AHRS-S305

Attitude and Heading Reference System
Owner's Manual

Watson Industries, Inc.
3035 Melby Street
Eau Claire, WI 54703

P: 715 839 0628
F: 715 839 8248
E: support@watson-gyro.com

Table of Contents

Introduction 3
Product Description 3
Installation 3
  Orientation: 3
  Mounting: 3
  Environment: 3
  Power: 4
  Calibration 4
Theory of Operation 4
  Error Correction 7
  Centrifugal Force Compensation: 7
  Delta Velocity Compensation: 7
Operation 8
  Initialization 8
  Normal Operation 8
  Special Operation Modes 9
    Reference Mode 9
    Free Mode 9
    Command Mode 9
Interface 9
  RS-232 Output Format 9
  RS-232 Input Commands 11
  Analog Outputs 13
  Analog Inputs 14
    User Channel Inputs 14
    Forward Velocity Analog Input 14
Specifications 15
Connections / Dimensions 16
WARNING 17
Customer Service 19
Appendix A 20
Appendix B 22
  Activating Command Mode (Double Spacebar Mode) 22
  Determining Output Channels 22
  Setting Output Channels 22
  Adjust Time Constants 23
  Setting Output Format 23
  Setting Baud Rate 23
Appendix C 25

Watson Industries prides itself on solving customer problems and serving their needs in a timely fashion. This manual is intended to facilitate this goal and to provide written information about your product. We ask that you carefully read this manual. Becoming familiar with the manual will help you understand the product's capabilities and limitations, as well as provide you with a basic understanding of its operation. If, after reading the manual, you require further assistance, do not hesitate to call Watson Industries with your questions and comments.

CAUTION!

Watson Sensors are rugged devices that have been used successfully in a number of harsh environments. The components have been qualified to withstand a mechanical shock of 500g 's or greater, and most enclosures provide an added level of protection. However, dropping a sensor from waist height onto a hard floor can cause a shock level of 600g's. At this level, damage is likely to occur.

Introduction

This manual is intended to help in understanding the installation and operation requirements of the Watson Attitude and Heading Reference System.

Product Description

Attitude and heading gyros need frequent correction to compensate for the 15º per hour of earth rotation. Watson Industries has produced a solid-state gyro system, which models these functions for an attitude gyro and a slaved heading gyro. This system uses a microprocessor to integrate angular rate sensor data and provides a closed loop system of error correction to adjust biases from earth rotation and from instrument offsets. Interface to the microprocessor is done through a 16-bit A/D and a 14-bit D/A converter. The solid state vibrating structure angular rate gyros used in this system provide extremely high reliability, low power consumption, shock resistance and low cost.

Installation

Orientation:

This device utilizes an earth's magnetic field orientation sensor, so orientation is important. The base plate of the AHRS is intended to be mounted on top of a horizontal surface with the connector toward the forward direction of the vehicle.

Mounting:

The unit has four 0.15” diameter mounting holes (clearance for 6-32 screws). A mounting plate is provided for a flat surface mount. Use non-magnetic hardware. The unit may be adhesively mounted at any of its surfaces. If high shock loads are expected (greater than 10G or repeated shocks greater than 5G), the appropriate shock mounting should be used to prevent damage. Vibration isolation should be used for use in 2.5G or greater vibration environments. Symmetry is very important in such mount designs (consult Watson Industries for application notes on this if needed).

Environment:

Avoid mounting sites that are subject to significant temperature variation over the duration of the test. Temperature variation will induce noticeable rate sensor bias drift, which will result in degraded attitude accuracy.

High level AC magnetic fields, such as from large transformers, motors, or soldering guns, are to be avoided as being potentially damaging to the circuitry, even if the system is not powered. Exposure to high DC magnetic fields are to be avoided since this can produce a lingering self-magnetization of the sensor, which can cause distortion of the heading reference.

Watson Industries provides brass connectors with the device. Ideally, the unit should be installed at least 4 feet away from all small magnetic masses and further spacing for larger masses. If the unit is being installed in a vehicle, ship, etc., some calibration will still be required. Static Heading Calibration software is available on our website at http://www.watson-gyro.com

For shipboard applications, install the sensor near the center of gravity. For all applications, it is preferable to install the device where linear dynamic effects are minimized.

This is a magnetic sensitive device. Use non-magnetic hardware.

Power:

This unit has an internal regulator to allow operation over a wide voltage input range. Best operation is obtained at either 12 or 24 VDC level, although operation is fully satisfactory down to 10 VDC and up to 35 VDC. Power draw of the unit is about 3 Watts. The AHRS power system is isolated from the AHRS signal system. Internal capacitors are provided to remove a reasonable level of power line noise, however, capacitors should be added for long power line wiring or if noise is induced from other loads on the circuit.

Calibration

The AHRS is calibrated at the factory before it is shipped to the user. It is recommended that the unit be returned to the factory annually for evaluation and recalibration.

Theory of Operation

The Earth's Magnetic Field can be described as a Vector T located in the horizontal geographic coordinate system Oζ ξ η (See Figure 1).

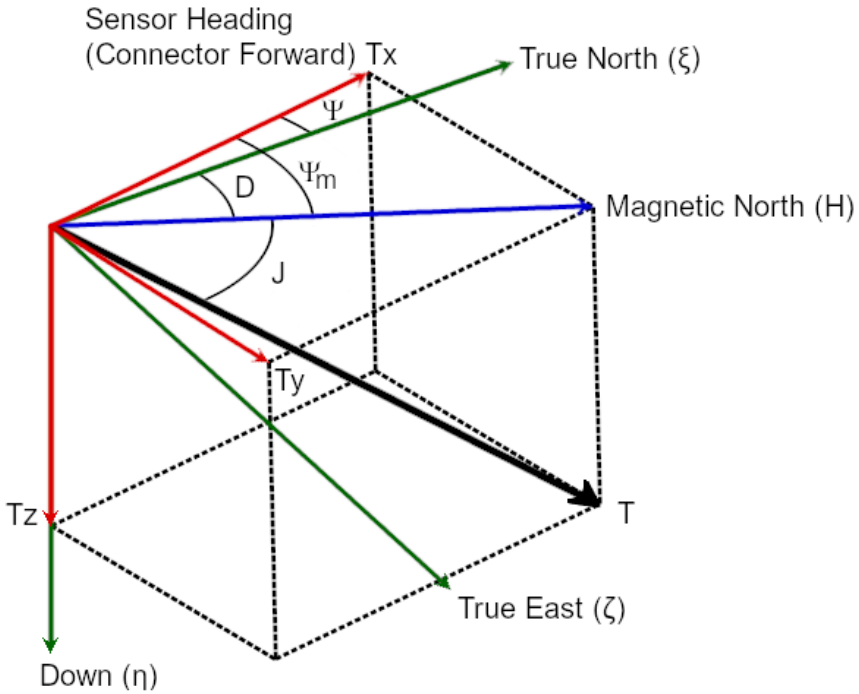


Figure 1

Where:

T - Earth's Magnetic Field Vector
H – Magnetic North
Tx & Ty - Vector of Horizontal Components of Earth's Magnetic Field
Tz - Vector of Vertical Component of Earth's Magnetic Field
J - Magnetic Dip Angle
D - Magnetic Declination (also known as Magnetic Variation)
Ψ_m - Magnetic Heading
Ψ - True North Heading
ξ - True North Axis (geographic)
η - Down Axis (geographic)
ζ - True East Axis (geographic)

The microprocessor transforms the X, Y, and Z measurements to a horizontal geographical coordinate system and calculates the magnetic heading Ψ_m as:

$$\Psi_m = \text{Atan}\ (-T_y/T_x)$$

Where T_X and T_X are coordinate transformed to the horizontal system for Fluxgate Magnetometer measurement. To calculate D, the AHRS must be turned to true North or its true direction needs to be known.

$$D = \Psi - \Psi_m$$

If you are only interested in the variation of declination, you do not need to know True Heading. However, when the measurements are taken, the AHRS has to be oriented in the same Azimuth position. For more details about declination measurement, please contact Watson Industries. Watson Industries provides software for calibrating the heading of the AHRS calibration because each unit will likely have significant magnetic deviations. Your location on the globe will also cause error in the magnetic heading (Ψ_m) by Total field strength (T), Magnetic Dip Angle (J) and Leveling Error (ΔL). The following is a general relationship for small leveling errors:

$$\Delta\Psi_m = T * \text{sine}\ (J) * \Delta L$$

Table 1 lists a general relationship between Magnetic Dip Angle and latitudes on the Earth's surface.

Latitude	0	30	45	56	70	80
Dip Angle	0°	45°	60°	68°	80°	85°

Table 1. Magnetic Dip Angle versus Latitude

The standard terminology for the axes for linear and rotational motions are shown in Figure 2. These same axes are related in Figure 3 to earth coordinates.

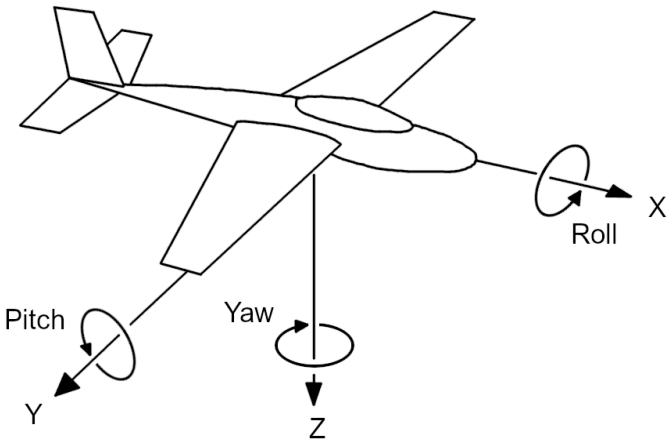


Figure 2. Body Axis Definitions.

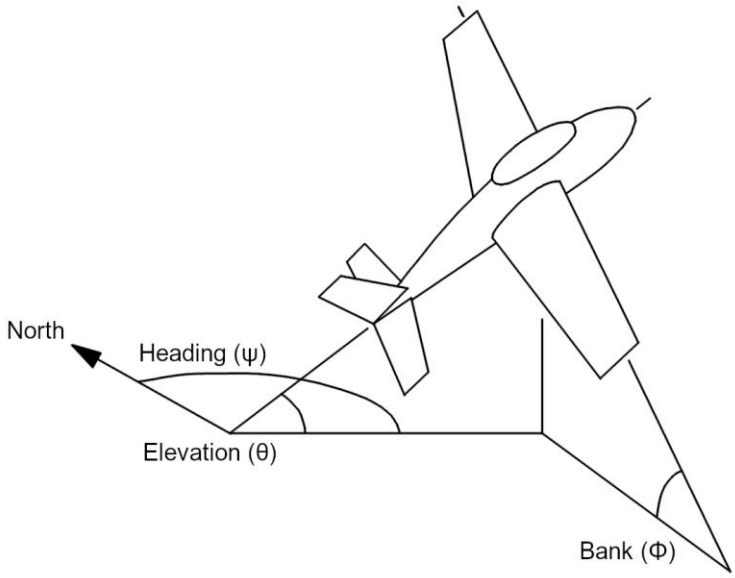


Figure 3. Earth Referenced Axis Definitions.

Error Correction

The correction systems, which all attitude systems use, unfortunately also allow errors from the forces from vehicle maneuvers to enter the system. To control these effects, a balance of time constant and error limits are used:

	Limiting Factor Causing Error Reduction:				
Axis of Error Limit	Bank Angle Error	Elevation Angle Error	Heading Angle Error	Centrifugal Force Offset	Acceleration Force Offset
Bank	±10º	None	None	±5 g	None
Elevation	None	±10º	None	None	±5 g
Heading	None	None	±20º	None	None

It would not be a problem to cross over into these limits since the rate of deterioration from the original reference should be about 0.03 degrees per second. However, prolonged strong maneuvers should be avoided if accuracy is to be maximized. In normal attitudes, error is corrected with a 30-second time constant.

While this AHRS is "all attitude", the accuracy deteriorates rapidly within about 5 degrees of straight up or straight down.

Centrifugal Force Compensation:

The compensation for centrifugal force is based on calculating the horizontal turn rate and multiplying it by the forward velocity. The result is subtracted from the vertical reference accelerometers for the roll axis. This system directly depends on the quality of the velocity signal.

Delta Velocity Compensation:

The compensation for forward acceleration is based on calculating the changes in average forward velocity. The result is subtracted from the vertical reference accelerometers for the pitch axis. This is limited in unusual attitudes and the error correction system is locked out when the attitude and conditions are outside of a reasonable range. This system also directly depends on the quality of the velocity signal.

Operation

The angular rate sensor signals are coordinate transformed and then integrated to produce attitude and heading outputs that reflect normal attitude coordinates. These attitude and heading signals are compared against three accelerometers and a triaxial fluxgate magnetometer to derive short-term absolute errors. These errors are filtered over a long time constant and are used to adjust biases in the system so that the long-term convergence of the system is to the vertical references and the magnetic heading. Compensations for centrifugal forces and velocity changes on the accelerometers are used to improve overall stability and accuracy.

