Attitude and Heading Reference System

AHRS

Interface Control Document

Revision 1.8

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

1

CHANGE STATUS LOG			
DOCUMENT: Inertial Labs™ AHRS Interface Control Document			
REVISION	DATE	AFFECTED PARAGRAPHS	REMARKS
1.0	Jan. 19, 2012	All	Released version.
1.1	Feb. 06, 2012	6.4.1 6.4.7 6.4.6	**For AHRS firmware since v.4.9.1.6** 1. Inserted 4 bytes float for set-point azimuth in the AHRS message after each calibration run (Table 6.14). 2. 2D calibration is realized and its description is added. 3. Because of added 2D calibration the AHRS answer on GetClbRes command is updated (Table 6.16).
1.2	Feb. 13, 2012	6.2	**For AHRS firmware since v.4.9.2.0** Added commands NMEAcont, NMEAreq for new NMEA output data format and description of this format (Table 6.7).
1.3	May 25, 2012	3 6.2	**For AHRS manufactured in 2012** 1. Format updates. 2. Changed AHRS specifications in section "Angular Rate" (Table 3.1). 3. Added note to Table 6.6.
1.4	May 20, 2013	5 6.2	1. Updated links on website for AHRS connectors. 2. Augmented Note 2 under Table 6.6 for AHRS firmware since v.4.9.6.3.
1.5	Sep. 24, 2013	6 6.4.1 6.4.2 6.4.7 6.4.1, 6.4.5 6.4.10 6.4.1, 6.4.5 6.4.8, 6.4.10	**For AHRS firmware since v.4.9.9.0** 1. Corrected byte numbers in Table 6.2. 2. StopClb command that was used both to stop data accumulation in the run and to finish calibration with multiple runs, is separated on two commands: a) StopClbRun command for stop data accumulation in the run, see section 6.4.2; b) FinishClb command for finish calibration with multiple runs, see section 6.4.7. 3. Corrected Tables 6.14, 6.15, 6.17 for changed fields of AHRS messages at calibration procedures. 4. Added estimation of accuracy of hard/soft iron calibration, with appropriate change in AHRS output data.
1.6	Oct. 11, 2013	3	1. Document format updates. 2. Updated AHRS specifications
1.7	Mar. 11, 2014	3 6.2	1. Updated AHRS specifications. 2. Updated notes to Table 6.6.
1.8	Sep. 11, 2015	All 6.2	1. Copyediting. Changed AHRS photos. 2. Changed notes to Table 6.6.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

2

TABLE OF CONTENTS

Inertial Labs, Inc[TM] Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

3

1. INTRODUCTION

1.1. Description of the System

The **Inertial Labs^{TM} Attitude and Heading Reference System (AHRS)** is a high-performance strap-down system that determines absolute orientation (heading, pitch and roll) for any device on which it is mounted. Orientation is determined with high accuracy for both motionless and dynamic applications.

The Inertial Labs^{TM} AHRS utilizes 3-axes each of precision MEMS gyroscopes, MEMS accelerometers and fluxgate magnetometers to provide accurate heading, pitch and roll 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 and magnetometers measure absolute pitch, roll and magnetic azimuth at AHRS initial alignment as well as ongoing corrections to gyroscopes during operation.

Fig.1.1. The Inertial Labs^{TM} AHRS

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

4

Fig.1.2 shows the AHRS 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°.
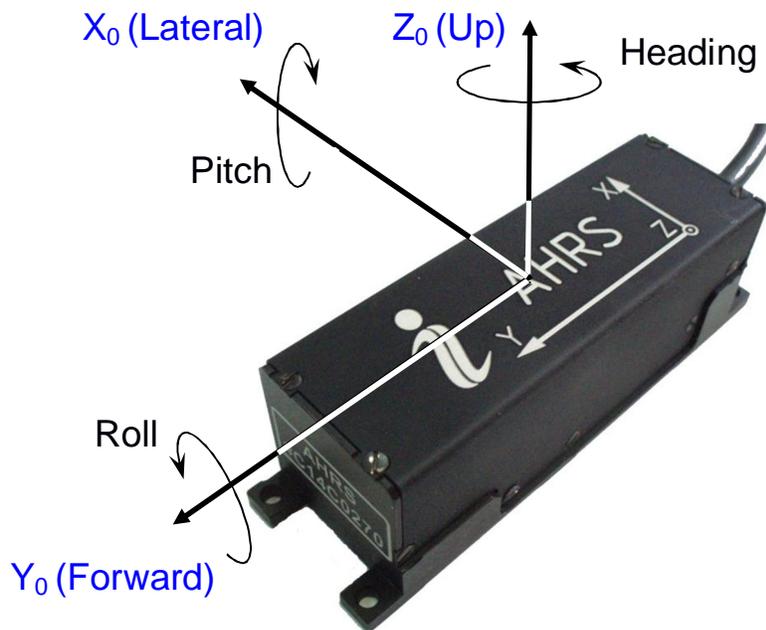
Fig.1.2. Coordinate system of the Inertial Labs^{TM} AHRS

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

The orientation angles measured by the Inertial Labs^{TM} AHRS are not limited and are within common ranges:
- Heading   0…360?;
- Pitch   ±90°;
- Roll   ±180°.

Also the Inertial Labs^{TM} AHRS provided orientation calculation in quaternion form.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

5

1.2. Principles of the Inertial Labs^{TM} AHRS Operation

Fig.2.1 shows the operational diagram of the Inertial Labs^{TM} AHRS.The AHRS uses gyros to measure absolute angular rate of the carrier object, then its orientation angles (heading, pitch and roll) are obtained by using special integration of gyros outputs.

Accelerometers are used to determine initial attitude of the AHRS and to correct gyros drift in the tilt angles (pitch, roll) determination. Magnetometers are used to determine initial heading of the AHRS and to correct gyros drift in the heading angle determination.
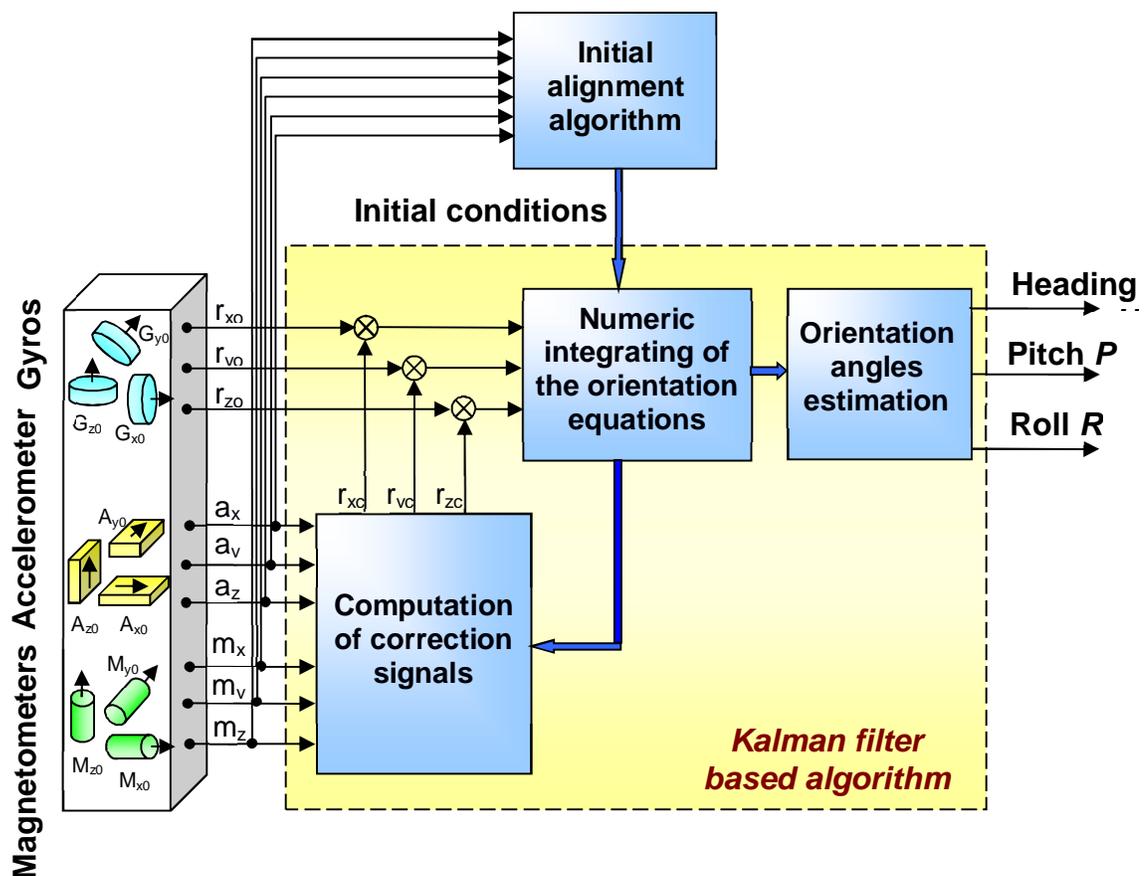
Fig.2.1. Operational Diagram of the Inertial Labs^{TM} AHRS

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

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

6

After starting the Inertial Labs^{TM} AHRS, it requires about 60 seconds for the initial alignment process. During this the 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 AHRS</u> during initial alignment process. If this requirement is not met then large errors may occur in orientation angles determination.

