DIGS™100 SX
Downhole Inertial Guidance Systems &
AHRS (Attitude Heading Reference System)
Technical User's Guide

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3 SAFETY AND HANDLING INFORMATION

- **Always use caution when using the** DIGS™100 UNIT!

- **Supplying too high an input voltage could permanently damage the unit**. Input power is specified at +3.8 V to + 5.5 V. The unit is calibrated at +5 V ± 0.3 V.

- The DIGS™100 AHRS is a sensitive scientific instrument containing shock and vibration sensitive inertial and other sensors. **Excessive shock and/or vibration can damage these sensors and can adversely affect sensor performance and unit output.**

- **Avoid exposure to electrostatic discharge (ESD)**. Observe proper grounding whenever handling the DIGS™100 AHRS.

- **Properly attach connector and ensure that it has been wired correctly before applying power** to the DIGS™100 AHRS.

- **The x-axis of the unit must be pointed in the direction of forward motion**.

4 GETTING STARTED

This section contains directions and references for a quick start to using the DIGS™100 AHRS.

For additional support, please contact the distributor representing your location. If there isn't a local representative for your location, please contact our Headquarters for assistance and someone from our Sales Team will assist you.

The DIGS™100 AHRS Software Development Kit (SDK) is an optional product to assist first time users of the DIGS™100 AHRS. This kit provides the user everything they need to facilitate a rapid setup and test of the unit. The SDK (P/N SDK-SX-001) and includes display software with user defined options including the following components and is seen in Figure 1:

- Turn-Key Solution for DIGS™100 AHRS on User PC
- All Cabling, Interface Connectors and Software Included and Ready for Use
- Easy Integration of Direct AHRS RS-422/485 to PC's USB Port
- Includes PC Display Software for AHRS
- Data Record Capability
- Multiple User Selected Field Options for Programming and Initializing the Unit
- User Defined Bandwidth Settings and Data Output Rate on AHRS
- Battery-Powered Power Supply *(9 V, 1.5 Hours Typical)*
- Self-Test Switch

Figure 1 SDK Power Supply/Self-Test, SDK to PC Cabling, CD-ROM

The following steps will allow the user to quickly set up a DIGS™100 AHRS and interface it with its SDK.

1. Connect all units together per the User Guide under this section (Getting Started) to the PC. Do not turn on the power yet. Follow all steps in Section 4 carefully.
2. Follow the instructions from the enclosed disc under Linx SW labeled "STOP! Read This First - Installation Guide" to load the VCP drivers for the USB interface.
3. Copy the Glamr.msi software and setup.exe applications to the PC hard drive from the header file on the disc.
4. Run the Glamr.msi to install the Glamr and select the com port to LINX if not selected.
5. Apply power to the unit to see data on the screen. Turn the self-test switch to ON to see a change in the sensor data that ensures the unit is functioning. Then switch OFF.
6. Follow the instructions in the following sections of the User Guide Glamr Software Installation (Section 4.5) to change any factory settings for your application.

4.1   *RS-422/485 to USB Power Supply & Converter Cable*

Contained in the Software Development Kit is a complete RS-422/485 to USB Converter cable including battery powered power supply and self-test switch (see photo below). The power supply uses USB power.

An RS-422/485 to USB converter (requires additional drivers that are included in a CD-ROM) is also included.

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This power supply converter cable and self-test switch enables the user to quickly connect the DIGS™100 AHRS to their PC to ease integration and testing. Connect the cable to the unit and the converter board to the PC with the USB cable. The user should not need to turn on the power switch yet until the rest of the software is installed.

4.2   DIGS™100 AHRS Mating Connector

The DIGS™100 AHRS mating connector and mating pins are contained in a separate package to enable customer-specific wiring options. If the SDK was purchased, then the customer also has an RS-422/485 Converter board, USB connector mate, and mating pins.

Connector to Unit

Figure 2 Unit Connector

4.3   STOP! Read This First

You must first install the USB drivers from the enclosed USB Driver CD ROM before using Glamr to read the unit. Look on the CD ROM under Linx SW and perform the instructions in "Read Me First - Installation Guide" (Figure 5).

Note: This driver is designed for Windows programs only.

Figure 3 Read Me First Installation Guide

4.4   *Installing the SDM-USB-QS-S Drivers*

4.4.1 *Introduction*

Introduction

The Linx SDM-USB-QS-S module requires that device drivers be installed on the host PC before they can interact. The drivers tell the PC how to talk to the module. These drivers are for Windows 98, XP, NT, Windows 7, and Windows . For Windows 10 installation, please see the note. The set for Windows are the direct drivers, which offer program functions that allow a custom application to directly control the module through the USB port.

Figure 4 SDK Installation Disc

NOTE: This is for the installation on machines running the Windows 10 Operating System.

1. Install LINX driver first. This is updated for Windows 10 and is found here:

https://linxtechnologies.com/wp/wp-content/uploads/qs_driver_installer.zip

Do **NOT** use the FTDI device driver that Windows 10 provides. It does not work with the LINX product even though they are using the FTDI parts. The PID was changed so it is unique.

2. When installing Glamr, there will be an error message saying "Combined.OCX could not be registered."   This is due to missing some DLLs.   To get these dependencies, user needs to install a Microsoft Redistribution package. This package (language dependent for our foreign customers) can be found at:

https://www.microsoft.com/en-us/download/details.aspx?id=29

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Figure 5 shows which files will be available to the user via the SDK Installation Disc. Test data and a User Guide for the unit are also included. If multiple units are purchased, the respective User Guides for each different product will be located on the disc. The most recent revision of this guide will be available from the product page on the Gladiator website.

Name	Date modified	Type	Size
Linx SW	10/13/2017 2:47 PM	File folder	
990-SDK-005-REV-B	6/17/2016 7:52 AM	Adobe Acrobat D...	114 KB
Demo Read me	7/12/2011 1:02 PM	Text Document	1 KB
Glamr_1p3p72p7_2017-09-12	9/12/2017 7:15 PM	Application	661 KB
Read Me First - Installation Guide	11/23/2009 8:24 AM	Adobe Acrobat D...	558 KB
setup	9/12/2017 7:01 PM	Application	666 KB
SetupGlamr_1p3p72p7	9/12/2017 7:01 PM	Windows Installer ...	412 KB

Figure 5 Files on Installation Disc

4.4.2 Installing the Direct Drivers

The drivers are included in the Linx SW folder and should be saved onto the hard drive of a PC or onto a flash drive. Click on the **QS_Driver_Installer.msi** for the Setup Wizard.

Click Next
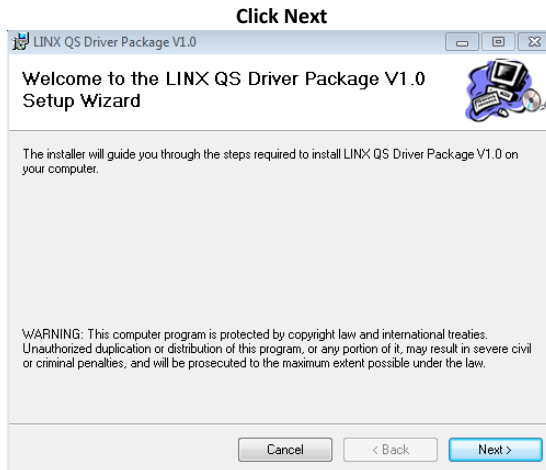
Figure 6 Driver Setup Wizard

Read License, click I Agree, then Next

Figure 7 License Agreement Prompt

Click on Next upon arrival at the Installation Folder prompt
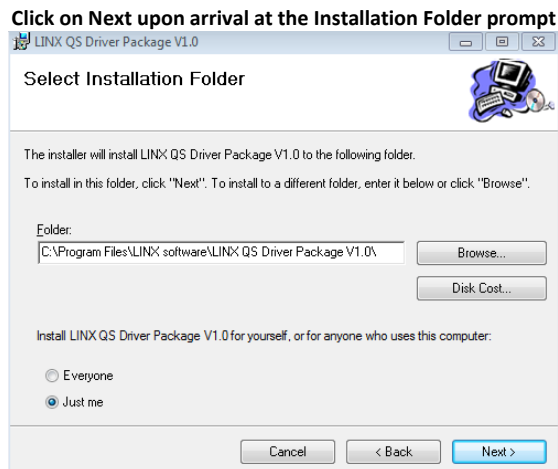
Figure 8 Installation Folder Prompt

Click on Next at the Driver Package Information prompt
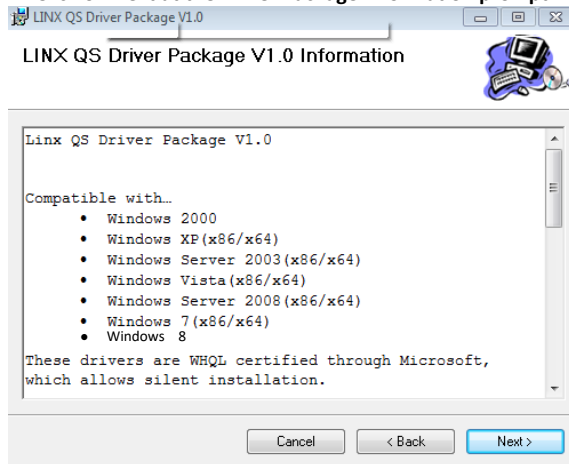
Figure 9 Driver Package Information Prompt

Note: Plug the connector cable into the USB port before you turn the device power on to avoid Windows loading as a mouse driver.

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Allow Driver Installation to complete
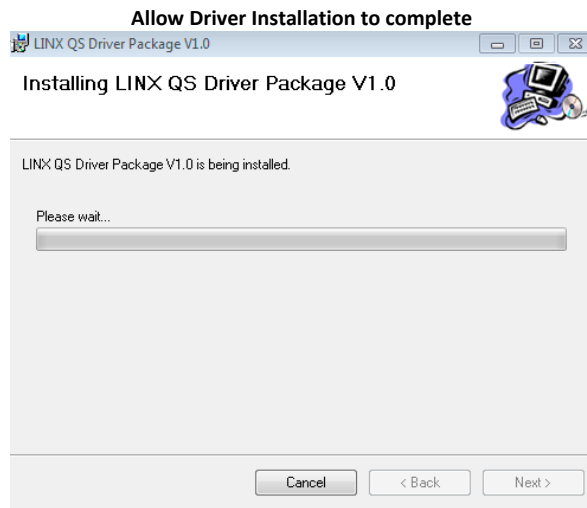
Figure 10 Driver Installation Status

4.5 *GLAMR Software Installation*

Now install the GLAMR application off of the CD-ROM. Open the Glamr file (Fig. 11) in the enclosed CD-ROM and install the application to the desired location on the hard drive.

Commented [MC2]: New picture needed.

Figure 11 Glamr Location on SDK CD-ROM

Once Glamr is installed, create a shortcut on your desktop to the application. Right click on the Glamr Software icon on your hard drive file. Select create shortcut. Drag this shortcut file and drop on your desktop, as seen in Figure 12.

Figure 12 Glamr Shortcut Software Icon

Open the Glamr software and a window will appear as in Figure 13.
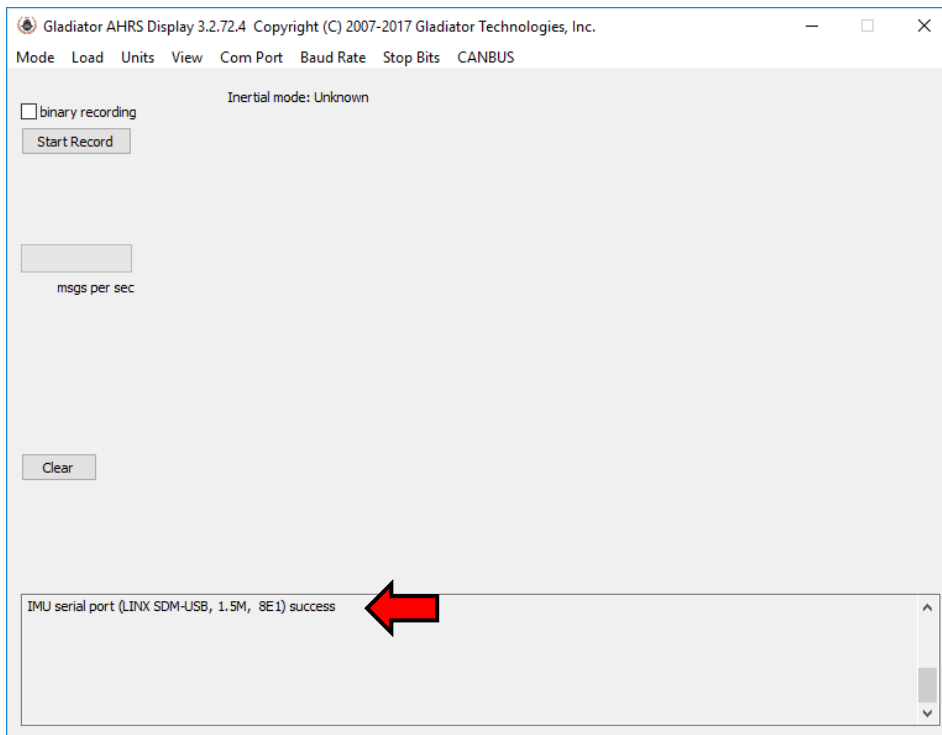
Figure 13 Glamr Screen before Selecting Correct COM Port Settings

The bottom of the Gladiator AHRS Display may read "IMU serial port (LINX SDM-USB, 115200, 8E1) Error opening." "LT=1" may also appear if the interface is not LINX.

Only one copy of Glamr can be open at a given time. Always make sure there is not another copy open on the task bar. If there are multiple copies of Glamr open, a message will appear at the bottom of the AHRS Display window.

Reconnect the USB plug to the SDK. The "LINX" port should have a checkmark next to it. The bottom of the window should now read "IMU serial port (LINX SDM-USB, 115200, 8E1) success," as shown in Figure 14.
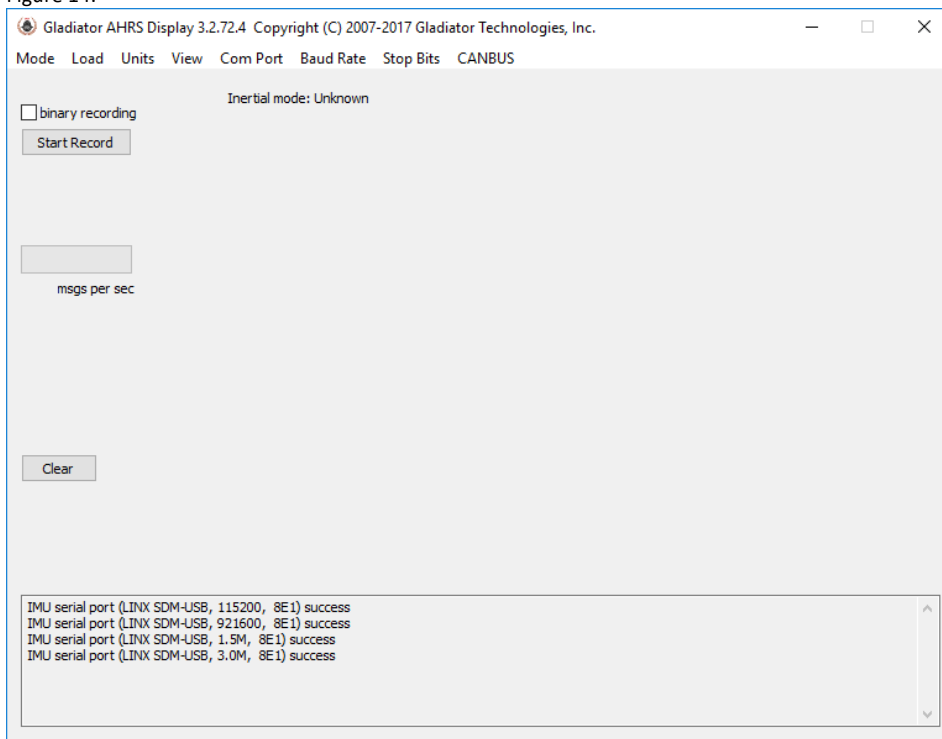
Figure 14 Confirmed Correct IMU Port with Message "success"

Turn on the power switch located on the SDK and you should see data appear in the window as seen in Figure 15. Movement of the AHRS will see changes in rate and acceleration for each axis located within the AHRS. To see rapid change, the record function will capture real time data without the filter effect on the screen.

4.6   Select Applicable Baud Rate

The baud rate needs to be at least 20% higher than the message rate times number of bits per message so that AHRS may receive commands from the host. Here is a guideline of relationship between baud rate and message rate:

		Baud Rate →				
Data Rate		115200	921600	1.5 M	3.0 M	Bits/second
↓	100	Yes	Yes	Yes	Yes	19800
	200	Yes	Yes	Yes	Yes	39600
	500	*	Yes	Yes	Yes	99000
	1000		Yes	Yes	Yes	198000
	2500		Yes	Yes	Yes	495000
	5000			Yes	Yes	990000
	6000			Yes	Yes	1188000

Note that the 500 Hz Data Mode is a special case. Please refer to Section 4.8.1 for more details.

Figure 15 Baud Rate Selection for 1000 Hz Data Rate (External Sync)

Commented [MC3]: Need external sync screenshot at 1 kHz
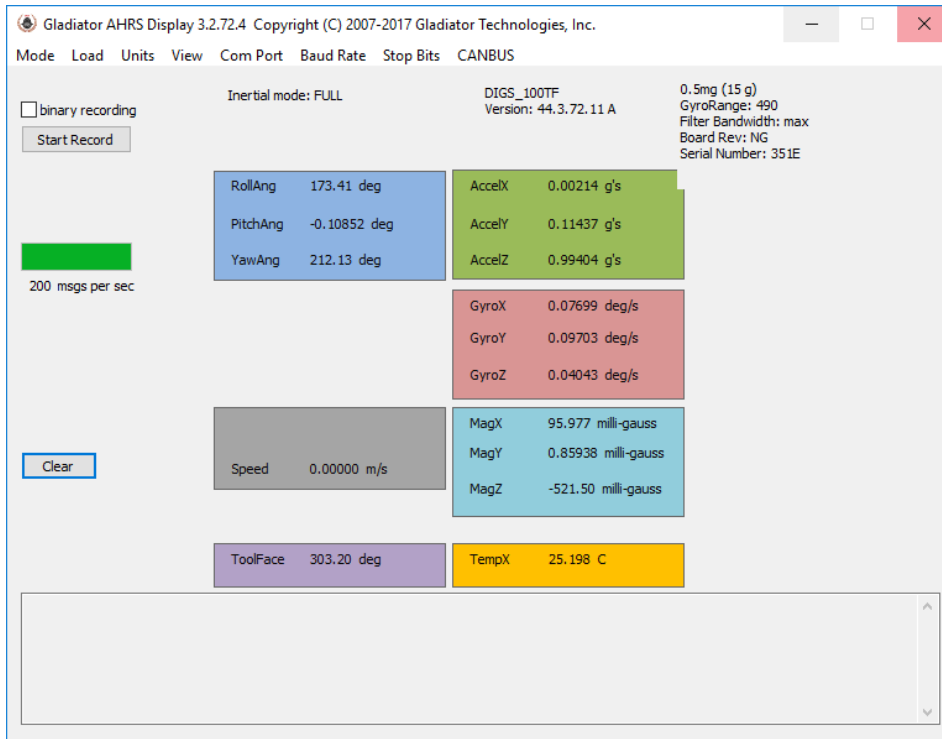
Figure 16 AHRS Data in Full Mode at 200 Hz Data Rate

The next message "Msg out-of-sequence: exp 0, act 96" indicates that the program saw a skip in the message count. This case will happen at start-up and can be ignored.

4.7 Self-Test in Glamr

Glamr includes a self-test function. The user can initiate the self-test by the momentary switch (Fig. 17), contained within the box that is included in the DIGS 100 AHRS SDK.

Figure 17 Power and Self-Test Momentary Switch

Press the switch button to activate self-test of the sensors. The Glamr display will now show "SELF-TEST" is activated while also showing the data outputs. This message is located just above the data rate status bar. You should see a delta change in the X, Y, and Z sensor outputs when you initiate self-test per the data sheet (Fig. 18).

