ADS-C232-1AD

Dual Axis Vertical Reference
Owner's Manual

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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 near that 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, given some resonance, damage is possible.

Introduction

The Watson Industries Vertical Reference represents a significant advancement in inertial sensor technology. It is a highly accurate and rugged device with many advantages over other types of angular rate and incline-sensing devices. This manual describes operation of the Watson Industries Vertical Reference and also provides useful application information to the system designer.

Product Description

The Watson Industries Vertical Reference System is an entirely solid-state sensor that provides exceptional rejection from the adverse effects of inertia and short-term lateral accelerations. It does this through the use of both an accelerometer based vertical reference and an angular rate sensor which is integrated to provide additional information on angular position. It can be a functional replacement for mechanical gyros which are often more expensive and which cannot provide the reliability of a solid-state sensor. Theory of operation is described with more detail later in this manual. The specifications, size and pinouts are also described later in this document

The Watson Vertical References provide for two types of analog output voltages. One is proportional to angular rate and the other is proportional to angular displacement. Full-scale analog outputs produce an output of ±10 volts dependent upon the direction of angular position or rotation. During rotation, positive voltage output occurs in the direction of the rotational arrow indicated in figure 2. At horizontal and zero angular rotation rate, both outputs for displacement and rotation rate are near zero. A power supply, providing a regulated ±15 Volts DC, is required to operate the unit.

Special options in power supply, output voltage, scale calibration, and special packaging are available as custom units. Pricing and delivery information on custom units is available by contacting the factory.

Installation

Orientation

The base of the unit is to be mounted on top of a horizontal surface with the single foot toward the forward direction of the vehicle. The ADS drawing, with wire call outs, is located in Figure 2. The ADS is a rugged device and will withstand harsh environments. However, due attention needs to be paid to the nature of the sensor and its prime function, which is to measure attitude and motion.

Mounting

The unit has three 0.12” diameter mounting holes for using three # 4 (or 3 mm) screws. To avoid distortion, the unit must be attached to a clean, flat surface, and the fasteners must be tightened evenly.

Environment:

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

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.

Power

The unit requires a regulated ±15 VDC dual power supply (0.6Watts). STABLE POWER IS REQUIRED. The system is sensitive to power supply changes. The power ground is already connected internally to the signal ground. Do not connect the ground wires externally. 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.

Theory of Operation

In order to obtain an accurate signal in both the short-term and in the long-term, the Vertical Reference relies upon a Watson Industries angular rate sensor (ARS) combined with solid-state accelerometers. The position output is generated by integrating the angular rate output. This signal is compared with the output from the accelerometer and the resultant error signal is passed through a long time constant filter and fed back as a bias to the rate sensor. The system is damped by sending a portion of the error directly to the position integrator. By using a long time constant, the effect of the short-term errors in the accelerometer is minimized. Thus, the adverse effects of inertia, damping and short-term lateral accelerations on the pendulum essentially do not show up on the vertical reference output. See Figure 1 for system overview.

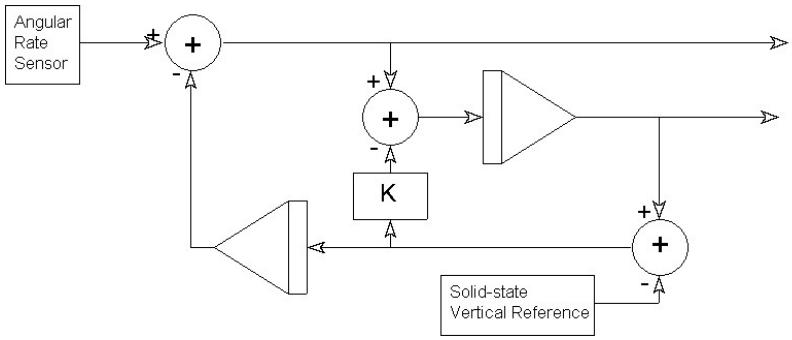


Figure 1 – System Overview

The solid-state angular rate sensor has a sensing mechanism consisting of a piezoelectric transducer element in a "ring" configuration. The drive plates induce a resonance in opposite directions. When a rotation occurs, the momentum stored in the vibrating elements causes a precession of vibration energy that is demodulated to accurately depict the rotation rate.