Since the Inertial Labs^{TM} AHRS uses magnetic sensors for heading reference, it directly determines just the magnetic heading.

The Inertial Labs^{TM} AHRS also provides true North heading when the current magnetic declination is set. Declination, also called magnetic variation, is the difference between true and magnetic North, relative to a point on the Earth. Declination angle vary throughout the world, and changes slowly over time. Declination angle can be entered directly to the Inertial Labs^{TM} AHRS memory using special command (see Table 6.2) or the Inertial Labs^{TM} AHRS Demo Program. Also, the declination can be calculated by AHRS itself based on entered latitude, longitude, altitude and date (see section "6.3.6. LoadAHRSPar command" for details).

Both AHRS and AHRS Demo Program calculate the declination using the World Magnetic Model produced by the U.S. National Geophysical Data Center and the British Geological Survey.
http://www.ngdc.noaa.gov/geomag/WMM/DoDWMM.shtml

The World Magnetic Model is the standard model of the US Department of Defense, the UK Ministry of Defense, the North Atlantic Treaty Organization (NATO), and the World Hydrographic Office (WHO) navigation and attitude/heading referencing systems.

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^{TM} AHRS and host computer.
This document is intended for all parties requiring such information, including engineers and researchers responsible for implementing the interface.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

7

3. SPECIFICATIONS

Table 3.1. Inertial Labs[TM] AHRS specifications

Parameter	Units	Value		
Output signals		Euler angles; Quaternion; Accelerations; Angular rates; Magnetic field, Delta Theta and Delta Velocity		
Update rate	Hz	1 … 200 (user settable)		
Start-up time	sec	< 1		
Full Accuracy Data (Warm-up Time) [1]	sec	30		
Heading				
Range	deg	0 to 360		
Angular Resolution	deg	0.01		
Static Accuracy in whole Temperature Range [2]	deg	0.4		
Dynamic Accuracy [3]	deg RMS	0.7		
Noise (at 200 Hz output)	deg RMS	0.03		
Attitude				
Range: Pitch, Roll	deg	±90, ±180		
Angular Resolution	deg	0.01		
Static Accuracy in whole Temperature Range [4]	deg	0.1		
Dynamic Accuracy [5]	deg RMS	0.3		
Noise (@100 Hz)	deg RMS	0.02		
Sensors		**Accelerometers**	**Gyroscopes**	**Magnetometers**
Technology type		MEMS	MEMS	Fluxgate
Measurement range		±2 g, ±6 g	±250/500/1000/2000 deg/sec	±1.6 Gauss
Bandwidth [6]		50	50	50
Resolution		0.1 mg (at ±2g range)	0.01 deg/sec (at ±250deg/sec range)	10 nT
Bias in-run stability (RMS, Allan Variance)		50 ug	4 deg/hr	0.1 nT
SF accuracy		0.1 %	0.01 %	0.02 %
Noise density		40 ug√Hz	0.009 deg/sec√Hz	3 uG/√Hz
Non-linearity		0.05%	0.01%	0.02%
Axis misalignment		0.15 mrad	0.15 mrad	0.15 mrad
Environment				
Operating temperature	deg C	-40 to +70		
Storage temperature	deg C	-50 to +85		
MTBF	hours	55,500		
Electrical				
Supply voltage [7]	V DC	+5.5 to +6.5		
Current draw in readiness mode	mA	105		
Current draw in sleep mode	mA	30		
Connector	-	6-pin Female Binder series 718 (RS-232) 8-pin Female Binder series 712 (RS-422) 8-pin Male Binder series 712 (RS-485)		
Output Interface	-	RS-232, RS-422, RS-485 and USB (with external converter)		
Output data format		Binary or NMEA 0183 ASCII characters		
Mechanical				
Size	mm	90 × 27 × 26		
Weight	gram	73		

[1] including time of initial alignment, it may be decreased on request.
[2] in homogeneous magnetic environment, for latitude up to ±65 deg. Heading static accuracy in whole temperature range = 0.7 deg for AHRS with ±6 g accelerometers dynamic range
[3] dynamic accuracy may depend on type of motion. Heading dynamic accuracy in whole temperature range = 1.0 deg for AHRS with ±6 g accelerometers measurement range
[4] attitude static accuracy in whole temperature range = 0.2 deg for AHRS with ±6 g accelerometers measurement range
[5] dynamic accuracy may depend on type of motion. Attitude dynamic accuracy in whole temperature range = 0.5 deg for AHRS with ±6 g accelerometers measurement range
[6] Gyroscopes, accelerometers and magnetometers bandwidth can be increased up to 400Hz though with increasing of the sensors noise and noise in calculated orientation angles
[7] AHRS model with 9 to 40 V DC supply voltage is available

Inertial Labs, Inc[TM] Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

8

4. MECHANICAL INTERFACE

4.1. Where to install the Inertial Labs^{TM} AHRS <u>for tests</u>

The Inertial Labs^{TM} AHRS has magnetometers with wide dynamic range and its sophisticated calibration algorithms allow it to operate in many environments. For optimal performance however, you should mount the Inertial Labs^{TM} AHRS with the following considerations in mind.

● *Locate the Inertial Labs^{TM} AHRS away from local sources of magnetic fields*

The place for testing must not have ferromagnetic (magneto-susceptible) materials and the lab room itself must have the level of intrinsic magnetic and electro-magnetic fields suitable for the magnetic heading system testing:

– inside and near the lab room there must be no powerful source of magnetic, electrical and electro-magnetic fields. The magnetic field intensity must not be different from the Earth magnetic field intensity at the test site more than 0.01%;
– small ferromagnetic objects must be at least 3 meters from the test table. Large size ferromagnetic objects such as cars and trucks must be at least 15 m from the table;
– it is necessary to conduct a regular check-up of the magnetic field uniformity inside the lab room.

It is highly recommended to degauss AHRS before heading test to remove permanent magnetization of some components in the AHRS (if you accidentally expose the unit to a large magnetic field). You can use a hand-held degausser (tape eraser) to demagnetize the AHRS. Most audio and video degaussing units can be used. Follow the instructions for your demagnetizer.

If heading accuracy is not checked and only pitch and roll accuracy are tested then there are no requirements to magnetic fields and ferromagnetic materials near the position of the Inertial Labs^{TM} AHRS mounting,

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

9

- *The Inertial Labs^{TM} AHRS should be mounted in a physically stable location*

Choose a location that is isolated from excessive shock, oscillation, and vibration. Special rotary table must be used for the Inertial Labs^{TM} AHRS accuracy testing, that mounted on a special testing basement which is free from the laboratory oscillations and vibrations.

Tests on vibrations and shocks are fulfilled separately from the main accuracy tests.

4.2. Where to install the Inertial Labs^{TM} AHRS on the object

It is necessary to follow the recommendations listed in the section 4.1 whenever it is possible, when installing the Inertial Labs^{TM} AHRS on a carrier object.

- *Inertial Labs^{TM} AHRS should be installed on an object as far as possible from large ferromagnetic masses of the object and powerful sources of magnetic, electrical and electro-magnetic fields*

Inertial Labs^{TM} AHRS software allows compensation of hard and soft iron effects of the carrier object on the heading measurement accuracy. For this purpose, field calibration of the AHRS magnetometers is provided. This calibration does not require any additional equipment, but it requires turns of the carrier object on which the AHRS is mounted.

Note that the above field calibration is correct until the residual magnetic field of the object surrounding the AHRS is changed. If this field is changed due to displacement of ferromagnetic masses of the object or magnetic field sources, the AHRS should be re-calibrated.

Field calibration procedure of the Inertial Labs^{TM} AHRS can be performed by two means:

- by AHRS itself using special commands described in the section 6.4;
- using the Inertial Labs^{TM} AHRS Demo Program.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

10

The AHRS Demo Program provides more variants of the field calibration and is more convenient for use, but it requires connection of the AHRS to PC. Calibration of the AHRS itself is performed while it is connected to the host system on the carrier object.