Commented [MC4]: Re-take with SELF-TEST
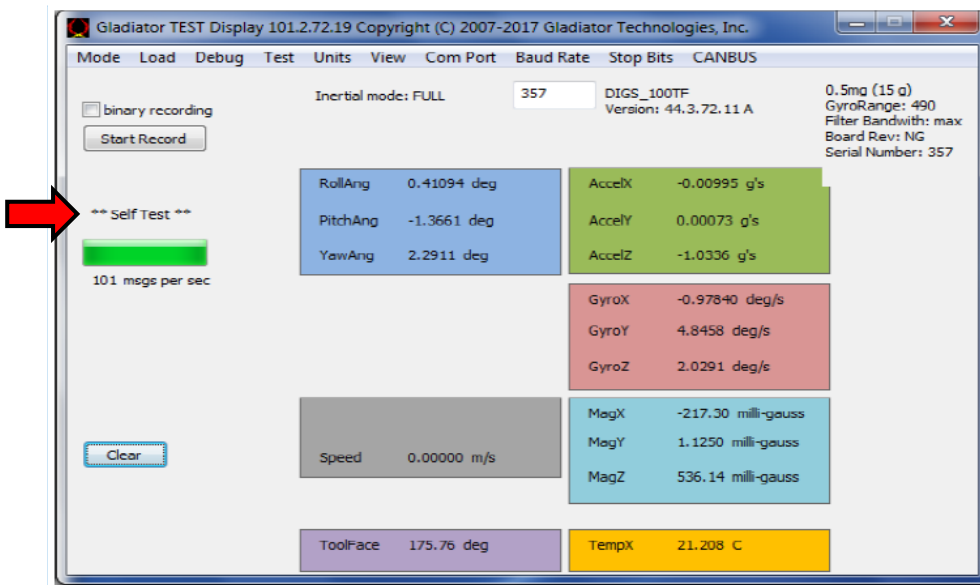
Figure 18 Self-Test Display When Activated On

4.8 Setting the Mode and Data Rate

The SDK software also has a data rate adjustment and data set selection. This feature is selected under Mode as shown in Figure 19. This allows a reduced data set in Spec mode.
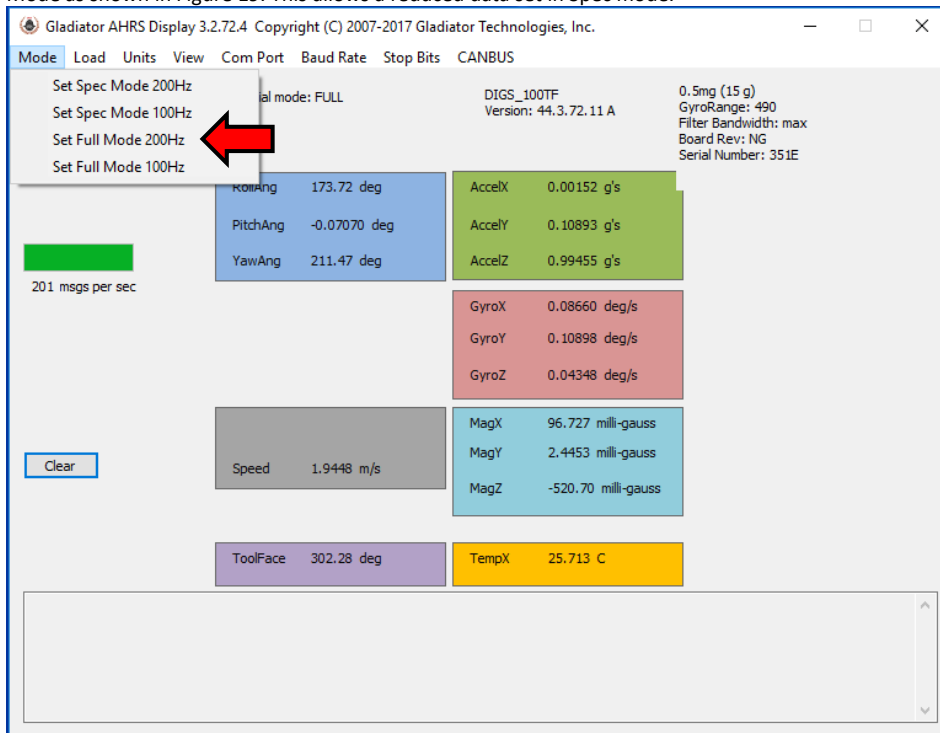
Figure 19 Mode Selection / Data Rate

4.9   *Unit Display Options*

The SDK software also can set the dimensional units of the display. This is selected under Units. Figure 20 shows the Rate unit selection.
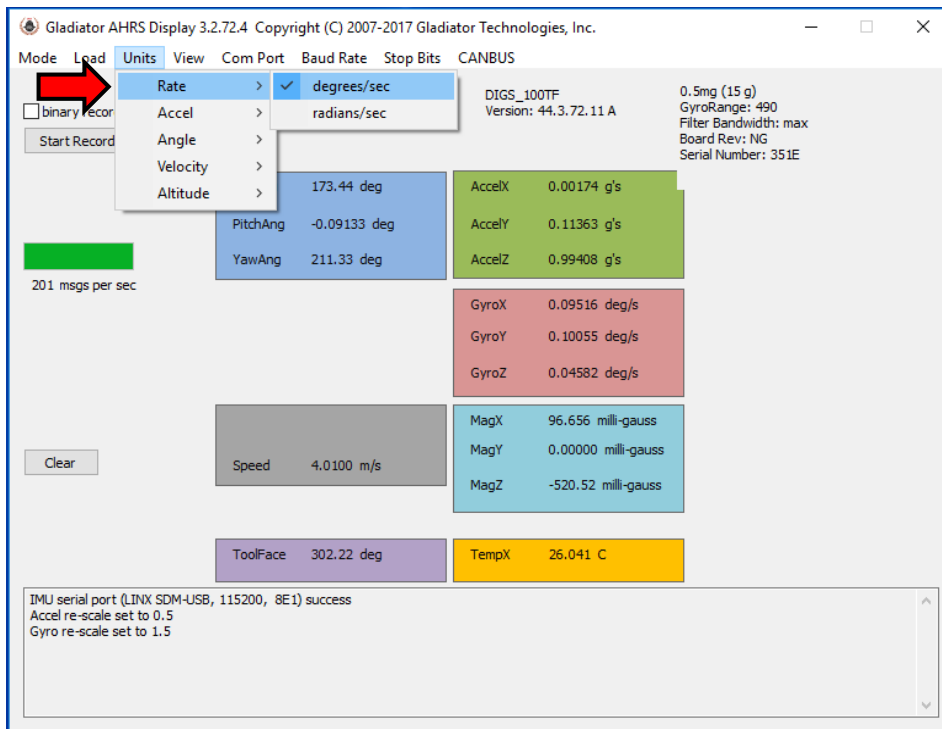
Figure 20 Units of Measure Selection Options

Figure 21 shows the Accel unit selection.

Figure 21 Accelerometer Units of Measure Selection Options

Other unit options are available for angle, velocity, and altitude.

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4.10 *Data Record Feature*

The SDK software also has a data record feature that captures data outputting from the AHRS and puts in .csv format. This enables the user to easily convert these data files to Excel or database format. The user should select with their mouse the Start Recording (Fig. 22) button to initiate data record function. When they wish to stop recording, simply click the Stop Recording button.
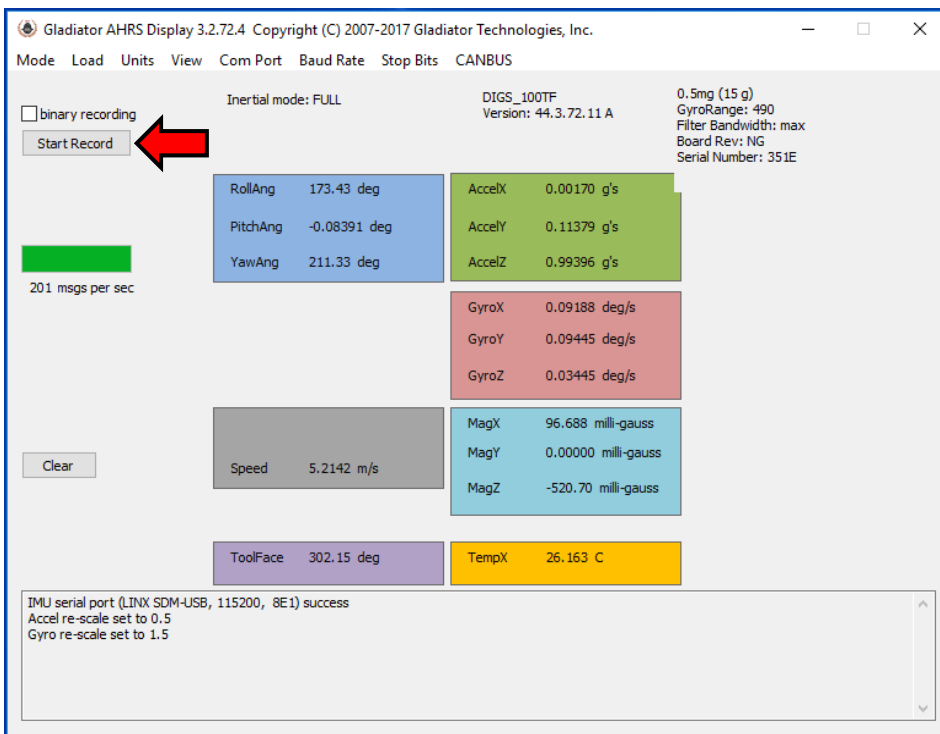
Figure 22 Data Record Options

Select "Start Record" and designate the file name and location before the recording begins. To begin Data Record function, click on Open as per Figure 23. After the designated file is established, click the desired length of time to record then click OK (Fig. 24).
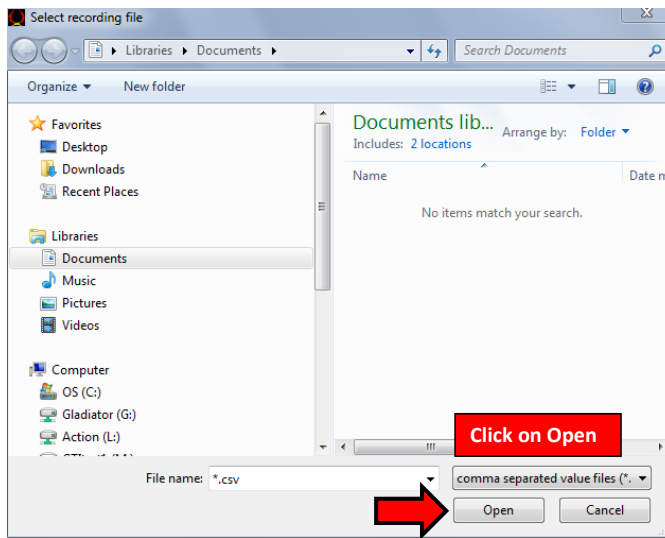
Figure 23 Saving Data Record Files

Once the file has been opened for recording, Glamr will prompt the user to select the recording time. The user has option to specify specific time interval (in seconds), as well as to record until manually stopped. At higher rates (1000 Hz), there is a large amount of data being saved, so the file location should be local to the PC or on a file server with high speed access.
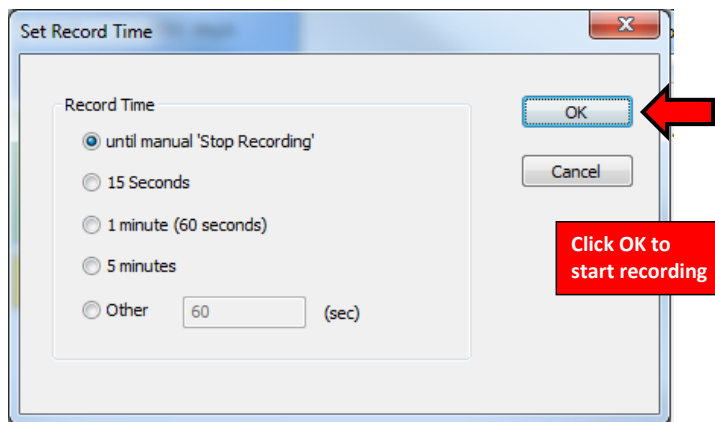
Figure 24 Saving Data Record Time

4.11 *Bandwidth Filtering Capability*

Note that our standard DIGS™100 AHRS is optimized for high bandwidth, so the AHRS bandwidth is set at 200 Hz. True bandwidth with the -3 dB point is approximately 50 Hz, which includes the 100 Hz sampling effects. These are the settings for the standard unit when shipped and the noise may not be optimized for an end-user's specific application. The high bandwidth is ideal for dynamic applications where the high bandwidth would be required to close control loops in flight control in a UAV, for example. However, in UAV navigation, a lower bandwidth would be possible and we would see an improvement in peak-to-peak noise. Laboratory uses, automotive monitoring, or stabilization applications would likely prefer reduced peak-to-peak noise and could tolerate reduced bandwidth.

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The DIGS™100 AHRS Software Development Kit offers the end-user the capability to set bandwidth filtering in permanent memory that enables the end-user to set lower bandwidth than 50 Hz and benefit from the reduced peak-to-peak noise of the sensors in the DIGS™100 AHRS. To utilize this capability, select the Load menu (Fig. 25).
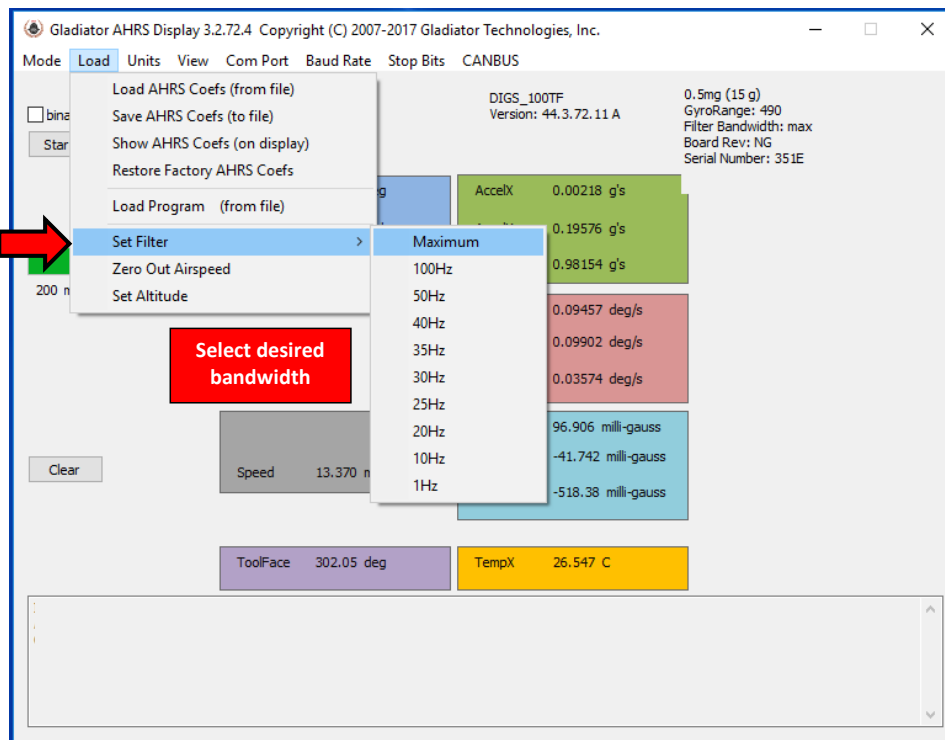
Figure 25 Select Desired Bandwidth Filter from Drop Down Menu

Now select the desired true bandwidth of the gyros with the software filter. The user can select from 200 Hz (standard units are shipped with this setting) or from the other bandwidth options all the way down to 1 Hz. Once this is set and the user takes and confirms data with this new setting, the DIGS™100 AHRS bandwidth filter setting will remain at the setting until the user changes it in the same manner as detailed in this section.

To help with troubleshooting, users can change what is displayed in the message section of Glamr. This is accessed through the View tab as shown in Figure 26.
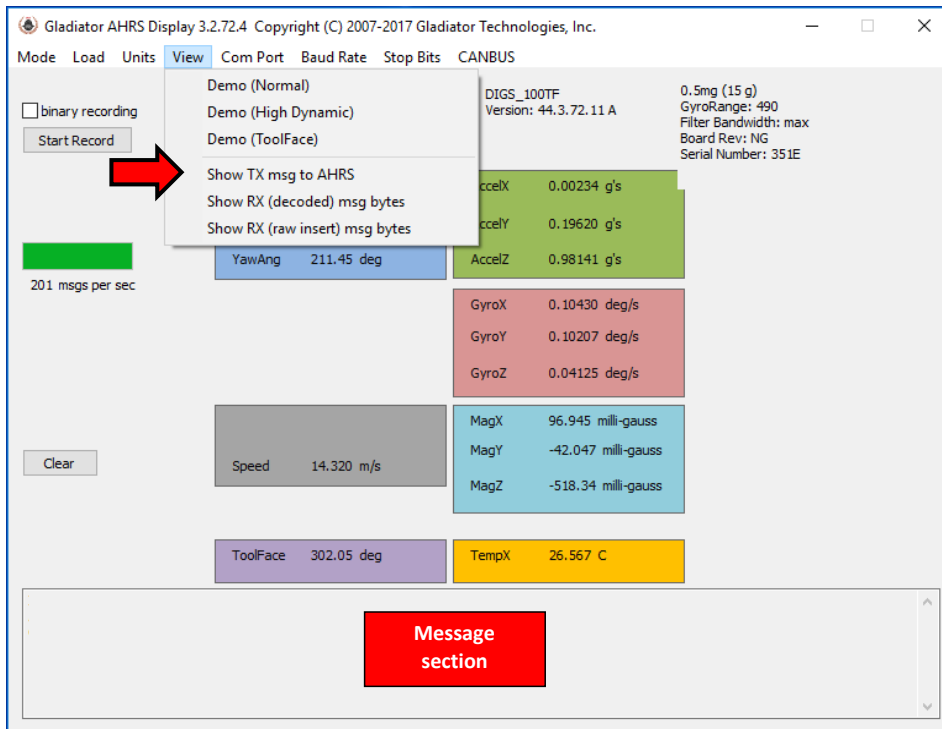
Figure 26 Message Options for Troubleshooting

4.12 *Zeroing Out the Airspeed*

Upon receipt of the unit from the factory, the user should reset the airspeed by selecting the Zero Out Airspeed from the Load menu as pictured in Figure 27.
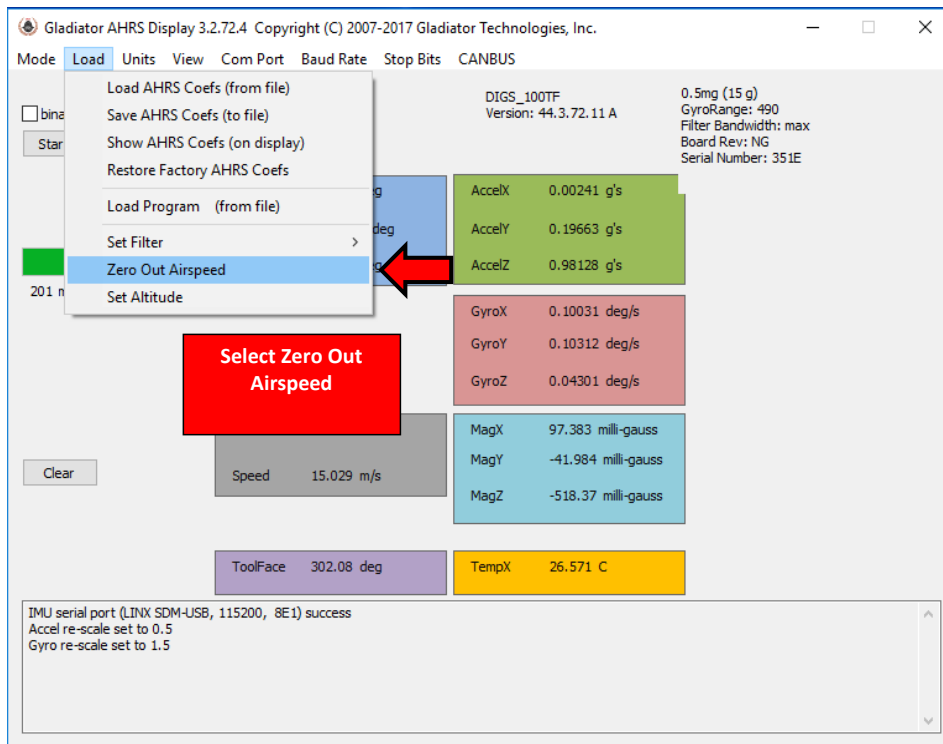
Figure 27 Zero Out Airspeed from Load Menu

4.13 *Loading Initial Parameters*

The AHRS SDK provides the user with the capability of loading initial parameters. The options are shown under Load (Fig. 28) and results in reading the prior coefficients that were loaded into the AHRS. These values can then can be updated per Figure 29.
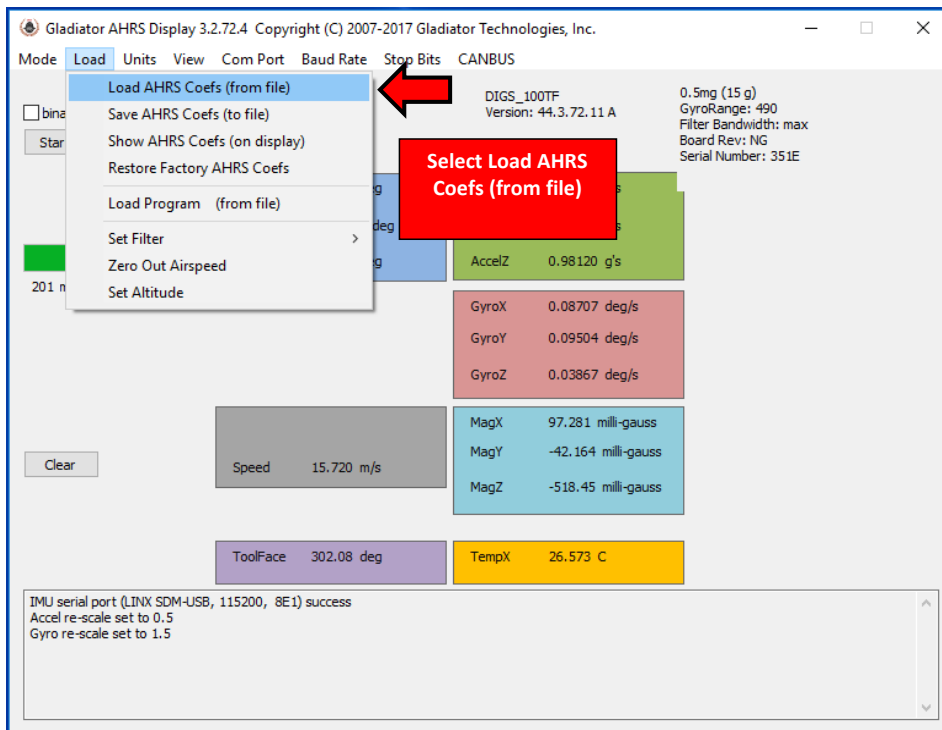
Figure 28 Loading AHRS Coefficients

Upload AHRS Coefs			
0	Coef Revision	Load	Coef Revision - keep this number
1.000000	Filter K	Cancel	Filter K - Per Table for Selected Bandwidth
1.000000	Wheel Diameter, ft		Wheel Diameter - Per Table for Velocity Input
0.000000	Airspeed Offest, meters/sec		Airspeed Offset - Adjusted for zero
0.000000	Mag Deviation, deg		Magnetic Deviation - Local Deviation from North
0.000000	Initial Altitude, meters		Initial Altitude - Offset of Barometric Pressure
OPMODE_FULL200	Operation Mode		Operational Mode Selected
1.000000	Angle Delay, sec		Angle Delay - keep this number
0.025000	Blending Filter K		Blending Filter K - keep this number
0.000000	GPS Velocity K1, meters		GPS Velocity K1 - keep this number
1.000000	Accel Threshold T, mg		Accel Threshold - keep this number
0.000000	Vehicle X Offset Input, meters		Vehicle X Offset - Offset from Vehicle CG forward
0.000000	Vehicle Y Offset Input, meters		Vehicle Y Offset - Offset from Vehicle CG right
0.000000	Vehicle Z Offset Input, meters		Vehicle Z Offset - Unit Offset from Vehicle CG up
0.000000	GPS X Offset Input, meters		GPS X Offset - Antenna Offset CG forward *Ignore this setting*
0.000000	GPS Y Offset Input, meters		GPS Y Offset - Antenna Offset CG right *Ignore this setting*
0.000000	GPS Z Offset Input, meters		GPS Z Offset - Antenna Offset CG up *Ignore this setting*
19.0	Miminum Temperature, C		Minimum Temperature Unit has ever seen
26.7	Maximum Temperature, C		Maximum Temperature Unit has ever seen
0.7417	Runtime, hours		Unit Run time in hours

Figure 29 Definitions for Uploading AHRS Coefficients

4.14 *Wheel Diameter – IMPORTANT*

The AHRS incorporates an algorithm correction for turning error. The data and display reflects this turning error correction and will work properly when you port into the unit external velocity through the spare external data port. This results in displaying your roll angle accurately. When inputting a value into the wheel diameter, the user has several options available depending upon their application:

- If you input Wheel Diameter as a positive number, then the unit will determine that you are using a wheel counter for external velocity input.