Since the output of the vertical reference involves the synchronizing of an integrator to a reference, a rotation exceeding either the full scale limits of displacement or angular rate could greatly disturb the synchronization and produce large errors. Returning the unit to a displacement and angular rate within range would allow the unit to again synchronize. Depending on the extent of output saturation, the synchronization will occur in less than sixty (60) seconds.

Operation

Initialization

Ideally, the ADS should be stationary when it is turned on. If not, the sensor readings may not be accurate after initialization. The time required for the initialization process is not the same for every type of ADS, 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 ADS 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 ADS 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 ADS. For more information, see the Interface section of this manual.

Normal Operation

In normal operation, the ADS takes data from its internal rate sensors and integrates them in a closed loop system, with the accelerometers as a long-term reference, to generate the Bank, and Elevation 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 ADS units may have differing ranges, the rate gyros in a typical ADS 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.

Special Operation Modes

Reference Mode

This mode is usually used for calibration or diagnostics. When in reference mode, the ADS 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, and the X and Y angular rate data channels output X and Y Rate Bias values

The reference mode can be selected through the terminal mode. 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, the ADS 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 through command mode (See Appendix B). 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 ADS is initialized and its readings are stable.

Interface

RS-232 Output Format

The standard RS-232 output is received from the 12-pin connector. The digital output pin map can be found in the Connections section of this manual. The RS-232 output consists of a string of decimal ASCII characters sent asynchronously at regular intervals. By default, the string is sent at 9600 baud with eight data bits, one stop bit and no parity. The RS-232 signal is referenced to signal ground. The number of strings sent per second depends on the baud rate and the output format. The maximum rate is 250 strings per second. The contents of a typical string are formed as follows: (See Appendix B for information on how to change the data string.)

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 over-range condition is indicated (see below).

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

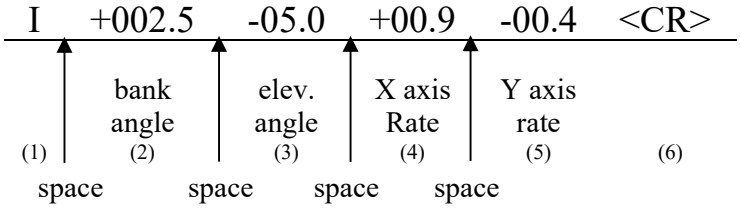
3. A six character string representing the elevation angle starting with a space, then a "+" or a "-", followed by two digits, a decimal point and one digit for up to ±89.9 degrees.

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

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

6. 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:



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). 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 to 38.4K, 19.2K, or 4800 baud.

The error over range condition is indicated by the use of a lower case "i" or "r" when the calculated attitude 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 message. In this format, there are nominally 9 bytes sent that represent 4 fourteen-bit output channels followed by a carriage return. Again, this 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. See Appendix C for more information. 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 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. For 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):

Char†	Command mode Rqd	Saveable Setting	Description
I	Yes	No	Set the unit to Inertial Mode See the Normal Operation section for more details.
Z	No	No	Reset the count on the timer channel. See Appendix A for more details.
R	Yes	No	Set the unit to Reference Mode See the Special Operation Modes section for more details.
F	No	No	Set the unit to Free Mode See the Special Operation Modes section for more details.
K	No	No	Clear the Free Mode Command.
L	Yes	No	Show channel labels The unit will output a line of text showing which channels are currently set for output. The label abbreviations for each channel are defined in Appendix A.
!	No	No	Reinitialize the unit. Starts the reinitialization process for the unit. The unit will not reinitialize unless it receives a spacebar character within 2.5 seconds