More detailed description of the field calibration procedure is given in the section 6.4. Calibration of the Inertial Labs^{TM} AHRS on hard and soft iron,

- ***It is preferable to locate the Inertial Labs^{TM} AHRS as close to the center of mass of the object as possible***

With such location, effects of linear accelerations during oscillations on the AHRS accelerometers are reduced, and therefore, orientation angle determination errors are also reduced.

4.3. Mechanically mounting the Inertial Labs^{TM} AHRS

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

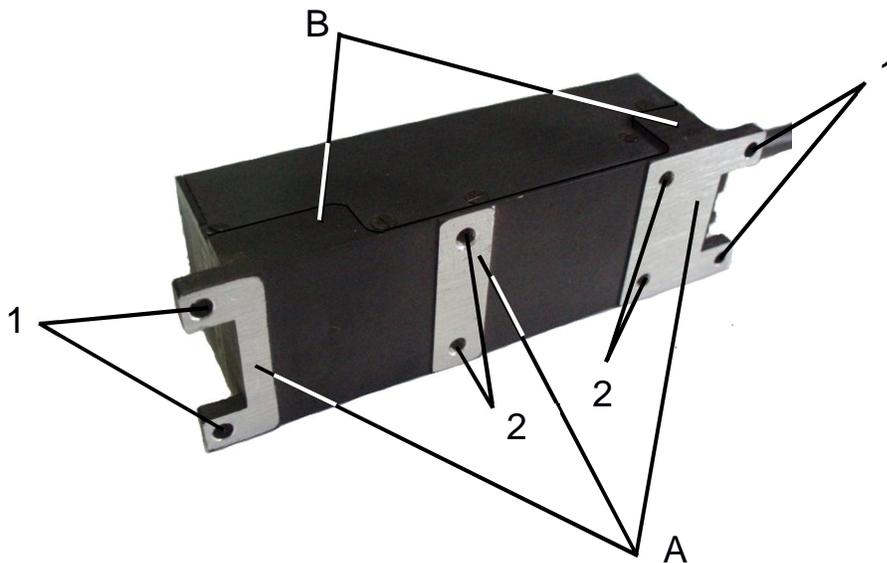**Fig.4.1. AHRS mounting surfaces A, B and mounting holes 1, 2**

The bottom base surface (A) has 4 holes $\varnothing$2.6 mm on 4 lugs (see Fig.4.1, positions 1) and 4 threaded holes M3x6 mm (see Fig.4.1, positions 2)

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

11

which are designed for the AHRS mounting. Lateral base surface B is designed for the AHRS alignment during mounting.

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

Also the Inertial Labs^{TM} AHRS 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 the angles of the AHRS mounting are correctly stored in the AHRS nonvolatile memory. See Appendix B. Variants of the Inertial Labs^{TM} AHRS mounting relative to carrier object axes.

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

There are two variants of the Inertial Labs^{TM} AHRS 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 AHRS (see Fig.4.1, positions 2).

Note: It is recommended to use holes in lugs for the AHRS mounting because of threaded holes in the aluminum case of the AHRS 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.

Fig.4.2 sows the outline drawings of the Inertial Labs^{TM} AHRS. All dimensions are in millimeters.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

12
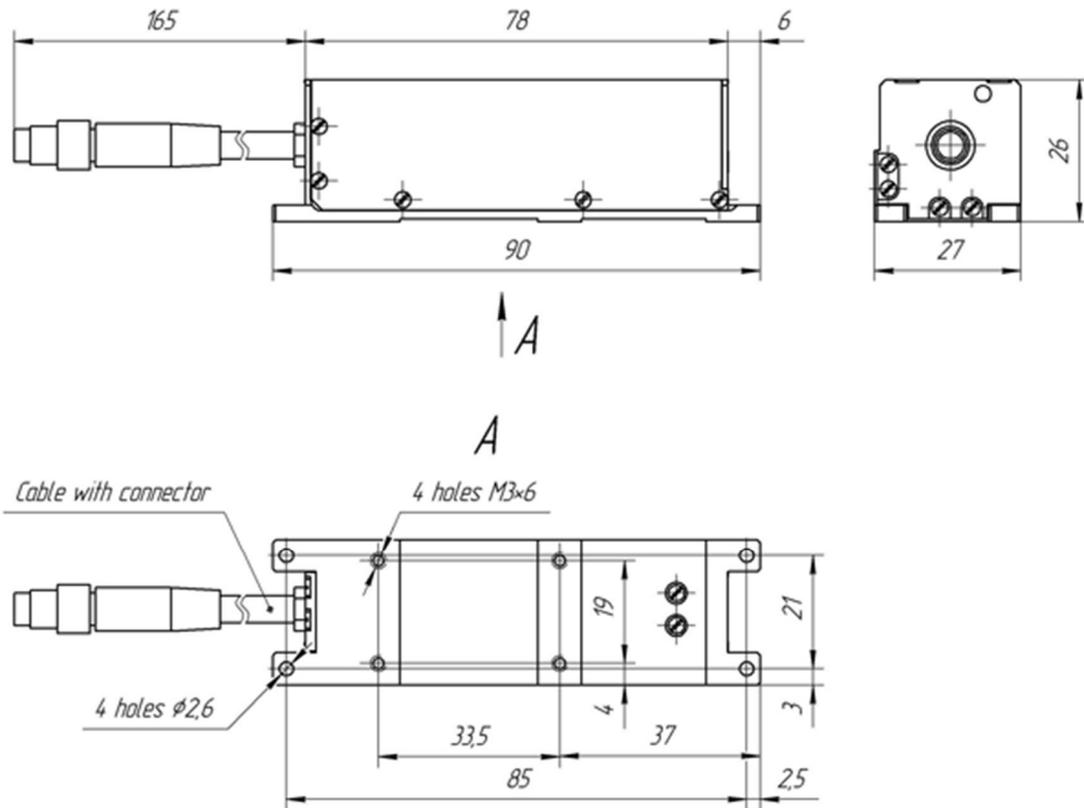
**Fig.4.2. The Inertial Labs^{TM} AHRS outline drawing
(all dimensions are in millimeters)**

5. ELECTRICAL INTERFACE

The Inertial Labs^{TM} AHRS has the Binder Series 718 female 6 pin connector (cordset), part # 79-3464-52-06
(see https://www.binder-usa.com/products/partsdetail/89904).

For electrical connection of the Inertial Labs^{TM} AHRS 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 https://www.binder-usa.com/products/partsdetail/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.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

13

Fig.5.1 shows the Inertial Labs^{TM} AHRS connector pinout. Pin color fits to wire color in mating cordset.
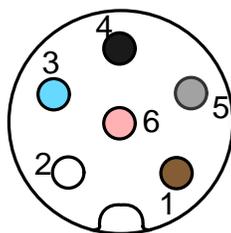
**Fig.5.1. The Inertial Labs^{TM} AHRS connector pinout
(mating side of the connector)**

Table 5.1 Pin diagram of the Inertial Labs^{TM} AHRS 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 AHRS 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	85	90	mA
Power	$V_{DD} = +6V$	90	510	540	mW

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

For tests, the Inertial Labs^{TM} AHRS can be connected to PC by wire as Fig.5.2 shows. At this, for the Inertial Labs^{TM} AHRS powering the AC/DC adapter can be used which receives the power from the 100…240V

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

14

50…60Hz AC power source. This AC/DC adapter is provided by the Inertial Labs and is included in the delivery set.
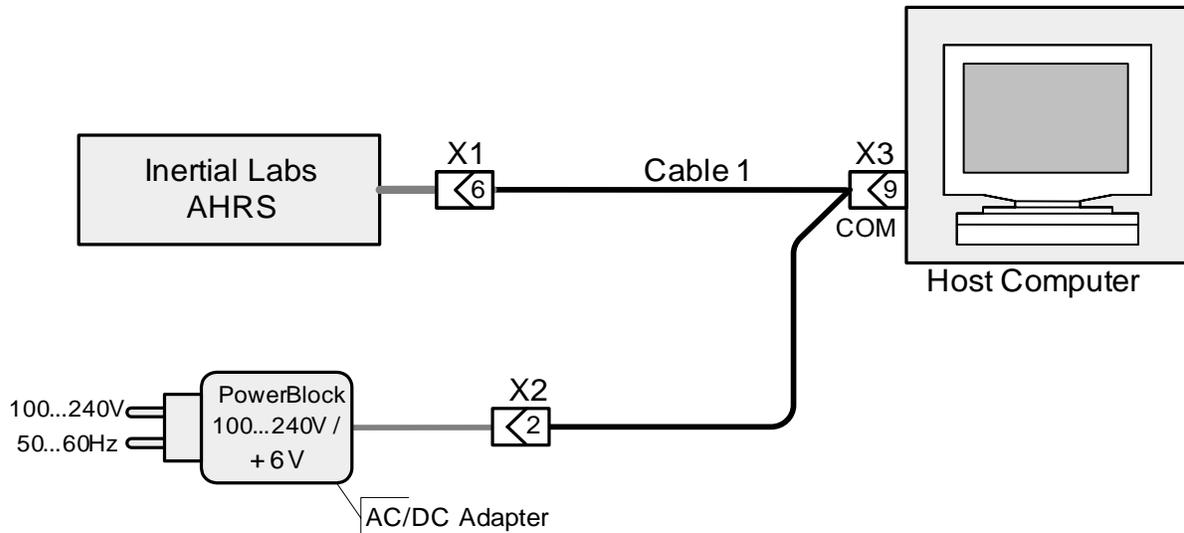
Fig.5.2. The diagram of electric connection of the Inertial Labs^{TM} AHRS to host computer (PC)

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

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

Also Inertial Labs AHRS Demo software is included in the delivery set for quick evaluation of the Inertial Labs^{TM} AHRS.

