Table 6.4 – Table 6.6 show these payloads where is denoted:

word = unsigned 2 byte integer;
sword = signed 2 byte integer.

Table 6.4. The VG message payload at Full Output Data format
(at VGcont1 or VGreq1 command)

Byte number	0 – 1	2 – 3	4 – 5	6 – 17	18 – 27	28 – 29	30 – 31	32 – 33
Parameter	Yaw	Pitch	Roll	Ugyro, Uacc	Reser-ved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	6×2 byte sword	10 bytes	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Raw sensor data (gyros, accelero-meters)			Combi-ned voltage VDC* 1000	Temper ature in each sensor

Notes:
1. USW is unit status word (see section 6.5 for details).
2. The following data are recorded in the field «Vdd» sequentially:
- the VG input voltage;
- stabilized voltage supplied to the VG sensors;

3. In the «Utermo» field ADC codes are recorded sequentially from 7 temperature sensors inside gyros, accelerometers and inside VG housing.
4. The low byte is transmitted by first.

Table 6.5. The VG message payload at Quaternion of Orientation format
(at VGcont2 or VGreq2 command)

Byte number	0 – 1	2 – 3	4 – 5	6 –13	14 – 27	28 – 29	30 – 31	32 – 33
Parameter	Yaw	Pitch	Roll	Lk0, Lk1, Lk2, Lk3	Reser-ved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	4× 2 byte sword	14 bytes	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Quaternion of orientation *10000			Supply voltage, VDC* 1000	Temper ature, °C*10

Notes:
1. USW is unit status word (see section 6.5 for details).
2. Vdd is input voltage of the VG.
3. Utermo is averaged temperature in 3 accelerometers.
4. The low byte is transmitted by first.

Table 6.6. The VG message payload at Orientation + Sensor Outputs format
(at VGcont3 or VGreq3 command)

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	Reserved	Reserved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	3× 2 byte sword	3× 2 byte sword	3× 2 byte sword	4 byte	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Angular rates, deg/s *KG	Accele-rations g*KA				Supply voltage, VDC* 1000	Temperature, °C*10

Notes:

1. Values of KG, KA scale factors:
KG=100; KA=10000; for VG part number VG-G300-A2-TGA-C1-V1.1,
KG=100; KA=5000; for VG part number VG-G300-A6-TGA-C1-V1.1,
KG=400; KA=5000; for VG part number VG-G75-A6-TGA-C1-V1.1.

2. Originally angular rates and linear accelerations are in the VG axes (X is a lateral axis, Y is a longitudinal axis, Z is a vertical axis). Starting from VG firmware v.4.9.6.3 axes X, Y, Z are changed to the carrier object axes if non-zero alignment angles are set for VG mounting (see Appendix A. Variants of the Inertial Labs™ VG mounting relative to the object axes).

3. USW is unit status word (see section 6.5 for details).

4. Vdd is input voltage of the VG.

5. Utermo is averaged temperature in 3 accelerometers.

6. The low byte is transmitted by first.

At the **"NMEA Output"** the VG output 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

$PAHR,RRRR.rr,PPP.pp,HHH.hh,TTT.t,V.vv,SSSS*CC<CR><LF>

where PAHR is identifier and other fields are listed in the Table 6.7.

Table 6.7.The VG message in NMEA format
(at NMEAcont or NMEAreq command)

Field	RRRR.rr	PPP.pp	HHH.hh	TTT.t	V.vv	SSSS	CC
Parameter	Roll	Pitch	Yaw	Temperature	Vdd	USW	Check sum
Note	deg	deg	deg	ºC	VDC	hex written with ASCII	

Notes:

1. USW is unit status word (see section 6.5 for details).
2. Temperature is averaged value for 3 accelerometers.
3. Vdd is input voltage of the VG.
4. Check sum consists of a "*" and two hex digits representing XOR of all characters between, but not including "$" and "*".

***Important note*:** The VG maximum data rate is limited to 50 Hz in the NMEA output format

6.3. Control of the Inertial Labs™ VG

After power connection the VG is in the idle mode. Red light of the indicator lamp near the connector signifies readiness of the Inertial Labs™ VG to receive commands from the host computer. When the VG 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 VG:

- VGcont1, VGcont2, VGcont3;
- VGreq1, VGreq2, VGreq3;
- NMEAcont, NMEAreq
- GetDataReq;
- Stop;
- ReadVGPar;
- LoadVGPar;
- LowPowerOn;
- LowPowerOff.
- GetVerFirmware;
- GetBIT.

All these commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command. See Appendix B for exact structure of these commands.