			after the "!" command is received.
_	Yes	Yes	Select decimal output format; This is the underscore character "_" See the RS-232 Output Formats section above for more details.
^	Yes	Yes	Select binary output format See Appendix C for more detail on the binary format.
:	Yes	Yes	Toggle serial data output on non-command character The unit will output a line of data whenever it receives a non-command character (such as a carriage return). When this command is received, it will toggle from Off to On; On to Off.‡
+	Yes	Yes	Toggle serial data transmission The unit will not output any data via the RS-232 port. When this command is received, it will toggle from Off to On; On to Off.‡
*	Yes	Yes	Toggle initialization message The unit will not transmit the text header during initialization When this command is received, it will toggle from On to Off; Off to On.
&	Yes	Yes	Activate unit settings menu Transmits a menu which allows any of several operating parameters to be set. See Appendix A for details on settings that can be changed through the menu.
"	Yes	N/A	Save the active settings Any settings that can be saved are placed into EEPROM so the unit will use them as a default the next time it powers on.

† All command characters that are alphabetic letters are treated case-insensitively. For example, the unit will accept an "F" or an "f" character to activate free mode.

‡ 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 would also need to be turned off to allow the free flow of data. It should also be noted that if the "+" command is on, the unit will still transmit responses to other command characters. It will also transmit the initialization message, unless that is also toggled off using the "*" command.

The commands "~", "@", "#", "$", '(", ")", "{", "}", "|", "<", ">" 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 or hexadecimal modes because command characters recognized by the system are not produced in those modes.

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 analog outputs can be found on the 12-pin connector. The outputs include:

Signal	Pin	Range	Output Range	0 VDC	Scale Factor
Bank (X Angle)	10	±30°*	±10V	0°	3.0°/V *
Elevation (Y angle)	3	±30°*	±10V	0°	3.0°/V *
Roll Rate (X Axis)	9	±100°/s	±10V	0°/s	10°/s/V
Pitch Rate (Y Axis)	2	±100°/s	±10V	0°/s	10°/s/V

* The Analog output range for Bank & Elevation is menu selectable. This also changes the analog scale factor for Bank & Elevation.

The output range for both Bank and Elevation are menu selectable.

Available Ranges	Output Range	0 VDC	Scale Factor
±30°	±10V	0°	3.0°/V
±45°	±10V	0°	4.5°/V
±60°	±10V	0°	6.0°/V
±90°	±10V	0°	9.0°/V
±180°*	±10V	0°	18°/V

*Maximum Elevation range is ±90°

See Appendix B for more information on selecting Bank and Elevation ranges.

Built in Test Digital Output

Built-In Test is an active low digital output that continuously monitors the internal sensors for faults. This signal is available on pin 5 of the connector. This output is High (3.3VDC) when the unit is operating normally. This output is Low (ground) when a fault is indicated. The BIT Test Flag of the Flag channel gives a similar indication. Flag reset is normal operation; Flag Set is a fault condition. The BIT status byte that is available as part of the output message will give more information on the fault conditions.