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

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

15

X1

6

Cable 1

X3

9

COM

X2

2

X1-Male Cable Connector
Binder 718

Do not connect	1
Tx-RS232	2
Rx-RS232	3
GND	4
Vdd	5
Do not connect	6

X3(COM)-Female
Connector DB -9F in the case

1	DCD
2	Rx
3	Tx
4	DTR
5	SG
6	DSR
7	RTS
8	CTR
9	RI

X2(Power)

	GND
	Vdd

PR-002B

Fig.5.3. The diagram of the interface cable 1 for the Inertial Labs^{TM} AHRS connections to the COM-port of host computer and to the AC/DC adapter
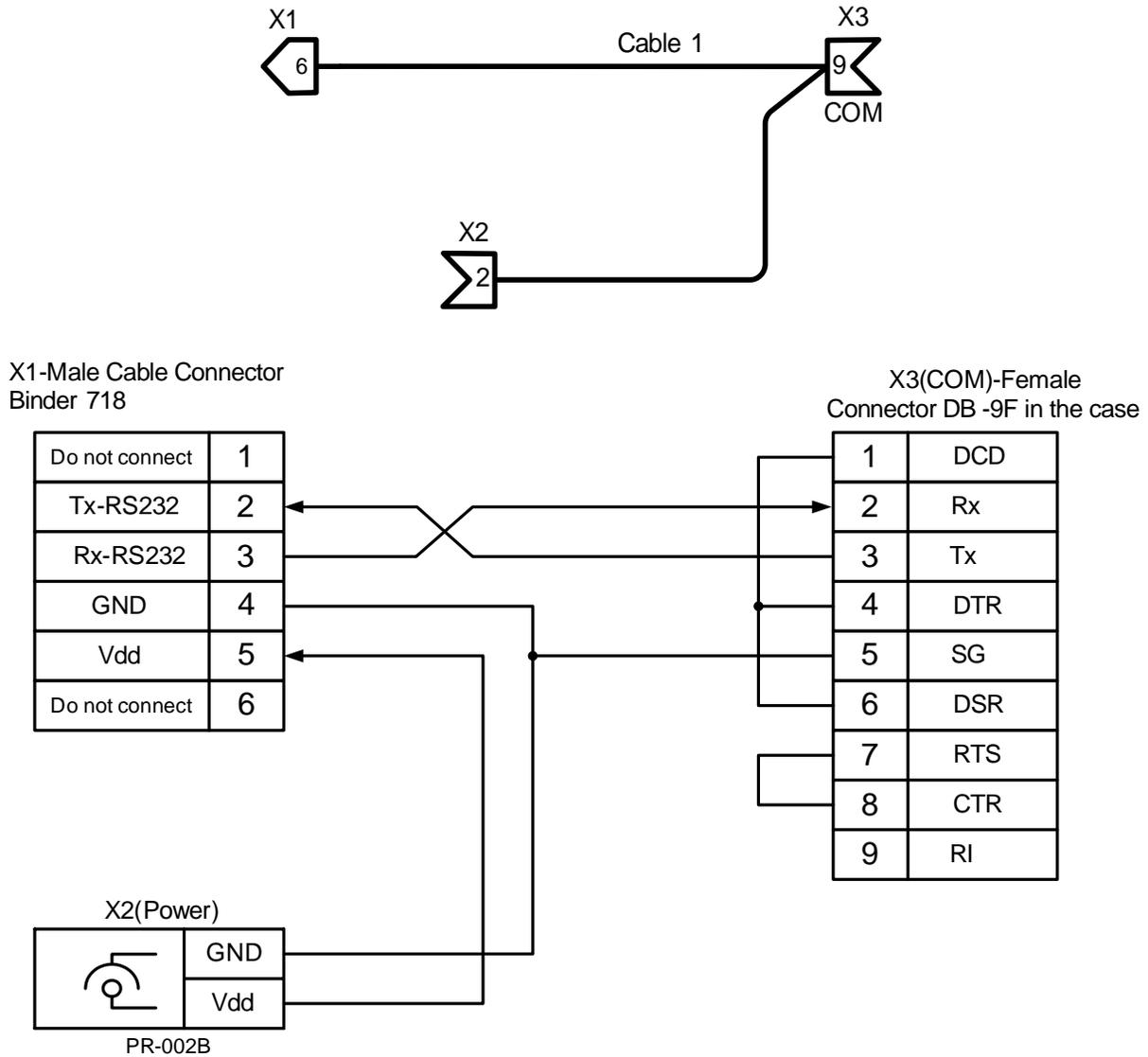
6. SOFTWARE INTERFACE

After power connection the primary initialization of the Inertial Labs™ AHRS microprocessor takes place and the main program starts working. The time of the device pretreatment is no more than 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™ AHRS have the byte structure shown in the Table 6.2. Exception is done for the AHRS output in the NMEA text format (see section 6.2).

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

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

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

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

17

The <u>Check sum</u> 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 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.

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

6.1. Operational modes of the Inertial Labs^{TM} AHRS

The Inertial Labs^{TM} AHRS can operate in the five modes:

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

2. **Continuous** operating mode. In this mode the AHRS 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 AHRS's indicator lights green.

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

4. **Calibration** operating mode. In this mode the embedded calibration procedure is performed for compensation of hard and soft iron effects of the carrier object. See section 6.4 for more details.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

18

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

6.2. Output Data Formats of the Inertial Labs^{TM} AHRS 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 (since AHRS firmware version 4.9.2)

The <u>default</u> is the "**Orientation + Sensor Outputs**" data format. It provides the AHRS output in the form of 3 orientation angles (heading, pitch and roll) and calibrated outputs of the 9 sensors (gyros, accelerometers, magnetometers) that give information about current angular rate, linear acceleration of the AHRS and components of outer magnetic field along the AHRS measurement axes (see Fig.1.2).

More correctly, these 9 sensors output are integrated angular rate, linear acceleration (specific force), magnetic field increments. In the AHRS 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 is good for using the AHRS as an 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 AHRS developers for full control of calculations in the AHRS microprocessor. Also this format can be used by the user in case of issues to get full data from the AHRS for sending to the developers.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

19

The structure of the AHRS output in the above output data formats corresponds to the Table 6.2 where payload depends on chosen output data format. 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 AHRS message payload at Full Output Data format
(at AHRScont1 or AHRSreq1 command)

Byte number	0 – 1	2 – 3	4 – 5	6 – 23	24 – 27	28 – 29	30 – 31	32 – 33
Parameter	Heading	Pitch	Roll	Ugyro, Uacc, Umag	Reserved	USW	Vdd	Utermo
Length	2 byte word	2 byte sword	2 byte sword	9×2 byte sword	4 byte	2 byte word	2 byte word	2 byte sword
Note	Orientation angles, deg*100			Raw sensor data (gyros, accelerometers, magnetometers)			Combined voltage VDC*1000	Temperature 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 AHRS input voltage;
- stabilized voltage supplied to the AHRS sensors;
3. In the «Utermo» field ADC codes are recorded sequentially from 7 temperature sensors inside gyros, accelerometers and magnetometers.
4. The low byte is transmitted by first.

