

GPS Compass Magnetometer

OWNER'S MANUAL

PART NUMBER: GCM-360



**WATSON INDUSTRIES, INC.
3035 MELBY STREET
EAU CLAIRE, WI 54703**

Phone: (715) 839-0628

Fax: (715) 839-8248

email: support@watson-gyro.com

Table Of Contents

Introduction.....	3
Product Description	3
Installation	3
Orientation	3
Mounting.....	3
GPS Antenna Mounting.....	4
Figure 1 Antenna Spacing.....	4
Environment.....	4
Power / Connectors.....	4
Theory of Operation	5
Operation	7
Initialization	7
Normal Operation	7
Special Operation Modes	8
Reference Mode.....	8
Interface	8
RS-232 Output Format.....	8
RS-232 Input Commands.....	10
Specifications.....	12
Connections	13
Dimensions	14
Figure 5 GCM-360.....	14
Figure 6 GPS Antenna Dimensions	15
Warning	16
Customer Service.....	17
Appendix A.....	18
Appendix B	20
Activating Command Mode (Double Spacebar Mode).....	20
Accessing the Main Menu.....	20
Appendix B.1 Set Output Channels.....	20
Appendix B.2 List Output Channels	21
Appendix B.3 Setting Antenna Spacing.....	21
Appendix B.4 Set Baud Rate.....	21

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 200g '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

The GPS compass magnetometer provides heading, GPS coordinates and sensor information. It uses a 3-axis fluxgate magnetometer, a triaxial accelerometer and a microprocessor. This sensor is also equipped with a dual GPS antenna system that provides heading data even when the vehicle is not in motion. The unit measures the Earth's Magnetic Field with a precision 3-axis fluxgate magnetometer and uses tilt information (bank and elevation) from three accelerometers for coordinate transformations. The heading information is susceptible to disturbance by acceleration since the angle sensors are sensitive to dynamic accelerations. This unit will output several data items including GPS true north heading, magnetic heading, GPS latitude, GPS longitude, X axis magnetic field, Y axis magnetic field, Z axis magnetic field and GPS UTC time. The unit will also output GPS magnetic variation (which is the angle from magnetic north to true north – positive in clockwise easterly direction).

Product Description

Watson Industries GCM-360 uses solid-state fluxgate magnetometer and silicon accelerometers. Interface to the microprocessor is done through a 16-bit A/D converter. There are no physical adjustments required by the user. All of the primary transducers are locked into position during manufacture. Adjustments are made with the aid of PC-based maintenance software, which communicates with the GCM-360 via the RS-232 serial connection. Calibration is achieved by using the maintenance software to store data in non-volatile memory within the GCM-360.

The GCM has an internal GPS module and two external GPS antennas. This allows the GCM to output GPS True North heading along with magnetic heading. The GPS receiver also provides velocity data that is available for serial output. This unit outputs GPS Latitude & Longitude based on the position of the aft antenna.

Installation

Orientation

The base plate of the unit is to be mounted on top of a horizontal surface with the connector toward the forward direction of the vehicle. The GCM drawing, with wire call outs, is located in Table 2. The "Fore" antenna must be placed ahead of the "Aft" Antenna on a line parallel to the axis of forward motion. The appropriate distance between the antennas is defined by the antenna spacing (see Figure 1).

Mounting

The unit has four 0.15" diameter mounting holes (clearance for 6-32 screws). Please use non-magnetic mounting hardware. The unit may be adhesively mounted at any of its surfaces. If high shock loads are expected (greater than 20G or repeated shocks greater than 10G), the appropriate

shock mounting should be used to prevent damage. Vibration isolation should be added when operated in 4G rms or greater vibration environments.

GPS Antenna Mounting

The GPS antennas have magnetic mounts two M 2.6 mounting holes (See Figure 6) and need an unobstructed view of the sky to receive signals from GPS satellites. Both antennas need a minimum 6" x 6" ground plane. Nothing between or around the antennas can be higher than these ground planes.

Antenna spacing is directly related to the GPS heading accuracy. The antennas must be placed within 1 cm of the spacing selected to maintain accuracy. The "Fore" antenna is placed ahead of the "Aft" Antenna on a line parallel to the axis of the vehicle. This sensor allows antenna spacing (in millimeters) from 0.3m up to 5m (See Appendix B). The larger the spacing, the more accurate the GPS heading output will be. Unfortunately, with larger spacing values there is also an increased risk of signal reflections between GPS antennas that can degrade accuracy.

Please Note: Adjustable antenna spacing was implemented for GCM-360 sensors Rev B and later. Earlier models require a fixed value for spacing that is set at the factory.

