DCP Manual **Version 3.1.02**

3DM-GX1®
Data Communications Protocol

MicroStrain® Little Sensors, Big Ideas®

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Overview

This document describes the communications protocol associated with the 3DM-GX1® Gyro Enhanced Orientation Sensor, firmware version 3.1.00 and higher.

RS-232 Communications

The 3DM-GX1® is capable of communicating with a host system using either the RS-232 or RS-485 communications standards. By default, it is set for RS-232. This is typically the most convenient and reliable method for communications between a host computer and a single 3DM-GX1® device (or multiple 3DM-GX1®'s each connected to a separate serial port).

RS-232 Signals Definition

Signal	Name	Direction	Function
TxD	**Transmit Data**	**Host to 3DM-GX1®**	**Asynchronous Serial Data from Host**
RxD	**Receive Data**	**3DM-GX1® to Host**	**Asynchronous Serial Data to Host**
GND	**Signal Ground**	**N/A**	**Signal Ground Reference**

RS-232 Asynchronous Character Format	
Baud Rate	**19.2K / 38.4K (default) / 115.2K**
Parity:	**None**
Data Bits:	**8**
Stop Bits:	**1**

RS-485 Communications

RS-485 communications allows for multiple 3DM-GX1® devices to share the same data transmission bus. This minimizes the wiring required for multiple devices since they can be daisy-chained together. It also allows for cable lengths of up to 4,000 ft. The half duplex nature of the protocol, however, requires additional considerations when structuring the host computer's software since simultaneous communications between multiple devices are not permitted, and the devices cannot transmit and receive simultaneous.

RS-485 Signals Definition

Signal	Name	Direction	Function
A (-)	**N/A**	**Bi-Directional**	**Asynchronous Differential (-)**
B (+)	**N/A**	**Bi-Directional**	**Asynchronous Differential (+)**
GND	**Signal Ground**	**N/A**	**Signal Ground Reference**

RS485 Asynchronous Character Format	
Baud Rate	**19.2K / 38.4K (default) / 115.2K**
Parity:	**1 bit used in MARK/SPACE mode to identify whether the transmitted byte contains a device command/address or data.**
Data Bits:	**8**
Stop Bits:	**1**

The RS-485 Protocol uses the same data packet format as RS232 mode. However, each command byte transmitted by the host must identify itself as a command byte as distinct from all other data bytes. This is accomplished by utilizing a 9-bit "byte" format. The ninth bit (Bit 8), when set to 1, identifies the byte as a command byte. When Bit 8 is set to 0, the byte is identified as a data byte. Command data bytes which follow the command byte for commands 0x09, 0x08 and 0x10 should have their Bit 8 set to 0. All bytes generated by the 3DM-GX1®'s will have Bit 8 set to 0.

Many personal computers (PC) UARTS and even some microcontroller UARTS do not directly support 9 bit serial communications. To circumvent this limitation, the parity bit can be used as the ninth bit. On a PC this is known as MARK/SPACE parity and has nothing to due with the parity of the sent byte. With MARK parity set on a PC UART, a 1 will be transmitted in the parity bit location regardless of the parity of the byte. With SPACE parity set on a PC UART, a 0 will be transmitted in the parity bit location regardless of the parity of the byte. The use of MARK/SPACE parity therefore allows for the setting and clearing of Bit 8 as needed.

Every command byte in RS-485 mode must additionally contain the address of the target 3DM-GX1® on the network. This is accomplished by using bits 0 through 3 to contain the address, and bits 4 through 7 to contain the command. (All commands that are functional for RS-485 mode have values between 0 and 15, and can therefore be fully defined with 4 bits.)

The format of the resulting combined command/address byte is shown below:

Command/Address Byte Format for RS-485 Communications

Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADDR	**CMD3**	**CMD2**	**CMD1**	**CMD0**	**ADR3**	**ADR2**	**ADR1**	**ADR0**

ADDR	Ninth bit which, when set to 1, indicates that the byte is a command/address byte
CMD3:0	4 bits containing the desired command
ADR3:0	4 bits containing the target 3DM-GX1® address

Example: Request Gyro-Stabilized Vectors from a 3DM-GX1® with device address #4

Address = 4
Command = 2

The Command/Address Byte would be:

Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
1	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**

which is 24 hex, or 36 decimal. In addition, Bit 8 must is set to one to identify the byte as a command/address byte. This can be done using 9 bit mode on a microcontroller, or by setting the parity bit to MARK on a PC UARTS.