- If you input Wheel Diameter as a zero, then the unit will be scaled to use a differential input of 1.45 differential psi via a pitot tube analog voltage input of 0 V to 5 V = 500 Knots.

- If you input Wheel Diameter as a negative number, then the unit will be scaled as 0 to 5 Volts, scaled from 0 to 500 Knots linear voltage proportional to true air speed.

Case	Wheel Diameter Value	Condition
1	+ Diameter in feet	Uses logic level pulses of 3.3 V to 5 V rising edge per one turn and computes velocity as π times diameter divided by period measured between pulses
2	Zero Diameter	Airspeed 0 V to 5 V analog input, 1.45 differential pressure sensor from pitot tube input
3	-1 Diameter	Airspeed 0 V to 5 V analog input, linear velocity from 0 to 500 knots Assumes GPS update rate of 4 Hz (same as -4 in case 5 below).
4	-2 Diameter	Airspeed 0 V to 5 V analog input, linear velocity from 0 to 500 knots
5	-3 Assumes 3 Hz Update -4 Assumes 4 Hz Update -5 Assumes 5 Hz Update -10 Assumes 10 Hz Update -20 Assumes 20 Hz Update -50 Assumes 50 Hz Update -100 Assumes 100 Hz Update	Airspeed 0 V to 5 V analog input, linear velocity from 0 to 500 knots Assumes GPS update rate of 3 Hz (-3) up to 100 Hz (-100) and all cases in between (-5 is 5 Hz update etc.)

Figure 30 External Air/Wheel Speed Input Conditions

4.15 *Attitude Indicator Display*

The latest versions of the DIGS™100 AHRS SDK includes new GUI software including attitude indicator display, heading, airspeed (if ported into the AHRS), and altitude (the user will need to set the barometric pressure as indicated in other sections of the User Guide for correct readings). Please note that the GUI Attitude Indicator Display is for laboratory uses only and is **not** flight certified (Fig. 33).

After downloading the "Glamr_AHRS.exe" or later executable contained in the AHRS SDK, the user can verify that it has been downloaded correctly when the Glamr icon in Figure 31 is seen on the desktop.

Figure 31 GLAMR AHRS Desktop Icon

The user will also need to click SetupGlamrINSGPSA.msi and Demo Read me.txt to install and use the attitude indicator display feature.

Now open the Glamr application and power up the AHRS. Click on the View menu (Fig. 32) and select Demo. The new attitude display on the DIGS™100 AHRS SDK should appear and move accordingly to the unit's movements (Fig. 34).
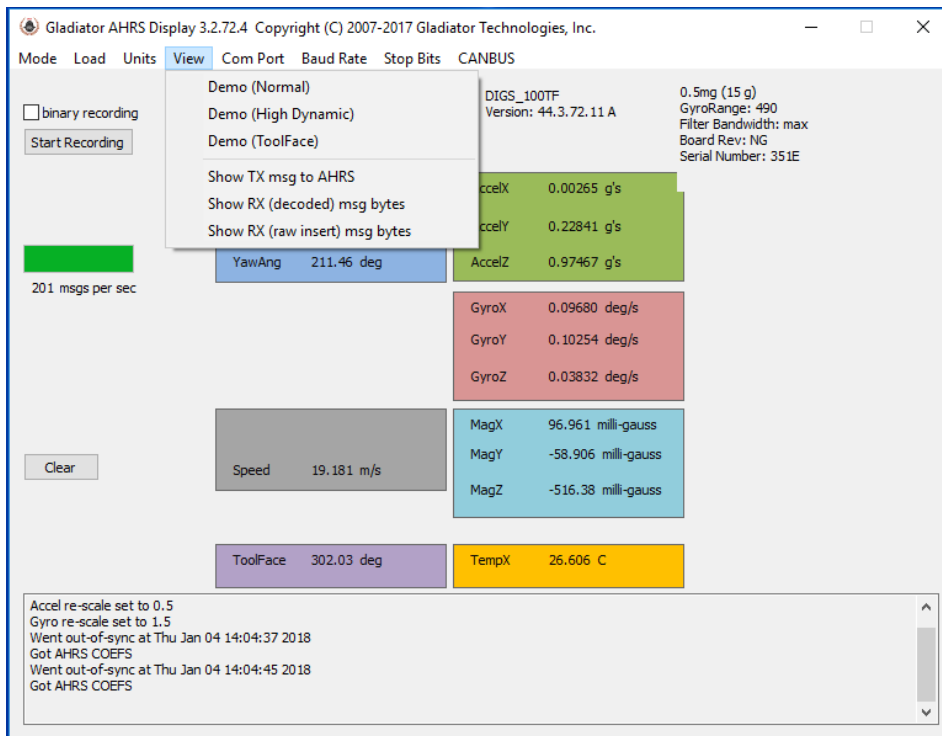
Figure 32 Glamr Display Software
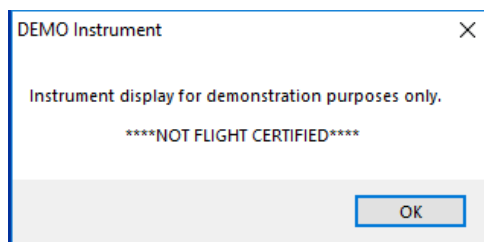
Figure 33 Warning Notice
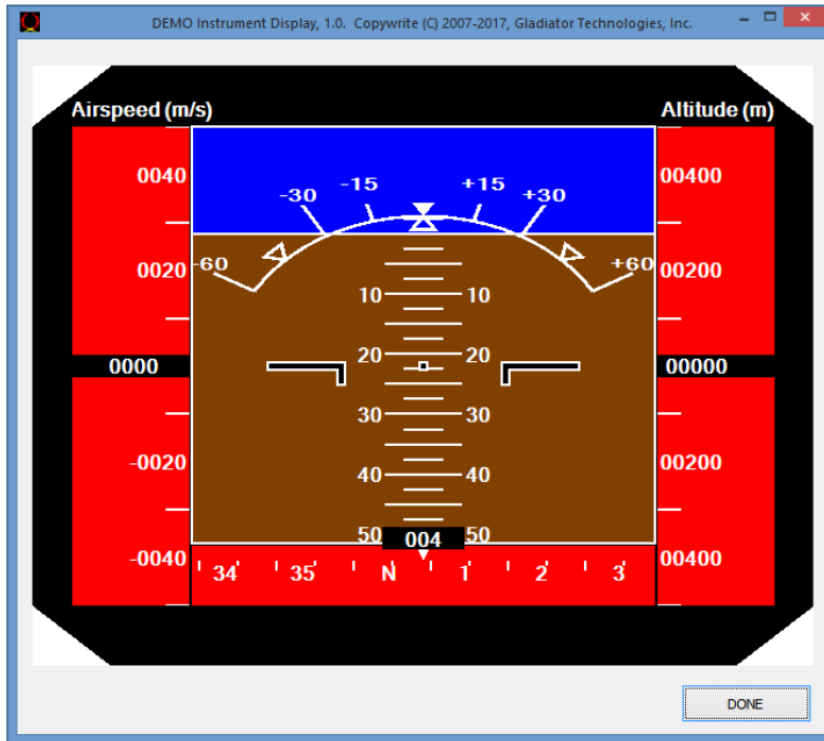
Figure 34 GUI Attitude Indicator Display

5   PATENT AND TRADEMARK INFORMATION

The DIGS™100 AHRS is a newly developed unit containing significant intellectual property and it is expected to be protected by United States of America (USA) and other foreign patents pending. DIGS™ is an official and registered trademark that identifies the Gladiator Technologies brand name for our digital inertial and integrated GPS systems products.

6 APPLICABLE EXPORT CONTROLS

The DIGS™100 AHRS has been self-classified by Gladiator Technologies with pending Commodity Classification by the U.S. Department of Commerce under the Export Administration Regulations (EAR), as ECCN7A994 and as such may be exported without a license using symbol NLR (No License Required) to destinations other than those identified in country group E of supplement 1 to Part 740 (commonly referred to as the T-5 countries) of the Export Administration Regulations. Items otherwise eligible for export under NLR may require a license if the exporter knows or is informed that the items will be used in prohibited chemical, biological, or nuclear weapons or missile activities as defined in Part 774 of the EAR. Copies of official U.S. Department of Commerce Commodity Classifications are available upon request.

7 USER LICENSE

Gladiator Technologies grants purchasers and/or consignees of Gladiator's DIGS™100 AHRS a no cost, royalty free license for use of the following software code for use with the DIGS™100 AHRS. Companies or persons not meeting the criteria as a purchaser or consignee are strictly prohibited from use of this code. Users in this category wanting to use the code may contact the factory for other user license options.

8 STANDARD LIMITED WARRANTY

Gladiator Technologies offers a standard one year limited warranty with the factory's option to either repair or replace any units found to be defective during the warranty period. Opening the case, mishandling, or damaging the unit will void the warranty. Please see Gladiator Technologies' Terms & Conditions of sale regarding specific warranty information.

9 QUALITY MANAGEMENT SYSTEM

Gladiator Technologies' Quality Management System (QMS) is certified to AS9100 Rev. C and ISO9001:2008. UL-DQS is the company's registrar and our certification number is 10012334ASH09.

Please visit our website at www.gladiatortechnologies.com to view our current certificates.

10 THEORY OF OPERATION

The DIGS™100 AHRS is a digital 9 Degree of Freedom MEMS (Micro Electro-Mechanical System) AHRS that provides the following output data: roll, pitch, and yaw angles; X, Y, and Z angular rates; X, Y, and Z linear acceleration, as well as unit temperature. Utilizing Gladiator proprietary thermal modeling process, this unit is fully temperature compensated, with temperature-corrected bias and scale factor, plus corrected misalignment and g-sensitivity.

The unit features:

- The RS-422/485 digital interface provides serial data outputs enabling the user to monitor the outputs during use. Internal sampling is done at 8 kHz. The nominal output rate in the DIGS™100 AHRS is 100 Hz or 200 Hz ± 5%. An RS-422/485 to USB converter is available in Gladiator's DIGS™100 AHRS Software Development Kit (SDK) to enable a quick AHRS to PC integration and ease of use.

- Three MEMS gyro signals with active filtering and 50X over sampled with a 16-bit A/D converter when set at 100 Hz. The gyros are available in a standard range of ± 490°/sec.

- Three MEMS accelerometer signals with analog buffering and 50X over sampled with a 16-bit A/D converter when set at 100 Hz. The accelerometers are available in standard range of ± 15g's.

- The internal temperature sensor outputs are 50X over sampled with a 16-bit converter when set at 100 Hz. These temperature measurements are co-located with each gyro, magnetometer, and accelerometer to enable accurate temperature compensation of the AHRS outputs.

- The calibration process measures temperature at a minimum of five set points from -40°C to +85°C and a nine-point correction table is generated that identifies temperature based offsets for each of the AHRS data sets. Depending upon the variable, up to a 4th order thermal model is used to create a correction model.

- Though a precision orthogonal mounting block is used in the DIGS™100 AHRS, misalignment error correction is also essential in enabling high performance navigation from a MEMS inertial sensor assembly. The calibration process also corrects and compensates for internal misalignment errors for all sensors in all three axes.

- In addition, "g-sensitivity" errors associated with the AHRS are also modeled and calibrated to correct these performance errors associated with acceleration inputs in all three AHRS axes.

- All of the calibration data is then loaded into an internal memory EEPROM enabling a look-up table for thermal modeling correction of the outputs during use.

The DIGS™100 AHRS data sheet is available to our customers via download on our website. For more information please see Gladiator's website at www.gladiatortechnologies.com. Copies of the User Guides are available upon request at suport@gladiatortechnologies.com.
The DIGS™100 AHRS SDK software design enables updates to the AHRS interface. As these software enhancements and upgrades become approved, Gladiator will make these available to our AHRS customers.

11 DIGS™100 AHRS PRODUCT DESCRIPTION

The DIGS™100 AHRS offers open-loop FOG (fiber optic gyroscope) performance utilizing our own low noise MEMS gyros and accelerometers. This high-performance Attitude and Heading Reference System (AHRS) employs a Kalman filter and features accurate Pitch, Roll, and Yaw angles, as well as very low in-run bias and excellent bias over temperature.

This ruggedized package features the temperature compensated RS-422/485 output of heading, pitch and roll angles, angular rates in three axes, linear accelerations in three axes, and altitude. Built-in software enables an external velocity input (user supplied), turning error correction, as well as an external sync (up to 5 kHz). The signature features of the DIGS™100 AHRS are the low noise MEMS inertial sensors, hard and soft iron calibrated internal triax magnetometer, and barometric pressure sensor providing integrated attitude and heading information.

- **NON-ITAR High Performance Commercial MEMS AHRS**1" Ø (diameter) x 2.28" Length
- **Heading (Yaw/Toolface) Angles** 0.5° 1σ
- **Pitch & Roll Angles** 0.1° 1σ
- **Low Gyro Noise** 0.0028°/sec/√Hz
- **Low Accel Noise** 0.075mg/√Hz
- **In-Run Gyro Bias** 5°/hour 1 σ
- **Bias Over Temperature** $\leq$ 0.1°/sec 1σ
- **Compensated Misalignment** 1 mrad
- **Compensated G-Sensitivity** 0.01°/sec/g 1σ
- **Low Voltage** +3.8 V to 5.5 V (single sided power)
- **Light Weight** < 43 grams
-
- **RS-422/485 Data Rate 100 Hz or** 200 Hz (8 kHz internal sampling)
- **Wide Sensor Bandwidth** 250 Hz
- **Bandwidth Filtering Capability**
- **External Sync Input** (5 kHz)
- **Shock Resistant** 500g's
- **Low Power** < 255 mW at 5.0 V typical
- **MTBF** 124,334 Hours

The DIGS™100 AHRS performance is optimized with Fixed Gain Kalman Filter Aiding and fully compensated bias, scale factor, misalignment, g-sensitivity, heading, pitch and roll angles, and altitude information. The unit is environmentally sealed in a rugged enclosure that is EMI resistant and includes a MIL-SPEC connector. The unit is highly durable and can withstand environmental vibration, shock, and EMI typically associated with commercial aircraft requirements. The DIGS™100 AHRS is well suited for commercial flight control, navigation, marine, antenna stabilization and pointing, general aviation as well as laboratory use.

11.1 *Outline Drawing and 3D Solid Models*

Please go to the applicable product of interest on our website at www.gladiatortechnologies.com where a user can download the 3D Solid Model, 2D outline drawing, and other product information.

11.1.1 *3D Solid Model*

Figure 35 shows the DIGS™100 AHRS in a 3D environment.
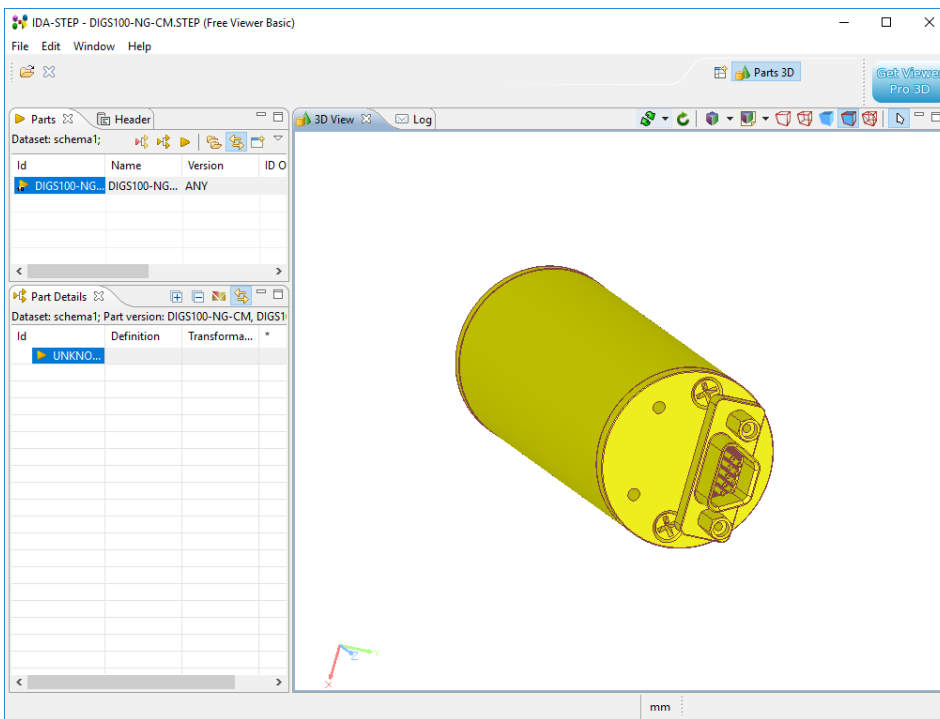
Figure 35 DIGS 100 AHRS 3D Solid Model

11.1.2 *Outline Drawing*
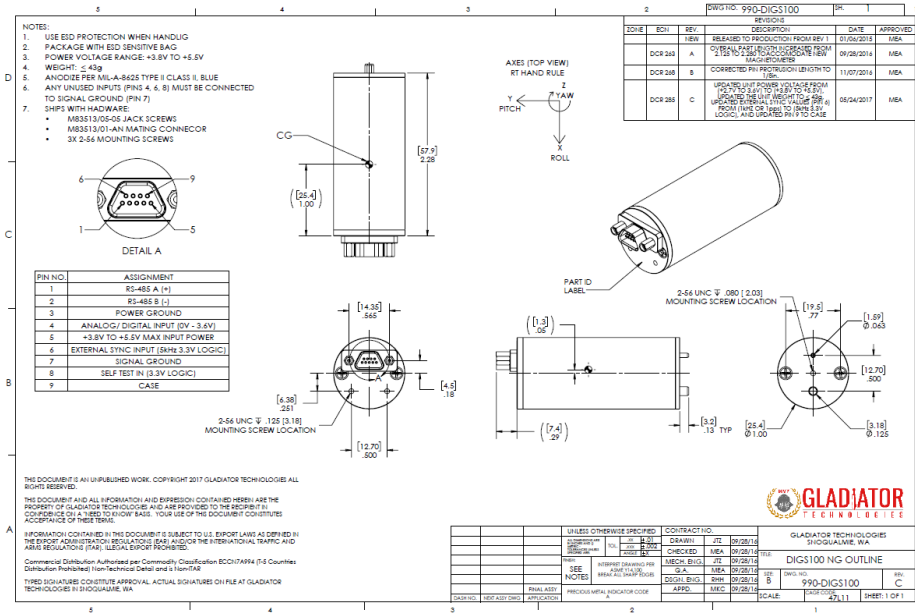
Figure 36 DIGS 100 AHRS Outline Drawing

11.1.3 *Outline Exploded View & Axis Orientation*
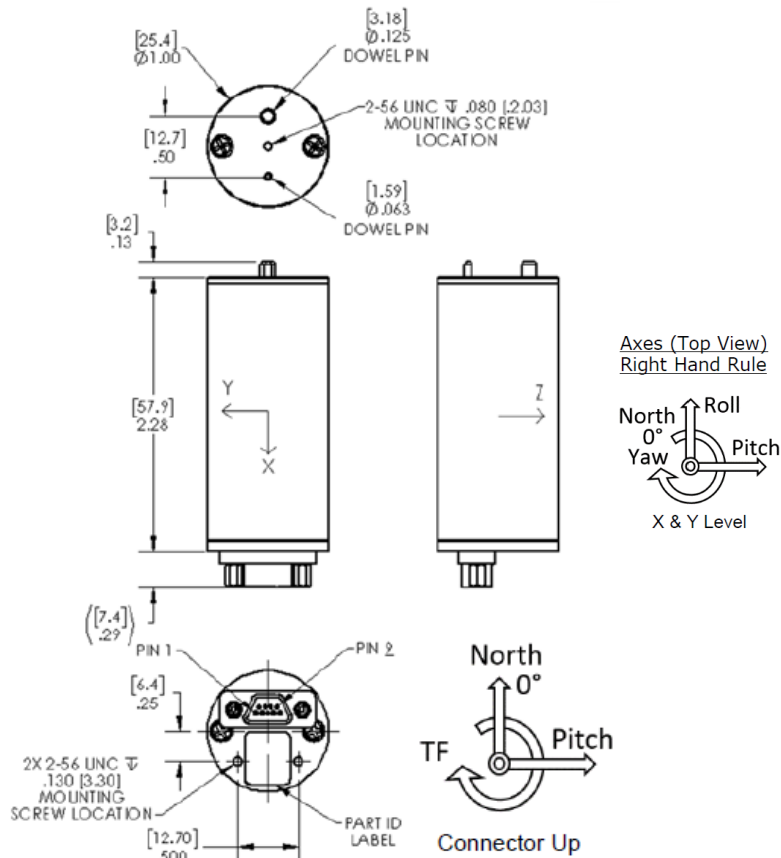
Figure 37 DIGS 100 AHRS Exploded Outline Drawing (metric in [mm])