GPS Antenna Spacing (meters)	GPS Heading: Accuracy: Static
0.5m *	0.5° rms
1.0m	0.25° rms
2.0m	0.13° rms
5.0m	0.07° rms

* Factory Default setting (as shipped)

Figure 1 Antenna Spacing

Caution: The GPS heading accuracy is directly related to the accuracy of the antenna placement and GCM alignment. Antenna placement must be within 1 cm of the chosen spacing for accuracy.

Environment

Avoid mounting sites that are subject to significant temperature variation over the duration of the test.

Watson Industries provides brass connectors with the device. Ideally, the unit should be installed at least 4" 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 / Connectors

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 consumption of the unit is about 5.3 Watts. 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. The GCM power system is isolated from the GCM signal system.

Note: The signal ground is connected to case.

The SMA GPS antenna connectors are on the front of the case. This type of connector should be torqued to a maximum of 5 in-lbs. The GPS Antennas are supplied with +5 VDC, less than 40mA each. The minimum gain requirement for these antennas is 20 dB. For more information on the connectors and pinout of the GCM-360 see Table 2.

Theory of Operation

The Earth's Magnetic Field can be described as a Vector T located in the horizontal geographic coordinate system $O\xi\zeta\eta$ (See Figure 2).

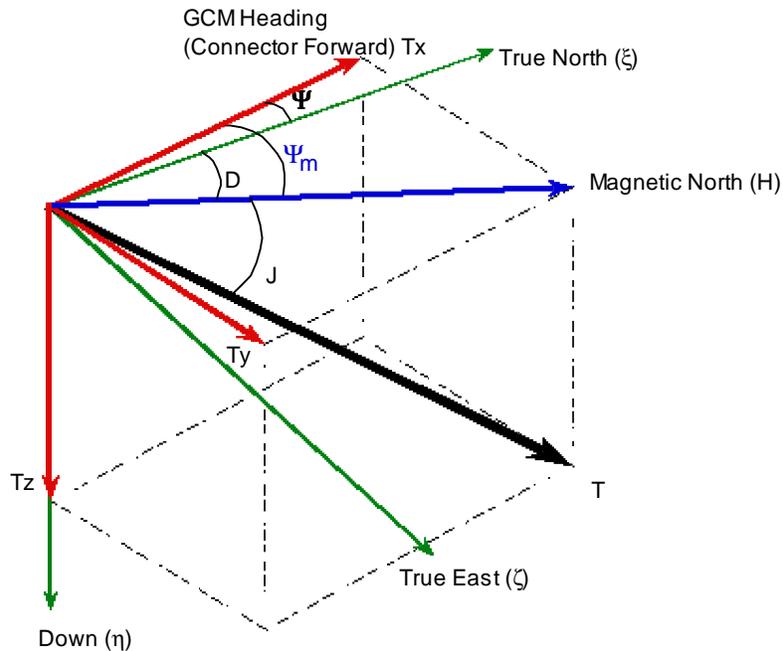


Figure 2

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_y are coordinate transformed to the horizontal system for Fluxgate Magnetometer measurement. To calculate D, the GCM 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 GCM 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 magnetic heading of the GCM 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 3. These same axes are related in Figure 4 to earth coordinates.

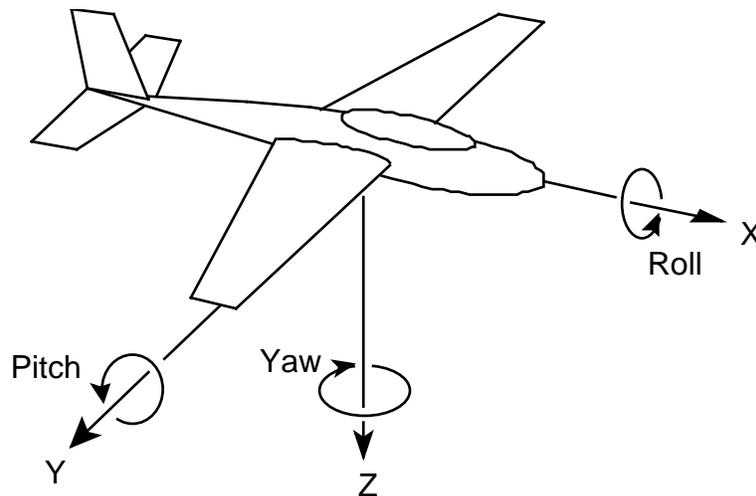


Figure 3. Body Axis Definitions.