6.3.1. VGcont1, VGcont2, VGcont3 commands

The commands **VGcont1, VGcont2, VGcont3** are used to start the Inertial Labs[TM] VG in the "Continuous" operating mode with one of three variants of output data:

- **VGcont1** command, code 0x80 – Full Output Data format,
- **VGcont2** command, code 0x82 – Quaternion Of Orientation format,
- **VGcont3** command, code 0x83 – Orientation+Sensor Outputs format.

All these commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command.

In order to identify to the host system that VG received one of these commands, the VG answers back immediately on this command prior to completion of the initial alignment process. The VG 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 6.2 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 VG.

After receiving of any from these commands the VG starts process of initial alignment that takes usually 30 seconds. This process includes the VG gyros drift estimation, therefore don't move the VG during its initial alignment. If this requirement is not met then large errors may be occurred in orientation angles calculation.

Note: Default time 30 seconds of the initial alignment can be changed (see section 6.3.6. LoadVGPar command) but only in agreement with developers of the Inertial Labs[TM] VG.

After completing of the initial alignment the VG gives out message with block of the initial data (payload is 50 bytes of the data – see the Table 6.8) and goes to the "Continuous" operating mode.

Table 6.8. Structure of the payload of 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	Reserved	**float**	**3*4**	
36-39	Initial Yaw	**float**	**4**	degrees
40-43	Initial Roll	**float**	**4**	degrees
44-47	Initial Pitch	**float**	**4**	degrees
48-49	USW (see section 6.4)	**word**	**2**	0 – successful initial alignment; ≠0 – unsuccessful

In the “Continuous” operating mode set by any of above commands VGcont1, VGcont2, VGcont3, the program in the VG microprocessor operates in the endless loop, providing the process of data reading from ADC and orientation angles calculating. Data blocks are transmitted according to chosen variant of output data in messages described in the Table 6.2. In all variants the message payload has 34 bytes of data which structure depends on chosen variant of output data (see section 6.2).

The update rate of data blocks is set by the user in range (1...100) Hz. Default update rate is100 Hz.

6.3.2. VGreq1, VGreq2, VGreq3 commands

The commands **VGreq1, VGreq2, VGreq3** are used to start the Inertial Labs™ VG in the “On Request” operating mode with one of three variants of output data:

- **VGreq1** command, code 0x84 – Full Output Data format,
- **VGreq2** command, code 0x86 – Quaternion Of Orientation format,
- **VGreq3** command, code 0x87 – Orientation + Sensor Outputs format.

All these commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command.

In order to identify to the host system that VG received one of these commands, the VG answers back immediately on this command prior to completion of the initial alignment process. The VG 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 6.2 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 VG.

After receiving of any from these commands the VG starts process of initial alignment that takes usually 30 seconds. This process includes the VG gyros drift estimation, therefore don't move the VG during its initial alignment. If this requirement is not met then large errors may be occurred in orientation angles calculation.

Note: Default time 30 seconds of the initial alignment can be changed (see section 6.3.6. LoadVGPar command) but only in agreement with developers of the Inertial Labs™ VG.

After completing of the initial alignment the VG gives out message with block of the initial data (payload is 50 bytes of the data – see the Table 6.8) and goes to the "On Request" operating mode.

In the "On Request" operating mode the VG sends only one data block after each request command GetDataReq (see section 6.3.4) issued from host computer. Data blocks have structure described in the Table 6.2 with payload depending on chosen variant of output data format (see section 6.2 for details).

6.3.3. NMEAcont, NMEAreq commands

The **NMEAcont** command is used to start the Inertial Labs™ VG in the "Continuous" operating mode with NMEA format of output data (see Table 6.7). The NMEAcont command has the byte structure shown in the Table 6.2 where payload is one byte equal to 0x88.

The **NMEAreq** command is used to start the Inertial Labs™ VG in the "On Request" operating mode with NMEA format of output data (see Table 6.7). The NMEAreq command has the byte structure shown in the Table 6.2 where payload is one byte equal to 0x89.

In order to identify to the host system that VG received one of these commands, the VG answers back immediately on this command prior to completion of the initial alignment process. The VG 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 6.2 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 VG.

Then the VG starts process of initial alignment that takes usually 30 seconds. This process includes the VG gyros drift estimation, therefore don't move the VG during its initial alignment. If this requirement is not met then large errors may be occurred in orientation angles calculation.

Note: Default time 30 seconds of the initial alignment can be changed (see section 6.3.6. LoadVGPar command) but only in agreement with developers of the Inertial Labs™ VG.