Specifications

Attitude			
	Range: Bank	±180° (±30° †)	Digital (Analog)
	Range: Elevation	±90° (±30° †)	Digital (Analog)
	Resolution:	0.02°	Binary mode (14 bit)
	Analog Scale Factor:	3°/V †	±10V Output
	Accuracy: Static	±0.5°	(up to 75°)
*	Accuracy: Dynamic	0.5%	
Angular Rate			
	Range: Roll, Pitch	±100°/sec	
	Resolution:	0.025°/sec	Binary mode (14 bit)
	Analog Scale Factor:	10°/sec/V	±10V Output
	Scale Factor Accuracy:	0.5%	
	Bias: Roll, Pitch	< 0.3°/sec	±0.02°/sec Binary mode (14 bit)
	Non-Linearity:	< 0.2%	Full scale range
	Bandwidth:	50 Hz	
	Noise:	< 0.06°/sec rms	
Acceleration			
	Range: X, Y, Z	±10g	
	Resolution:	4mg	
	Scale Factor Accuracy:	1%	
	Bias:	< 10mg	
	Non-Linearity:	0.5%	Full scale range
	Bandwidth:	3 Hz	
Environmental			
	Temperature: Operating	-40°C to +85°C	
	Temperature: Storage	-55°C to +85°C	
	Vibration: Operating	5g rms	20 Hz to 2 KHz
	Vibration: Survival	10g rms	20 Hz to 2 KHz
	Shock: Survival	500g	1mS ½ sine wave
Electrical			
	Frame Rate:	250 Hz	Maximum
	Startup Time: Data	5 sec	
	Startup Time: Fully operational	10 sec	
	Input Power: Positive	12 to 16VDC	0.7W
	Input Power: Negative	-12 to -16VDC	0.3W
	Input Current:	40mA @ ±15VDC	
	Digital Output:	RS-232	
	Analog Output:	±10VDC	
	Analog Output Impedance:	300 Ohm	Per line
Physical			
	Axis Alignment:	< 0.25°	
	Size: Including Mounting Flanges	1.2"W x 2.8"L x 1.35"H	3.0 x 7.1 x 3.4 (cm)
	Weight:	2.1 oz	60 grams
	Connection:	Amp 4-794627-2 (12 pin)	Mating Connector Incl.

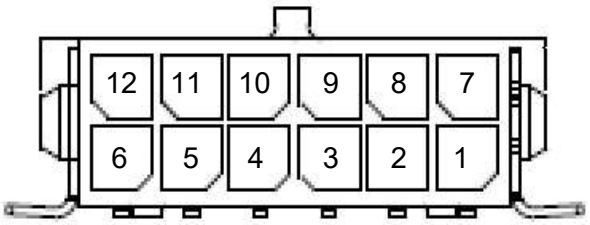
* Actual accuracy can be calculated as the listed percentage multiplied by the change in value over the entire dynamic maneuver.

† The Analog output range for Bank & Elevation is menu selectable. This also changes the analog scale factor for Bank & Elevation.

Specifications are subject to change without notice.

This product may be subject to export restrictions. Export Classification ECCN 7A994.

Connections



12 Pin Connector

Pin	Description
1	RS-232 TXD
2	Y Angular Rate Analog Output
3	Elevation (Y) Angle Analog Output
4	-15 VDC Power In
5	Built in Test (BIT) Output
6	Power Ground
7	RS-232 RXD
8	Signal Ground
9	X Angular Rate Analog Output
10	Bank (X) Angle Analog Output
11	Factory use (Do not Connect)
12	+15 VDC Power In

The RS-232 serial and analog output connections are referenced to Signal Ground on pin 8. The power ground is already connected internally to the signal ground.

The mating connector is made by Amp-Tyco Electronics. One mating connector is included with each sensor. Each connector consists of two parts: the connector receptacle and the receptacle contacts (Qty 12). Additional connectors may be purchased from Amp-Tyco Electronics or electronics vendors such as Digikey and Mouser.

Connector Receptacle Housing:

Vendor	Part Number
AMP-Tyco	1-794617-2
Digikey	A30298-ND
Mouser	571-1794617-2

26-30 AWG Contacts (Qty 12):