Initialization

Ideally, the AHRS should be stationary and level when it is turned on. If not, the sensor readings may not be accurate for after initialization. The time required for the initialization process is not the same for every type of AHRS, but typically takes 4 to 5 seconds. During this time, a message is sent from the unit via the RS-232 serial link. This message gives information about the AHRS such as the full model number, serial number, and software revision. The message can be read by using a terminal program or by using the terminal mode of Watson Industries' communication software.

The AHRS can also be "re-initialized" after it has been turned on. This is especially useful if the sensor has been used in severe maneuvers that have over ranged the angular rate sensors and caused significant errors to accumulate. Sometimes re-initializing the unit will allow for a faster recovery than waiting for the error correction routines to correct the sensor readings. There are several ways to re-initialize the AHRS. For more information, see the Interface section of this manual.

Normal Operation

During normal operations, the AHRS will output highly accurate inertial data for the user to interpret. This data can be output several different ways. The most common way to acquire data from the AHRS is to use the RS-232 serial output. There are two RS-232 output formats: decimal and binary. The exact formatting structure is discussed later in the Interface section of this manual. The AHRS generates many different data items for output. Any combination of these data items can be selected for transmission via the RS-232 serial link. The AHRS also has analog outputs (see Interface section) that can be used to send data to the user.

In normal operation, the AHRS takes data from its internal rate sensors and integrates them in a closed loop system, with the accelerometers and the magnetometer as a long-term reference, to generate the Bank, Elevation and Heading data. In most cases, these algorithms provide for very stable and accurate output signals; however, the user should be aware that exceeding the normal ranges of the sensors would affect accuracy. For example, while custom AHRS units may have differing ranges, the rate gyros in a typical AHRS have a maximum rate of 100°/s. Care should be taken not to exceed this rate because the closed loop system will receive inaccurate rate data. This will result in errors in the angle output signals.

While this AHRS is "all attitude", the accuracy deteriorates rapidly within about 5 degrees of straight up or straight down. Operation for any extended period of time in this orientation is not recommended. If these few operational precautions are observed, the AHRS should provide very accurate data for a wide variety of applications.

Special Operation Modes

Reference Mode

This mode is usually used for calibration or diagnostics. When in reference mode, the AHRS will output data generated directly from the sensor reference signals rather than as a product of the closed loop integration used for normal operation. The reference command provides the same sensor information as in normal operation mode with the following differences:

> Bank and Elevation are obtained directly from the accelerometers - no gyro stabilization.
> Angular Rate Sensors are not close-loop bias corrected.

The reference mode can be selected either through a serial input command. Note that reference mode is never a default setting. It must be re-selected when re-powering the unit.

Free Mode

While in Free Mode, also sometimes referred to as Coast Mode, the AHRS will output data from the sensors without correction by the references. For example, the Bank Angle data output in Free Mode is calculated directly from the X-axis Rate Sensor. In this case, the angle is a direct integration of the roll rate. Free Mode can be used to totally reject effects from dynamic accelerations, but accuracy degrades with time. It is intended for use over periods of a few minutes at a time. This mode provides similar sensor information as in normal operation mode with the following differences:

> Bank and Elevation are obtained directly from the rate gyros.
> Angular Rate Sensors are not close-loop bias corrected.

Free mode can be accessed either through a serial input command. Note that free mode is never a default setting. It must be re-selected when re-powering the unit. The user should not enter free mode until after the AHRS is initialized and its readings are stable.

Command Mode

In this mode, the AHRS will output sensor data normally unless it receives a valid serial input command. Once a command is received, the AHRS will send data in response and await the next command. Using this mode, the user can retrieve the EEPROM map, baud rates, output formats, and many other operational settings of this sensor. Having access to this information makes the Command Mode useful in assisting the factory to remotely troubleshoot the certain operational problems that can occur. For more details, see Appendix B.

Interface

The AHRS has analog and digital interface capabilities.

RS-232 Output Format

The nominal RS-232 output consists of a string of decimal ASCII characters sent asynchronously at regular intervals at about 11.85 strings per second. The string is sent at 9600 baud with eight data bits, one stop bit and no parity. The contents of the string are formed as follows:

1. A single letter and a space used to indicate the start of the data string. the letter “I” indicates the start of an inertial data string. The letter “R” indicates the start of a reference data string. If the letter is in lower case (“i” or “r”), an error overrange condition is indicated (see below).

2. A seven character string representing the bank angle starting with a "+" or a "-", followed by three digits, a decimal point, one digit and a space for up to ±179.9 degrees.

3. A six character string representing the elevation angle starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±89.9 degrees.

4. A six character string representing the heading angle by three digits, a decimal point, one digit and a space for zero to 359.9 degrees.

5. A six character string representing the X axis accelerometer starting with a space, then a "+" or a "-", followed by one digit, a decimal point and two digits for up to ±9.99 g.

6. A six character string representing the Y axis accelerometer starting with a space, then a "+" or a "-", followed by one digit, a decimal point and two digits for up to ±9.99 g.

7. A six character string representing the Z axis accelerometer starting with a space, then a "+" or a "-", followed by one digit, a decimal point and two digits for up to ±9.99 g.

8. A six character string representing the X axis angular rate starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±99.9 degrees/second.

9. A six character string representing the Y axis angular rate starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±99.9 degrees/second.

10. A six character string representing the Z axis angular rate starting with a "+" or a "-", followed by two digits, a decimal point, one digit and a space for up to ±99.9 degrees/second.

11. A six character string representing the velocity starting with a "+" or a "-", followed by three digits, a decimal point and one digit for up to ±799.9 Km/hr.

12. The string is terminated by a carriage return. There will then be a short interval with no data transmission before the next string begins.

Example:

I	+002.5	-05.0	273.4	+1.02	+0.15	-1.57	-00.4	+01.2	+10.4	+001.4	<CR>	
(1)	bank angle (2)	elev. angle (3)	Head. angle (4)	X axis accel (5)	Y axis accel (6)	Z axis accel (7)	X axis rate (8)	Y axis rate (9)	Z axis rate (10)	Velocity (11)		(12)
	space	space	space	space	space	space	space	space	space	space		

The string transmission rate can be improved by reducing the amount of information (data items) transmitted. The data items transmitted can be changed by using special commands to modify

the EEPROM of the unit (see Appendix B). In addition, more channels are available for output (see Appendix A).

The system is protected from inadvertent write-over of the EEPROM by requiring two spacebar commands during the initialization interval to access the EEPROM or related functions.

The baud rate may be changed from the nominal value of 9600 baud by modifying the default value in the EEPROM of the unit. See Appendix B for more details on changing the baud rate.