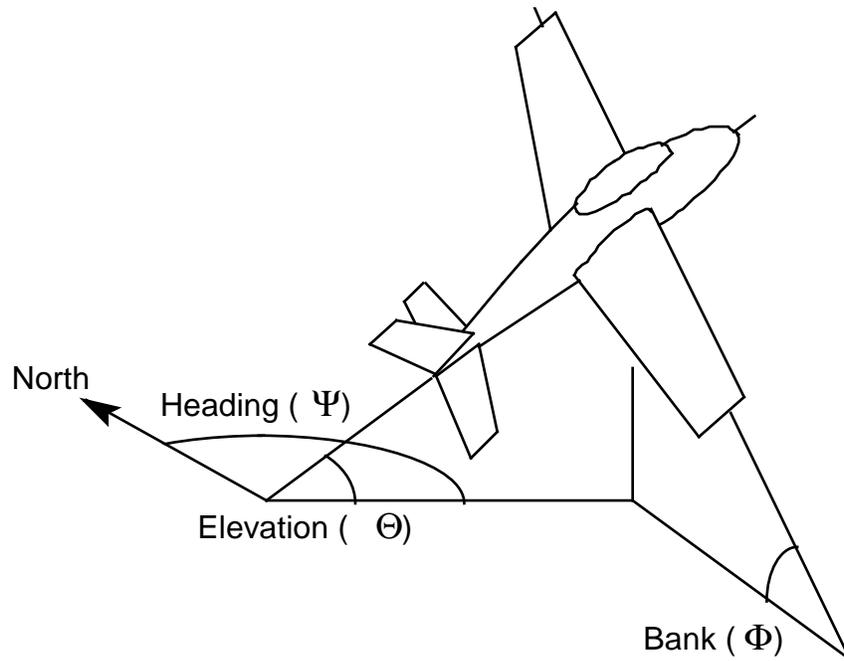


Figure 4. Earth Referenced Axis Definitions.

Operation

Initialization

During this time, a message is sent from the unit via the RS-232 serial link. This message gives information about the GCM such as the full model number, serial number, and firmware revision. The message can be read by using a terminal program or by using the terminal mode of Watson Industries' communication software.

The GCM can also be “re-initialized” after it has been turned on. There are several ways to re-initialize the GCM. For more information, see the Interface section of this manual.

Normal Operation

During normal operation, the GCM will output highly accurate data for the user to interpret. This data is transmitted in several different ways. The most common way to acquire data from the GCM 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 GCM generates fourteen different data items for output: X, Y, and Z accelerations; Bank, Elevation, and Magnetic Heading; GPS True Heading, Magnetic Variation, and Ground Track Heading; X, Y, and Z magnetometers; Latitude and Longitude. Any combination of these data items can be selected for transmission via the RS-232 serial link.

In normal operation, the GCM takes data from its internal sensors to generate 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.

Special Operation Modes

Reference Mode

This mode is usually used for factory calibration or diagnostics. When in reference mode, the GCM will output data generated directly from the sensor reference. This mode is not recommended for normal use. This mode provides sensor information similar to normal operation mode with the following differences:

Magnetic Heading output is directly from the raw Magnetic data (Heading is not leveled).
X, Y and Z Accelerometer outputs are directly from raw Accelerometer data (not dynamically corrected).

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

Interface

RS-232 Output Format

The standard 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 mating connector for the RS-232 is a 9 Pin Male D-Sub. 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 284.44 strings per second. See Appendix B for information on how to change the data string. 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 nine character string representing the GPS Universal Time (UTC) starting with six digits, a decimal point, one digit and a space for up to 235959.9 Hours minutes seconds tenth seconds (HHMMSS.S). Note: The field is filled with asterisks when the data is invalid. (“*****.*)”))
3. A six character string representing the Magnetic Heading angle with three digits, a decimal point, one digit and a space for zero to 359.9 degrees.
4. A six character string representing the GPS True North Heading angle with three digits, a decimal point, one digit and a space for zero to 359.9 degrees. The field is filled with asterisks when the data is invalid. (“***.*)”))
5. A seven character string representing the GPS Magnetic Variation starting with a “+” or a “-“, followed by three digits, a decimal point, one digit and a space for up to ± 179.9 degrees. The field is filled with asterisks when the data is invalid. ((+***.*)”))
6. A five character string representing the X Axis Magnetometer starting with a “+” or a “-“, followed by three digits and a space for up to ± 999 mGauss.

7. A five character string representing the Y Axis Magnetometer starting with a “+” or a “-“, followed by three digits and a space for up to ± 999 mGauss.
8. A five character string representing the Z Axis Magnetometer starting with a “+” or a “-“, followed by three digits and a space for up to ± 999 mGauss.
9. A ten character string representing the GPS Latitude starting with a “+” or a “-“, followed by two digits, a decimal point, five digits and a space for up to ± 89.99999 degrees. Note: The field is filled with asterisks when the data is invalid. (“+**.*”)
10. A eleven character string representing the GPS Longitude starting with a “+” or a “-“, followed by three digits, a decimal point, five digits and a space for up to ± 179.99999 degrees. The field is filled with asterisks when the data is invalid. (“+***.*”)
11. 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	161409.9	271.8	269.4	-001.1	-001	+181	+568	+44.86405	-091.46836	<CR>
↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
(1)	UTC	Magnetic Heading (3)	True North Heading (4)	Magnetic Variation (5)	X Mag (6)	Y Mag (7)	Z Mag (8)	Latitude (9)	Longitude (10)	(11)
space	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). 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.