Vendor	Part Number
AMP-Tyco	1-794611-2
Digikey	A33279-ND
Mouser	571-1-794611-2

Dimensions

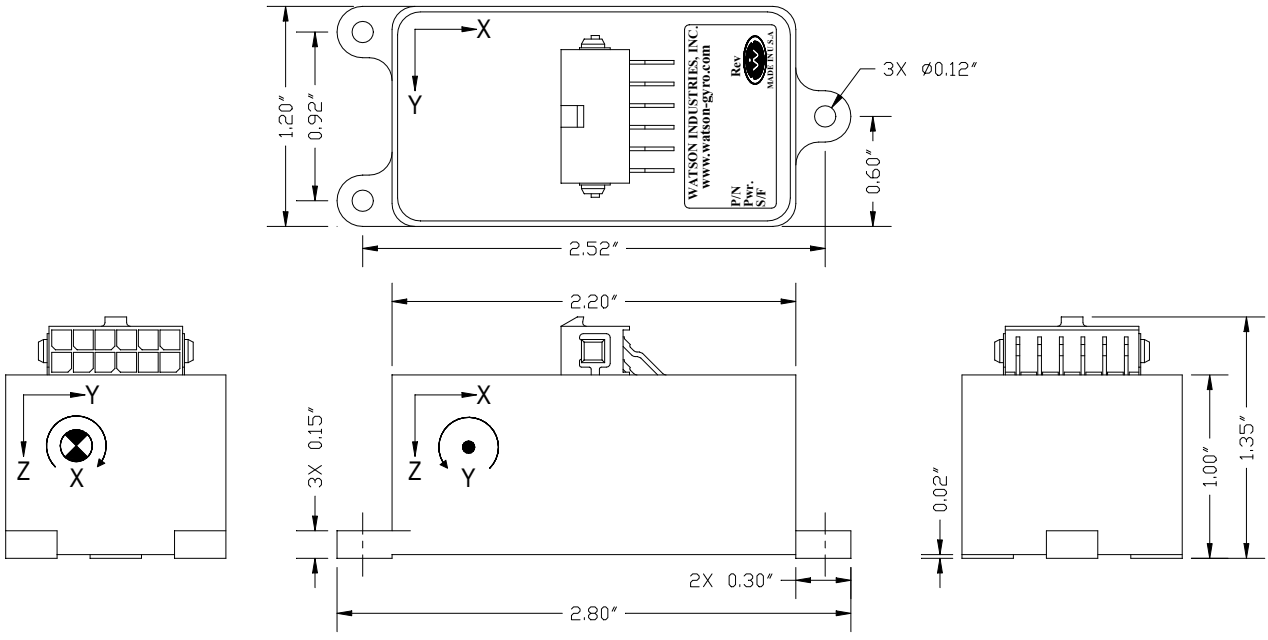


Figure 2 – ADS Dimensions

WARNING

Rough handling or dropping of this unit is likely to cause damage. Over-voltage and/or miswiring of this unit will cause damage. 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	16383
Bank	BK	±179.9º	±180º
Elevation	EL	±89.9º	±180º
X Acceleration	XA	±9.99 g	±10 g
Y Acceleration	YA	±9.99 g	±10 g
Z Acceleration	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
Bank Pendulum (simulated)	XI	±179.9º	±180º
Elevation Pendulum (simulated)	YI	±89.9º	±180º
Temperature	TP	-40º to 88ºC	-40º to 88ºC (7 bit)
Flag Bits	FL	3 ASCII chars representing Octal digits	1 byte
Status Bits	ST	3 ASCII chars representing Octal digits	1 byte
Built In Test (BIT) Status Bits	BT	3 ASCII chars representing Octal digits	1 byte

The Flag Bits contain the following information:

Bit	Description (If Set)
0	Bank Error Flag
1	Elevation Error Flag
2	Unit Temp Out of Range Flag
3	BIT Test Flag
4	X Rate Out of Range Flag
5	Y Rate Out of Range Flag
6	Checksum Error Flag
7	Unused

Example: The Flag channel output in ASCII Decimal is “042”

Octal Digit	0		4			2		
Binary Equivalent	0	0	1	0	0	0	1	0
Flag 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	X Rate Out Range (>140 º/s)
Bit 4	Reset	Y Rate in Range
Bit 3	Reset	No BIT Error
Bit 2	Reset	Unit Temp in Range (-40º to +85º C)
Bit 1	Set	Elevation Error
Bit 0	Reset	No Bank Error

The Status Bits contain the following information:

Bit	Description
0 to 2	Show the current system time constant, using the following equation: $TC=2^{(\text{Flag Value} + 1)}$
3	If set, Reference Command selected
4	If set, Unit is in Initialization
5	If set, Free Mode selected
6	If set, Command Mode is Selected
7	Unused