After completing of the initial alignment the VG gives out message with block of the initial data (payload is 50 bytes of the data – see the Table 6.8) and goes to

- "Continuous" operating mode in case of NMEAcont command;
- "On Request" operating mode in case of NMEAreq command.

In the "Continuous" operating mode the VG sends out data blocks with update rate set by user in range (1...50) Hz. Default update rate is 50 Hz.

In the "On Request" operating mode the VG sends only one data block after each request command GetDataReq (see section 6.3.4) issued from host computer.
In both operating modes the data blocks are transmitted in the form of sentences with printable ASCII characters like the NMEA 0183 format (see Table 6.7).

6.3.4. GetDataReq command

The **GetDataReq** command (code 0xCA in the “Payload” field, see the Table 6.2) is used to get one data block from the VG in the “On Request” operating mode. Command GetDataReq is valid if one of the VGreq1, VGreq2, VGreq3, NMEAreq commands was sent before.

As answer on the GetDataReq command the VG outputs one block of orientation data with structure described in the Table 6.2 and payload according to the Table 6.4, Table 6.5 or Table 6.6 depending on chosen variant of output data format.

At the NMEA format of output data set by the NMEAreq command the VG outputs one block of orientation data with structure described in the Table 6.7.

6.3.5. Stop command

At receiving the **Stop** command (code 0xFE in the “Payload” field) the VG stops work in an operating mode and goes to the idle mode. At that the light indicator of the VG changes its color to red.

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

6.3.6. LoadVGPar command

The **LoadVGPar** command (code 0x40 in the “Payload” field) is used to load the block of the VG parameters (which are available for changing by user) into the VG nonvolatile memory. After sending the LoadVGPar command, the block of the VG parameters must be send to the VG in the message shown the Table 6.2 with payload shown in the Table 6.9. This message should be sent without pause after sending the LoadVGPar command.

Table 6.9. Payload of the message following after the LoadVGPar command (block of parameters for loading to the VG)

Byte	Parameter	Format	Length	*Note*
0-1	Update rate	**word**	**2**	(1 … 100) Hz, default is 100 Hz
2-3	Initial alignment time	**word**	**2**	seconds, default is 30 sec
4-7	Initial heading	**float**	**4**	degrees
8-11	Latitude	**float**	**4**	degrees
12-15	Longitude	**float**	**4**	degrees
16-19	Altitude	**float**	**4**	meters
20-23	Date (Year, Month, Day)	**float**	**4**	Year + (Month -1)/12 + Day/365
24-27	Alignment angle A1	**float**	**4**	Angles of VG mounting on the carrier object, degrees (see Appendix A)
28-31	Alignment angle A2	**float**	**4**	
32-35	Alignment angle A3	**float**	**4**	
36-49	Reserved		**14**	**Should be all zeros**

The VG calculates the check sum of received parameters and returns it for a checking. Byte structure of this message is shown in the Table 6.2 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™ VG Demo Program.

2. Before using **LoadVGPar** command it is necessary to use **ReadVGPar** command (see below) to read parameters from the VG at first. After that user can change some parameters listed in the Table 6.9, and to send back all block of parameters to the Inertial Labs™ VG.

3. Default time 30 seconds of the initial alignment can be changed but only in agreement with developers of the Inertial Labs™ VG.

6.3.7. ReadVGPar command

The **ReadVGPar** command (code 0x41 in the “Payload” field, see the Table 6.2) is used to read block of the Inertial Labs™ VG parameters (50 bytes) from the VG nonvolatile memory.

After receiving ReadVGPar command, the VG sends out the message with structure according to Table 6.2 and payload shown in the Table 6.10.

Table 6.10. Payload of the VG answer on the ReadVGPar command (block of parameters read from the VG)

Byte	Parameter	Format	Length	*Note*
0-1	Measurement rate	word	2	Hz
2-3	Initial alignment time	word	2	seconds
4-7	Magnetic declination	float	4	degrees
8-11	Initial heading	float	4	degrees
12-15	Longitude	float	4	degrees
16-19	Altitude	float	4	meters
20-23	Date (Year, Month, Day)	float	4	Year + (Month -1)/12 + Day/365
24-27	Alignment angle A1	float	4	Angles of VG mounting on the carrier object, degrees (see Appendix A)
28-31	Alignment angle A2	float	4	
32-35	Alignment angle A3	float	4	
36-43	Device ID	char	8	**only read**
44-49	Reserved		6	

6.3.8. LowPowerOn command

The **LowPowerOn** command (code 0xB0 in the “Payload” field, see the Table 6.2) switches the VG to low power “Sleep” mode. At this command all VG sensors are switched off, processor core and part of periphery are switched off. No outputs are from the VG, Its microprocessor only waits command from the host computer to exit from the Sleep mode. In the Sleep mode the VG’s indicator lamp is off.