A text header that is sent by the GCM during initialization 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 as a default) suppressed or restored by a “*” command from the interfacing computer.

Data transmission sent by the GCM can also be suppressed or restored by a “+” command from the interfacing computer.

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 format. In this format, there are nominally 23 words sent that represent 7 fourteen bit and 2 twenty-eight 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 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. 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):

1. An “R” or “r” will set the outputs to their Reference Command modes replacing the Inertial mode. This mode is used for factory calibration or diagnostics. Command mode is required for access to this command.
2. An “T” or “t” sets the unit to Inertial. 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 “!” will reinitialize the unit. As a precaution, access to initialization is inhibited. A spacebar command must be sent within about 2 seconds of the “!” command for initialization to occur. This command does not require command mode to be in effect.
4. 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.
5. 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.
6. 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.

7. 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.

8. The “&” command calls a menu which allows any of several parameters to be set. From this menu, the user can change data channels for serial output, GPS antenna spacing, and baud rate. Command mode is required for access to this command.
9. 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.

These and other changes are made nonvolatile in the unit on EEPROM by keying in the quote (“) character.

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.

Specifications

Attitude

Range: Bank	±180°	
Range: Elevation	±90°	
Resolution:	0.02°	Binary mode (14 bit)
Accuracy: Static	±0.5°	

Magnetic Heading

Range:	0° - 360°	
Resolution:	0.02°	Binary mode (14 bit)
* Accuracy: Static	±1.5°	Dependant on Magnetic Latitude

GPS Heading

Range:	0° - 360°	
Resolution:	0.02°	Binary mode (14 bit)
Accuracy: Static	±0.5°	Using GPS (0.5 m antenna spacing)

Acceleration

Range: X, Y, Z	±10 g	
Resolution:	4 mg	
Scale Factor Accuracy:	1%	
Bias: X, Y, Z	< 10 mg	
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: X, Y, Z	< 5 mGauss	
Non-Linearity:	< 0.01%	Full scale range
Bandwidth:	10 Hz	

GPS Positioning

Range: Latitude	±90°	
Range: Longitude	±180°	
Resolution: Latitude, Longitude	0.0000013°	Binary mode (28 bit)
Accuracy: Latitude, Longitude	±0.6 m (with DGPS)	±2.5 m (without DGPS)

Environmental

Temperature: Operating	-30°C to +70°C	
Temperature: Storage	-40°C to +85°C	
Vibration: Operating	5 g rms	20 Hz to 2 KHz
Vibration: Survival	10 g rms	20 Hz to 2 KHz
Shock: Survival	500g	10mS ½ sine wave

Electrical

Frame Rate:	284.44 Hz	Maximum
Startup Time: Data	5 sec	
† Startup Time: Satellite Acquisition	5 min	Typical
Input Power:	10 to 35 VDC	5.3 W
Input Current:	420 mA @ 12 VDC	220 mA @ 24 VDC
Digital Output:	RS-232	

Physical

Axis Alignment:	< 0.25°	
Size: Including Mounting Flanges	3.24"W x 5.78"L x 3.50"H	8.2 x 14.7 x 8.9 (cm)
Weight:	30 oz (1.9lb)	850 grams (0.9Kg)
Connection: RS-232	9 pin female "D" subminiature	
Connection: Power	9 pin male "D" subminiature	
Connection: Antenna (Qty 2)	SMA	Antenna cable length: 3.0 m

* Static heading accuracy is dependent on the magnetic environment.

This sensor will meet or exceed this spec within the 48 contiguous United States.

† Acquisition time for GPS units is typical for the contiguous United States. Acquisition time may differ due to interference in your geographic area.

- Specifications are subject to change without notice.
- This product may be subject to export restrictions. Please consult the factory.