The 3DM-GX1® will respond by transmitting a data packet as outlined in the Gyro-Stabilized Vectors data packet definition. Each byte of this response will be in 9 bit format with Bit 8 set to 0 to indicate that data and not a command is being transmitted over the network. This allows the other 3DM-GX1® units on the network to ignore the bytes.

Response Byte Format for RS-485 Communications

The Command/Address Byte would be:

Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

where D7-D0 represent the transmitted data and bit 8 is always zero indicating that the byte is not a command/address byte.

Communications Commands

The host computer controls what data the 3DM-GX1® will transmit by issuing one or more single byte commands (in some cases, additional data bytes must follow the command byte). Each command will cause the 3DM-GX1® to transmit a data record of a fixed number of bytes.

There are two modes of communications. In Polled mode (the default), the 3DM-GX1® will transmit a single data record for each command byte it receives. In Continuous mode, a command byte is stored in memory, and the corresponding data record is transmitted continuously by the 3DM-GX1® with no further intervention by the host.

Polled Command Mode (default)

In polled mode, the 3DM-GX1® will transmit a data packet each time a command byte is issued by the host computer. The 3DM-GX1® will not transmit unsolicited data packets. The user may issue a command at any time. The 3DM-GX1® will respond by transmitting the corresponding data packet upon completion of the current calculation cycle. Multiple commands issued by the host will be buffered on-board the 3DM-GX1® up to 15 deep, with one being processed at the completion of each successive calculation cycle.

Continuous Mode (Not functional when using RS-485 communications)

In Continuous mode, a command byte is stored in memory, and the corresponding data record is transmitted continuously by the 3DM-GX1® with no further intervention by the host. To enter continuous mode, the host computer must issue the "Set Continuous Mode" command byte (0x10), followed by a null byte (0x00), followed by another command byte of the user's choosing. The 3DM-GX1® responds by transmitting the corresponding data packet at the completion of every calculation cycle. This provides a stream of data at the maximum possible rate, and at uniformly spaced time intervals (i.e., the calculation cycle time interval) with no gaps. The host computer must be capable of the buffering and interpreting the data stream at sufficient speed to prevent loss of data. For example, if the host issues the 0x10 byte followed 0x00, followed by the 0x04 byte, the 3DM-GX1® will be set into continuous mode and will continuously transmit the "Send Instantaneous Quaternion" data packet.

Once continuous mode is set, it will remain in effect until it is terminated by the host issuing the "Set Continuous Mode" command byte followed by 0x00, followed by the null command byte (0x00). Note that while in continuous mode, the selected data packet to be transmitted at each calculation cycle can be changed at any time by issuing the "Set Continuous Mode", followed by 0x00, followed by the new desired command byte.

Normally, the 3DM-GX1® starts in Polled Mode on power up. In some applications, it may be desirable to have the 3DM-GX1® enter continuous mode immediately on power-up. To accomplish this, the user can set the value of the LSB of EEPROM location 132 to the desired command byte (the MSB of location 132 should be set to 0x00). On subsequent power-ups, the 3DM-GX1® will automatically enter continuous mode with the selected command active. Note that following power-up the user may subsequently turn continuous mode off by issuing the "Set Continuous Mode" byte followed by 0x00. To disable the automatic power-up entry into continuous mode, set the value of EEPROM location 132 to 0x0000.

Continuous command mode is only functional when utilizing RS-232 serial communications. Issuing the "Set Continuous Mode" byte, or setting EEPROM location 132 will have no effect when utilizing RS-485 serial communications.

Combined Continuous and Polled Mode

While in continuous mode, the host computer may still issue individual commands as in polled mode. The responses to these commands will be interleaved with the continuous mode responses. At the completion of each calculation cycle, the 3DM-GX1® first transmits the response to the continuous mode command if continuous mode is active. The 3DM-GX1® then transmits the response to any individual command that has been issued in polled mode. In this case, two data packets will be transmitted (one for the continuous command, and one for the polled command) during the same calculation cycle. The host computer's data interpretation software must be capable of differentiating such data packets.

Whenever a polled command is issued while operating in continuous mode, the calculation cycle in which it is interpreted may be extended beyond its normal duration due to the extra processing required. This is particularly true for the "Capture Bias" command which requires a significant amount of time to execute. Therefore, the continuous data stream may contain irregular time intervals at the points where polled commands were issued. The exact time interval can be determined by examining the "TimerTicks" value that is returned as part of the response to most commands.

Calculation Cycle, and Data Output Rate

The 3DM-GX1®'s on-board processor continuously executes a calculation cycle. The steps in this cycle include the following:

1. Convert raw sensor outputs into digital form
2. Scale sensor outputs into physical units (including temperature, alignment, and G-sensitivity compensation). This provides the Instantaneous Vector quantities.
3. Compute the Gyro-Stabilized Vector quantities using the complementary filtering algorithm.