Example: The Status channel output in ASCII Decimal is “112

Octal Digit	1		1			2		
Binary Equivalent	0	1	0	0	1	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	Command mode active
Bit 5	Set	Not in Reference mode
Bit 4	Reset	Not in Initialization
Bit 3	Set	Free mode active
Bit 2		
Bit 1	2	The Current System Time Constant = $2^{(\text{Flag Value}+1)}$
Bit 0		$=2^{(2+1)} = 2^{(3)} = 8$ seconds

The Built In Test (BIT) Status Bits contain the following information:

Bit	Description
0	If set, X Accelerometer Sensor Failure
1	If set, Y Accelerometer Sensor Failure
2	If set, Z Accelerometer Sensor Failure
3	If set, Sensor Temperature out of range
4	If set, X Angular Rate Sensor Failure
5	If set, X Angular Rate Sensor Failure
6	Unused
7	Unused

Example: The BIT Test channel output in ASCII Decimal is “042”

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

This translates into the information below:

Bit 7	Reset	
Bit 6	Reset	
Bit 5	Set	X Rate Sensor Failure
Bit 4	Reset	No Y Rate Sensor Failure
Bit 3	Reset	Temp Sensor in range
Bit 2	Reset	No Z Accelerometer Failure
Bit 1	Set	Y Accelerometer Failure
Bit 0	Reset	No X Accelerometer Failure

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) Typing '&' 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
  4 = SELECT ANALOG ATTITUDE FULL SCALE RANGE
  5 = SET NEW BAUD RATE
```

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 TIME SINCE RESET?
```

5) Type 'Y' to output the channel, type 'N' to remove the channel.
   After the last 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’ with start the command 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.

Adjusting Time Constants

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 ‘1’ to set up channel.

These settings can dramatically change the operation of the sensor and we recommend that any changes be made with the direction of Watson Industries engineering.

Selecting Analog Attitude Full Scale Range

1) Activate Command Mode (See above).
2) To change which channels are output type '&' (this will bring up the main menu again).
3) To update the scale factor for the analog Bank output, type ‘4’ at the main menu.
   This will bring up the menu:

```
SELECT ATTITUDE FOR SCALE FACTOR UPDATE (OR 'Q' TO QUIT):
  1 = ANALOG BANK ANGLE
  2 = ANALOG ELEVATION ANGLE
```

4) To change the Bank Angle setting. type ‘1’ at this menu.
   This will bring up the menu:

```
      THE CURRENT SETTING IN DEG/V IS:  3.0
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
      1 = BANK ANGLE SCALE FACTOR 3.0 DEG/V
      2 = BANK ANGLE SCALE FACTOR 4.5 DEG/V
      3 = BANK ANGLE SCALE FACTOR 6.0 DEG/V
      4 = BANK ANGLE SCALE FACTOR 9.0 DEG/V
      5 = BANK ANGLE SCALE FACTOR 18 DEG/V
```

5) Change the Analog Bank Range to a new setting.

   To change the Bank Angle to Scale Factor 3.0°/V , type ‘1’.
   To change the Bank Angle to Scale Factor 4.5°/V , type ‘2’.
   To change the Bank Angle to Scale Factor 6.0°/V , type ‘3’.
   To change the Bank Angle to Scale Factor 9.0°/V , type ‘4’.
   To change the Bank Angle to Scale Factor 18°/V , type ‘5’.

6) To update the scale factor for the analog Elevation output, type ‘4’ at the main menu. This will bring up the menu:

```
SELECT ATTITUDE FOR SCALE FACTOR UPDATE (OR 'Q' TO QUIT):
      1 = ANALOG BANK ANGLE
      2 = ANALOG ELEVATION ANGLE
```

7) To change the Elevation Angle setting. type ‘2’ at this menu. This will bring up the menu:

```
      THE CURRENT SETTING IN DEG/V IS:  3.0
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
      1 = ELEVATION ANGLE SCALE FACTOR 3.0 DEG/V
      2 = ELEVATION ANGLE SCALE FACTOR 4.5 DEG/V
      3 = ELEVATION ANGLE SCALE FACTOR 6.0 DEG/V
      4 = ELEVATION ANGLE SCALE FACTOR 9.0 DEG/V
      5 = ELEVATION ANGLE SCALE FACTOR 18 DEG/V
```

8) Change the Analog Elevation Range to a new setting.