11.2 *Center of Gravity*

Some applications need to know the CG (center of gravity) of the package, which is simply the mass center. The CG is also near the center line of the package at the midpoint along the x-axis with the following offsets:

- X offset = 0.00 inches (along the x-axis direction towards connector) (0 mm)
- Y offset = 0.00 inches (along the y-axis direction) (0 mm) from the centerline
- Z offset = 0.00 inches (along the Z-axis direction) (0 mm) from the centerline

11.3 *DIGS™100 AHRS Block Diagram*
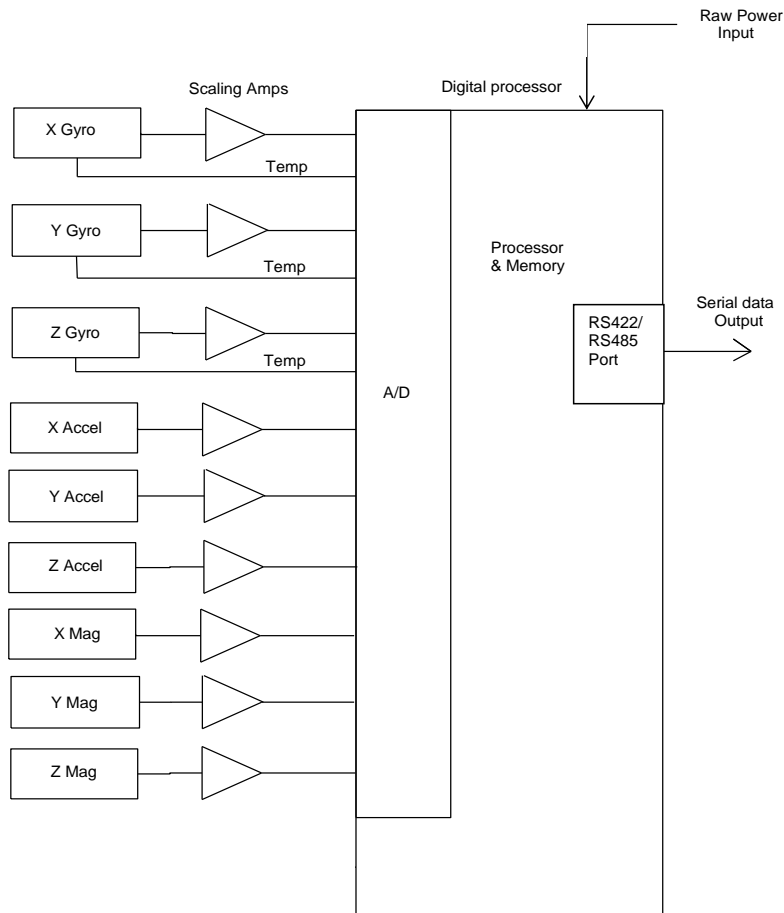
Figure 38 DIGS 100 AHRS Block Diagram

11.4 *DIGS 100 AHRS Part Naming Convention & Part Numbers*

DIGS100AHRS-490-15-100

DIGS	100	AHRS	490	15	100
Product Make *"Downhole Inertial Guidance"*	**Product Model** *"100"*	**Product Type** *"Attitude Heading Reference System"*	**Gyro Rate Range** *"490°/sec"*	**Accelerometer Linear range** *"15g's"*	**Specific Unit Configuration** *"100"*
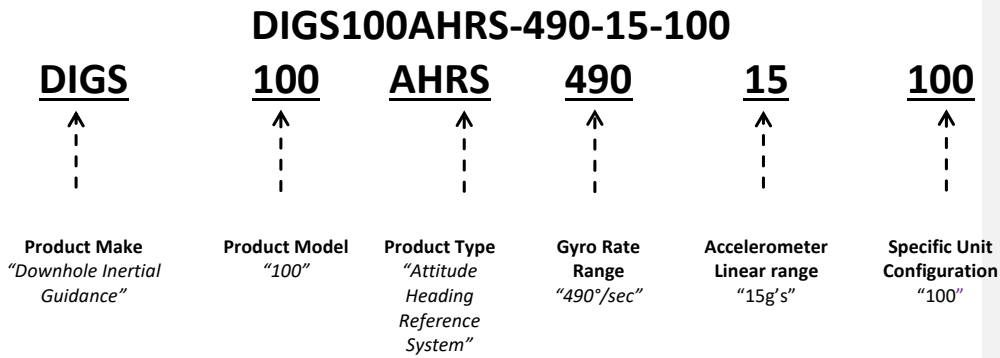
Figure 39 Gladiator Technologies Part Naming Convention

DIGS 100 AHRS
DIGS100-490-15-100

Figure 40 DIGS 100 AHRS Part Number Configurations

11.5 *DIGS 100 AHRS Pin Assignments*

The DIGS™100 AHRS has a nine pin MIL-SPEC connector interface which provides the electrical interface to the host application. The signal pin-out is as follows:

Pin No.	Assignment
1	RS-422/485 A (+)
2	RS-422/485 B (-)
3	Power Ground (Twist with Power)
4	Analog/Digital Input (0 V to 3.6 V)
5	+3.8 V to 5.5 V Max Input Power
6	External Sync Input (1 kHz 3.3 V logic)
7	Signal Ground
8	Self Test In (3.3 V Logic)
9	Case

Note: This symbol denotes a Twisted Pair

Note: Any unused inputs (Pins 4, 6, 9) must be connected to Signal Ground (Pin 7).

Outputs	Serial Sequence at 200 Hz
1, 2, 3	Gyros: Roll (X), Pitch (Y), Yaw (Z)
4, 5, 6	Accelerometers: (X), (Y), (Z)
7	IMU Temperature ± 0.5° C typical
8, 9, 10	Magnetometers: (X), (Y), (Z)
11,12,13,14	Angles: Roll, Pitch, Yaw, Toolface
15	Velocity (As Input if available)

Figure 41 DIGS 100 AHRS Pin Assignments and Outputs

NOTE: User to provide either analog or external velocity for Forward Velocity functions to be enabled (Pin 4).

NOTE: If the input pins have long wires with no termination, they can pick up noise in a high EMI environment and upset the proper operation of the AHRS. Pin 6 is particularly vulnerable to noise pickup and can cause data drops. Pin 4 is used for either an analog or digital pulse velocity input. Pin 8 is Self Test and is OK if connected to a logic level signal source otherwise it should be grounded.

11.6 *DIGS™100 AHRS Performance Specification*

See applicable current revision data sheet available on our website at www.gladiatortechnologies.com.

12 DIGS™100 AHRS MESSAGING PROTOCOL

12.1 *Serial Communication Settings*

Parameter	Value
Bits/second:	115200, 921600, 1.5 Mbit, 3.0 Mbit
Data bits:	8
Parity:	E
Stop bits:	1

Figure 42 Serial Communication Settings

12.2 *AHRS Message Packet Format*

At power-up, the AHRS enters operational mode using the last commanded mode setting. Please refer to the Gladiator Technologies Software Reference for additional information.

12.3 *Sample Data Format*

Figure 43 provides a sample AHRS data format output in Excel. The real output includes both the header information and data (see rows with MSGCOUNT) that contain actual output data. Also included are the multiplier information, averages, and units of measure for additional clarity. The AHRS Software Development Kit also includes the actual Excel file as in Figure 43, so that the user can quickly identify the formulas to use in their system integration directly from the sample data file.

MSGCOUN	GYRX (°/s)	GYRY (°/s)	GYRZ (°/s)	ACCX (mg	ACCY (mg	ACCZ (mg	TEMPX (C)	MAGX (m(	MAGY (m(	MAGZ (m(	ROLL_ANC	PITCH_AN	YAW_ANC	TF (deg)	SPEED (m/
174	0.28	0.06	0	2	638	-771	22.06	0	-467	-30	39.59	-0.13	269.82	359.67	0
175	0.3	0.1	0.06	1	637.5	-770.5	22.07	0	-467	-31	39.58	-0.13	269.82	359.75	0
176	-0.06	0.1	0.07	1	638.5	-770.5	22.05	0	-467	-30	39.59	-0.13	269.82	359.78	0
177	-0.36	0.09	0.04	2	637.5	-771.5	22.05	0	-467	-30	39.59	-0.13	269.82	359.71	0
178	-0.39	0.1	0.06	2	639	-770.5	22.07	0	-467	-30	39.6	-0.13	269.82	359.69	0

Figure 43 Screenshot of DIGS 100 AHRS Sample Data

Please note that when the customer uses the Glamr interface it automatically rescales the data. This is displayed in Figure 43, as well as the sample Excel file included in the DIGS 100 AHRS Software Development Kit (SDK).

12.4 *Sync Input (1 kHz to 5 kHz)*

The optional input to the AHRS is a sync square wave to Pin 6. This allows the data stream to be synchronized to an external clock if the unit is in IMU Mode. For example, if the user wants to supply and sync an external GPS to the AHRS the GPS generates a 5 kHz square wave which is sent to the AHRS when the GPS signal is valid. However, any external 1 kHz clock of logic level can be used to synchronize the data.

Commented [MC5]: Verify w/Jim

12.4.1 *Specification*

- Clock 5 kHz ± 5% square wave (40 - 60 duty cycle not critical)
- Data sample starts on the rising edge only
- 3.3 V or 5 V logic is acceptable
- Input has diode protection for levels below -0.7 V or above 5.5 V to 10.5 V to protect the CPU, but may cause performance problems.

12.4.2 *Status Bit*

The AHRS will operate on an internal 5 kHz clock until an external clock is detected. Then the AHRS will automatically switch over and set Status Bit 1 true. It should be noted that as the internal and external clocks are asynchronous, the transition to Ext Sync will take up to five external clock periods to align. The status bit will be set true during that transition period, as well. When the Message Counter is reset to zero, this will be the first data package with all samples on the external clock. Refer to the timing diagram to see the relationship between the external clock and data transmission (Fig. 45). The AHRS will revert to the internal clock if the external clock is not present for 4 mSec. The AHRS will revert to the internal clock if the external clock is removed and data will continue to be sent. In most cases the timing of the external sync application is not critical and the data can be used as is.

12.5 *Bandwidth vs. Noise*

Note that our standard DIGS 100 AHRS is optimized for high bandwidth, so the gyros are set at 250 Hz. True bandwidth which includes the data sampling effects has the -3 dB point is approximately the sample frequency divided by two. These are the settings for the standard unit when shipped and the noise may not be optimized for an end-user's specific application. The high bandwidth is ideal for dynamic applications where the high bandwidth would be required to close control loops in flight control in a UAV, for example. However, in a downhole survey application a lower bandwidth would be possible and the unit would output an improvement in peak-to-peak noise.

			Output Data Rate			
Bandwidth Hz	100Hz	200Hz	500Hz	1000Hz	2500Hz	5000Hz
250	N/A	N/A	1	1	1	1
100	N/A	1	0.715	0.4665	0.2222	0.12
50	0.957	0.792	0.467	0.2692	0.1181	0.061
40	0.92	0.715	0.395	0.222	0.0957	0.049
35	0.89	0.667	0.356	0.1974	0.0842	0.043
30	0.848	0.61	0.314	0.1718	0.0726	0.037
25	0.792	0.544	0.27	0.14536	0.0609	0.031
20	0.715	0.47	0.222	0.1181	0.049	0.025
10	0.46	0.27	0.118	0.0609	0.0248	0.0125
1	0.061	0.031	0.0125	0.0062	0.00251	0.00125

Figure 44 Bandwidth Frequency and Output Data Rate

The DIGS™100 AHRS Software Development Kit offers the end-user the capability to set bandwidth filtering in permanent memory. This enables the end-user to set lower bandwidth than the sensor bandwidth in order to benefit from the reduced peak-to-peak noise of the sensors in the AHRS.

12.5.1 *Timing Diagram*

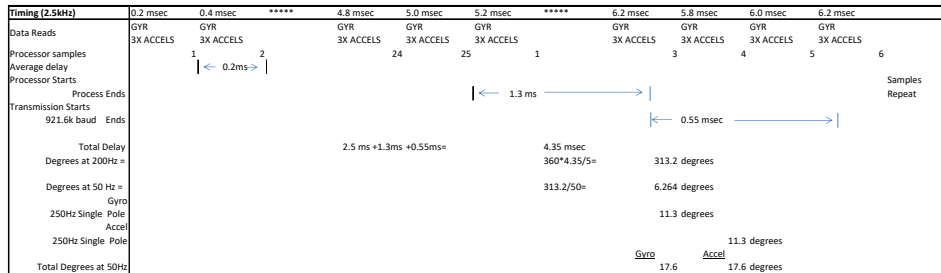| Timing (2.5kHz)	0.2 msec	0.4 msec	*****	4.8 msec	5.0 msec	5.2 msec	*****	6.2 msec	5.8 msec	6.0 msec	6.2 msec	
Data Reads	GYR 3X ACCELS	GYR 3X ACCELS		GYR 3X ACCELS	GYR 3X ACCELS	GYR 3X ACCELS		GYR 3X ACCELS	GYR 3X ACCELS	GYR 3X ACCELS	GYR 3X ACCELS	
Processor samples		1	2		24	25	1		3	4	5	6
Average delay		← 0.2ms →										
Processor Starts												Samples
Process Ends						← 1.3 ms →						Repeat
Transmission Starts												
921.6k baud Ends								← 0.55 msec →				
Total Delay				2.5 ms +1.3ms +0.55ms=				4.35 msec				
Degrees at 200Hz =								360*4.35/5=	313.2 degrees			
Degrees at 50 Hz =								313.2/50=	6.264 degrees			
Gyro 250Hz Single Pole									11.3 degrees			
Accel 250Hz Single Pole										11.3 degrees		
								Gyro	Accel			
Total Degrees at 50Hz								17.6	17.6 degrees			

Figure 45 Timing Diagram (5 kHz) at 921.6 kBaud

The AHRS will revert to the internal clock if the external clock is removed and data will continue to be sent.
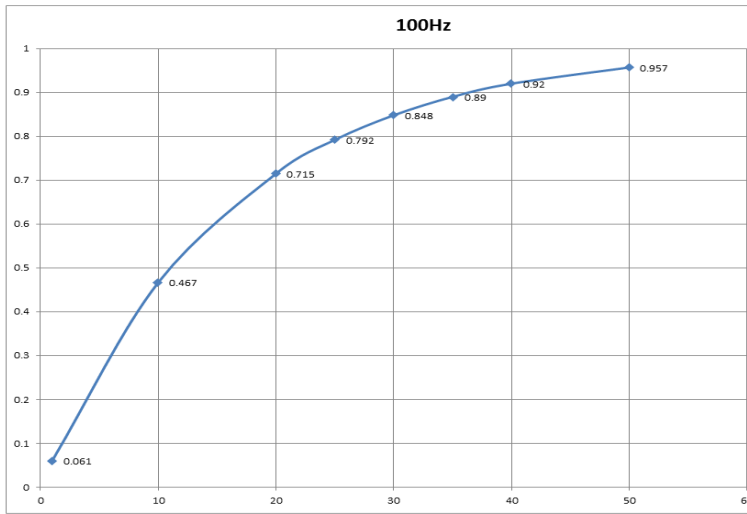

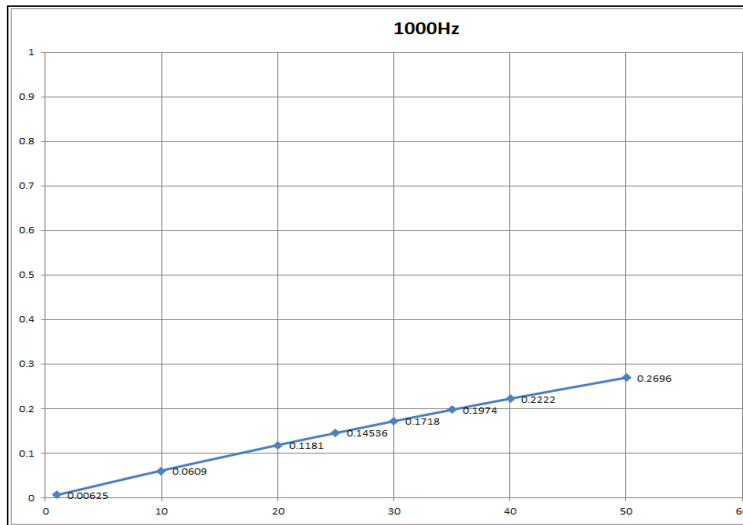*Figure 46 AHRS Bandwidth vs. Peak-to-Peak Noise 100 Hz*

Figure 47 AHRS Bandwidth vs. Peak-to-Peak Noise 1 kHz

13 SAMPLE TEST DATA & TEST METHODS

13.1 *Gladiator ATP*

13.1.1 *Rate Spin Test*

Data is captured at 100 Hz data rate. The unit is mounted on an orthogonal test fixture and spun at about half of the full-scale rate range. Only the rate scale factors and AHRS misalignments are measured. The data has been scaled by the test software. The spin rate in the data below was 144°/sec. Each column is the data taken for the axis name at the top of the column during the test at the left. The final values printed in green fall within the "passing" values for the unit (note that all passed).

Test	gyroX	gyroY	gyroZ	accelX	accelY	accelZ	temp X
PX	287.8462	-0.06891	-0.03536	-0.087	0.694	-44.5115	2367.037
NX	-287.844	0.07629	0.03147	-0.093	-1.4375	-30.4705	2365.582
Diff/2	287.8451	-0.0726	-0.03342	0.003	1.06575	-7.0205	0.7275
Ave	0.00105	0.00369	-0.00194	-0.09	-0.37175	-37.491	2366.31
PY	0.02855	287.8857	-0.0816	43.099	-1.7785	-44.4015	2359.097
NY	-0.01274	-287.918	0.08923	45.3635	-1.858	-30.4305	2358.762
Diff/2	0.020645	287.9017	-0.08542	-1.13225	0.03975	-6.9855	0.1675
Ave	0.007905	-0.01602	0.003815	44.23125	-1.81825	-37.416	2358.93
PZ	-0.02359	-0.10392	287.9387	42.7085	-5.561	-3.083	2359.86
NZ	0.05938	0.1322	-287.96	39.3505	8.2295	-2.992	2359.053
Diff/2	-0.04149	-0.11806	287.9494	1.679	-6.89525	-0.0455	0.4035
Ave	0.017895	0.01414	-0.01069	41.0295	1.33425	-3.0375	2359.457
RSF Norm	0.999462	0.999659	0.999824				Temp °C
							23.62
Gyro							
Mis-Align				Input Rate			
deg/sec							
x		0.0207	-0.0415	x			
y	-0.0726		-0.1181	y			
z	-0.0334	-0.0854		z			
Gyro							
Mis-align				Input Rate			
mrad							
x		0.072	-0.144	x			
y	-0.252		-0.410	y			
z	-0.116	-0.297		z			

Figure 48 Rate Spin Test Data

13.1.2 *AHRS Tumble Test*

Data is captured at 100 Hz data rate. The unit is mounted on an orthogonal test fixture and placed in ±
1g and ± 0g's in this test. During this test, the AHRS biases are measured, as well as the AHRS g-
sensitivity.

Test	gyroX	gyroY	gyroZ	accelX	accelY	accelZ	temp X
PX	0.01046	-0.00631	0.00392	1003.626	-1.9935	0.2275	2358.177
NX	0.00414	-0.00819	0.00193	-996.302	-1.793	-0.152	2355.963
Diff/2	0.00316	0.00094	0.000995	999.964	-0.10025	0.18975	1.107
Ave	0.0073	-0.00725	0.002925	3.662	-1.89325	0.03775	2357.07
PY	0.00581	0.00523	0.00154	-0.048	1001.753	0.653	2366.998
NY	0.00359	0.00566	0.00056	-0.3295	-998.166	-0.5465	2368.141
Diff/2	0.00111	-0.00021	0.00049	0.14075	999.9593	0.59975	-0.5715
Ave	0.0047	0.005445	0.00105	-0.18875	1.79325	0.05325	2367.57
PZ	0.00629	0.00495	-0.00017	-0.16	1.3615	1000.562	2368.066
NZ	0.00113	0.00271	-7E-05	-0.1755	2.343	-999.513	2364.69
Diff/2	0.00258	0.00112	-5E-05	0.00775	-0.49075	1000.037	1.688
Ave	0.00371	0.00383	-0.00012	-0.16775	1.85225	0.52425	2366.378
Bias °/s,mg	0.0052	0.0007	0.0013	-0.18	-0.02	0.05	23.64
ASF Norm				1.0000	1.0000	1.0000	Temp °C
			Input g =	Accel In			
Gyro °/s /g				g's			
x	0.0032	0.0011	0.0026	x			
y	0.0009	-0.0002	0.0011	y			
z	0.0010	0.0005	-0.0001	z			
				Accel			
				Mis-Align	mrads	Accel In	
				0.14	0.01	x	
			-0.10		-0.49	y	
			0.19	0.60		z	

Figure 49 Tumble Test Data

13.1.3 *Heading ATP*

The unit is mounted in a special magnet free test area. With a proprietary test method, both hard and soft iron magnetic calibration is done. The unit is then rotated slowly around on a rotary table to verify heading outputs versus calibrated data.