A text header is sent by the AHRS during initializations that identifies the unit by part number and by serial number and gives the date of last calibration. Additionally, a line of text characters that identifies the data channel columns is sent if the serial output is set to ASCII decimal. This whole message can be temporarily or permanently suppressed or restored by a "*" command from the interfacing computer. For more information, see the RS-232 Input Commands section.

Data transmission sent by the AHRS can also be suppressed or restored by a "+" command from the interfacing computer. For more information, see the RS-232 Input Commands section.

The error overrange condition is indicated by the use of a lower case "i" or "r" when the calculated attitude or heading error exceeds the ranges listed above. Internal functions that require these error values are disabled while the condition exists. The system will continue to operate in an extended time constant mode with a low level of error accumulation until the condition is cleared. Occasional blips of this condition are expected with no detectable affect on the resulting data.

The other output format available is a binary format. The binary format provides generally the same information as the decimal ASCII format, but in a compact binary file format. In this format, there are nominally 13 words sent that represent 6 fourteen-bit output channels followed by a carriage return. Again, the number of channels may be reduced to improve the update rate by using special commands to modify the EEPROM of the unit. This format is for highly experienced users only. Information on the binary format can be found in Appendix C. Consult the factory for further details.

RS-232 Input Commands

The RS-232 input commands are provided for the purpose of unit test and installation set-up. Use the same parameters that are used for the RS-232 output (9600 baud ASCII nominal, or as reset in the units EEPROM).

Note: Many commands require command or "Double spacebar mode" in order to access them. Fore more information on how to activate Command Mode, see the instructions in Appendix B.

These commands are available to the user (others are used at the factory for alignment and calibration):

1. An "R" or "r" will set the outputs (analog and serial) to their Reference Command modes. This mode is used in installation to physically align the unit. Command mode is required for access to this command. See the special operation modes section of this manual for more information on Reference Mode.

2. An “I” or “i” will clear the Reference Command mode if it had been set by the serial input. This is the default mode at power up and is the normal operating mode. Command mode is required for access to this command.

3. An “F” will disconnect the references from the attitude system and is the Free Mode Command. This mode is used to make the system ignore the references during high maneuvers and brief disturbances. This mode is not intended for use except in brief intervals, since errors will grow geometrically. Command mode is required for access to this command. See the special operation modes section of this manual for more information on Free Mode.

4. A “K” will clear the Free Mode Command. Command mode is required for access to this command.

5. A “V” will disconnect the velocity input from the attitude system and is the Velocity Inhibit Command. This mode is used to protect the system from accumulating errors when the velocity reference is not functioning. This command does not require command mode, it may be used at any time.

6. A “C” will clear the Velocity Inhibit Command. This command does not require command mode, so it may be used at any time.

7. An “!” will reinitialize the unit. Further, the access to initialization is inhibited such that a spacebar command must be sent within 2.5 seconds of the “!” command for initialization to be engaged.

8. An “L” in the decimal mode will return a line of characters that will identify the data columns. Command mode is required for access to this command.

9. An “_” command will change the output format to decimal ASCII. This change is made non-volatile in the unit on EEPROM by keying in the quote (“) character. Command mode is required for access to this command.

10. A “^” command will change the output format to binary. This change is made non-volatile in the unit on EEPROM by keying in the quote (“) character. Command mode is required for access to this command.

11. A “:” command will toggle the output to send a frame of data upon receiving any non-command character (On to Off; Off to On). This change is made non-volatile in the unit on EEPROM by keying in the quote (“) character. Command mode is required for access to this command.

Note: To test if this command is active when the unit is not flowing data send a carriage return (or any other non-command character to the sensor, and observe if there is any output.

12. A “+” command will suppress or restore the transmission of data. This command will toggle the data transmission (On to Off; Off to On). Command mode is required for access to this command.

Note: It is possible for both the ":" and the "+" commands to be active at the same time. The "+" command determines whether the sensor is allowed to transmit data. So in this case, the ":" command must also be turned off to allow the free flow of data.

13. An "*" command will suppress or restore the initialization message in the Decimal ASCII mode. This command will toggle the transmitting of the text header during initialization (On to Off; Off to On). This change is made non-volatile in the unit on EEPROM by keying in the quote (") character. Command mode is required for access to this command.

14. An "&" command brings up a menu to select baud rates. This change is made non-volatile in the unit on EEPROM by keying in the quote (") character. Command mode is required for access to this command.

15. The "N" command is used to offset the heading output from any given angle to North. This can be used as a calibration means, but is only recommended for small adjustments. To use this command, first send an "R" command on the keyboard to place the sensor into reference mode (see above). Second, aim the vehicle platform to the North reference required. Third, send an upper case "N" to the unit to enter the adjustments. This is a nonvolatile correction. It can be used with any North reference and will help to correct for local magnetic distortions. Command mode is required for access to this command.

The commands "~", "@", "#", "$", "(", ")", "{", "}", "|", "<", ">", "S", "M", "X", "T", "D", and "?" are used by the Watson factory to calibrate the unit and should be used only with the assistance of the factory. If an undesired function is called, a "Q", and sometimes Escape or a Delete will interrupt the command and return to operation with the least disturbance to the system. All other unspecified characters such as carriage return, line feed and space are ignored by the system.

If there are problems with the system "hanging up" during the binary output mode, check for crosstalk between the serial transmit and receive line in your installation. In addition, check to see that the communications program used is not sending an echo. This will not happen in the decimal mode because command characters recognized by the system are not produced in this mode.

Analog Outputs

Analog signals are output from a 14 bit digital to analog converter through an operational amplifier. Each analog output has a 300 ohm resistor in series to eliminate oscillations from high capacitance loads. The output range for all of the analog output channels is ±10 Volts with respect to the common signal ground. The outputs include:

Signal	Pin	Range	Output Range	0 VDC	Scale Factor
Bank	6	±180°	±10V	0°	18°/s/V
Elevation	7	±90°	±5V	0°	18°/s/V
North Heading Angle	8	±180°	±10V	North	18°/s/V
South Heading Angle	9	±180°	±10V	South	18°/s/V
Heading Rate	10	±100°/s	±10V	0°/s	10°/s/V

Roll Rate (X Axis)	11	±100°/s	±10V	0°/s	10°/s/V
Pitch Rate (Y Axis)	12	±100°/s	±10V	0°/s	10°/s/V
Yaw Rate (Z Axis)	13	±100°/s	±10V	0°/s	10°/s/V

Analog Inputs

User Channel Inputs

The AHRS allows the user to input analog data that can then be added to the serial data output. This allows the system to act as a data acquisition unit for other vehicle information such as engine RPM, engine temperature, fuel remaining, altitude/depth or any other important data. The four analog user inputs have one megohm input impedance, 16 bit A/D conversion resolution, ±10 volt input range and have a bandwidth of DC to 25 Hertz.