Connections

9 –Pin Male Power Connector

Pin	Description
1	Power Ground
2	+ 12 or + 24 VDC
3 - 5	No Connection
6	Factory use (Do not Connect)
7 - 8	No Connection
9	Signal Ground

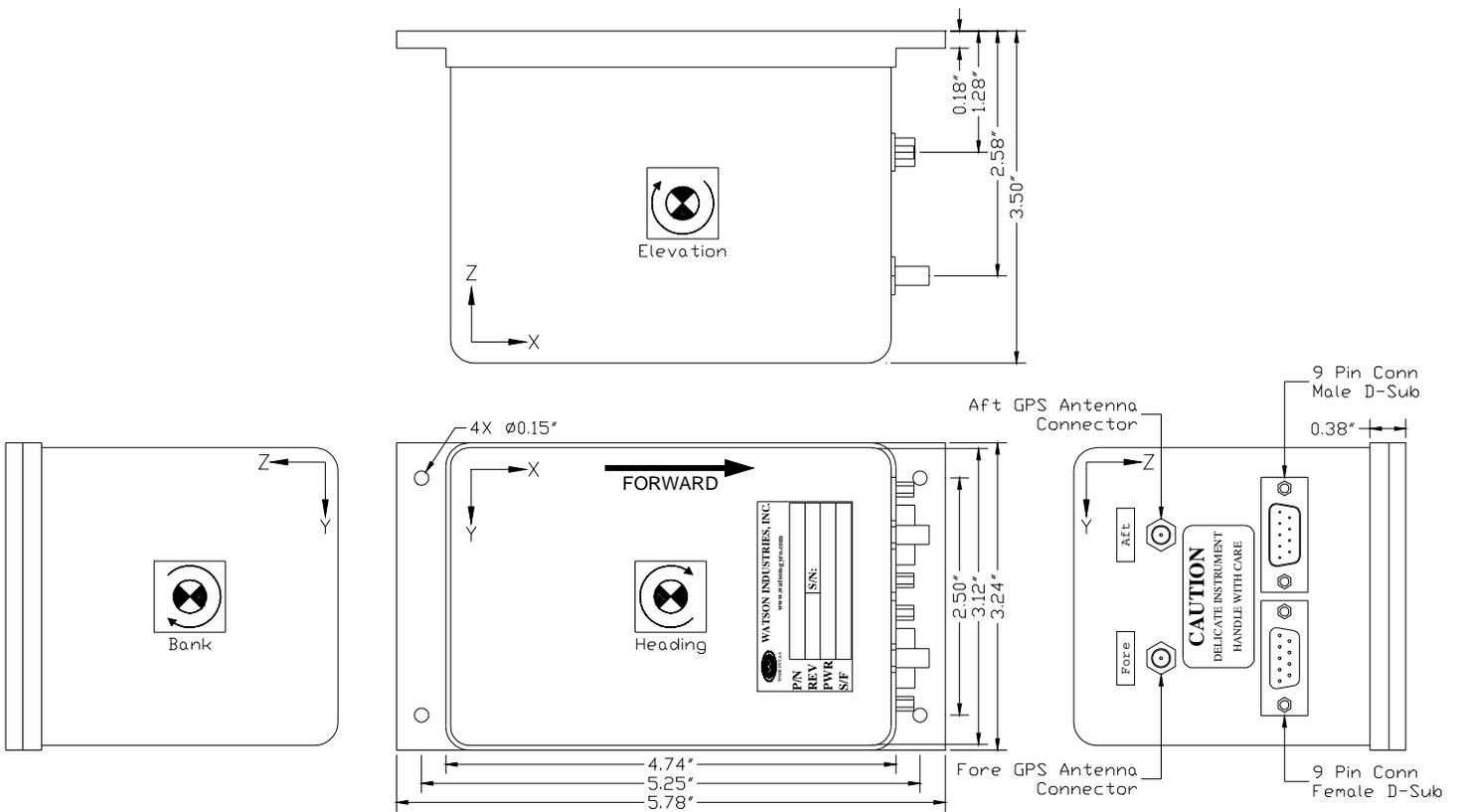
9 –Pin Female RS-232 Connector

Pin	Description
1	No Connection
2	TXD*
3	RXD
4	Shorted to pin 6
5	Signal Ground
6	Shorted to pin 4
7	Shorted to pin 8
8	Shorted to pin 7
9	+5V Power **

* User Receives data on this line

** Power for optional wireless (Bluetooth) adapter

Table 2. Pin Out



Dimensions

Figure 5 GCM-360

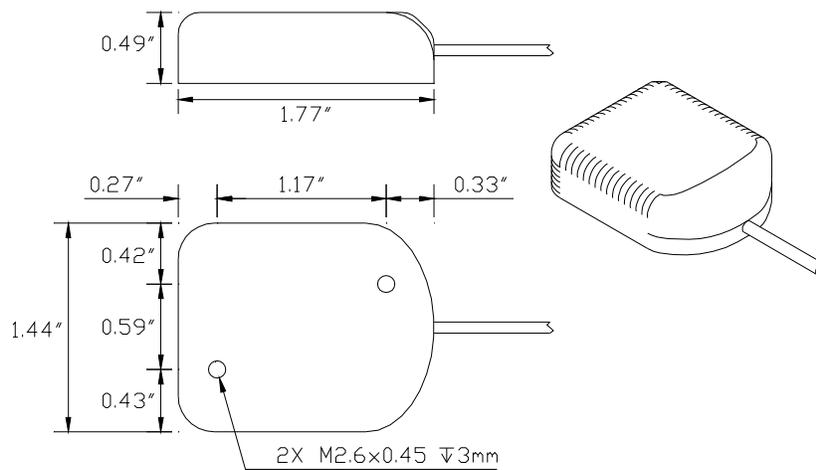


Figure 6 GPS Antenna Dimensions

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 two full years 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 two full years 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.