Heading ATP   **SN357**   10/30/2017
Digs100TF-490-15-100

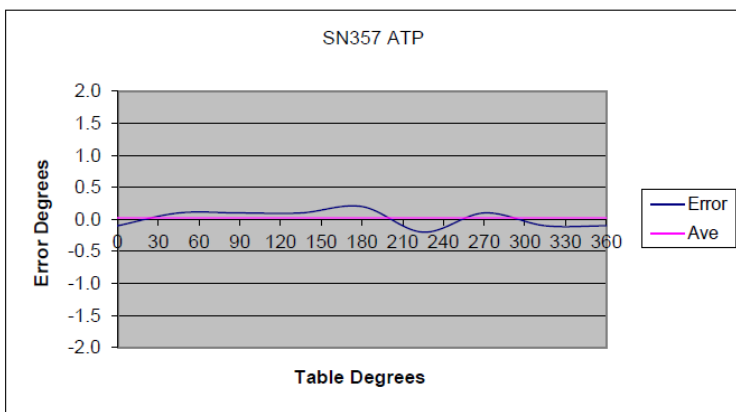| Table Position degrees from N	Heading AHRS °	Error degrees	Average degrees
0	-0.1	-0.1	0.0
45	45.1	0.1	0.0
90	90.1	0.1	0.0
135	135.1	0.1	0.0
180	180.2	0.2	0.0
225	224.8	-0.2	0.0
270	270.1	0.1	0.0
315	314.9	-0.1	0.0
360		-0.1	0.0
ave err =		0.0	

Figure 50 ATP Heading Error

13.1.4 *Pitch and Roll ATP*

Pitch and Roll ATP is done on precision mounting blocks at 45° angles. Self-test is also verified again during this testing. Compare Figure 51 to Figs. 52 and 53 as a sample bench reading versus at ± 45 degrees.
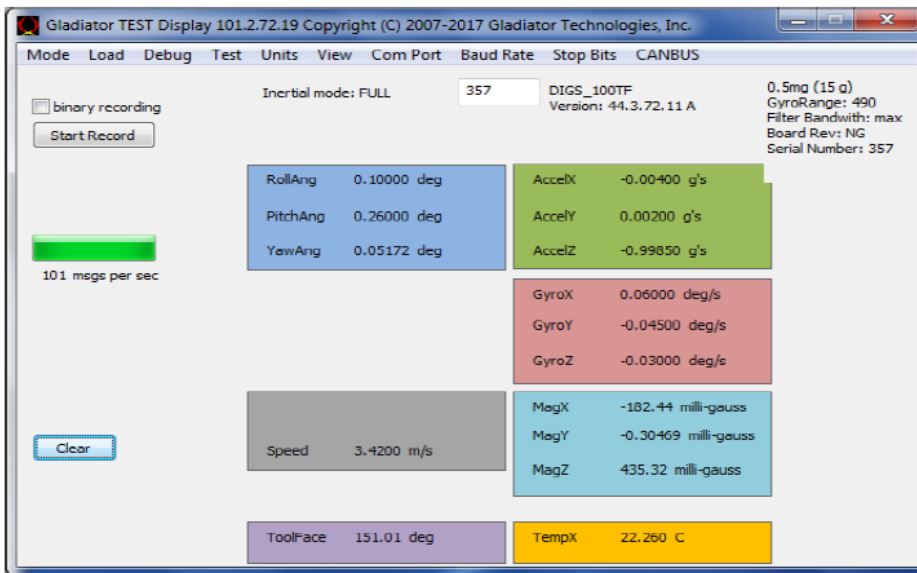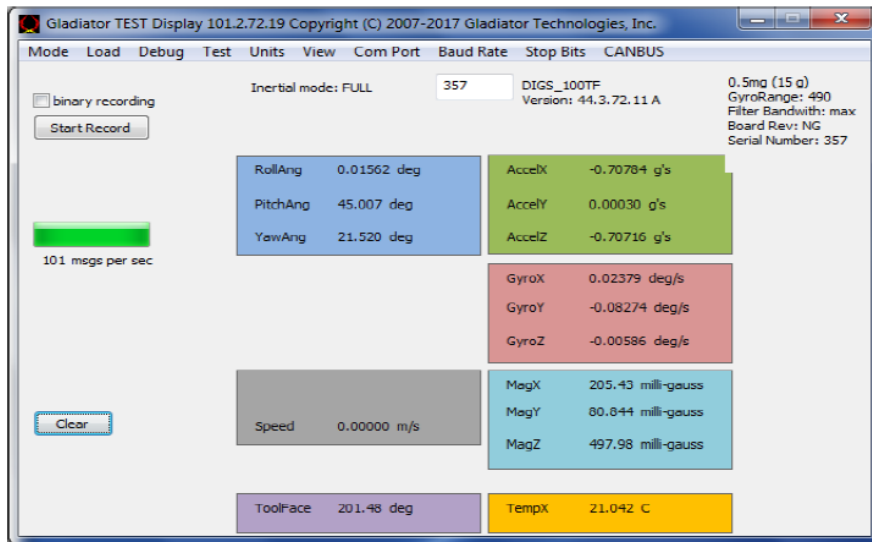

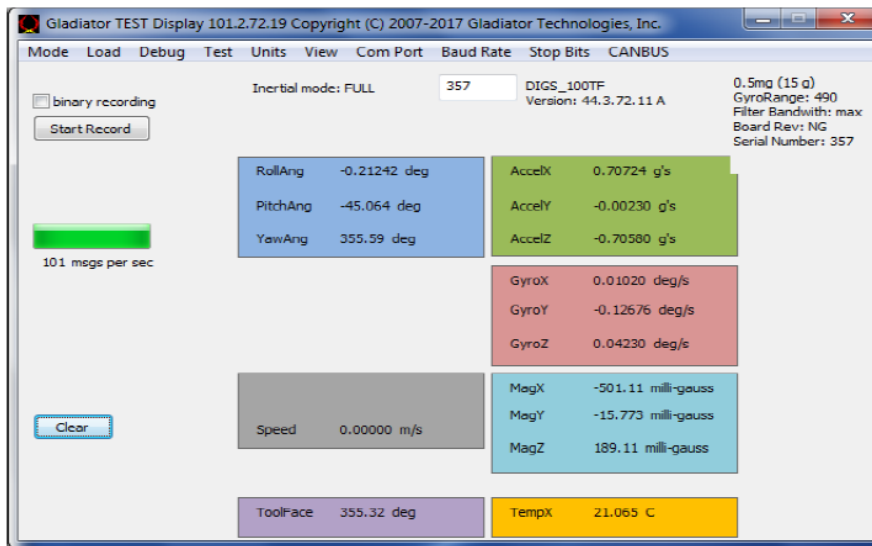*Figure 51 Initial Bench Readout*

Figure 52 Pitch Up 45°

Figure 53 Pitch Down 45°

13.2 *Angle Random Walk and Allan Deviation*

The unit is mounted on an orthogonal fixture and is turned on with no input. Data is captured at 200 Hz data rate. The white noise due to angular rate is measured. ARW is typically expressed in our datasheets in degrees per second per square root hertz (°/sec/√Hz), which is standard for most MEMS gyros. However, our performances are now commensurate with higher performing small open loop FOGs and small RLG's, so we also denote ARW in degrees per square root hour [°/√h].
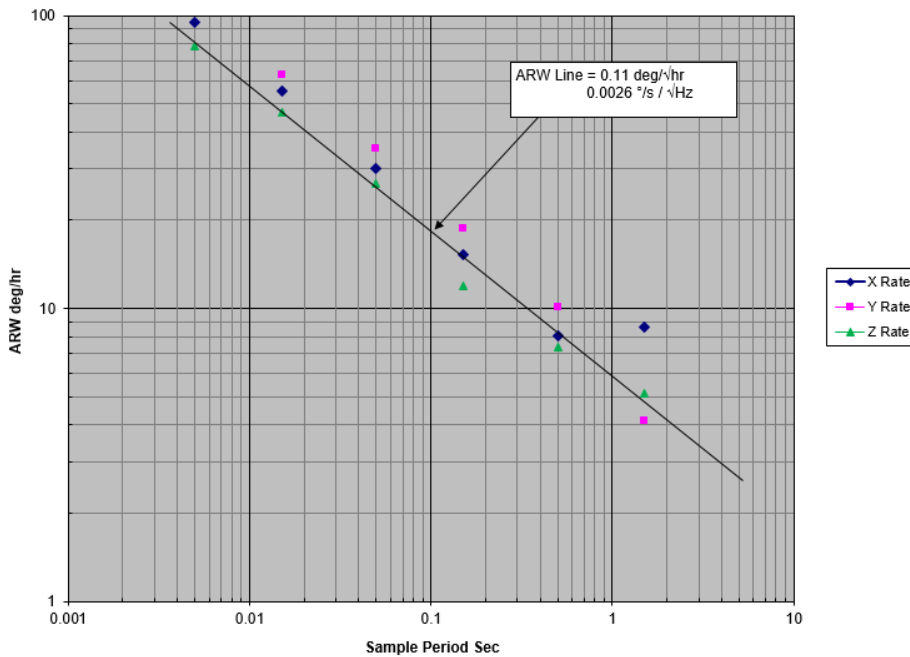

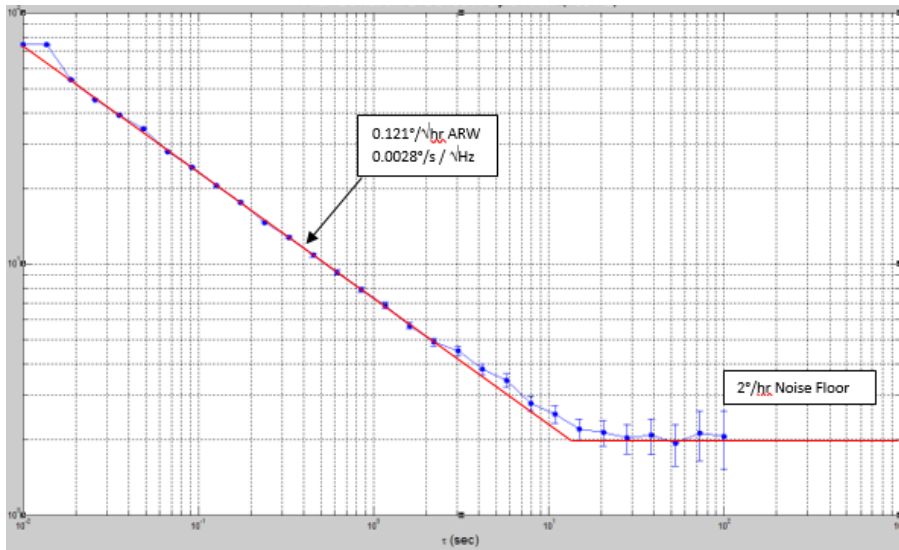*Figure 54 Angle Random Walk (ARW)*

Figure 55 Gyroscope Allan Deviation

13.3 *Velocity Random Walk and Allan Deviation*

The unit is mounted on an orthogonal fixture and is turned on with no input. Data is captured at 200 Hz data rate. Gladiator measures he velocity error accumulating with time, due to white noise in acceleration.. VRW is typically expressed in our datasheets in milli-g per square root hertz (mg/√Hz), which is standard for most MEMS accelerometers. However, our performances are now approaching higher performing quartz based servo accelerometers, so we also denote VRW in meters per second per square root hour [(m/s)/√h].
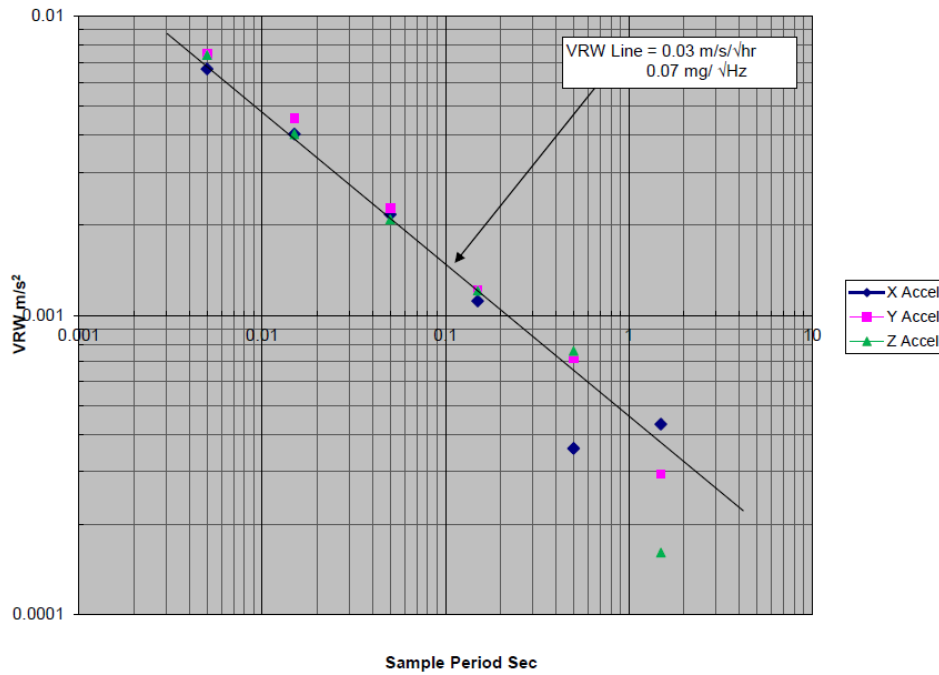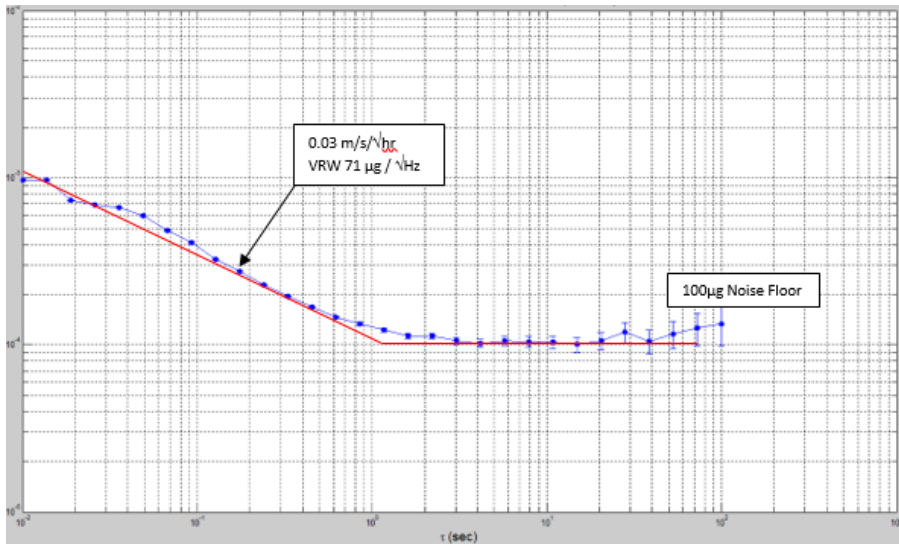

Figure 56 Velocity Random Walk (VRW)

Figure 57 Accelerometer Allan Deviation

13.4 *Bias In-Run*

The unit is placed on an orthogonal test fixture. Data is captured at 100 Hz data rate. Then the bias of the accelerometers and gyro s are measured at 1 Hz average. After a five-minute warm-up period, the data is taken for five minutes at ambient temperature. The test conditions should be similar to what a user should likely have during initial setup approximately within five minutes after turn-on.
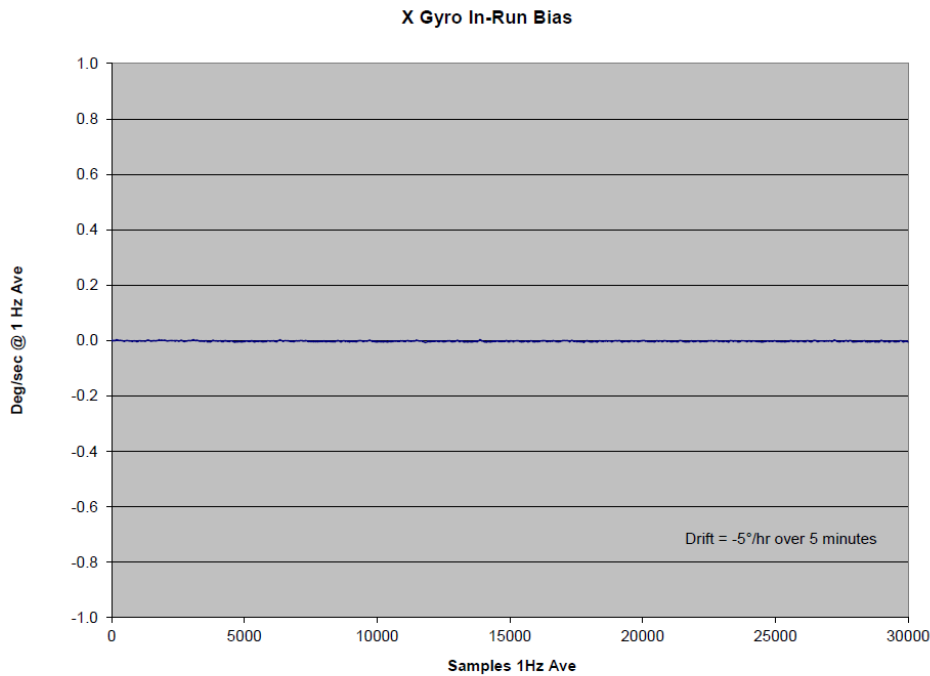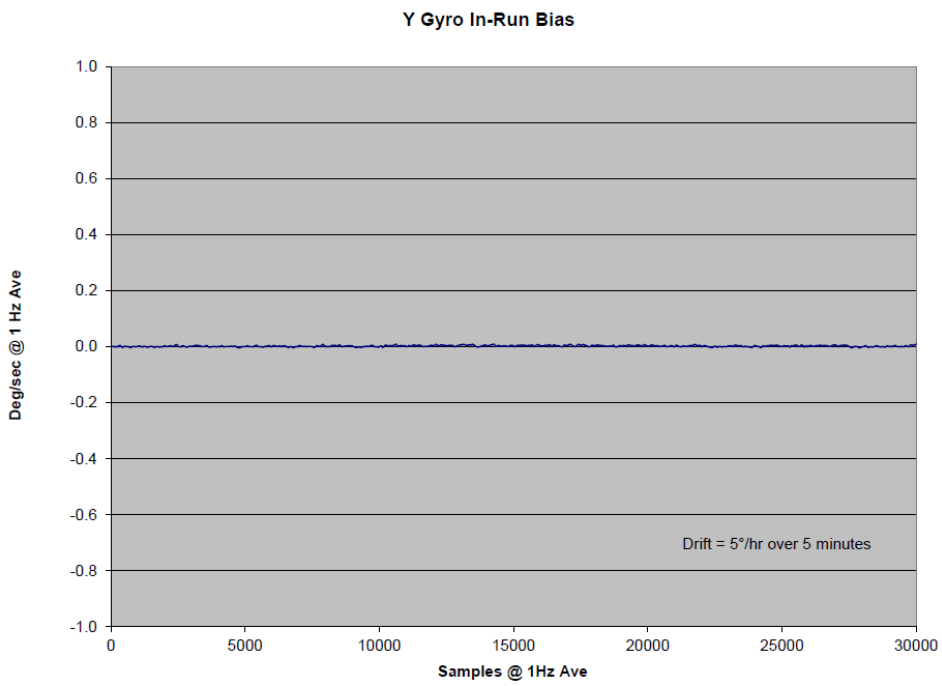

Figure 58 X Gyro Bias In-Run
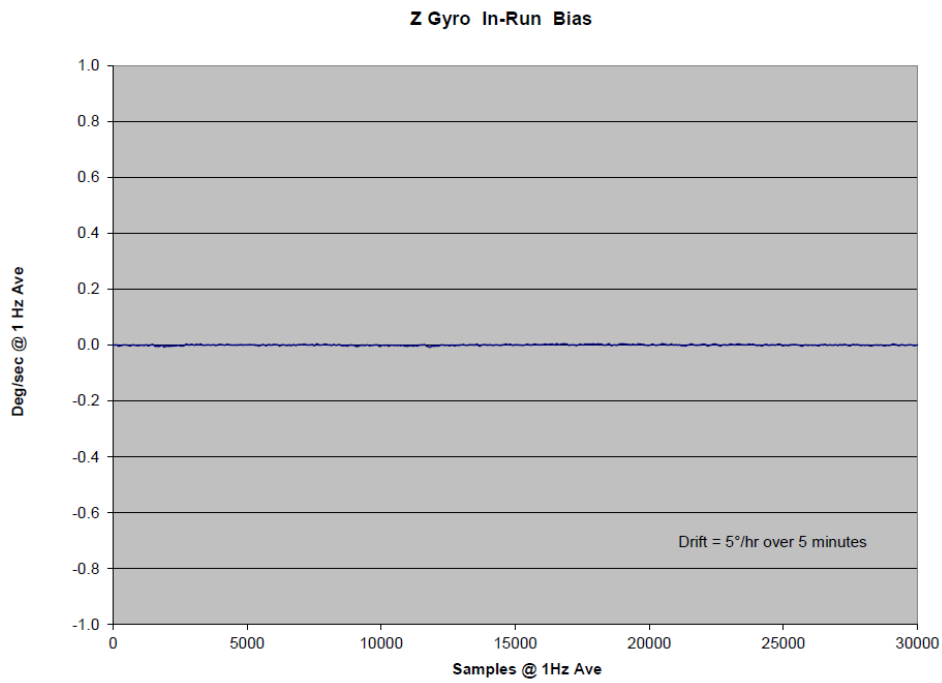
Figure 59 Y Gyro Bias In-Run