   To change the Elevation Angle to Scale Factor 3.0°/V , type ‘1’.
   To change the Elevation Angle to Scale Factor 4.5°/V , type ‘2’.
   To change the Elevation Angle to Scale Factor 6.0°/V , type ‘3’.
   To change the Elevation Angle to Scale Factor 9.0°/V , type ‘4’.
   To change the Elevation Angle to Scale Factor 18°/V , type ‘5’.

Setting Baud Rate

1) Activate Command Mode (See above).
2) Type '&'(this will bring up the main menu again).
3) To set new baud rate, type ‘5’.
   This will bring up the menu:

```
TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
(EFFECTIVE IMMEDIATELY - SAVE TO MAKE PERMANENT)
  1 = 38.4 K BAUD
  2 = 19.2 K BAUD
  3 =  9.6 K BAUD
  4 =  4.8 K BAUD
```

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

All of the data words have a high sign bit, but the delimiter byte is an ASCII carriage return character that has a low sign bit. One word per output parameter.

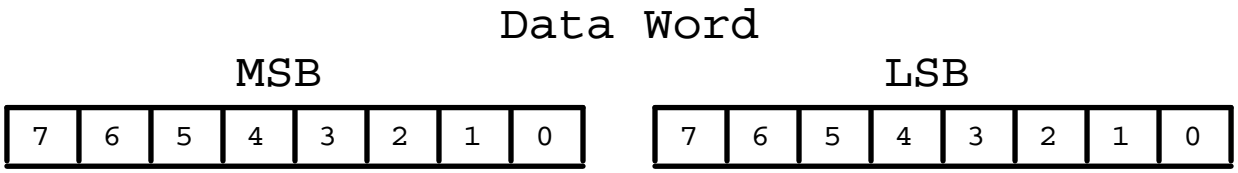
Example: Unit is sending out Bank, Elevation, X Angular Rate, & Y Angular Rate
The Unit is seeing these conditions:

Bank	Elevation	X Rate	Y Rate
15.0˚	-5.0˚	10.2˚/s	-3.1˚/s

Binary Output Format:

Word1	Word2	Word3	Word4	<CR> byte
0x85AA	0xFE9C	0x83A1	0xFF81	0x0D

The Carriage return byte is the only byte which has a value less than 128 (0x80). This is the Synchronizing Byte.



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 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 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	X Rate	Y Rate
0x85AA	0xFE9C	0x83A1	0xFF81

Split each word into two bytes:

Bank	Elevation	X Rate	Y Rate
0x85 0xAA	0xFE 0x9C	0x83 0xA1	0xFF 0x81

Remove the most significant bit from each byte:

Bank	Elevation	X Rate	Y Rate
0x05 0x2A	0x7E 0x1C	0x03 0x21	0x7F 0x01

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

Bank	Elevation	X Rate	Y Rate
0x05 0x54	0x7E 0x38	0x03 0x42	0x7F 0x02

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

Bank	Elevation	X Rate	Y Rate
0x0A 0xA8	0xFC 0x70	0x06 0x84	0xFE 0x04

Convert from hexadecimal to decimal counts:

Bank	Elevation	X Rate	Y Rate
2728	64624	1668	65028

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

Bank	Elevation	X Rate	Y Rate
2728	-912	1668	-508

Multiply the data (in counts) by the scale factor
Convert to units: counts * scale factor
For Bank & Elevation: Scale factor is: 180 ˚ / 32768 counts
For Angular Rate: Scale factor is: (200 ˚/s) / 32768 counts

Bank	Elevation	X Rate	Y Rate
14.991 ˚	-5.010 ˚	10.181 ˚/s	-3.100 ˚/s

The nominal interface settings are:

```
9600 Baud
8 Bit Data
1 Start Bit
1 Stop Bit
No Parity
```