<u>Inertial Output</u>	<u>Label</u>	<u>Full Scale Decimal</u>	<u>Full Scale Binary</u>
Time	TM	UTC ¹ HHMMSS.S	Seconds Since Reset 16,383 seconds
Bank Angle	BK	±179.9°	±180°
Elevation Angle	EL	±89.9°	±180°
Magnetic Heading Angle	MH	0.0 to 359.9°	0 to 360°
GPS True North Heading ²	TH	0.0 to 359.9°	0 to 360°
GPS Magnetic Variation ³	MV	±179.9°	±180°
GPS Ground Track Heading ⁴	GH	0.0 to 359.9°	0 to 360°
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 Magnetometer	XM	±999mGauss	±1000 mGauss
Y Magnetometer	YM	±999mGauss	±1000 mGauss
Z Magnetometer	ZM	±999mGauss	±1000 mGauss
Bank Pendulum (simulated)	XI	±179.9°	±180°
Elevation Pendulum (simulated)	YI	±89.9°	±180°
GPS Ground Track Velocity ⁵	VG	±399.9 Km/hr	±400 Km/hr
GPS Latitude ⁶	LT	±89.99999	±90° (4 bytes)
GPS Longitude ⁶	LN	±179.99999	±180° (4 bytes)
Temperature	TP	-40° to 88°C	-40° to 88°C (7 bit)
Status Bits	ST	3 ASCII chars representing Octal digits	1 byte
Flag Bits	FL	3 ASCII chars representing Octal digits	1 byte

Note: Certain channels use GPS data, which at times may be invalid. The behavior may also differ depending on whether the sensor is transmitting data in ASCII decimal or binary mode. The table below shows how each channel behaves in the event of invalid GPS data.

Channel	Output Format	
	ASCII Decimal	Binary
¹ GPS universal time (UTC)	Filled with asterisks "*****.*"	Normal operation (Seconds since reset)
² GPS True North Heading	Filled with asterisks "****.*"	Binary data (Zero)
³ GPS Magnetic Variation	Filled with asterisks "+****.*"	Binary data (Zero)
⁴ GPS Ground Track Heading	Filled with asterisks "****.*"	Binary data (Zero)
⁵ GPS Ground Track Velocity	Filled with asterisks "+****.*"	Binary data (Zero)
⁶ GPS Latitude & Longitude	Filled with asterisks "+**.* ***** +**.* *****"	Binary data (Zero) for each data item

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 Over Range Flag
- 5 Reference Command selected
- 6 Checksum Error Flag

Example: The status channel output in ASCII Decimal is “156”

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

- bit 6 is set - Checksum Error
- bit 5 is set - Unit is in Reference Mode
- bit 4 is reset - Velocity in Range
- bit 3 is set - System Error
- bit 2 is set - Heading Error
- bit 1 is set - Elevation Error
- bit 0 is reset - No Bank Error

The Flag Bits contains the following information:

- Bit Description (If Set)
- 0 Latitude & Longitude Data Loss
- 1 GPS Ground Track Velocity data loss
- 2 GPS Ground Track Heading data loss
- 3 GPS Magnetic Variation Data Loss
- 4 GPS True North Heading data loss
- 5 GPS Universal time (UTC) data loss
- 6 Logic Input Switches disabled

Example: The flag channel output in ASCII Decimal is “123”

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

- bit 6 is set - Logic Input disabled
- bit 5 is reset - valid GPS UTC data
- bit 4 is set - invalid GPS True North Heading data
- bit 3 is reset - valid GPS Magnetic Variation data
- bit 2 is reset - valid GPS Ground Track Heading data
- bit 1 is set - invalid GPS Ground Track Velocity data
- bit 0 is set - invalid GPS Latitude & Longitude data

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.

Accessing the Main Menu

- 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 = SET OUTPUT CHANNELS
- 2 = LIST CURRENT OUTPUT CHANNEL SELECTION
- 3 = SET GPS ANTENNA SPACING
- 4 = SET NEW BAUD RATE

Appendix B.1 Set Output Channels

- 1) To change the output channels, type '1' at the main menu.
This will bring up the following message:

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)

- 2) 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:

DOES YOU WANT OUTPUT OF TIME?