Figure 60 Z Gyro Bias In-Run
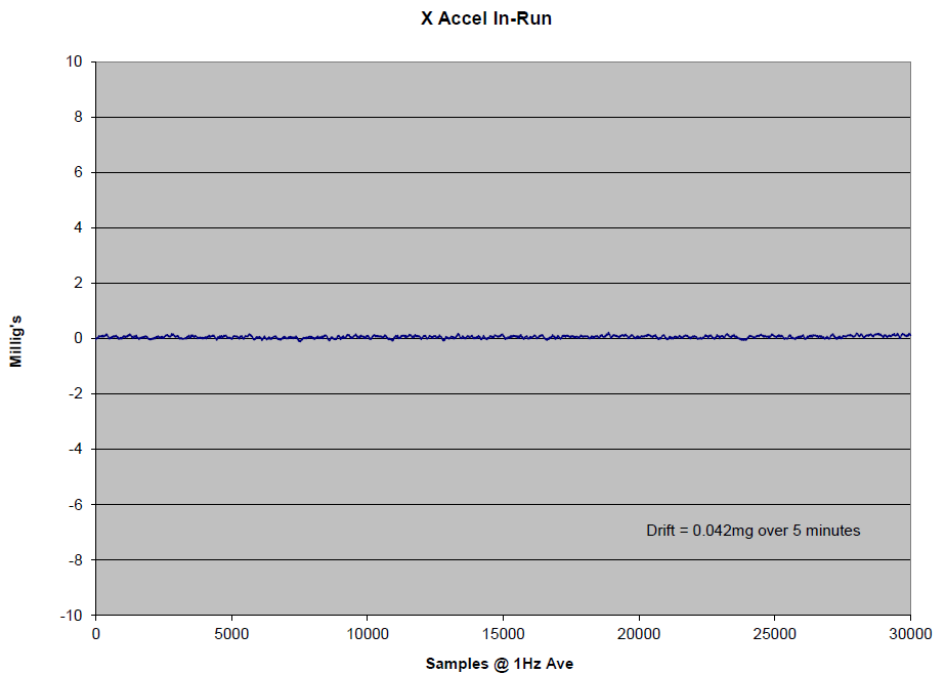
Figure 61 X Accelerometer Bias In-Run
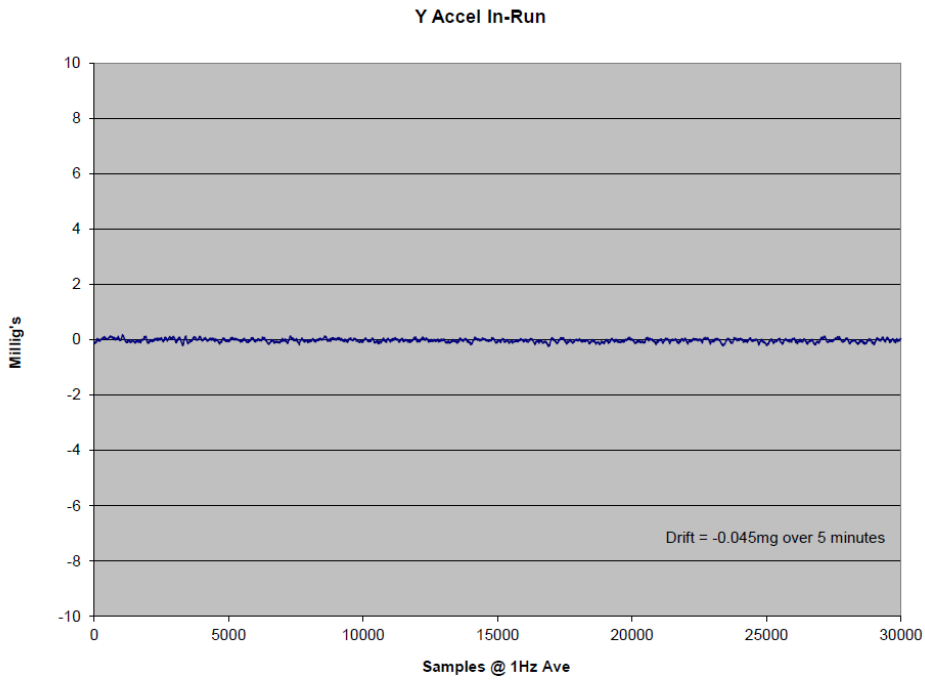
Figure 62 Y Accelerometer Bias In-Run
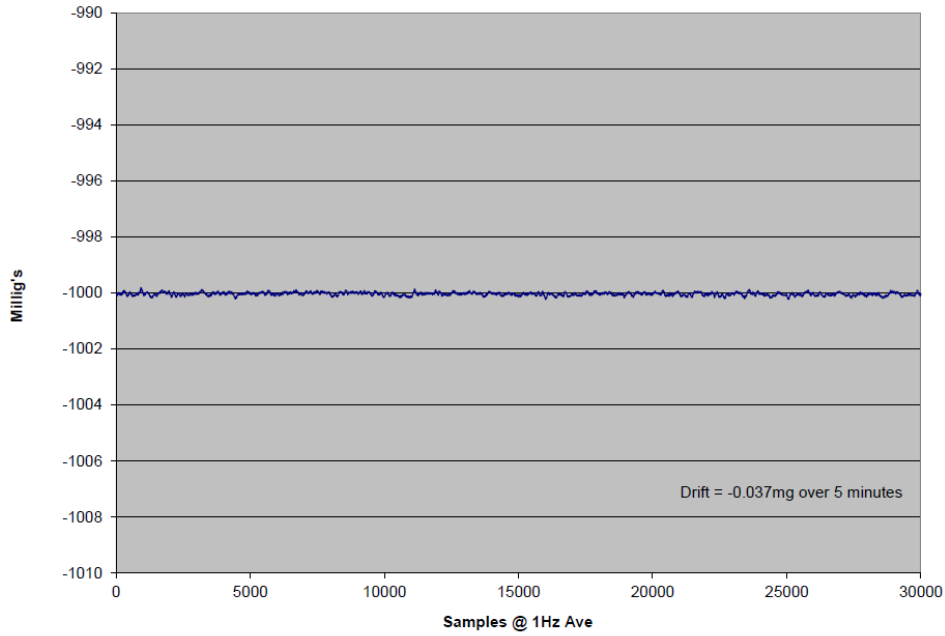
Figure 63 Z Accelerometer In-Run Bias

13.5 *Bias and Scale Factor over Temperature*

Data is captured at 100 Hz data rate. The temperature calibration process measures temperature at a minimum of five set points from -40°C to +85°C at a slew rate of approximately 1-2°/minute. A nine-point correction table is generated that identifies temperature based offsets for each of the IMU data set. Depending upon the variable, up to a 4th order thermal model is used to create a correction model that is stored in the unit. The black line is the model fit to the blue diamond data points (Fig. 64).

13.5.1 *Gyro Bias over Temperature*
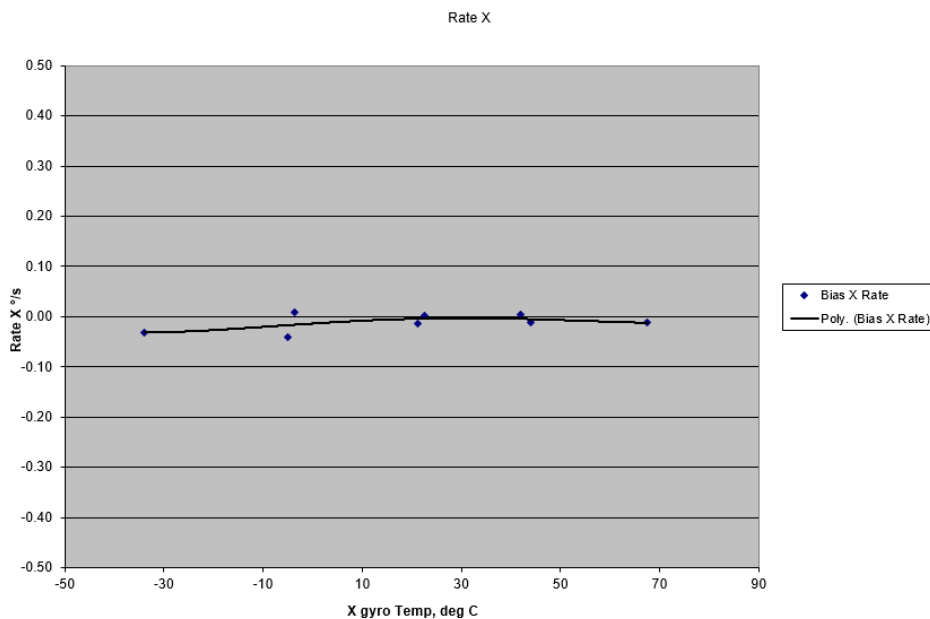
Figure 64 X Gyro Bias over Temperature
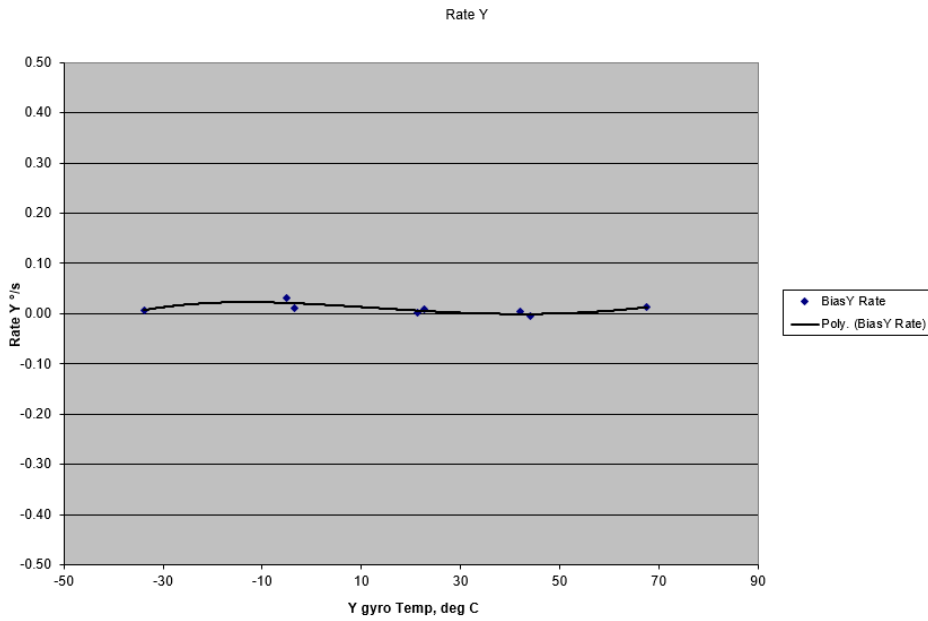
Figure 65 Y Gyro Bias over Temperature
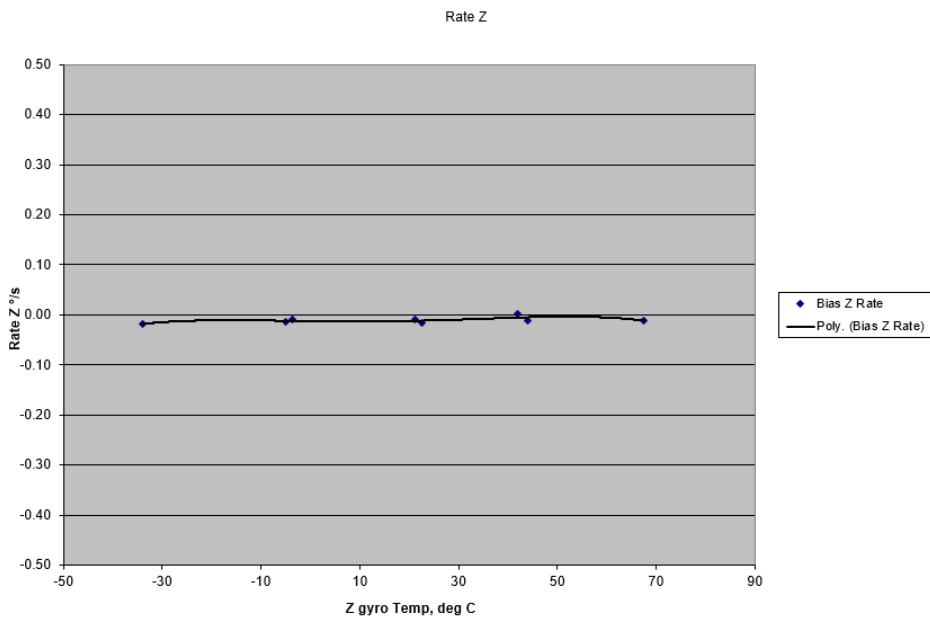
Figure 66 Z Gyro Bias over Temperature

13.5.2 *Gyro Scale Factor over Temperature*
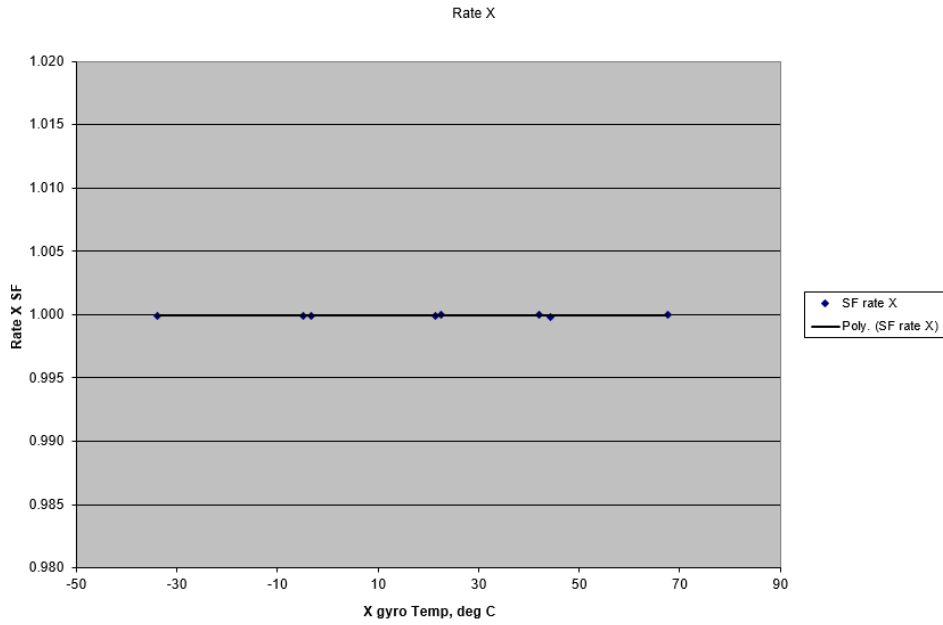
Figure 67 X Gyro Scale Factor over Temperature
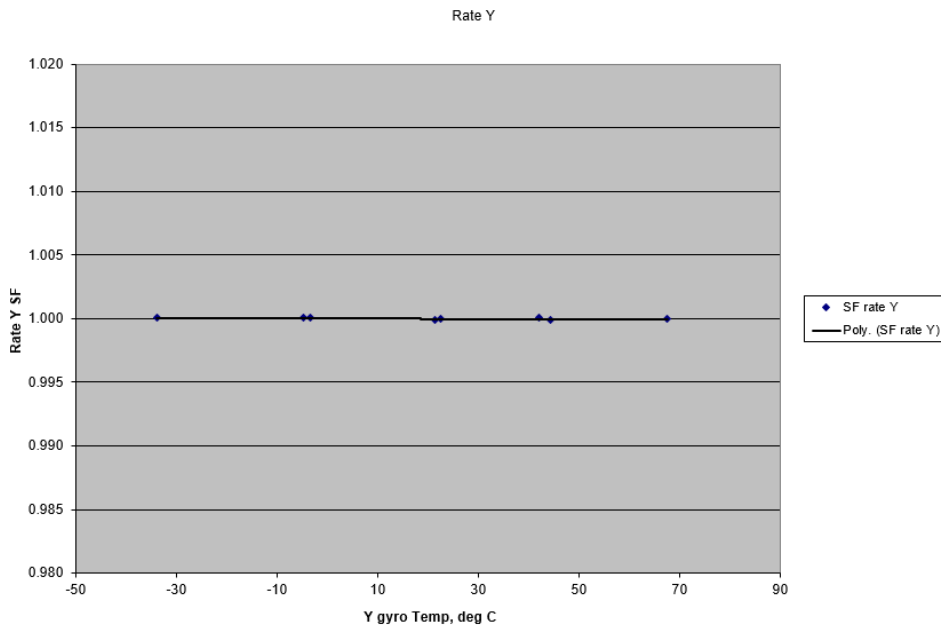
Figure 68 Y Gyro Scale Factor over Temperature
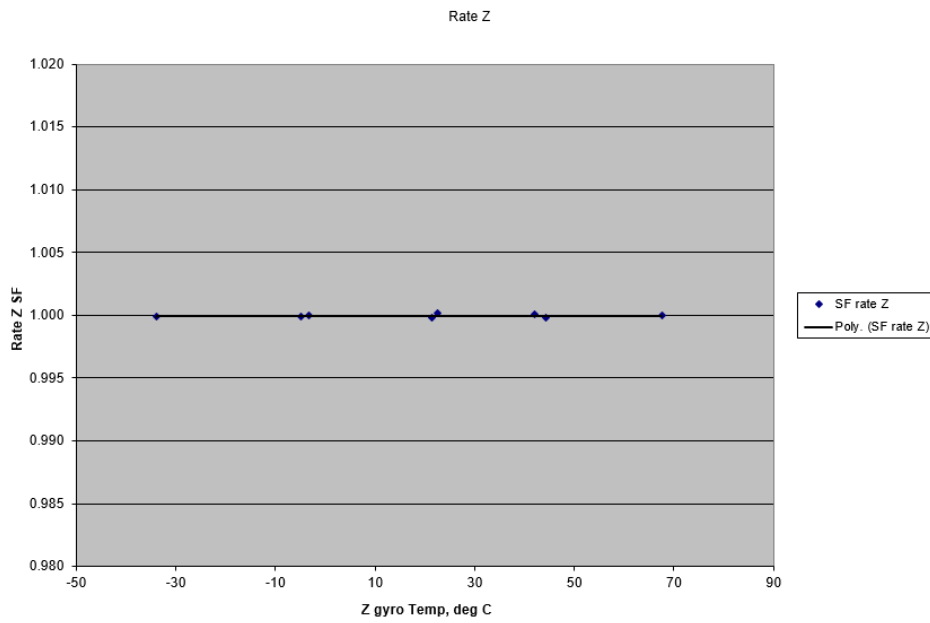
Figure 69 Z Gyro Scale Factor over Temperature

13.5.3 *Accelerometer Bias over Temperature*
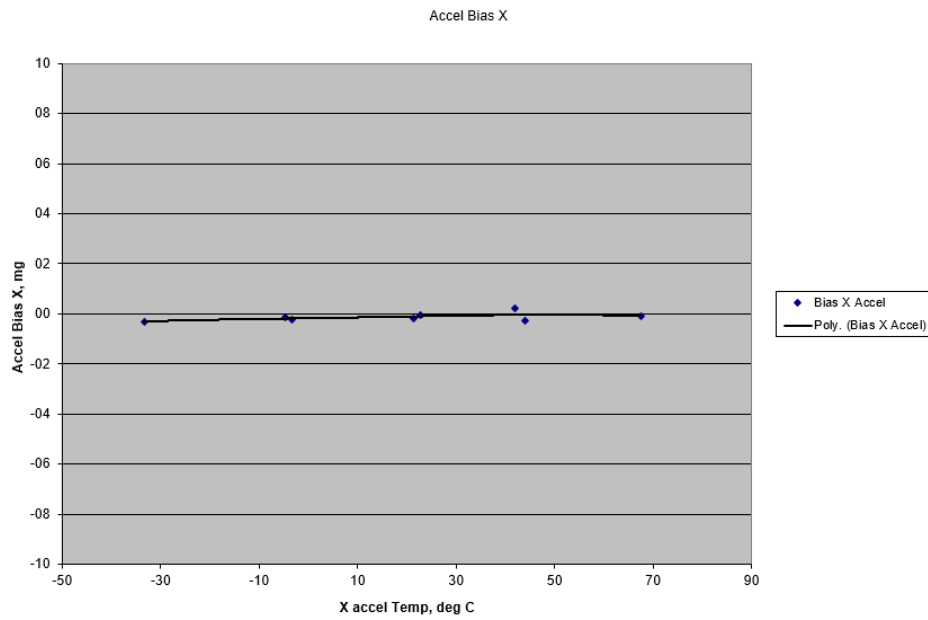
Figure 70 X Accelerometer Bias over Temperature
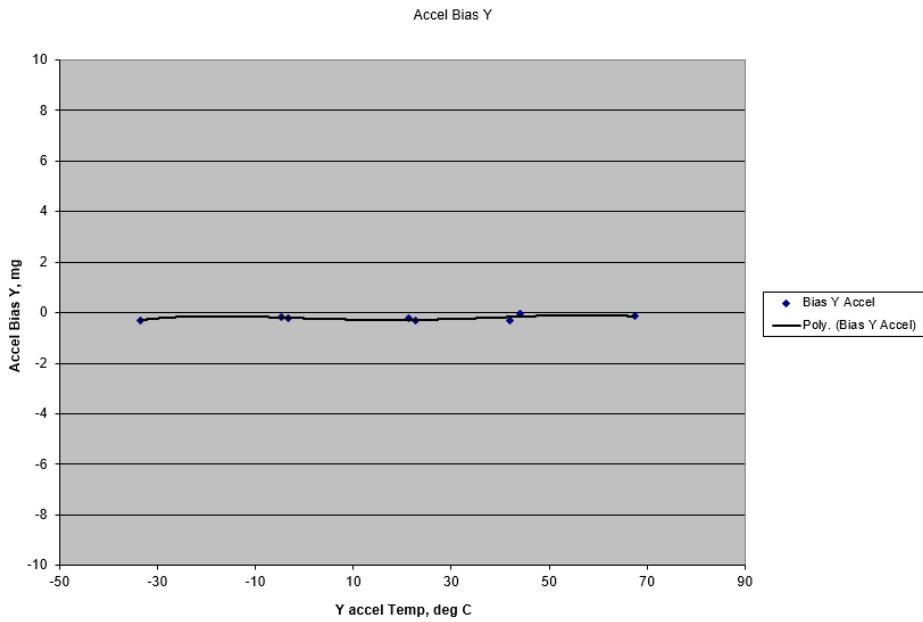
Figure 71 Y Accelerometer Bias over Temperature
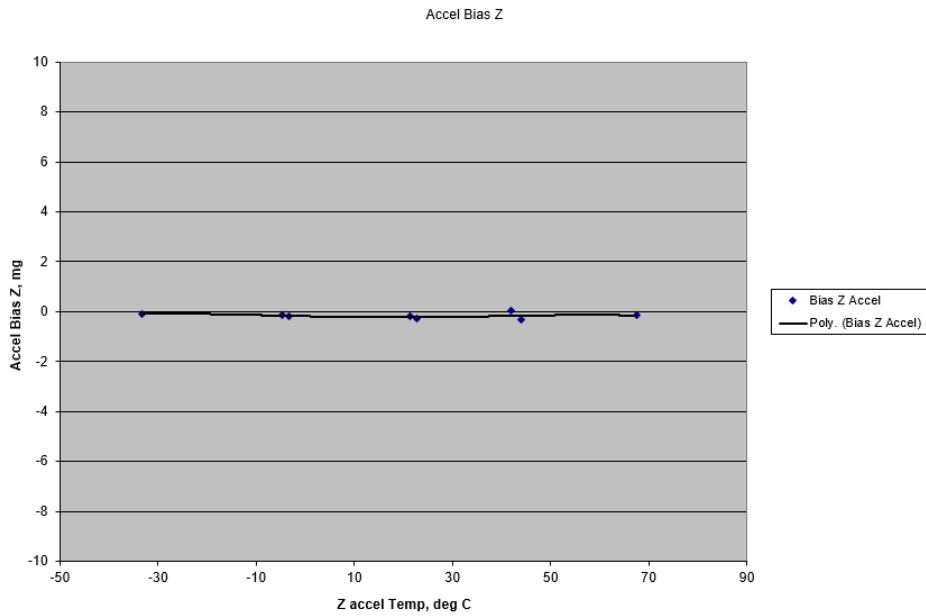
Figure 72 Z Accelerometer Bias over Temperature