Forward Velocity Analog Input

A vehicle speed input is used to assist in the correction of errors. It is also included in the parameter set that is available for serial output. Although its use is not always required, it is highly recommended that this signal be supplied to the AHRS.

The analog velocity input has one megohm input impedance, 16 bit A/D conversion resolution, and has a bandwidth of 25 Hertz. The range is ±800KPH for ±10 VDC. The unit requires an analog signal that is scaled to 80 KPH per volt. Forward motion should produce a positive signal with respect to signal ground. This input is on pin 22 of the 25 pin D-sub connector (the signal ground reference is pin 25).

Specifications

Attitude

	Range: Bank	±180°	
	Range: Elevation	±90°	
	Resolution:	0.02°	Binary mode (14 bit)
	Analog Scale Factor:	18°/V	±10V Bank ±5V Elevation
	Accuracy: Static	±0.5°	
*	Accuracy: Dynamic	2%	

Magnetic Heading

	Range:	0° - 360°	
	Resolution:	0.02°	Binary mode (14 bit)
	Analog Scale Factor:	18°/V	±10V Output
†	Accuracy: Static	±1°	
*	Accuracy: Dynamic	2%	

Angular Rate

	Range: Roll, Pitch, Yaw	±100°/sec	
	Resolution:	0.025°/sec	Binary mode (14 bit)
	Analog Scale Factor:	10°/sec/V	±10V Output
	Scale Factor Accuracy:	2%	
	Bias:	< 0.3°/sec	
	Non-Linearity:	< 0.05%	Full scale range
	Bandwidth:	20 Hz	

Acceleration

	Range: X, Y, Z	±10g	
	Resolution:	4mg	
	Scale Factor Accuracy:	1%	
	Bias:	< 10mg	
	Non-Linearity:	0.1%	Full scale range
	Bandwidth:	3 Hz	

Magnetic

	Range: X, Y, Z	±1000 mGauss	
	Resolution:	0.1 mGauss	Binary mode (14 bit)
	Scale Factor Accuracy:	1%	
	Bias:	< 5 mGauss	
	Non-Linearity:	< 0.01%	Full scale range
	Bandwidth:	10 Hz	

Environmental

	Temperature: Operating	-40°C to +85°C	
	Temperature: Storage	-55°C to +85°C	
	Vibration: Operating	2.5g rms	20 Hz to 2 KHz
	Vibration: Survival	10g rms	20 Hz to 2 KHz
	Shock: Survival	500g	10mS ½ sine wave

Electrical

	Frame Rate:	71.1 Hz	Maximum
	Startup Time: Data	5 sec	
	Startup Time: Fully operational	10 sec	
	Input Power:	10 to 35VDC	2.8W
	Input Current:	215mA @ 12VDC	115mA @ 24VDC
	Input Velocity: (Optional)	±10VDC	Full scale (±800kph)
	Digital Output:	RS-232	
	Analog Output:	±10VDC	
	Analog Output Impedance:	300 Ohm	Per line

Physical

	Axis Alignment:	< 0.25°	
	Size: Including Mounting Flanges	3.24"W x 5.78"L x 2.38"H	8.2 x 14.7 x 6.0 (cm)
	Weight:	21 oz (1.3lb)	595 grams (0.6Kg)
	Connection:	25 pin male "D" subminiature	

* Assumes accurate velocity data.
Actual accuracy can be calculated as the listed percentage multiplied by the change in value over the entire dynamic maneuver.

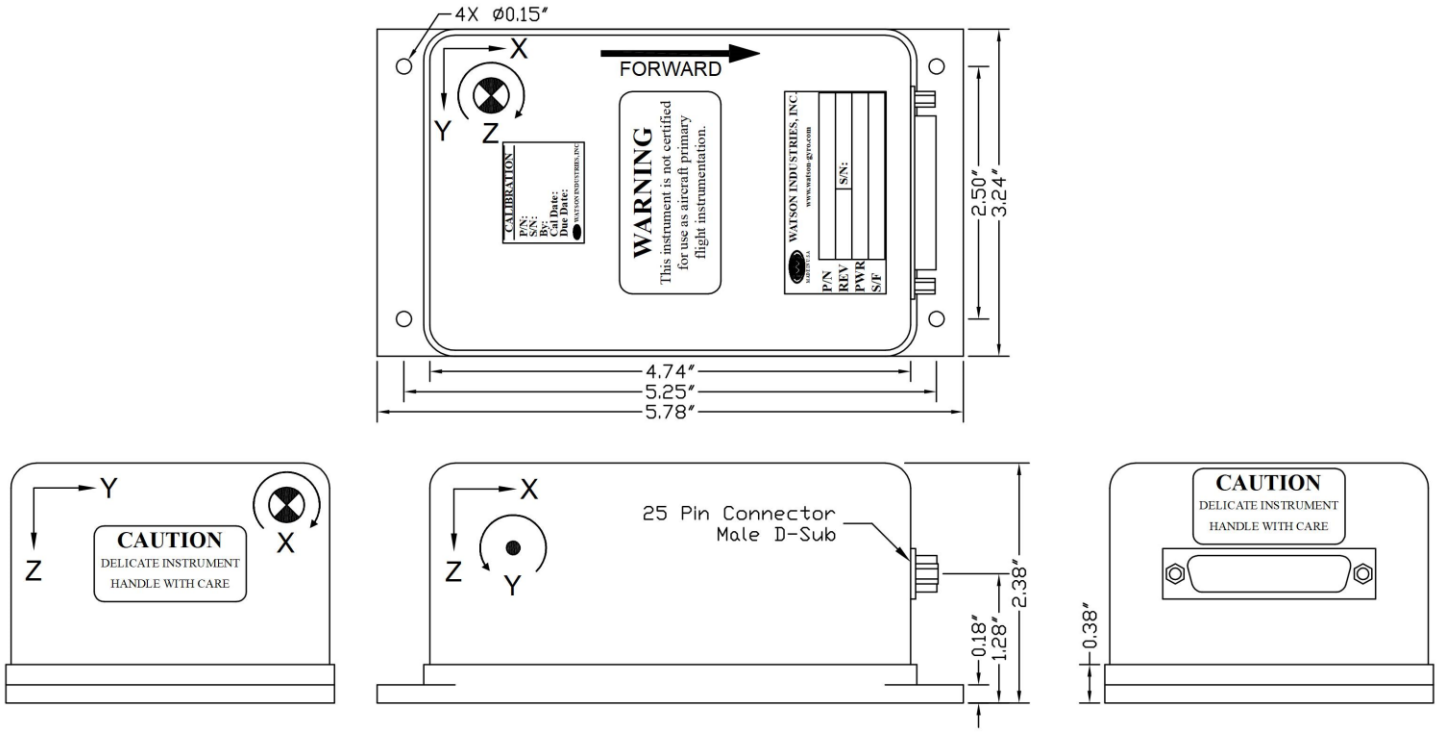
† Static heading accuracy is dependent on the magnetic environment.
This sensor will meet or exceed this spec within the 48 contiguous United States.