- 3) 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?

- 4) 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 (").

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

Appendix B.2 List Output Channels

- 1) To list the current output channel selection, type '2' at the main menu.
The sensor will show which channels are currently active.

Appendix B.3 Setting Antenna Spacing

- 1) Activate Command Mode (See above).
- 2) Type '&' (this will bring up the main menu again).
- 3) To set a new antenna spacing, type '3'.
This will bring up the menu:

CURRENT SPACING IS: 0.500
ENTER ANTENNA SPACING IN METERS (0.300 to 5.000), Q TO QUIT

- 4) Enter the Antenna Spacing with up to three decimal places.

Note: Input values outside the limit range are rejected (with 'ENTRY EXCEEDS LIMITS - TRY AGAIN' message) and the unit returns to the previous menu.

Appendix B.4 Set Baud Rate

- 1) To change the baud rate at which the sensor communicates, type '4' at the main menu.
This will bring up the menu:

TYPE IN THE NUMBER OF YOUR SELECTION (OR 'Q' TO QUIT):
(EFFECTIVE NEXT POWER-UP)

1 = 38.4 K BAUD

2 = 19.2 K BAUD

3 = 9.6 K BAUD

4 = 4.8 K BAUD

2) 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.

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

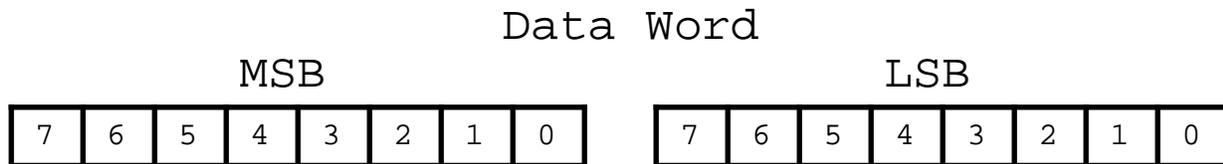
Example 1: The Unit is seeing these conditions:

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
15 seconds	313.2°	315.0°	-001.1°

Binary output Format:

Word1	Word2	Word3	Word3	<CR> byte
0x808F	0xEFB0	0xEFDC	0xFFCD	0x0D

Word 1 is the 2 byte Time Since Reset
 Word 2 is the 2 byte Magnetic Heading
 Word 3 is the 2 byte True North Heading
 Word 4 is the 2 byte Magnetic Variation



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 7th bit (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 7th bit (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:

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
0x808F	0xEFB1	0xEFDC	0xFFCD

Need split each word into two bytes:

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
0x80	0xEF	0xEF	0xFF
0x8F	0xB0	0xDC	0xCD

Remove the most significant bit from each byte:

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
0x00	0x6F	0x6F	0x7F
0x0F	0x30	0x5C	0x4D

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

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
0x00	0x6F	0x6F	0x7F
0x1E	0x60	0xB8	0x9A

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

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
0x00	0xDE	0xDF	0xFF
0x3C	0xC0	0x70	0x34

Convert from hexadecimal to decimal counts:

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
60	57024	57200	65332

Correct Magnetic Variation for the sign
If >32767 then subtract 65536 from the data

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
60	57024	57200	-204

Convert to units: counts x scale factor

- For Time Since reset: Scale factor is 16384/65526 counts
- For bank & elevation: Scale factor is: 180 ° / 32768 counts
- For Heading: Scale factor is: 360 ° / 65536 counts
- Magnetic Variation: Scale factor is: 180 ° / 32768 counts
- For Accelerations: Scale factor is 1.000g / 32768 counts
- For Magnetometer: Scale factor is 1000mg / 32768 counts

Time Since Reset	Magnetic Heading	True North Heading	Magnetic Variation
15	313.24°	314.21°	-1.12°

Example 2: The Unit is seeing these conditions:

X Mag	Y Mag	Z Mag	Latitude	Longitude
-002 mGauss	+314 mGauss	+567 mGauss	44.86403° equivalent to 4451.84233 N	-91.46668° equivalent to 09126.00199 W

Binary output Format:

Word1	Word2	Word3	Word4	Word5	Word6	Word7	<CR> byte
0xFFFF2	0x998F	0xA4A4	0x8FF9	0xE7F7	0xDFBD	0x9FF9	0x0D

Word 1 is the 2 byte X Magnetometer
 Word 2 is the 2 byte Y Magnetometer
 Word 3 is the 2 byte Z Magnetometer
 Word 4 & 5 form the 4 byte Latitude
 Word 6 & 7 form the 4 byte Longitude

Data Word



For two byte (1 word) data:

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 7th bit (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 7th bit (always set to 1). What remains is a signed fractional word with a resolution of 13 bits plus a sign bit.