Table 6.5. The AHRS message payload at Quaternion of Orientation format
(at AHRScont2 or AHRSreq2 command)

Byte number	0 – 1	2 – 3	4 – 5	6 – 13	14 – 27	28 – 29	30 – 31	32 – 33
Parameter	Heading	Pitch	Roll	Lk0, Lk1, Lk2, Lk3	Reserved	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	Temperature, ºC*10

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

20

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

Table 6.6. The AHRS message payload at Orientation + Sensor Outputs format
(at AHRScont3 or AHRSreq3 command)

Byte number	0 – 1	2 – 3	4 – 5	6 – 11	12 – 17	18 – 23	24 – 27	28 – 29	30 – 31	32 – 33
Parameter	Heading	Pitch	Roll	GyroX, GyroY, GyroZ	AccX, AccY, AccZ	MagX, MagY, MagZ	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	Magne tic fields, nT/10			Supply voltage, VDC* 1000	Tempe rature, ℃*10

Notes:
1. Values of KG, KA 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	18
KA	10000	5000	1000

2. Angular rates, linear accelerations and magnetic fields are in the carrier object axes (X is lateral axis, Y is longitudinal axis, Z is vertical axis). The AHRS orientation relative to the carrier object axes is set by alignment angles (see Appendix B. Variants of the Inertial Labs™ AHRS 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 AHRS.
5. Utermo is averaged temperature in 3 accelerometers.
6. The low byte is transmitted by first.

At the **"NMEA Output"** the AHRS 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.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

21

Table 6.7.The AHRS 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	Heading	Temperature	Vdd	USW	Check sum
Note	deg	deg	deg	℃	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 AHRS.
4. Check sum consists of a "*" and two hex digits representing XOR of all characters between, but not including "$" and "*".

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

6.3. Control of the Inertial Labs^{TM} AHRS

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

- AHRScont1, AHRScont2, AHRScont3;
- AHRSreq1, AHRSreq2, AHRSreq3;
- NMEAcont, NMEAreq
- GetDataReq;
- Stop;

- ReadAHRSPar;
- LoadAHRSPar;
- 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 C for exact structure of these commands.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

22

6.3.1. AHRScont1, AHRScont2, AHRScont3 commands

The commands **AHRScont1, AHRScont2, AHRScont3** are used to start the Inertial Labs^{TM} AHRS in the "Continuous" operating mode with one of three variants of output data:

– **AHRScont1** command, code 0x80 – Full Output Data format,
– **AHRScont2** command, code 0x82 – Quaternion Of Orientation format,
– **AHRScont3** 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 AHRS received one of these commands, the AHRS answers back immediately on this command prior to completion of the initial alignment process. The AHRS calculates the check sum of the message (without its header and check sum) and returns it for a checking. The 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 AHRS.

After receiving of any from these commands the AHRS starts process of initial alignment that takes usually 30 seconds. This process includes the AHRS gyros drift estimation, therefore don't move the AHRS 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. LoadAHRSPar command) but only in agreement with developers of the Inertial Labs^{TM} AHRS.

After completing of the initial alignment the AHRS 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.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

23

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	Average magn. field	**float**	3*4	3 numbers in ADC codes
36-39	Initial Heading	float	4	degrees
40-43	Initial Roll	float	4	degrees
44-47	Initial Pitch	float	4	degrees
48-49	USW (see section 6.5)	**word**	2	0 – successful initial alignment; ≠0 – unsuccessful

In the "Continuous" operating mode set by any of above commands AHRScont1, AHRScont2, AHRScont3, the program in the AHRS 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 is 100 Hz.

6.3.2. AHRSreq1, AHRSreq2, AHRSreq3 commands

The commands **AHRSreq1, AHRSreq2, AHRSreq3** are used to start the Inertial Labs^{TM} AHRS in the "On Request" operating mode with one of three variants of output data:

– **AHRSreq1** command, code 0x84 – Full Output Data format,
– **AHRSreq2** command, code 0x86 – Quaternion Of Orientation format,
– **AHRSreq3** command, code 0x87 – Orientation + Sensor Outputs format.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

24

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 AHRS received one of these commands, the AHRS answers back immediately on this command prior to completion of the initial alignment process. The AHRS 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 AHRS.

After receiving of any from these commands the AHRS starts process of initial alignment that takes usually 30 seconds. This process includes the AHRS gyros drift estimation, therefore don't move the AHRS 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. LoadAHRSPar command) but only in agreement with developers of the Inertial Labs^{TM} AHRS.

After completing of the initial alignment the AHRS 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 AHRS 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^{TM} AHRS 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.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

25

The **NMEAreq** command is used to start the Inertial Labs^{TM} AHRS 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 AHRS received one of these commands, the AHRS answers back immediately on this command prior to completion of the initial alignment process. The AHRS 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 AHRS.

Then the AHRS starts process of initial alignment that takes usually 30 seconds. This process includes the AHRS gyros drift estimation, therefore don't move the AHRS 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. LoadAHRSPar command) but only in agreement with developers of the Inertial Labs^{TM} AHRS.

After completing of the initial alignment the AHRS 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 AHRS 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 AHRS 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).

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

26

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 AHRS in the "On Request" operating mode. Command GetDataReq is valid if one of the AHRSreq1, AHRSreq2, AHRSreq3, NMEAreq commands was sent before.

As answer on the GetDataReq command the AHRS 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 AHRS 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 AHRS stops work in an operating mode and goes to the idle mode. At that the light indicator of the AHRS changes its color to red.

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

6.3.6. LoadAHRSPar command

The **LoadAHRSPar** command (code 0x40 in the "Payload" field) is used to load the block of the AHRS parameters (which are available for changing by user) into the AHRS nonvolatile memory. After sending the LoadAHRSPar command, the block of the AHRS parameters must be send to the AHRS 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 LoadAHRSPar command.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

27

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

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	Magnetic declination, Mdec	**float**	4	degrees, if Mdec > 360 then AHRS calculates it
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 AHRS mounting
28-31	Alignment angle A2	**float**	4	on the carrier object,
32-35	Alignment angle A3	**float**	4	degrees (see Appendix B)
36-49	Reserved		14	**Should be all zeros**

The AHRS 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^{TM} AHRS Demo Program.
2. Before using **LoadAHRSPar** command it is <u>necessary</u> to use **ReadAHRSPar** command (see below) to read parameters from the AHRS 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^{TM} AHRS.
3. Default time 30 seconds of the initial alignment can be changed but only <u>in agreement with developers</u> of the Inertial Labs^{TM} AHRS.
4. It is necessary to set current latitude, longitude, altitude, year, month, day <u>only in two cases</u> :
    a) if the magnetic declination is unknown so its calculation <u>inside the AHRS</u> is required for current place and date;
    b) before hard/soft iron calibration of the AHRS magnetometers (see section 6.4)

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

28

6.3.7. ReadAHRSPar command

The **ReadAHRSPar** command (code 0x41 in the "Payload" field, see the Table 6.2) is used to read block of the Inertial Labs^{TM} AHRS parameters (50 bytes) from the AHRS nonvolatile memory.

After receiving ReadAHRSPar command, the AHRS 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 AHRS answer on the ReadAHRSPar command (block of parameters read from the AHRS)

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	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 AHRS
28-31	Alignment angle A2	**float**	4	mounting on the carrier
32-35	Alignment angle A3	**float**	4	object, degrees (see Appendix B)
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 AHRS to low power "Sleep" mode. At this command all AHRS sensors are switched off, processor core and part of periphery are switched off. No outputs are from the AHRS, Its microprocessor only waits command from the host computer to exit from the Sleep mode. In the Sleep mode the AHRS's indicator lamp is off.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

29

6.3.9. LowPowerOff command

The **LowPowerOff** command (code 0xBA in the "Payload" field, see the Table 6.2) awakes the AHRS 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 AHRS (50 bytes) from the AHRS nonvolatile memory. As answer the AHRS 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 AHRS answer on the GetVerFirmware command

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

6.3.11. GetBIT command

The Inertial Labs[TM] AHRS has continuous built-in monitoring of its health. In both "Continuous" and "On Request" operation modes the AHRS 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 AHRS is in Idle or "On Request" operation mode (after AHRSreq1, AHRSreq2 or AHRSreq3 command). For this the **GetBIT** command (code 0x1A in the "Payload" field) is used. In answer the AHRS sends out the message with data according to the Table 6.12.

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

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

In the Table 6.12 Utermo100 is the AHRS temperature in 1/100 °C increments.

Inertial Labs, Inc[TM] Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

30

6.4. Calibration of the Inertial Labs^{TM} AHRS on hard and soft iron

The Inertial Labs^{TM} AHRS software allows compensation of hard and soft iron effects of the carrier object on the heading determination accuracy. For this purpose, field calibration of the AHRS magnetometers is provided (see Appendix A, The AHRS calibration). Inertial Labs utilizes several types of field calibration depending on the carrier object type.