6.3.9. LowPowerOff command

The **LowPowerOff** command (code 0xBA in the “Payload” field, see the Table 6.2) awakes the VG from the Sleep mode and switches it to the idle mode with normal power consumption.

6.3.10. GetVerFirmware command

The **GetVerFirmware** command (code 0x1F in the “Payload” field) is used to read firmware version of the VG (50 bytes) from the VG nonvolatile memory. As answer the VG sends out the message with structure according to the Table 6.2 and payload shown in the Table 6.11.

Table 6.11. Payload of the VG answer on the GetVerFirmware command

Byte	Parameter	Format	Length	*Note*
0-49	Firmware version	**char**	**50**	

6.3.11. GetBIT command

The Inertial Labs™ VG has continuous built-in monitoring of its health. In both "Continuous" and "On Request" operation modes the VG sends out Unit Status Word (USW) in each data block (see Table 6.4 – Table 6.6). The USW is described in the section 6.5.

The USW can be got in any time if the VG is in Idle or "On Request" operation mode (after VGreq1, VGreq2 or VGreq3 command). For this the **GetBIT** command (code 0x1A in the "Payload" field) is used. In answer the VG sends out the message with data according to the Table 6.12.

Table 6.12. Payload of the VG answer on the GetBIT command

Byte number	0 – 1	2 – 3
Parameter	Utermo100	USW
Length	2 byte word	2 byte word

Utermo100 is the VG temperature in 1/100 °C increments.

6.4. The Unit Status Word definition

The Unit Status Word (USW) provides the VG state information. The low byte (bits 0-7) of USW indicates failure of the VG. If this byte is 0, the VG operates correctly, if it is not 0, see the Table 6.18 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 6.13 and Table 6.14.

Table 6.13. The Unit Status Word description

	Bit	Parameter	Description
Low (failure) byte	0	Initial Alignment	0 – Successful initial alignment 1 – Unsuccessful initial alignment due to VG moving
	1	VG 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	Reserved	
	5	Electronics	0 – No failure 1 – Failure detected
	6	Software	0 – No failure 1 – Failure detected
	7	VG mode	See the Table 6.19
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	Reserved	
	14	Environmental Temperature	0 – Temperature is within the operating range 1 – Temperature is out of the operating range
	15	VG mode	See the Table 6.19

The VG indicates its current mode of operation in the bits 7 and 15 as the Table 6.14 shows.

Table 6.14. Indication of the VG current operational modes

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

APPENDIX A.
Variants of the Inertial Labs^{tm} VG mounting relative to the object axes

The Inertial Labs^{TM} VG can be mounted on the object in any known position (up to upside-down, upright etc.) relative to the object axes. Such mounting doesn't change right determination of the object orientation if angles of the VG mounting are correctly stored in the VG nonvolatile memory.

To store angles of mounting in the VG please use the Inertial Labs^{TM} VG Demo Program (item «Device option …» from the «Options» menu) or send LoadBlockPar command to the VG directly (see structure of the message following after the LoadVGPar command in the Table 6.9).

Angles of the VG position (alignment angles) are set in next order (like yaw, pitch and roll setting):

- first alignment angle sets position of the VG longitudinal axis Y relative to longitudinal axes of the object measured in the horizontal plane of the object. Clockwise rotation is positive;
- second alignment angle is equal to angle of inclination of the VG longitudinal axis Y relative to the horizontal plane of the object. Positive direction is up;
- third alignment angle is equal to inclination angle of the VG lateral axis X measured around VG' longitudinal axis. Positive rotation is X axis moving down.

All angles are set in degrees.

Some examples of the Inertial Labs VG mounting relative the carrier object are shown on Fig.A.1.

To check correctness of the alignment angles please run the VG using the Inertial Labs VG Demo program.