For four byte (2 words – 1 long word) data:

Bit 7 of the High Byte is set to 1. Bits 6 to 0 of the High Byte are the upper 7 bits of the data. (sign plus 6 bits of data). Bit 7 of the 2nd Byte is set to 1. Bits 6 to 0 of the 2nd Byte are the next 7 bits of the data. Bit 7 of the 3rd Byte is set to 1. Bits 6 to 0 of the 3rd Byte are the next 7 bits of the 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 7th bit (always set to 1). The 3rd byte is then connected to the LSB as the lower 16 bit word. This word is then shifted left to shift out the 7th bit (always set to 1). The 2nd byte is connected to the lower word. These 3 bytes are then shifted left to shift out the 7th bit (always set to 1). The MSB is then connected to the 3 lower bytes as a 32 bit long word. This long word is then shifted left to shift out the 7th bit (always set to 1). What remains is a signed fractional long word (32 bits) with a resolution of 27 bits plus a sign bit.

To convert binary data:

X Mag	Y Mag	Z Mag	Latitude		Longitude	
0xFFFF2	0x948F	0xA4A4	0x8FF9	0xE7F7	0xDFBD	0x9FF9

Split each word into two

bytes:

X Mag	Y Mag	Z Mag	Latitude		Longitude	
0xFF	0x94	0xA4	0x8F	0xE7	0xDF	0x9F
0xF2	0x8F	0xA4	0xF9	0xF7	0xBD	0xF9

Remove the most significant bit from each byte:

X Mag	Y Mag	Z Mag	Latitude		Longitude	
0x7F	0x14	0x24	0x0F	0x67	0x5F	0x1F
0x72	0x0F	0x24	0x79	0x77	0x3D	0x79

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

X Mag	Y Mag	Z Mag	Latitude	Longitude
0x7F	0x14	0x24	0x0F	0x5F
0xE4	0x1E	0x48	0x79	0x3D
			0x67	0x1F
			0xEE	0xF2

Shift Latitude & Longitude lower two bytes once (to remove 1 bit space in second byte):

X Mag	Y Mag	Z Mag	Latitude	Longitude
0x7F	0x14	0x24	0x0F	0x5F
0xE4	0x1E	0x48	0x79	0x3D
			0xCF	0x3F
			0xDC	0xE4

Shift Latitude & Longitude lower three bytes once (to remove 1 bit space in third byte):

X Mag	Y Mag	Z Mag	Latitude	Longitude
0x7F	0x14	0x24	0x0F	0x5F
0xE4	0x1E	0x48	0xF3	0x7A
			0x9F	0x7F
			0xB8	0xC8

Shift all bytes for each parameter left once (to remove 1 bit space a top of high byte):

X Mag	Y Mag	Z Mag	Latitude	Longitude
0xFF	0x28	0x48	0x1F	0xBE
0xC8	0x3C	0x90	0xE7	0xF4
			0x3F	0xFF
			0x70	0x90

X Mag	Y Mag	Z Mag	Latitude	Longitude
0xFFC8	0x283C	0x4890	0x1FE73F70	0xBEF4FF90

Convert from hexadecimal to decimal counts:

X Mag	Y Mag	Z Mag	Latitude	Longitude
65480	10300	18576	535248752	3203727248

Correct data items for the sign:

X, Y or Z magnetometer:

If $>32767[(2^{15})-1]$ then subtract 65536 (2^{16}) from the data

Latitude & Longitude:

If $>2147483647 [(2^{31})-1]$ then subtract 4294967296 (2^{32}) from the data

X Mag	Y Mag	Z Mag	Latitude	Longitude
-56	10300	18576	535248752	-1091240048

Multiply the data (in counts) by the scale factor

Convert to units: counts * scale factor

For X Mag: Scale factor is 1000 mG / (2^{15}) or 32768 counts = -56 counts * (1000 mG / 2^{15} counts) = -1.71 mG

For Y Mag: Scale factor is 1000 mG / (2^{15}) or 32768 counts = 10300 counts * (1000 mG / 2^{15} counts) = 314.33 mG

For Z Mag: Scale factor is 1000 mG / (2^{15}) or 32768 counts = 18576 counts * (1000 mG / 2^{15} counts) = 566.89 mG

For Latitude: Scale factor is: $180^\circ / 2^{31}$ or 2147483648 counts = 535248752 counts * ($180^\circ / 2^{31}$ counts) = 44.86403°

For Longitude: Scale factor is: $180^\circ / 2^{31}$ or 2147483648 counts = -1091240048 counts * ($180^\circ / 2^{31}$ counts) = -91.46668°

X Mag	Y Mag	Z Mag	Latitude	Longitude
-1.71 mGauss	314.33 mGauss	566.89 mGauss	44.86403°	-91.46668°