13.5.4 *Accelerometer Scale Factor Bias over Temperature*
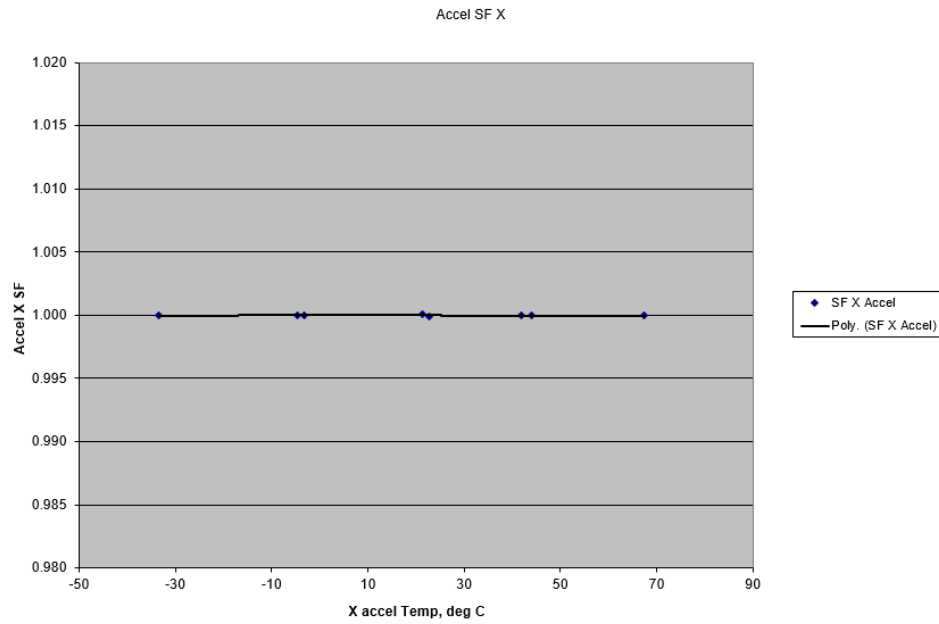
Figure 73 X Scale Factor over Temperature
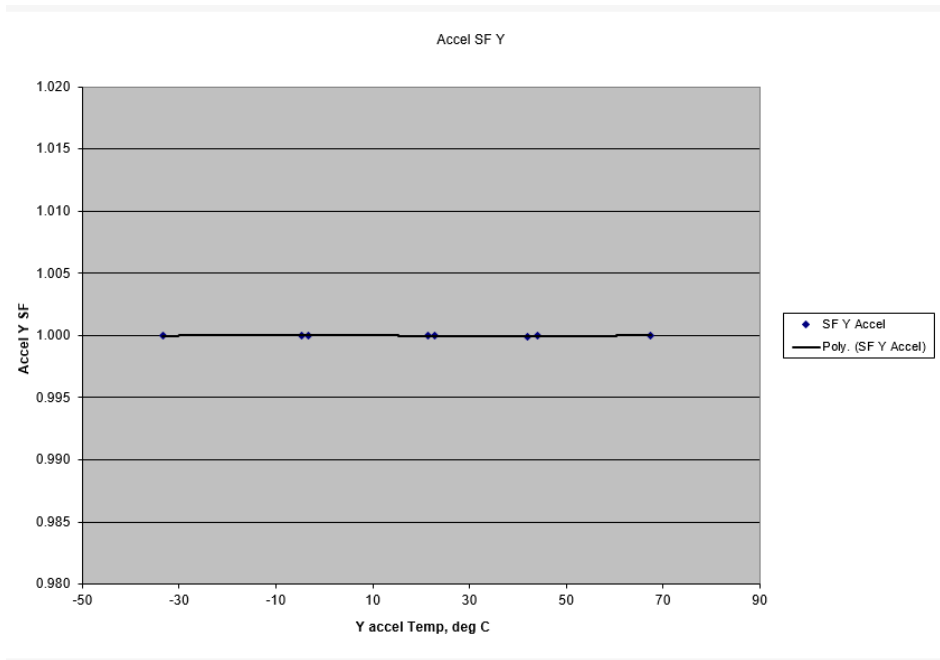
Figure 74 Y Accelerometer Scale Factor over Temperature
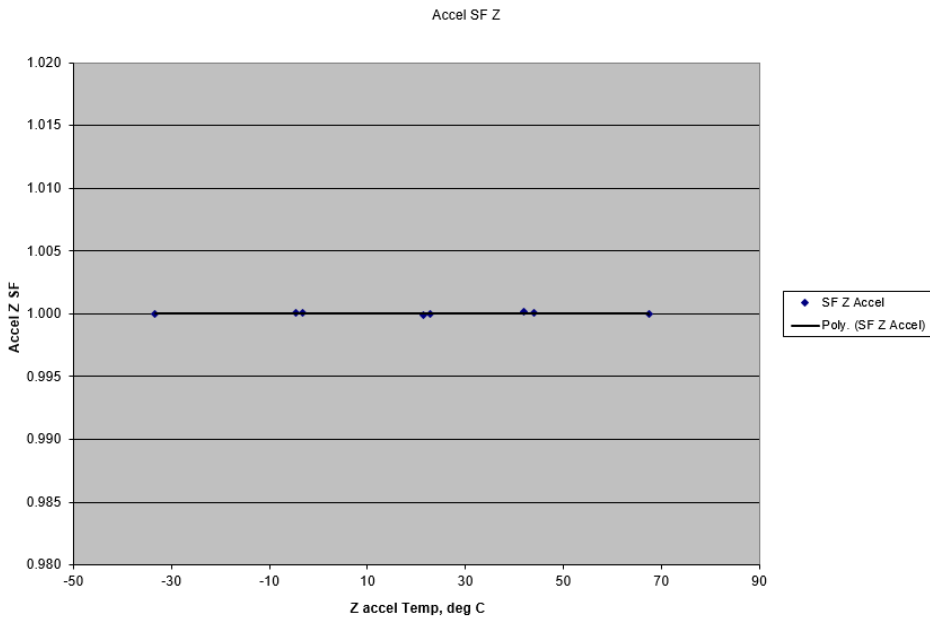
Figure 75 Z Accelerometer Scale Factor over Temperature

13.6 Bias Turn-On (from a Cold Start)

The DIGS 100 is **NOT** specified for this condition. This data is supplied for customer reference only. Data is captured at 100 Hz data rate for 25 minutes and we chart 1 Hz average data for the first five minutes. Test conditions assume a unit has been powered off for a minimum of at least five minutes and then data is taken at ambient temperature from initial power-on to determine sample turn-on transient performance. It should be noted that most of the turn-on transient occurs during the initial two minutes after power-on and after that it performs near the specified Bias In-Run performance level.
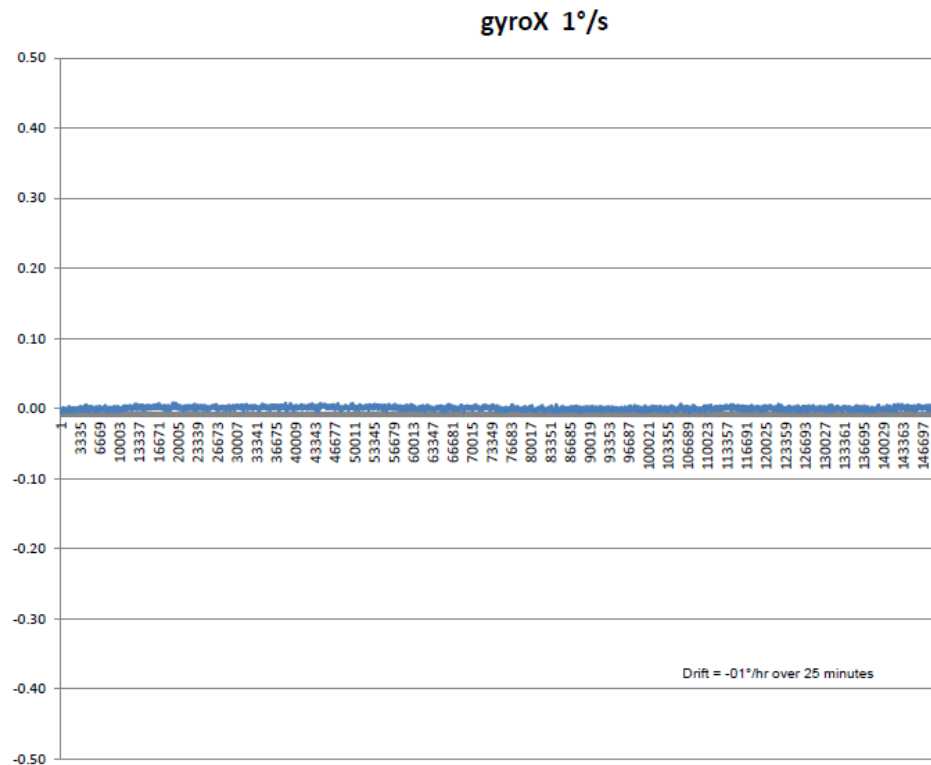
Figure 76 X Gyro Bias Turn-On
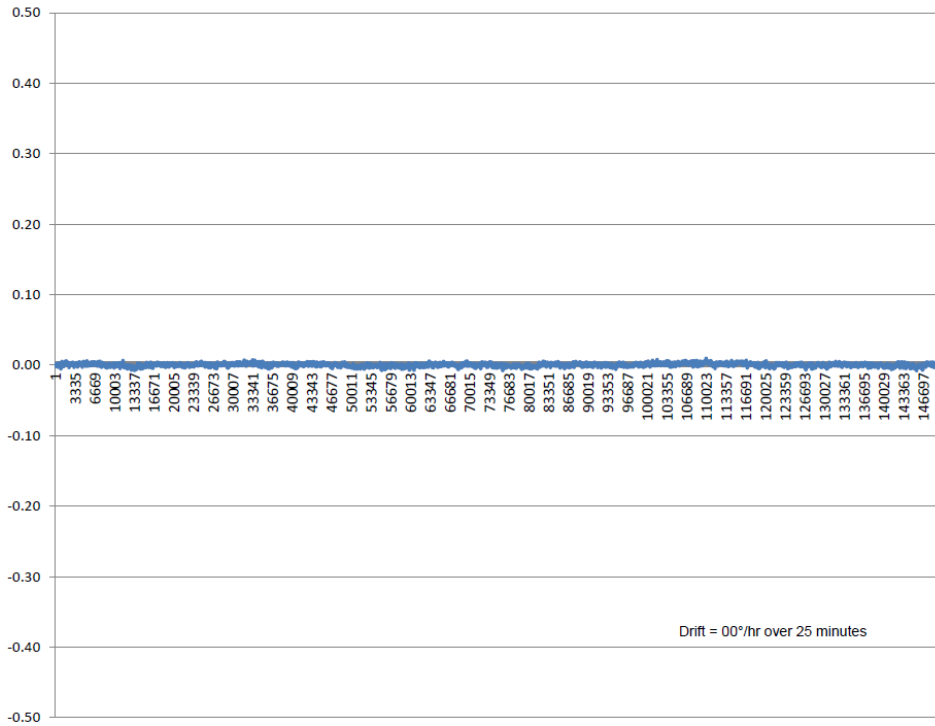
Figure 77 Y Gyro Bias Turn-On
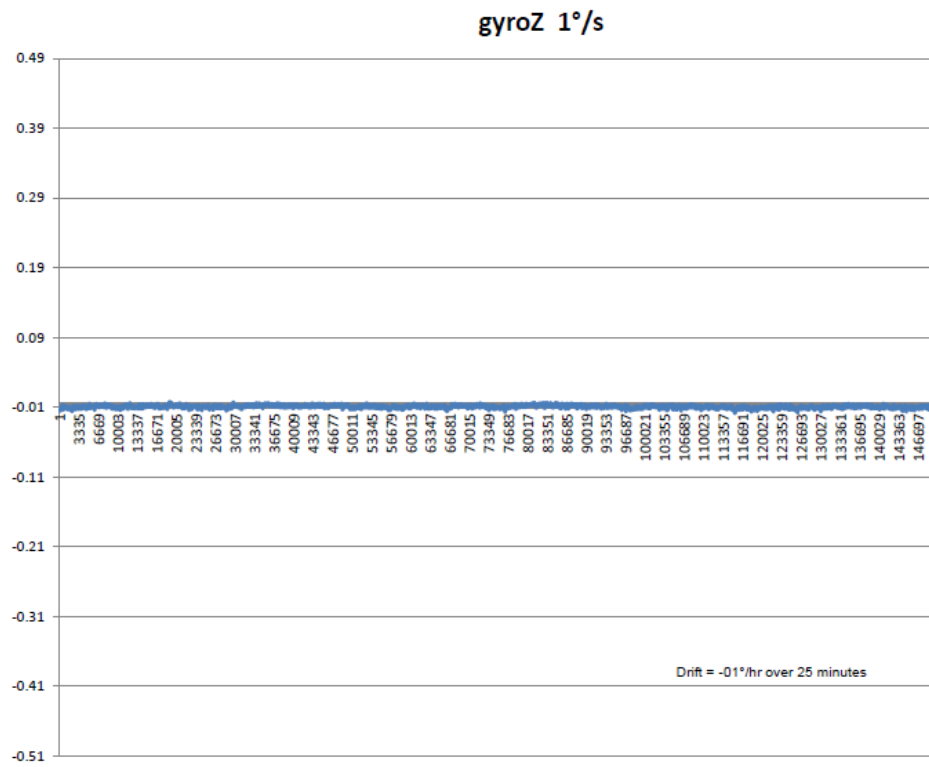
Figure 78 Z Gyro Bias Turn-On
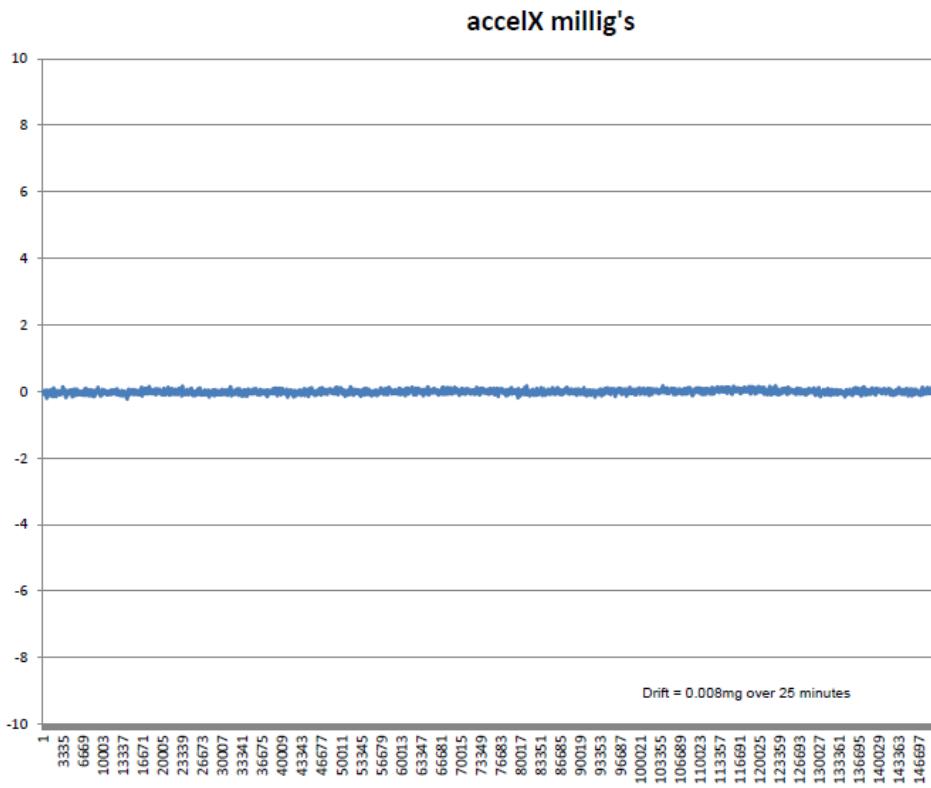
Figure 79 X Accelerometer Bias Turn-On

accelY millig's

Drift = -0.007mg over 25 minutes
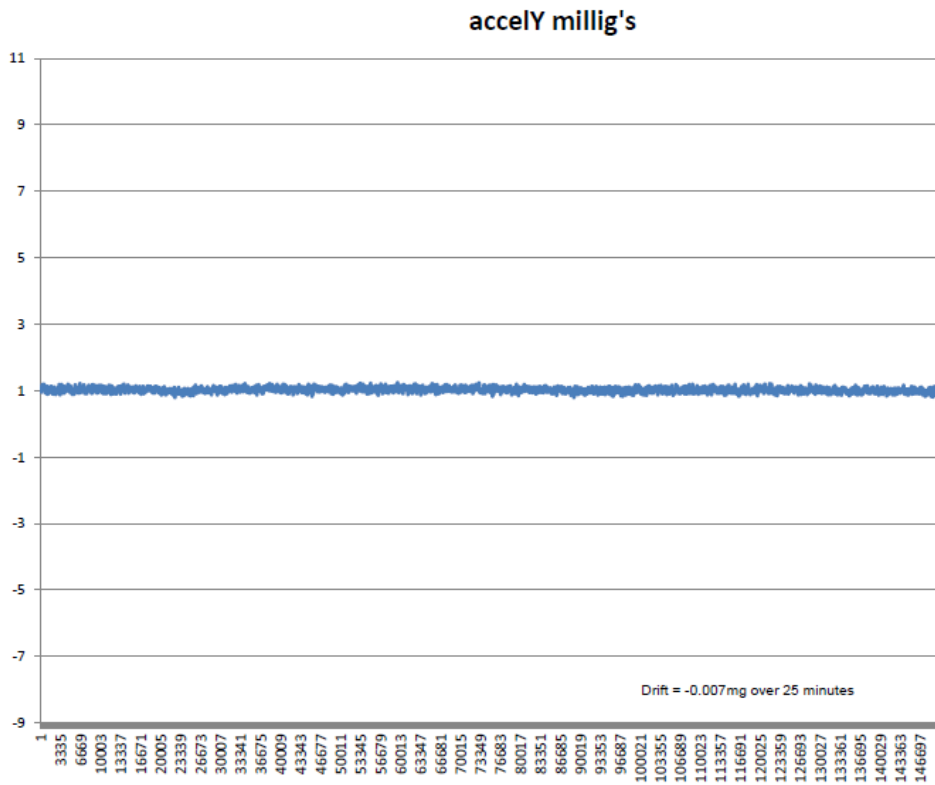
Figure 80 Y Accelerometer Bias Turn-On
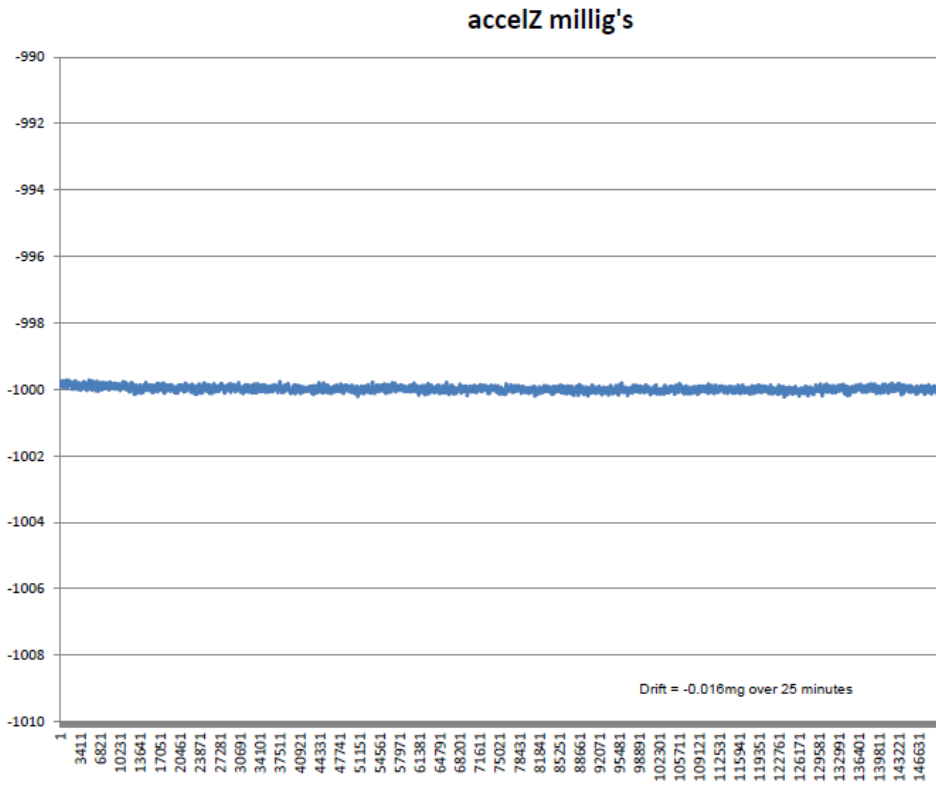
Figure 81 Z Accelerometer Bias Turn-On

13.7 Random and Sine Vibration

13.7.1 Random Vibration

Data is captured at 200 Hz data rate on a factory shaker. The unit is subject to random frequencies with total energy contained in the vibration profile of 5.74g$_{rms}$. The delta shift for each gyro and accelerometer is measured before and after the run. Also measured during vibe is the Vibration Rectification Coefficients (VRC) of the unit.