4. If host has issued a command byte (or if operating in continuous mode), compute appropriate response data and transmit. (e.g., Euler Angles, Matrix, Quaternions, Vectors, etc.)

Step 4 in this cycle is only executed if the 3DM-GX1® has received a command byte from the host (or if the device is in continuous mode).

The calculation cycle continuously repeats itself (even if no data is requested by the host). The time required to complete a calculation cycle determines the fundamental limit on the maximum data output rate. Generally, only one new data record can be generated and transmitted for each calculation cycle.

The duration of each calculation cycle must be an integer multiple of the timer tick interval. By default, the tick interval is 6.5536 milliseconds. The duration of the calculation cycle is affected in part by what data is requested (Euler Angles, for example, require more processing to compute than the Orientation Matrix). For most data records the calculation cycle is two or three tick intervals. This corresponds to maximum data output rates of 76.29 Hz (1/(2*0.0065536 sec)) and 50.86 Hz (1/(3*0.0065536 sec)) respectively.

In some applications, it may be advantageous to modify the timer tick interval. This can be done by modifying the values stored in the four non-volatile memory locations as follows (changes will not take effect until power is cycled):

EEPROM 238	(valid values = 1, 4, 16, default = 16)
EEPROM 240	(valid values = 1 through 16, default = 16)
EEPROM 242	(valid values = 1 through 256, default = 256)
EEPROM 246	(valid values = 1 through 100, default = 1)

The product of these four values gives the timer tick interval in 1e-7 seconds. (Note that if any EEPROM is set to an invalid value, its default value will be utilized instead.) For example, to achieve a 10msec tick interval, set the values as follows:

EEPROM 238 = 4
EEPROM 240 = 10
EEPROM 242 = 250
EEPROM 246 = 10

(i.e., 4*10*250*10*1e-7 = 0.010 seconds)

Once the timer tick interval is set for 10 msec, the device will then be capable of generating output records of up to 100 Hz (one record per calculation cycle). In order to definitively determine the data output rate being achieved, the host system should issue a series of command bytes. The difference in the timer tick values received in the resulting data records will indicate the elapsed time between records. To convert into units of seconds, multiply by the timer tick interval.

Data Quantities Available

The 3DM-GX1® is capable of calculating and reporting data of various types. These can be accessed by selecting and sending the appropriate command byte (see Command Set Summary and Command Set Detail sections). The data that is available is the following:

RawMag – (3 components)

These are the raw voltage outputs of the three axis magnetometer. They are expressed in terms of A/D converter codes where 0 represents 0 Volts, and 65535 represents 5 volts. They are not scaled into physical units, nor are the individual components necessarily orthogonal, or forming a right-handed coordinate system. For most applications, transmitting the MagField, or StabMagField quantities will be more appropriate.

RawAccel – (3 components)

These are the raw voltage outputs of the three axis accelerometer. They are expressed in terms of A/D converter codes where 0 represents 0 Volts, and 65535 represents 5 volts. They are not scaled into physical units, nor are the individual components necessarily orthogonal, or forming a right-handed coordinate system. For most applications, transmitting the Accel, or StabAccel quantities will be more appropriate.

RawAngRate – (3 components)

These are the raw voltage outputs of the three axis rate gyroscope. They are expressed in terms of A/D converter codes where 0 represents 0 Volts, and 65535 represents 5 volts. They are not scaled into physical units, nor are the individual components necessarily orthogonal, or forming a right-handed coordinate system. For most applications, transmitting the AngRate, or CompAngRate quantities will be more appropriate.

MagField – (X, Y and Z components)

This is a vector quantifying the direction and magnitude of the instantaneously measured magnetic field that the 3DM-GX1® is exposed to. This quantity is derived from the RawMag quantities, but has been scaled into physical units. It is expressed in terms of the 3DM-GX1®'s local coordinate system. Each component of the MagField vector is transmitted as a 16 bit signed integer. To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ MagGainScale), i.e.,

$$\text{Magnetic Field Vector (Gauss)} = \begin{pmatrix} \text{MagField\_X} \\ \text{MagField\_Y} \\ \text{MagField\_Z} \end{pmatrix} / (32768000/\ \text{MagGainScale})$$

MagGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #232. Its value is also listed in the Certification of Calibration document.