- Specifications are subject to change without notice.
- This product may be subject to export restrictions. Export Classification ECCN 7A994.

Connections / Dimensions

25 Pin Male “D” Subminiature Connector

Pin	Description
1	Power Ground
2	+10 to +35 VDC
3	RS-232 Input (RXD)
4	RS-232 Output (TXD)
5	Signal Ground
6	Analog Output 1 – Bank
7	Analog Output 2 – Elevation
8	Analog Output 3 – Heading North
9	Analog Output 4 – Heading South
10	Analog Output 5 – Heading Rate
11	Analog Output 6 – Roll Rate
12	Analog Output 7 – Pitch Rate
13	Analog Output 8 – Yaw Rate
14 - 17	No User Connection
18	Analog Input – User Channel 1
19	Analog Input – User Channel 2
20	Analog Input – User Channel 3
21	Analog Input – User Channel 4
22	Analog Input – Forward Velocity (±10 VDC)
23 - 24	No User Connection
25	Signal Ground



AHRS-S305

WARNING

1. Rough handling or dropping of this unit is likely to cause damage.

2. Over-voltage and/or miswiring of this unit will cause damage.

3. The non-magnetic connectors supplied with the unit must be used to preserve heading accuracy. The user must use non-magnetic hardware to install the unit.

4. This unit should be protected against prolonged exposure to high humidity and/or salt air environments.

DISCLAIMER

The information contained in this manual is believed to be accurate and reliable; however, it is the user's responsibility to test and to determine whether a Watson Industries' product is suitable for a particular use.

Suggestion of uses should not be taken as inducements to infringe upon any patents.

WARRANTY

Watson Industries, Inc. warrants, to the original purchaser, this product to be free from defective material or workmanship for a period of one full year from the date of purchase. Watson Industries' liability under this warranty is limited to repairing or replacing, at Watson Industries' sole discretion, the defective product when returned to the factory, shipping charges prepaid, within one full year from the date of purchase. The warranty described in this paragraph shall be in lieu of any other warranty, express or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose.

Excluded from any warranty given by Watson Industries are products that have been subject to abuse, misuse, damage or accident; that have been connected, installed or adjusted contrary to the instructions furnished by seller; or that have been repaired by persons not authorized by Watson Industries.

Watson Industries reserves the right to discontinue models, to change specifications, price or design of this product at any time without notice and without incurring any obligation whatsoever.

The purchaser agrees to assume all liabilities for any damages and/or bodily injury that may result from the use, or misuse, of this product by the purchaser, his employees or agents. The purchaser further agrees that seller shall not be liable in any way for consequential damages resulting from the use of this product.

No agent or representative of Watson Industries is authorized to assume, and Watson Industries will not be bound by any other obligation or representation made in connection with the sale and/or purchase of this product.

PRODUCT LIFE

The maximum expected life of this product is 20 years from the date of purchase. Watson Industries, Inc. recommends the replacement of any product that has exceeded the product life expectation.

Customer Service

All repairs, calibrations and upgrades are performed at the factory. Before returning any product, please contact Watson Industries to obtain a Returned Material Authorization number (RMA).

Return Address & Contact Information

Watson Industries, Inc.
3035 Melby Street
Eau Claire, WI 54703
ATTN: Service Department
Telephone: (715) 839-0628 Fax: (715) 839-8248 email: support@watson-gyro.com

Returning the Product

Product shall be packaged making sure there is adequate packing around all sides. Correspondence shall include:

- Customer's Name and Address
- Contact Information
- Equipment Model Number
- Equipment Serial Number
- Description of Fault

It is the customer's responsibility to pay all shipping charges from customer to Watson Industries, including import and transportation charges.

Appendix A

The following outputs are available via the RS-232 serial link. Their full scale ranges are listed for both decimal and binary format.

Inertial Output	Label	Full Scale Decimal	Full Scale Binary
Time Since Reset	TM	65535 seconds	16383 seconds
Bank	BK	±179.9º	±180º
Elevation	EL	±89.9º	±180º
Heading	HG	359.9º	±180º
X Accelerometer	XA	±9.99 g	±10 g
Y Accelerometer	YA	±9.99 g	±10 g
Z Accelerometer	ZA	±9.99 g	±10 g
X Angular Rate	XR	±99.9 º/s	±200 º/s
Y Angular Rate	YR	±99.9 º/s	±200 º/s
Z Angular Rate	ZR	±99.9 º/s	±200 º/s
Heading Rate	HR	±99.9 º/s	±200 º/s
X Magnetometer	XM	±999 mGauss	±1000 mGauss
Y Magnetometer	YM	±999 mGauss	±1000 mGauss
Z Magnetometer	ZM	±999 mGauss	±1000 mGauss
X inclinometer (simulated)	XI	±179.9º	±180º
Y Inclinometer (simulated)	YI	±89.9º	±180º
User Channel 1	U1	±9.99 VDC	±10 VDC
User Channel 2	U2	±9.99 VDC	±10 VDC
User Channel 3	U3	±9.99 VDC	±10 VDC
User Channel 4	U4	±9.99 VDC	±10 VDC
Forward Velocity	VS	±799.9 Km/hr	±800 Km/hr
Temperature	TP	-40º to 88ºC	-40º to 88ºC (7 bit)
Status Bits	ST	1 byte	1 byte
Flag Bits	FL	1 byte	1 byte

The Status Bits contain the following information:

Bit	Description (If Set)
0	Bank Error Flag
1	Elevation Error Flag
2	Heading Error Flag
3	System Error Flag
4	Velocity Error Flag
5	South Heading Flag
6	Checksum Error Flag
7	Not Used (always zero)

Example: The status channel output in ASCII Decimal is “040”

Octal Digit	0		4			0		
Binary Equivalent	0	0	1	0	0	0	0	0
Status Bit #	7	6	5	4	3	2	1	0

This translates into the information below:

Bit 7	Reset	
Bit 6	Reset	No Checksum Error
Bit 5	Set	South Heading Flag
Bit 4	Reset	No Velocity Error
Bit 3	Reset	No System Error
Bit 2	Reset	No Heading Error
Bit 1	Reset	No Elevation Error
Bit 0	Reset	No Bank Error

The Flag Bits contains the following information:

Bit	Description
0 to 2	Show the current system time constant, using the following equation: $TC=2^{(Flag\ Value + 1)}$
3	Reference Command selected
4	Velocity disabled
5	Free Mode selected
6	Logic Input Switches disabled
7	Not Used (always zero)

Example: The flag channel output in ASCII Decimal is “102”

Octal Digit	1		0			2		
Binary Equivalent	0	1	0	0	0	0	1	0
Status Bit #	7	6	5	4	3	2	1	0

This translates into the information below:

Bit 7	Reset	
Bit 6	Set	Logic Input Switches Disabled
Bit 5	Reset	Not in Free Mode
Bit 4	Reset	Velocity Enabled
Bit 3	Reset	Not in Reference Mode
Bit 2	Reset	Current System Time Constant = 010 Binary → Value = 2; so $2^{(2+1)} = 2^3 = 8$ seconds
Bit 1	Set	
Bit 0	Reset	

Appendix B

Activating Command Mode (Double Spacebar Mode)

1) Connect the unit to a DC power source that is off.
2) The viewing computer needs a valid bi-directional RS-232 serial port. Connect the serial port of the Watson sensor to the computer's serial port.
3) Open a terminal program (such as HyperTerminal) to interface with the unit. The default baud rate of the unit is 9600 baud. Make sure the computer's serial port is open.
4) Power-on the unit. A startup message will be transmitted by the unit and will appear in the terminal window unless it has been suppressed (See RS-232 Input Commands above).
5) During initialization, hit the space bar twice within close succession.

   Note: The sensor initialization time begins after the startup message is transmitted. Typically, this time period lasts 5 seconds, but could be as long as 127 seconds depending on your sensor.

6) Wait until after initialization is finished. At this point, command mode will be activated and the unit will accept keyboard commands.

   Note: Most Watson sensors have initialization times that are shorter than 30 seconds. Any extra keystrokes (other than two spacebars) sent during initialization will deactivate command mode.

**It can often take a few attempts to get the hang of step 5. Repeat steps 4-6 until successful.

Determining Output Channels

1) Activate Command Mode (See above).
2) To determine which channel present, first type '&'.
   This will bring up the main menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
  1 = ADJUST TIME CONSTANTS
  2 = SET OUTPUT CHANNELS
  3 = LIST CURRENT OUTPUT CHANNEL SELECTION
```

3) Typing in '3' will show which channels are currently active.

Setting Output Channels

1) Activate Command Mode (See above).
2) To change which channels are output type '&' (this will bring up the main menu again)
3) Now type '2' to set up channels.
   The following message will appear:

```
TO SET FOR OUTPUT FOR ANY OF THE FOLLOWING DATA ITEMS, PRESS Y
TO AVOID ANY OF THE FOLLOWING DATA ITEMS, PRESS N
TO QUIT AND DISREGARD ANY OTHER DATA, PRESS Q

***  DO YOU WANT TO PROCEED?  (Y/N/Q)
```

4) To proceed type 'Y'. Stop this process by typing either 'N' or 'Q'. If 'Y' is pressed, each channel will come up one at a time.

For example:

```
DO YOU WANT OUTPUT OF TIME SINCE RESET?
DO YOU WANT OUTPUT OF BANK ANGLE?
```

5) Type 'Y' to output the channel, type 'N' to remove the channel
After the last data channel is listed, this message will appear:

```
Y = GOBACK, N = INSTALL DATA & QUIT, Q = QUIT
DO YOU WANT TO TRY TO SET DATA AGAIN?
```

6) To accept the new channels type 'N'. Typing a 'Y' will start the command menu sequence over.
Typing a 'Q' at any time in the sequence will quit without updating the channels.
Changes made will not change the non-volatile settings. To make these new settings the default value, send a Quotation Mark (").

7) Press the space bar after quitting or updating the new channels to restart the data flow.

Adjust Time Constants

We recommend consulting the factory before altering sensor time constants.

Setting Output Format

There are two output formats.
Decimal output - "_" Command.
Binary output – "^" Command. (See Appendix C for more information on Binary Format.)

1) Activate Command Mode (See above).

2) Press the key Command corresponding to the format you want to switch into.
To make this output format the default the next time you power the unit on, send a Quotation Mark (").

3) Press the space bar to resume data transmission.

Setting Baud Rate

1) Activate Command Mode (See above).
2) Type '&'(this will bring up the main menu again).
3) Typing in '4' will allow the user to change the baud rate.
4) Change the baud rate to a new setting.

To change to 38,400 Baud, type '1'.
To change to 19,200 Baud, type '2'.
To change to 9,600 Baud, type '3'.
To change to 4,800 Baud, type '4'.

The baud rate change will take effect immediately. To make the new baud rate the default setting, send a quote symbol (“) using the new baud rate. Otherwise the old baud rate will return the next time the unit is powered up.

Note: The baud rate of the software that is communicating to the sensor will need to be changed to match the new setting.

5) Press the space bar to resume data transmission.

The factory settings for serial communications are 9.6K baud with 8 bits and one stop bit, no parity.

Appendix C

Binary Data Format

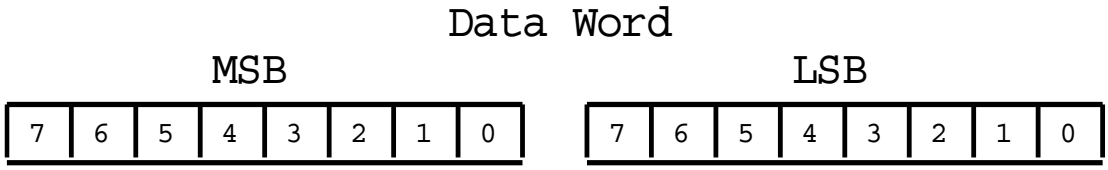
The unit will output up to 6 words at 71.11 frames per second set at 9600 Baud. One word per output parameter.

Example 1: The Unit is seeing these conditions:

Bank	Elevation	Heading	X angular rate	Y angular rate	Z angular rate
15.0˚	-5.0˚	315.0˚	10.0˚/sec	-15.0˚/sec	55.0˚/sec

Binary output Format:

Word1	Word2	Word3	Word4	Word5	Word6	<CR> byte
0x85AA	0xFE9C	0xF080	0x8399	0xFB99	0x91CC	0x0D



Bit 7 of the MSB is set to 1. Bits 6 to 0 of the MSB are the upper 7 bits of the data. (sign plus 6 bits of data)
Bit 7 of the LSB is set to 1. Bits 6 to 0 of the LSB are the lower 7 bits of the data.

As the data words are received, the LSB is shifted left to shift out the Bit 7 (always set to 1). The MSB is then connected to the LSB as a 16-bit word. This word is then shifted left to shift out the Bit 7 (always set to 1). What remains is a signed fractional word with a resolution of 13 bits plus a sign bit.

To convert binary data:

Bank	Elevation	Heading	X Rate	Y Rate	Z Rate
0x85AA	0xFE9C	0xF080	0x8399	0xFB99	0x91CC

Need split each word into two bytes:

Bank	Elevation	Heading	X Rate	Y Rate	Z Rate
0x85 0xAA	0xFE 0x9c	0xF0 0x80	0x83 0x99	0xFB 0x99	0x91 0xCC

Remove the most significant bit from each byte:

Bank	Elevation	Heading	X Rate	Y Rate	Z Rate
0x05 0x2A	0x7E 0x1C	0x70 0x00	0x03 0x19	0x7B 0x19	0x11 0x4C

Shift lower byte left once (to remove 1 bit space between bytes):

Bank	Elevation	Heading	X Rate	Y Rate	Z Rate
0x05 0x54	0x7E 0x38	0x70 0x00	0x03 0x32	0x7B 0x32	0x11 0x98

Shift lower & upper bytes left once (to remove 1 bit space a top of high byte):

Bank	Elevation	Heading	X Rate	Y Rate	Z Rate
0x0A 0xA8	0xFC 0x70	0xE0 0x00	0x06 0x64	0xF6 0x64	0x23 0x30

Convert from hexadecimal to decimal counts:

Bank	Elevation	Heading	X angular rate	Y angular rate	Z angular rate
2728	64624	57344	1636	63076	9008

Correct bank, elevation, and angular rates for the sign
If >32767 then subtract 65536 from the data

Bank	Elevation	Heading	X angular rate	Y angular rate	Z angular rate
2728	-912	57344	1636	-2460	9008

Convert to units: counts x scale factor
For bank & elevation: Scale factor is: 180 ˚ / 32768 counts
For heading: Scale factor is: 360 ˚ / 65536 counts
For Angular Rates: Scale factor is: (200 ˚/sec) / 32768 counts

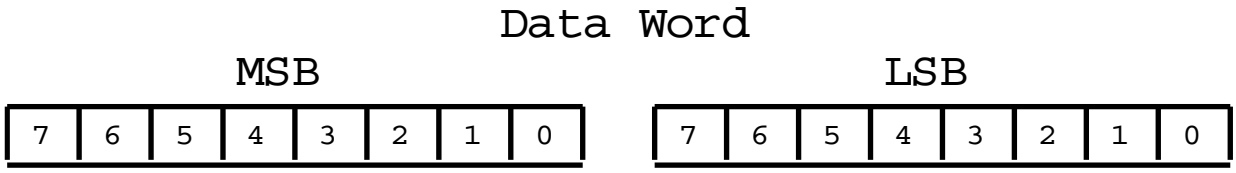
Bank	Elevation	Heading	X angular rate	Y angular rate	Z angular rate
14.985 ˚	-5.010 ˚	315 ˚	9.985 ˚/sec	-15.015 ˚/sec	54.980 ˚/sec

Example 2: The Unit is seeing these conditions:

X Acceleration	Y Acceleration	Z Acceleration	X angular rate	Y angular rate	Z angular rate
0.00 g	-0.28 g	-0.96g	10.0˚/sec	-15.0˚/sec	55.0˚/sec

Binary output Format:

Word1	Word2	Word3	Word4	Word5	Word6	<CR> byte
0x8080	0xFE9A	0xF9EE	0x8399	0xFB99	0x91CC	0x0D



Bit 7 of the MSB is set to 1. Bits 6 to 0 of the MSB are the upper 7 bits of the data. (sign plus 6 bits of data)
Bit 7 of the LSB is set to 1. Bits 6 to 0 of the LSB are the lower 7 bits of the data.

As the data words are received, the LSB is shifted left to shift out the Bit 7 (always set to 1). The MSB is then connected to the LSB as a 16-bit word. This word is then shifted left to shift out the Bit 7 (always set to 1). What remains is a signed fractional word with a resolution of 13 bits plus a sign bit.

To convert binary data:

X Accel	Y Accel	Z Accel	X Rate	Y Rate	Z Rate
0x8080	0xFE9A	0xF9EE	0x8399	0xFB99	0x91CC

Need split each word into two bytes:

X Accel	Y Accel	Z Accel	X Rate	Y Rate	Z Rate
0x80 0x80	0xFE 0x9A	0xF9 0xEE	0x83 0x99	0xFB 0x99	0x91 0xCC

Remove the most significant bit from each byte:

X Accel	Y Accel	Z Accel	X Rate	Y Rate	Z Rate
0x00 0x00	0x7E 0x1A	0x79 0x6E	0x03 0x19	0x7B 0x19	0x11 0x4C

Shift lower byte left once (to remove 1 bit space between bytes):

X Accel	Y Accel	Z Accel	X Rate	Y Rate	Z Rate
0x00 0x00	0x7E 0x34	0x79 0xDC	0x03 0x32	0x7B 0x32	0x11 0x98

Shift lower & upper bytes left once (to remove 1 bit space a top of high byte):

X Accel	Y Accel	Z Accel	X Rate	Y Rate	Z Rate
0x00 0x00	0xFC 0x68	0xF3 0xB8	0x06 0x64	0xF6 0x64	0x23 0x30

Convert from hexadecimal to decimal counts:

X Accel	Y Accel	Z Accel	X angular rate	Y angular rate	Z angular rate
0	64616	62392	1636	63076	9008

Correct bank, elevation, and angular rates for the sign
If >32767 then subtract 65536 from the data

X Accel	Y Accel	Z Accel	X angular rate	Y angular rate	Z angular rate
0	-920	-3144	1636	-2460	9008

Convert to units: counts x scale factor
For Bank & Elevation: Scale factor is: 180 ˚ / 32768 counts
For Heading: Scale factor is: 360 ˚ / 65536 counts
For Accelerations: Scale factor is 10g / 32768 counts
For Angular Rates: Scale factor is: (200 ˚/sec) / 32768 counts

X Accel	Y Accel	Z Accel	X angular rate	Y angular rate	Z angular rate
0.0000g	-0.2808g	-0.9595g	9.985 ˚/sec	-15.015 ˚/sec	54.980 ˚/sec