The next types of the calibration are realized in the Inertial Labs^{TM} AHRS firmware:

- 3D calibration;
- 2D-2T calibration;
- 2D calibration (since firmware version 4.9.1.6).

The next commands are used for the AHRS calibration:

- Start3DClb;
- Start2D2TClb;
- Start2DClb;
- StartClbRun;
- StopClbRun;
- FinishClb;
- AcceptClb;
- ClearClb;
- ExitClb;
- GetClbRes.

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 C for examples of these commands.

6.4.1. Start3DClb command for AHRS 3D calibration

The **3D calibration** is designed for carrier objects that can operate in full heading, pitch and roll ranges. At this calibration the carrier object should be rotated in all these ranges.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

31

To start the 3D calibration the host computer sends to the AHRS the **Start3DClb** command (code 0x23 in the "Payload" field) followed by message with block of parameters listed in the Table 6.13. This message have the byte structure shown in the Table 6.2, and should be sent <u>without pause</u> after sending the Start3DClb command.

Table 6.13. Payload of the message following after the Start3DClb, Start2D2TClb and Start2DClb commands (the block of parameters loaded to the AHRS)

Byte	Parameter	Format	Length	*Note*
0-3	Reserved	**byte**	4	
4-5	Time of data accumulation in one run	**word**	2	Seconds
6-9	Latitude	**float**	4	Degrees
10-13	Longitude	**float**	4	Degrees
14-17	Altitude	**float**	4	Meters
18-21	Date (Year, Month, Day)	**float**	4	Year + (Month -1)/12 + Day/365

The AHRS 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 (1 word).

Then the AHRS starts process of initial alignment. This process includes the AHRS gyros drift estimation, therefore <u>don't move the AHRS</u> during its initial alignment. Default time of the initial alignment is 30 seconds and can be changed (see section 6.3.6. LoadAHRSPar command) but only <u>in agreement with developers</u> of the Inertial Labs^{TM} AHRS.

After completing of the initial alignment the AHRS gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.8) and starts data accumulation during time specified in message sent after the Start3DClb command (see the Table 6.13).

During the AHRS data accumulation the object should be rotated in full azimuth, pitch and roll ranges. For example the object is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll. After full 360≠ rotation the object with the AHRS is turned over (the Z-axis is down) and the procedure described

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

32

above should be repeated. During this calibration the range of pitch and roll angles changing must be as much as possible.

Note: since AHRS firmware v.4.9.9.0 it provides estimation of 3D calibration quality in terms of possible AHRS heading accuracy. To allow this possibility it is necessary to include additional rotation of the AHRS with the carrier object in the horizon plane on about 360 degrees or more with pitch and roll near the level. Acceptable pitch and roll change can be set using AHRS Demo Software since ver.15.0.28 by the "Pitch/Roll threshold" parameter in the "Device Options".

After set accumulation time is reached or StopClbRun command is sent to the AHRS (see section 6.4.2 for details) the AHRS finishes data accumulation and calculates the calibration parameters.

After calculation of the calibration parameters that takes <0.5 seconds, the AHRS gives out message with the calibration results (see the Table 6.14) and it waits one of the next commands:

- the AcceptClb command (see section 6.4.3) to accept and save the calibration parameters (usually if the "Calibration success" byte in the AHRS message is nonzero and corresponds to satisfactory AHRS heading accuracy (see the Table 6.14 and Note below it));
- or the ExitClb command (see section 6.4.4) to exit from calibration procedure without accepting and saving its results (usually if the "Calibration success" byte in the AHRS message is equal to 0 or corresponds to not satisfactory AHRS heading accuracy (see the Table 6.14 and Note below it)).

The AHRS answers on these commands with checksum and goes to idle mode.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

33

Table 6.14. Payload of the AHRS message after calibration completed

Byte	Parameter	Format	Length	*Note*
0	Type of calibration	**byte**	1	1 for 2D calibration; 2 for 2D-2T calibration; 3 for 3D calibration
1	Number of used calibration runs	**byte**	1	
2	Percent of used data points	**byte**	1	for 2D and 3D calibrations only
3	Calibration success	**byte**	1	0 – calibration is not successful >0 – calibration is successful (see Note below)
4-39	Matrix for soft iron correction	**float**	9*4	Matrix Tm_c (3°3) by rows
39-51	Matrix for hard iron correction	**float**	3*4	Matrix Hm_0 (3×1)

Note: since AHRS firmware v.4.9.9.0 it provides estimation of the calibration quality as predicted AHRS heading accuracy. So nonzero value of byte #3 "Calibration success" is predicted maximum (3 sigma) heading error of the AHRS after calibration, in degrees*10. For example, byte #3 equal to 5 corresponds to the AHRS accuracy ±0.5 deg. If calibration is successful but AHRS cannot estimate predicted accuracy it returns byte #3 equal to 255.

6.4.2. StopClbRun command

After receiving the **StopClbRun** command (code 0x20 in the "Payload" field) the AHRS early stops data accumulation in the calibration run before set accumulation time is reached.

Then the calibration procedure continues in the same way as after set accumulation time was reached.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

34

6.4.3. AcceptClb command

The **AcceptClb** command (code 0x2E in the "Payload" field) is applied to accept the calibration parameters and to save them to the AHRS nonvolatile memory. This command can be used in the end of the calibration procedure.

The AHRS answers on this command. The AHRS 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).

6.4.4. ExitClb command

The **ExitClb** command (code 0xFE in the "Payload" field) is used to exit from the calibration without any calculations in the AHRS and without saving any calibration parameters. The AHRS stops work in operating mode and goes into the idle mode.

The AHRS answers on this command. The AHRS 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).

6.4.5. Start2D2TClb command for AHRS 2D-2T calibration

The **2D-2T calibration** is designed for objects that operate in full azimuth range but with limited range of pitch and roll angles. This calibration procedure involves a few full 360× rotations of the object in azimuth with different pitch angles.

To start the 2D-2T calibration the host computer sends to the AHRS the **Start2D2TClb** command (code 0x22 in the "Payload" field) followed by message with block of parameters listed in the Table 6.13. This message have the byte structure shown in the Table 6.2, and should be sent without pause after sending the Start2D2TClb command.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

35

The AHRS 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 (1 word).

The 2D-2T calibration procedure involves a few runs with full 360° rotations of the object with installed AHRS in heading with different pitch angles.

Set the object to the first pitch angle (usually the minimum pitch angle is set first). Then send the StartClbRun command followed by message (see section 6.4.6) to start the first run of the calibration.

After receiving the StartClbRun command with its message, the AHRS calculates the check sum of received block of parameters and returns it for checking. This check sum should be equal to the check sum in the StartClbRun command message that was sent to the AHRS. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

Then the AHRS starts process of initial alignment. This process includes the AHRS gyros drift estimation, therefore don't move the AHRS during its initial alignment. Default time of the initial alignment is 30 seconds and can be changed (see section 6.3.6. LoadAHRSPar command) but only in agreement with developers of the Inertial Labs™ AHRS.

After completing of the initial alignment the AHRS gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.8) and starts data accumulation during time specified in message sent after the Start2D2TClb command (see the Table 6.13). Rotate object in azimuth with approximately constant pitch and roll. This rotation must include one or more full 360 deg turns. Please, correct the time required for such rotation in the «Time of data accumulation» field of the message (Table 6.13) to provide necessary rotation.

After set accumulation time is reached or StopClbRun command is sent to the AHRS (see section 6.4.2 for details) the AHRS gives out message with result of the calibration run (see the Table 6.15).

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

36

Table 6.15. Payload of the AHRS message after each calibration run of the 2D-2T calibration

Byte	Parameter	Format	Length	Note
0	Type of calibration	byte	1	2 for 2D-2T calibration
1	Calibration run	byte	1	1, 2, …
2	Percent of used data points	byte	1	
3	Calibration success	byte	1	0 – unsuccessful; >0 – successful (see Note below)
4-7	Reserved	float	4	
8-11	Average pitch, deg	float	4	
12-15	Average roll, deg	float	4	
16-27	Reserved	float	3*4	
28-29	USW	word	2	See section 6.5

If the "Calibration success" byte is zero (calibration run is not successful) in the AHRS answer Table 6.15 then this run will be excluded from calculations in the 2D-2T calibration procedure. To complete this procedure, it is necessary to perform at least two successful runs with essentially different pitch angles.

Note: since AHRS firmware v.4.9.9.0 it provides estimation of the calibration quality as predicted AHRS heading accuracy. So nonzero value of byte #3 "Calibration success" is predicted maximum (3 sigma) heading error of the AHRS after calibration, in degrees*10. For example, byte #3 equal to 5 corresponds to the AHRS accuracy ±0.5 deg. If calibration is successful but AHRS cannot estimate predicted accuracy it returns byte #3 equal to 255.