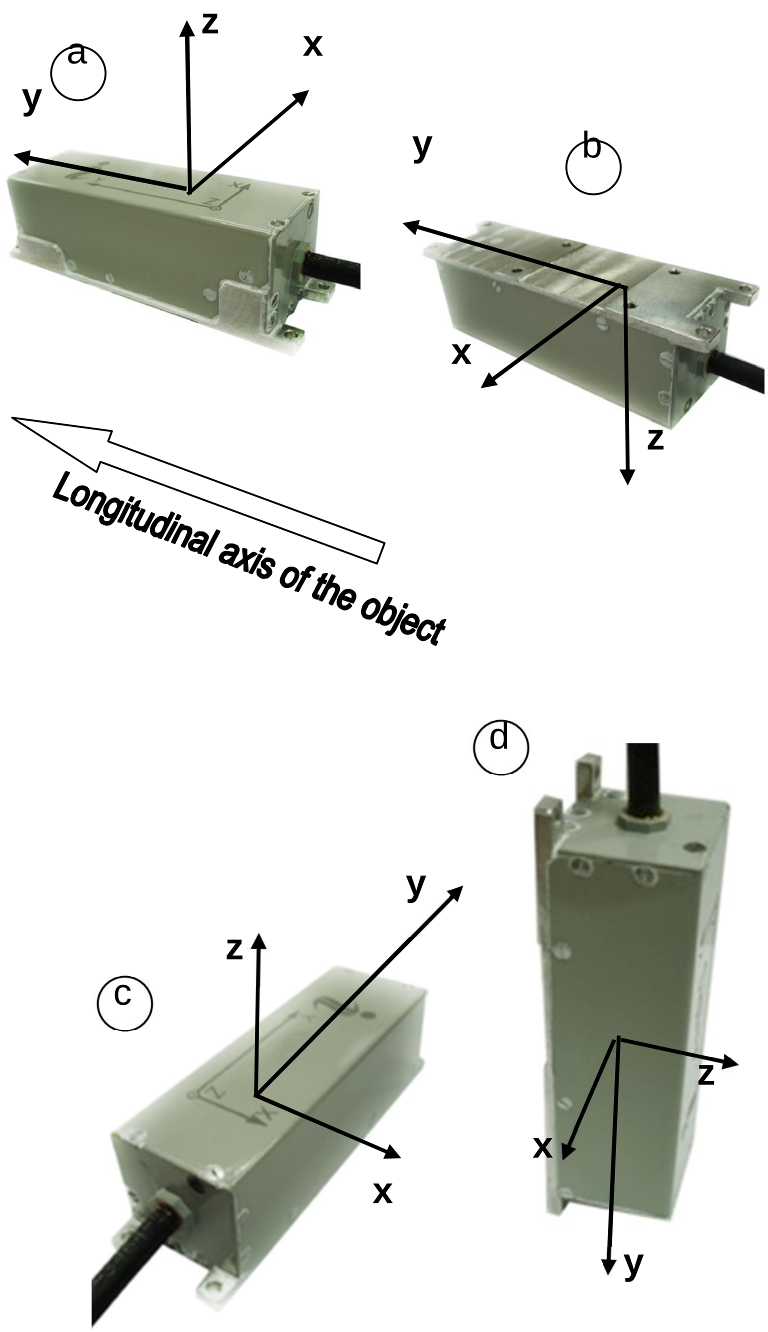

Fig.A.1. Examples of the Inertial Labs™ VG mounting on the carrier object

a – alignment angles are 0, 0, 0 (degrees);
b – alignment angles are 0, 0, 180 (degrees);
c – alignment angles are 90, 0, 0 (degrees);
d – alignment angles are 180, -90, 0 (degrees);

APPENDIX B.
Full list of the Inertial Labs^{tm} VG commands

All the VG commands have the byte structure shown in the Table 6.2. Payload for all commands has length 1 byte and contains code of the command. Below Table C.1 lists all commands with their exact structure in hexadecimal numbers.

Table B.1. List of the VG commands with exact structure

Command name	Code	Exact structure (hex)
Commands for Inertial Labs^{TM} VG control		
VGcont1	0x80	AA 55 00 00 07 00 80 87 00
VGcont2	0x82	AA 55 00 00 07 00 82 89 00
VGcont3	0x83	AA 55 00 00 07 00 83 8A 00
VGreq1	0x84	AA 55 00 00 07 00 84 8B 00
VGreq2	0x86	AA 55 00 00 07 00 86 8D 00
VGreq3	0x87	AA 55 00 00 07 00 87 8E 00
NMEAcont	0x88	AA 55 00 00 07 00 88 8F 00
NMEAreq	0x89	AA 55 00 00 07 00 89 90 00
GetDataReq	0xCA	AA 55 00 00 07 00 CA D1 00
Stop	0xFE	AA 55 00 00 07 00 FE 05 01
LoadVGPar	0x40	AA 55 00 00 07 00 40 47 00
ReadVGPar	0x41	AA 55 00 00 07 00 41 48 00
LowPowerOn	0xB0	AA 55 00 00 07 00 B0 B7 00
LowPowerOff	0xBA	AA 55 00 00 07 00 BA C1 00
GetVerFirmware	0x1F	AA 55 00 00 07 00 1F 26 00
GetBIT	0x1A	AA 55 00 00 07 00 1A 21 00