Axis	Sensor	Gyro			Accel			Gyro	Accel
	Test Units	X-G	Y-G	Z-G	X-A	Y-A	Z-A	Abs Ave	Input Abs
X Input	1 sigma on (deg/sec or mg)	0.1038			1296.93				
	Shift (deg/sec or mg)	**-0.0009**			**0.03**			0.0009	0.03
	VRE (deg/sec or mg)	0.0058			-2.31				
	VRC (°/hr or µg/grms^2)	**0.6**			**-70**			0.6	70
Y Input	1 sigma on (deg/sec or mg)		0.1090			1297.14			
	Shift (deg/sec or mg)		**0.0010**			**-0.02**		0.0010	0.02
	VRE (deg/sec or mg)		0.0065			-7.86			
	VRC (°/hr or µg/grms^2)		**0.7**			**-239**		0.7	239
Z Input	1 sigma on (deg/sec or mg)			0.0715			1181.68		
	Shift (deg/sec or mg)			**-0.0029**			**0.06**	0.0029	0.06
	VRE (deg/sec or mg)			-0.0035			-1.88		
	VRC (°/hr or µg/grms^2)			**-0.4**			**-57**	0.4	57

		°/hr	mg
5.75 grms Random PSD	Abs Ave Shift =	5.8	0.04
0.02 g²/Hz 50-1000 Hz, -3dB/octave to 2kHz	Stdev Shift =	7.0	0.04
	Abs Ave VRC =	0.6	122
grms= 5.74	Stdev VRC =	0.6	101
		°/hr/grms²	µg/grms²

Figure 82 Random Vibration Test Data

13.7.2 **Sine Vibration Test**

Data is captured at 200 Hz data rate on a factory shaker. The unit is subject to a 5g sine sweep of various frequencies from 30 Hz to 3000 Hz and delta shifts are calculated before and after the run. Also measured during vibe is the Vibration Rectification Coefficients (VRC) of the unit.

13.7.3 *Gyro Sine Vibration Response*
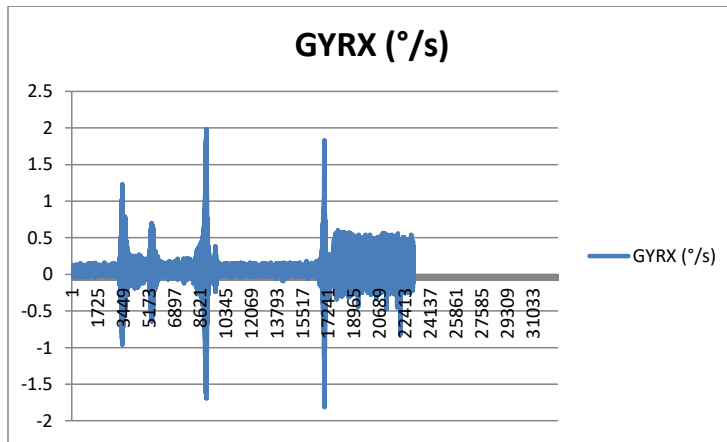
Figure 83 X Gyro Sine Vibration Response
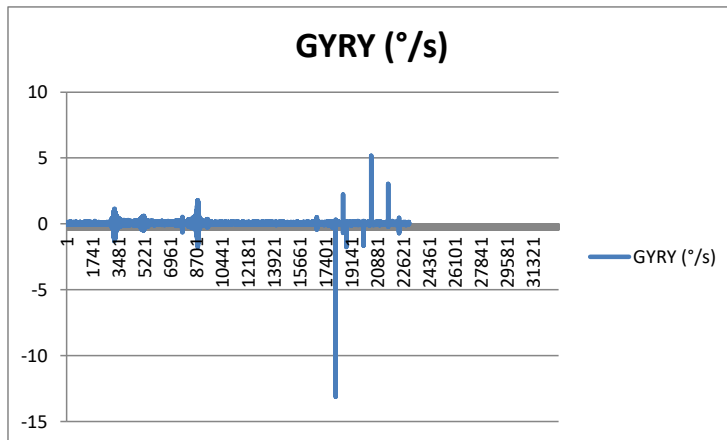
Figure 84 Y Gyro Sine Vibration Response
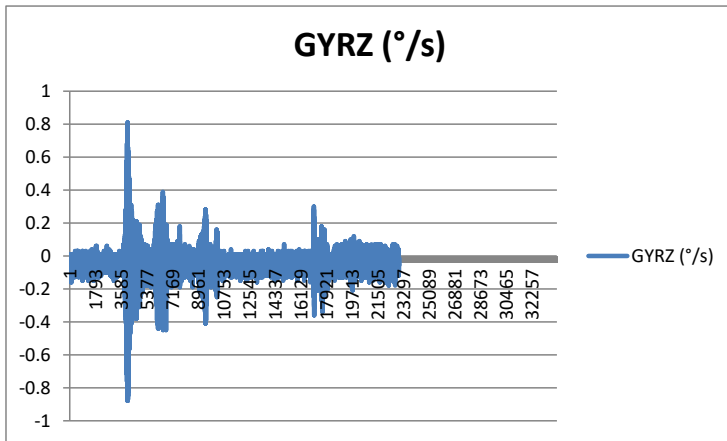
Figure 85 Z Gyro Sine Vibration Response

13.7.4 *Accelerometer Sine Vibration Response*
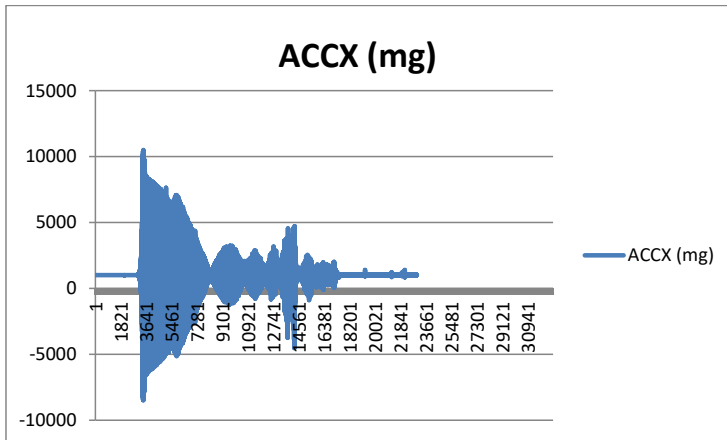
Figure 86 X Accelerometer Sine Vibration Response
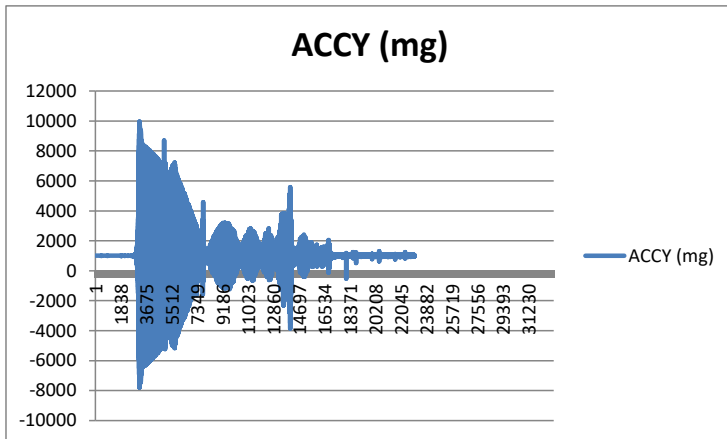
Figure 87 Y Accelerometer Sine Vibration Response
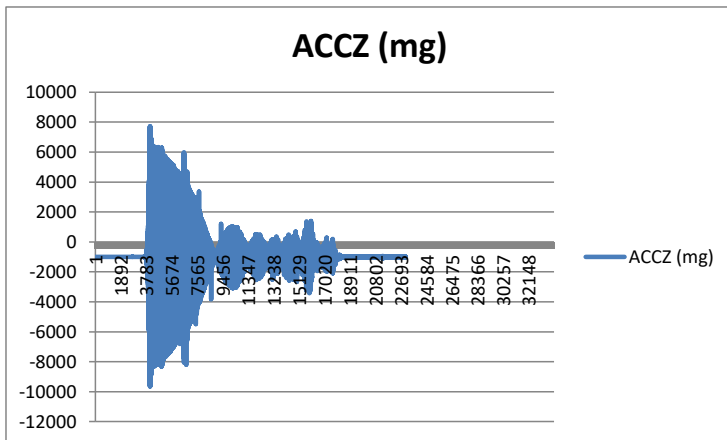
Figure 88 Z Accelerometer Sine Vibration Response

14 Mounting

Mounting for the DIGS™100 AHRS accommodates both metric and U.S. mounting screws. Mount the unit to a flat surface with 4ea Number 8 screws (U.S.) or 4ea Number 4 metric stainless steel screws. Be sure that the surface that you are mounting to is as clean and as level as possible in order to eliminate potential alignment errors. Adequate mounting to a surface should fall within a flatness of +/- 0.001" or +/- 0.025 mm. Avoid mounting near magnetic materials (if using the AHRS which contains a magnetometer) as this will degrade the heading accuracy (see sections below for more information).

Failing to mount the unit in this fashion can result in unaccounted stress in the sensors and therefore may affect data output. Gladiator Technologies strongly encourages the user to mount the unit correctly in the described manner to ensure proper functioning.

14.1 *Centrifugal Force Error Effects with Constant Turns*

Users should be aware that during constant turns Centrifugal Force can significantly affect Roll and Pitch accuracy of *ALL* inertial navigation systems (AHRS and Navigation Systems). It is important that a forward velocity input be input into these systems to correct for this centrifugal force error if there is sufficient velocity.

Commented [MC6]: Update torque requirement (get from Tyler)

15 Operation and Troubleshooting

15.1 *Technical Assistance*

Please contact the factory or your local Gladiator Technologies sales representative's office for technical assistance.

Tel : +33 (0) 1 34 94 77 00

https://alcyonelectronique.fr/

commercial@alcyonelectronique.fr

15.2 *Authorized Distributors and Technical Sales Representatives*

If you need additional assistance please contact your local distributor and/or the factor for further technical support: *http://www.gladiatortechnologies.com/Intl/Contact.html*

16 GLOSSARY OF TERMS

Gladiator Technologies has attempted to define terms as closely as possible to the IEEE Gyro and Accelerometer Panel Standards for Inertial Sensor Terminology. Please note that in some instances our definition of a term may vary and in those instances Gladiator Technologies' definition supersedes the IEEE definition. For a complete listing of IEEE's standard for inertial sensor terminology please go to www.ieee.org.

16.1 *Abbreviations and Acronyms*

6DOF: six degrees-of-freedom

AHRS: Inertial Measurement Unit

CVG: Coriolis Vibratory Gyro

ESD: Electro Static Discharge

IEEE: The Institute of Electrical and Electronics Engineers

MEMS: Micro Electro-Mechanical Systems

NLR: No License Required

16.2 *Definitions of Terms*

Acceleration-insensitive drift rate (gyro): The component of environmentally sensitive drift rate not correlated with acceleration.
NOTE—Acceleration-insensitive drift rate includes the effects of temperature, magnetic, and other external influences.

Acceleration-sensitive drift rate (gyro): The components of systematic drift rate correlated with the first power of a linear acceleration component, typically expressed in (°/h)/g.

Accelerometer: An inertial sensor that measures linear or angular acceleration. Except where specifically stated, the term accelerometer refers to linear accelerometer.

Allan variance: A characterization of the noise and other processes in a time series of data as a function of averaging time. It is one half the mean value of the square of the difference of adjacent time averages from a time series as a function of averaging time.

Angular acceleration sensitivity:
(accelerometer): The change of output (divided by the scale factor) of a linear accelerometer that is produced per unit of angular acceleration input about a specified axis, excluding the response that is due to linear acceleration.
(gyro): The ratio of drift rate due to angular acceleration about a gyro axis to the angular acceleration causing it.
NOTE—In single-degree-of-freedom gyros, it is nominally equal to the effective moment of inertia of the gimbal assembly divided by the angular momentum.

Bias:
(accelerometer): The average over a specified time of accelerometer output measured at specified operating conditions that have no correlation with input acceleration or rotation. Bias is expressed in $[m/s^2, g]$.
(gyro): The average over a specified time of gyro output measured at specified operating conditions that have no correlation with input rotation or acceleration. Bias is typically expressed in degrees per hour (º/h).
NOTE—Control of operating conditions may address sensitivities such as temperature, magnetic fields, and mechanical and electrical interfaces, as necessary.

Case (gyro, accelerometer): The housing or package that encloses the sensor, provides the mounting surface, and defines the reference axes.

Composite error (gyro, accelerometer): The maximum deviation of the output data from a specified output function. Composite error is due to the composite effects of hysteresis, resolution, nonlinearity, non-repeatability, and other uncertainties in the output data. It is generally expressed as a percentage of half the output span.

Coriolis acceleration: The acceleration of a particle in a coordinate frame rotating in inertial space, arising from its velocity with respect to that frame.

Coriolis vibratory gyro (CVG): A gyro based on the coupling of a structural, driven, vibrating mode into at least one other structural mode (pickoff) via Coriolis acceleration.
NOTE—CVGs may be designed to operate in open-loop, force-rebalance (i.e., closed-loop), and/or whole-angle modes.

Cross acceleration (accelerometer): The acceleration applied in a plane normal to an accelerometer input reference axis.

Cross-axis sensitivity (accelerometer): The proportionality constant that relates a variation of accelerometer output to cross acceleration. This sensitivity varies with the direction of cross acceleration and is primarily due to misalignment.

Cross-coupling errors (gyro): The errors in the gyro output resulting from gyro sensitivity to inputs about axes normal to an input reference axis.

Degree-of-freedom (DOF) (gyro): An allowable mode of angular motion of the spin axis with respect to the case. The number of degrees-of-freedom is the number of orthogonal axes about which the spin axis is free to rotate.

Drift rate (gyro): The component of gyro output that is functionally independent of input rotation. It is expressed as an angular rate

Environmentally sensitive drift rate (gyro): The component of systematic drift rate that includes acceleration-sensitive, acceleration-squared-sensitive, and acceleration-insensitive drift rates.

Full-scale input (gyro, accelerometer): The maximum magnitude of the two input limits.

G: The magnitude of the local plumb bob gravity that is used as a reference value of acceleration. *NOTE 1—g is a convenient reference used in inertial sensor calibration and testing. NOTE 2—In some applications, the standard value of g = 9.806 65 m/s^2 may be specified.*

Gyro (gyroscope): An inertial sensor that measures angular rotation with respect to inertial space about its input axis (es). *NOTE 1—The sensing of such motion could utilize the angular momentum of a spinning rotor, the Coriolis effect on a vibrating mass, or the Sagnac effect on counter-propagating light beams in a ring laser or an optical fiber coil.*

G sensitivity (gyro): the change in rate bias due to g input from any direction.

Hysteresis error (gyro, accelerometer): The maximum separation due to hysteresis between upscale-going and down-scale-going indications of the measured variable (during a full-range traverse, unless otherwise specified) after transients have decayed. It is generally expressed as an equivalent input.

Inertial sensor: A position, attitude, or motion sensor whose references are completely internal, except possibly for initialization.

Input angle (gyro): The angular displacement of the case about an input axis.

Input axis (IA):
(accelerometer): The axis(es) along or about which a linear or angular acceleration input causes a maximum output.
(gyro): The axis(es) about which a rotation of the case causes a maximum output.

Input-axis misalignment (gyro, accelerometer): The angle between an input axis and its associated input reference axis when the device is at a null condition.

Input limits (gyro, accelerometer): The extreme values of the input, generally plus or minus, within which performance is of the specified accuracy.

Input range (gyro, accelerometer): The region between the input limits within which a quantity is measured, expressed by stating the lower- and upper-range value. For example, a linear displacement input range of ±1.7g to ±12g.

Input rate (gyro): The angular displacement per unit time of the case about an input axis. For example, an angular displacement input range of ±150°/sec to ±300°/sec.

Input reference axis (IRA) (gyro, accelerometer): The direction of an axis (nominally parallel to an input axis) as defined by the case mounting surfaces, or external case markings, or both.

Linear accelerometer: An inertial sensor that measures the component of translational acceleration minus the component of gravitational acceleration along its input axis(es).

Linearity error (gyro, accelerometer): The deviation of the output from a least-squares linear fit of the input-output data. It is generally expressed as a percentage of full scale, or percent of output, or both.

Mechanical freedom (accelerometer): The maximum linear or angular displacement of the accelerometer's proof mass, relative to its case.

Natural frequency (gyro, accelerometer): The frequency at which the output lags the input by 90°. It generally applies only to inertial sensors with approximate second-order response.

Non-gravitational acceleration (accelerometer): The component of the acceleration of a body that is caused by externally applied forces (excluding gravity) divided by the mass.

Nonlinearity (gyro, accelerometer): The systematic deviation from the straight line that defines the nominal input-output relationship.

Open-loop mode (Coriolis vibratory gyro): A mode in which the vibration amplitude of the pickoff is proportional to the rotation rate about the input axis (es).

Operating life (gyro, accelerometer): The accumulated time of operation throughout which a gyro or accelerometer exhibits specified performance when maintained and calibrated in accordance with a specified schedule.

Operating temperature (gyro, accelerometer): The temperature at one or more gyro or accelerometer elements when the device is in the specified operating environment.

Output range (gyro, accelerometer): The product of input range and scale factor.

Output span (gyro, accelerometer): The algebraic difference between the upper and lower values of the output range.

Pickoff (mechanical gyro, accelerometer): A device that produces an output signal as a function of the relative linear or angular displacement between two elements.

Plumb bob gravity: The force per unit mass acting on a mass at rest at a point on the earth, not including any reaction force of the suspension. The plumb bob gravity includes the gravitational attraction of the earth, the effect of the centripetal acceleration due to the earth rotation, and tidal effects. The direction of the plumb bob gravity acceleration defines the local vertical down direction, and its magnitude defines a reference value of acceleration (g).

Power spectral density (PSD): A characterization of the noise and other processes in a time series of data as a function of frequency. It is the mean squared amplitude per unit frequency of the time series. It is usually expressed in $(°/h)^2$/Hz for gyroscope rate data or in $(m/s^2)^2$/Hz or g2/Hz for accelerometer acceleration data.

Principal axis of compliance (gyro, accelerometer): An axis along which an applied force results in a displacement along that axis only.

Proof mass (accelerometer): The effective mass whose inertia transforms an acceleration along, or about, an input axis into a force or torque. The effective mass takes into consideration rotation and contributing parts of the suspension.

Quantization (gyro, accelerometer): The analog-to-digital conversion of a gyro or accelerometer output signal that gives an output that changes in discrete steps, as the input varies continuously.

Quantization noise (gyro, accelerometer): The random variation in the digitized output signal due to sampling and quantizing a continuous signal with a finite word length conversion. The resulting incremental error sequence is a uniformly distributed random variable over the interval 1/2 least significant bit (LSB).

Random drift rate (gyro): The random time-varying component of drift rate.

Random walk: A zero-mean Gaussian stochastic process with stationary independent increments and with standard deviation that grows as the square root of time.

Angle random walk (gyro): The angular error buildup with time that is due to white noise in angular rate. This error is typically expressed in degrees per square root of hour [$°/\sqrt{h}$].

Velocity random walk (accelerometer): The velocity error build-up with time that is due to white noise in acceleration. This error is typically expressed in meters per second per square root of hour [$(m/s)/\sqrt{h}$].

Rate gyro: A gyro whose output is proportional to its angular velocity with respect to inertial space.

Ratiometric output: An output method where the representation of the measured output quantity (e.g., voltage, current, pulse rate, pulse width) varies in proportion to a reference quantity.

Rectification error (accelerometer): A steady-state error in the output while vibratory disturbances are acting on an accelerometer.

Repeatability (gyro, accelerometer): The closeness of agreement among repeated measurements of the same variable under the same operating conditions when changes in conditions or non-operating periods occur between measurements.

Resolution (gyro, accelerometer): The largest value of the minimum change in input, for inputs greater than the noise level, that produces a change in output equal to some specified percentage (at least 50%) of the change in output expected using the nominal scale factor.

Scale factor (gyro, accelerometer): The ratio of a change in output to a change in the input intended to be measured. Scale factor is generally evaluated as the slope of the straight line that can be fitted by the method of least squares to input-output data.

Second-order nonlinearity coefficient (accelerometer): The proportionality constant that relates a variation of the output to the square of the input, applied parallel to the input reference axis.

Sensitivity (gyro, accelerometer): The ratio of a change in output to a change in an undesirable or secondary input. For example: a scale factor temperature sensitivity of a gyro or accelerometer is the ratio of change in scale factor to a change in temperature.

Stability (gyro, accelerometer): A measure of the ability of a specific mechanism or performance coefficient to remain invariant when continuously exposed to a fixed operating condition.

Storage life (gyro, accelerometer): The non-operating time interval under specified conditions, after which a device will still exhibit a specified operating life and performance.

Strapdown (gyro, accelerometer): Direct-mounting of inertial sensors (without gimbals) to a vehicle to sense the linear and angular motion of the vehicle.

Third-order nonlinearity coefficient (accelerometer): The proportionality constant that relates a variation of the output to the cube of the input, applied parallel to the input reference axis.

Threshold (gyro, accelerometer): The largest absolute value of the minimum input that produces an output equal to at least 50% of the output expected using the nominal scale factor.

Turn-on time (gyro, accelerometer): The time from the initial application of power until a sensor produces a specified useful output, though not necessarily at the accuracy of full specification performance.

Warm-up time (gyro, accelerometer): The time from the initial application of power for a sensor to reach specified performance under specified operating conditions.

Zero offset (restricted to rate gyros): The gyro output when the input rate is zero, generally expressed as an equivalent input rate. It excludes outputs due to hysteresis and acceleration.