After each calibration run completed the AHRS sends message with payload shown in the Table 6.15, and it waits one of the next three commands from the host computer:

1. StartClbRun command followed by its message (see section 6.4.6) to start new calibration run. Before send this command the object should be turned to the next pitch angle. After sending this command the above described procedure of the calibration run with object rotation in heading should be performed.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

37

2. <u>FinishClb</u> command (see section 6.4.7 for details) to finish the calibration procedure and to calculate calibration parameters. After that the AHRS gives out message with the calibration results (see the Table 6.14) and waits one of the two commands:

   a. the AcceptClb command (see section 6.4.3) to accept and save the calibration parameters (usually if the "Calibration success" byte in the AHRS message is nonzero and corresponds to satisfactory AHRS heading accuracy (see the Table 6.14 and Note below it));

   b. or the ExitClb command (see section 6.4.4) to exit from calibration procedure without accepting and saving its results (usually if the "Calibration success" byte in the AHRS message is equal to 0 or corresponds to not satisfactory AHRS heading accuracy (see the Table 6.14 and Note below it)).

The AHRS answers on these commands with checksum and goes to idle mode.

Note: In AHRS firmware before v.4.9.9.0 to finish the 2D-2T calibration the **StopClb** command (code 0x20) was used instead of **FinishClb** (code 0x2C).

3. <u>ExitClb</u> command (see section 6.4.4) In this case the calibration finishes without any calculations in the AHRS and without saving any calibration parameters. The AHRS answers on this command with checksum and goes into the idle mode.

Notes:
1. Rotation of the object with the AHRS in heading <u>must include one or more full 360° turns</u>. Please, correct the time required for saving data in the **«Accumulation time»** window to attain necessary rotations.
2. During calibration run pitch and roll angles should be approximately constant.
3. If place of the AHRS mounting on the object is changed, or if the object is changed, then the AHRS should be re-calibrated on the hard and soft iron of this object.

6.4.6. StartClbRun command

If calibration procedure includes more than one run (like 2D-2T calibration) then the **StartClbRun** command (code 0x2B in the "Payload" field) is used to start each run.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

38

For unification with the StartClbRun command for some other calibration types, this command must be followed by message with block of parameters listed in the Table 6.16. But for the 2D-2T calibration the values of those 6 bytes don't influence, so these 6 bytes may be any, for example zeros. Only requirement is that this message should have the byte structure shown in the Table 6.2, and should be sent <u>without pause</u> after sending the StartClbRun command.

Table 6.16. Payload of the message following after the StartClbRun command (block of parameters loaded to the AHRS)

Byte	Parameter	Format	Length	*Note*
0-3	Reserved	float	4	
4-5	Reserved	word	2	

After receiving the StartClbRun command the AHRS calculates the check sum of received parameters and returns it for a checking. This check sum should be equal to the check sum in the StartClbRun command message that was sent to the AHRS. Byte structure of this message is shown in the Table 6.2 where payload is the calculated check sum (1 word).

6.4.7. FinishClb command for AHRS 2D-2T calibration

After receiving the **FinishClb** command (code 0x2C in the "Payload" field) the AHRS finishes the calibration procedure with multiple runs (like 2D-2T) and calculates the calibration parameters. After that the AHRS gives out message with the calibration results (see the Table 6.14).

Then the AHRS waits one of the next commands:
- the AcceptClb command (see section 6.4.3) to accept and save the calibration parameters;
- or the ExitClb command (see section 6.4.4) to exit from calibration procedure without accepting and saving its results.

Important note: In AHRS firmware before v.4.9.9.0 to finish the 2D-2T calibration the **StopClb** command (code 0x20) was used instead of **FinishClb** (code 0x2C).

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

39

6.4.8. Start2DClb command for AHRS 2D calibration

Since AHRS firmware version 4.9.1.5 the **2D calibration** is realized in the AHRS. This calibration is designed for carrier objects that operate in full azimuth range but with small pitch and roll angles (not more than a few degrees). This calibration procedure involves full 360° rotation of the carrier object in azimuth. During this rotation pitch and roll angles must be as close to zero as possible.

To start the 2D calibration the host computer sends to the AHRS the **Start2DClb** command (code 0x21 in the "Payload" field) followed by message with block of parameters listed in the Table 6.13. This message have the byte structure shown in the Table 6.2, and should be sent <u>without pause</u> after sending the Start2DClb command. Note that first 4 bytes in the payload (Reference azimuth) do not influence on the 2D calibration as it is noted in the Table 6.13.

The AHRS 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 (1 word).

Then the AHRS starts process of initial alignment. This process includes the AHRS gyros drift estimation, therefore <u>don't move the AHRS</u> during its initial alignment. Default time of the initial alignment is 30 seconds and can be changed (see section 6.3.6. LoadAHRSPar command) but only <u>in agreement with developers</u> of the Inertial Labs^{TM} AHRS.

After completing of the initial alignment the AHRS gives out the block of the initial data (payload is 50 bytes of the data – see the Table 6.8) and starts data accumulation during time specified in message sent after the Start2DClb command (see the Table 6.13). Rotate carrier object in azimuth with pitch and roll angles close to zero as possible. This rotation must include one or more full 360 deg turns. Please, correct the time required for such rotation in the «Time of data accumulation» field of the message (Table 6.13) to provide necessary rotation.

After set accumulation time is reached or StopClbRun command is sent to the AHRS (see section 6.4.2 for details) the AHRS finishes data accumulation and calculates the calibration parameters.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

40

After calculation of the calibration parameters that takes <0.5 seconds, the AHRS gives out message with the calibration results (see the Table 6.14) and it waits one of the next commands:

- the AcceptClb command (see section 6.4.3) to accept and save the calibration parameters (usually if the "Calibration success" byte in the AHRS message is nonzero and corresponds to satisfactory AHRS heading accuracy (see the Table 6.14 and Note below it));
- or the ExitClb command (see section 6.4.4) to exit from calibration procedure without accepting and saving its results (usually if the "Calibration success" byte in the AHRS message is equal to 0 or corresponds to not satisfactory AHRS heading accuracy (see the Table 6.14 and Note below it)).

The AHRS answers on these commands with checksum and goes to idle mode.

6.4.9. ClearClb command

The **ClearClb** command (code 0x2F in the "Payload" field) is used to clear parameters of the hard and soft iron calibration from the AHRS nonvolatile memory.

The AHRS answers on this command. The AHRS 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).

You should clear parameters of the soft and hard iron calibration if you uninstall the AHRS from the object to avoid incorrect azimuth determination with the standalone AHRS.

6.4.10. GetClbRes command

The **GetClbRes** command (code 0x2A in the "Payload" field) can be sent from the host computer to check the last calibration results of the AHRS. As answer on this command the AHRS sends out the message with the data block near the same as after completing calibration, see the Table 6.17.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

41

Table 6.17. Payload of the AHRS answer on request GetClbRes about calibration results

Byte	Parameter	Format	Length	*Note*
0	Type of calibration performed	byte	1	0 – AHRS is not calibrated; 1 – 2D calibration; 2 – 2D-2T calibration; 3 – 3D calibration; >0x80– AHRS is calibrated by loading calibration parameters from other software (e.g. Demo software).
1	Number of used calibration runs	byte	1	
2	Reserved	byte	1	
3	Calibration success	byte	1	0 – calibration is not successful >0 – calibration is successful (see Note below)
4-39	Matrix for soft iron correction	float	9*4	Matrix Tm_c (3°3) by rows
39-51	Matrix for hard iron correction	float	3*4	Matrix Hm_0 (3×1)

Note: since AHRS firmware v.4.9.9.0 it provides estimation of the calibration quality as predicted AHRS heading accuracy. So nonzero value of byte #3 "Calibration success" is predicted maximum (3 sigma) heading error of the AHRS after calibration, in degrees*10. For example, byte #3 equal to 5 corresponds to the AHRS accuracy ±0.5 deg. If calibration is successful but AHRS cannot estimate predicted accuracy it returns byte #3 equal to 255.

Inertial Labs, Inc™ Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

42

6.5. The Unit Status Word definition

The Unit Status Word (USW) provides the AHRS state information. The low byte (bits 0-7) of USW indicates failure of the AHRS. If this byte is 0, the AHRS 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 6.18 and Table 6.19.

Table 6.18. The Unit Status Word description

	Bit	Parameter	Description
Low (failure) byte	0	Initial Alignment	0 – Successful initial alignment 1 – Unsuccessful initial alignment due to AHRS moving or large changing of outer magnetic field
	1	AHRS 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	AHRS 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

Inertial Labs, Inc^TM Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

43

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	AHRS mode	See the Table 6.19

The AHRS indicates its current mode of operation in the bits 7 and 15 as the Table 6.19 shows.

Table 6.19. Indication of the AHRS current operational modes

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

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

44

APPENDIX A.
THE INERTIAL LABS^{TM} AHRS CALIBRATION

The Inertial Labs AHRS software allows to take into account influence of the carrier object soft and hard iron on the heading determination. For this purpose, field calibration of the AHRS magnetometers on hard and soft iron is provided. This calibration does not require any additional equipment, but it requires setting of the carrier object, where the AHRS is mounted, in specified positions.

There are several types of the calibration realized onboard the AHRS:
- 3D calibration;
- 2D-2T calibration;
- 2D calibration – since firmware version 4.9.1.5.

Other types of hard/soft iron calibration can be fulfilled with Inertial Labs AHRS Demo software.

3D calibration is designed for carrier objects that can operate in full heading, pitch and roll ranges. For this calibration the carrier object is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll. After full $360\times$ rotation the carrier object with the AHRS is turned over (the Z-axis is down) and the procedure described above should be repeated. During this calibration the range of pitch and roll angles changing must be as much as possible.

2D-2T calibration is designed for carrier objects that operate in full heading range but with limited range of pitch and roll angles. This calibration procedure involves a few full 360° rotations of the carrier object with installed AHRS in heading with different pitch angles. During each rotation, pitch and roll angles should be as constant as possible.

2D calibration is designed for carrier objects that operate in full azimuth range but with small pitch and roll angles (not more than a few degrees). This calibration procedure involves full 360° rotation of the carrier object with installed AHRS in the horizon plane. During this rotation pitch and roll angles must be as close to zero as possible.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

45

If place of the AHRS mounting on the carrier object is changed, or if the carrier object is changed, then the AHRS should be re-calibrated on the hard and soft iron of the carrier object.

APPENDIX B.
VARIANTS OF THE INERTIAL LABS^{TM} AHRS MOUNTING RELATIVE TO THE OBJECT AXES

The Inertial Labs^{TM} AHRS 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 AHRS mounting are correctly stored in the AHRS nonvolatile memory.

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

Angles of the AHRS position (alignment angles) are set in next order (like heading, pitch and roll setting):
- first alignment angle sets position of the AHRS 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 AHRS 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 AHRS lateral axis X measured around AHRS' longitudinal axis. Positive rotation is X axis moving down.

All angles are set in degrees.

Some examples of the Inertial Labs AHRS mounting relative the carrier object are shown on Fig.B.1
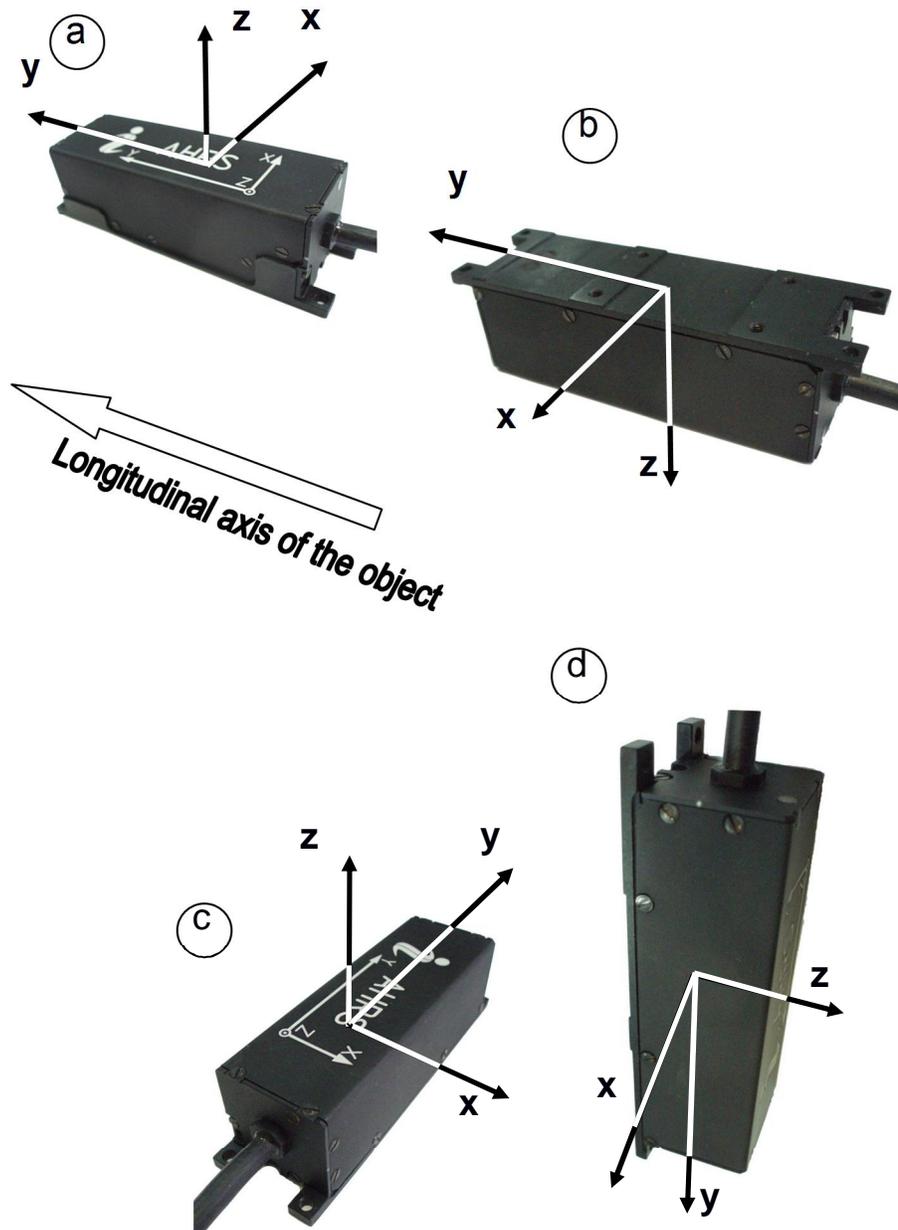
Fig.B.1. Examples of the Inertial Labs^{TM} AHRS mounting on the carrier object
a – alignment angles are   0, 0, 0   (degrees);
b – alignment angles are   0, 0, 180   (degrees);
c – alignment angles are   90, 0, 0   (degrees);
d – alignment angles are   180, -90, 0   (degrees);

To check correctness of the alignment angles please run the AHRS using the Inertial Labs AHRS Demo program. Default values of the AHRS alignment angles are all zero.

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

47

APPENDIX C.
FULL LIST OF THE INERTIAL LABS^{TM} AHRS COMMANDS

All the AHRS 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 C.1. List of the AHRS commands with exact structure

Command name	Code	Exact structure (hex)
Commands for Inertial Labs^{TM} AHRS control		
AHRScont1	0x80	AA 55 00 00 07 00 80 87 00
AHRScont2	0x82	AA 55 00 00 07 00 82 89 00
AHRScont3	0x83	AA 55 00 00 07 00 83 8A 00
AHRSreq1	0x84	AA 55 00 00 07 00 84 8B 00
AHRSreq2	0x86	AA 55 00 00 07 00 86 8D 00
AHRSreq3	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
LoadAHRSPar	0x40	AA 55 00 00 07 00 40 47 00
ReadAHRSPar	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
Commands for Inertial Labs^{TM} AHRS calibration		
Start2DClb	0x21	AA 55 00 00 07 00 21 28 00
Start2D2TClb	0x22	AA 55 00 00 07 00 22 29 00
Start3DClb	0x23	AA 55 00 00 07 00 23 2A 00
StartClbRun	0x2B	AA 55 00 00 07 00 2B 32 00
StopClbRun	0x20	AA 55 00 00 07 00 20 27 00
FinishClb	0x2C	AA 55 00 00 07 00 2C 33 00
AcceptClb	0x2E	AA 55 00 00 07 00 2E 35 00
ExitClb	0xFE	AA 55 00 00 07 00 FE 05 01
ClearClb	0x2F	AA 55 00 00 07 00 2F 36 00
GetClbRes	0x2A	AA 55 00 00 07 00 2A 31 00

Inertial Labs, Inc^{TM} Address: 39959 Catoctin Ridge Street, Paeonian Springs, VA 20129 U.S.A.
Tel: +1 (703) 880-4222, Fax: +1 (703) 935-8377 Website: www.inertiallabs.com

48