Accel – (X, Y and Z components)

This is a vector quantifying the direction and magnitude of the instantaneously measured acceleration that the 3DM-GX1® is exposed to. This quantity is derived from the RawAccel quantities, but has been scaled into physical units. It is expressed in terms of the 3DM-GX1®'s local coordinate system. Each component of the Accel vector is transmitted as a 16 bit signed integer. To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ AccelGainScale), i.e.,

$$\text{Acceleration Vector } (G^{*}) = \begin{pmatrix} Accel\_X \\ Accel\_Y \\ Accel\_Z \end{pmatrix} / \; (32768000/ \text{AccelGainScale})$$

* 1 G = 9.81m/sec^2

AccelGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #230. Its value is also listed in the Certification of Calibration document.

AngRate – (X, Y and Z components)

This is a vector quantifying the rate of rotation of the 3DM-GX1®. This quantity is derived from the RawAngRate quantities, but has been scaled into physical units. It is expressed in terms of the 3DM-GX1®'s local coordinate system. Each component of AngRate vector is transmitted as a 16 bit signed integer. To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ GyroGainScale), i.e.,

$$\text{Rotation Rate (rad/sec)} = \begin{pmatrix} AngRate\_X \\ AngRate\_Y \\ AngRate\_Z \end{pmatrix} / \; (32768000/ \text{GyroGainScale})$$

GyroGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #130. Its value is also listed in the Certification of Calibration document.

The output bias of the rate gyroscopes are prone to drift over time, and with changes in temperature. The AngRate quantity does not incorporate any automatic compensation for this drift. Therefore, the AngRate may be significantly non-zero when the 3DM-GX1® is stationary. (The CompAngRate quantity does incorporate automatic bias drift compensation.) The gyro bias can be manually zeroed by issuing the "Capture Gyro Bias" command at any time that the 3DM-GX1® is stationary.

StabMagField – (X, Y and Z components)

This is a gyroscopically stabilized estimate of the Magnetic Field vector. It is generated by the complementary filtering algorithm whose objective is to filter out artifacts due to transient magnetic interferences.

Each component of the StabMagField vector is transmitted as a 16 bit signed integer. To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ MagGainScale), i.e.,

$$\text{Gyro-Stabilized Mag Field Vector (Gauss)} = \begin{pmatrix} StabMagField\_X \\ StabMagField\_Y \\ StabMagField\_Z \end{pmatrix} / (32768000/ MagGainScale)$$

MagGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #232. Its value is also listed in the Certification of Calibration document.

StabAccel – (X, Y and Z components)

This is a gyroscopically stabilized estimate of the gravity vector. It is generated by the complementary filtering algorithm whose objective is to filter out artifacts due to transient linear accelerations.

Each component of the StabAccel vector is transmitted as a 16 bit signed integer. To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ AccelGainScale), i.e.,

$$\text{Gyro-Stabilized Acceleration Vector } (G^*) = \begin{pmatrix} Accel\_X \\ Accel\_Y \\ Accel\_Z \end{pmatrix} / (32768000/ AccelGainScale)$$

[*] 1 G = 9.81m/sec^2

AccelGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #230. Its value is also listed in the Certification of Calibration document.

CompAngRate – (X, Y and Z components)

This is a bias compensated estimate of the AngRate vector. It is equivalent to the AngRate minus an estimate of the gyro bias.

The bias of the rate gyroscopes are prone to drift over time, and with changes in temperature. The complementary filtering algorithm includes a component that attempts to continuously estimate this gyroscopes bias. The resulting CompAngRate vector should be close to zero when the 3DM-GX1® is stationary. The gyro bias can be manually zeroed, over-riding the complementary filter's bias tracking algorithm, by issuing the "Capture Gyro Bias" command at any time the 3DM-GX1® is stationary.

Each component of CompAngRate vector is transmitted as a 16 bit signed integer. To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ GyroGainScale), i.e.,

$$\text{Bias Compensated Rotation Rate (rad/sec)} = \begin{pmatrix} AngRate\_X \\ AngRate\_Y \\ AngRate\_Z \end{pmatrix} / (32768000/ GyroGainScale)$$

GyroGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #130. Its value is also listed in the Certification of Calibration document.

TimerTicks

This is the value of the on-board clock tick counter sampled at the beginning of the current calculation cycle. By default, each clock tick has a duration of 6.5536 msec. The value of TimerTicks rolls over from +32767 to –32768 (or from +65535 to 0 if TimerTicks is treated as an unsigned 16 bit integer). This rollover occurs approximately every 7 minutes. The host computer's software must be capable of detecting and compensating for this rollover if a real-time record of when data was received is required.

Time (sec) = TimerTicks*0.0065536

Note: The default tick interval of 6.5536 msec can be modified by the user. See Calculation Cycle and Data Output Rate section.

M

This is a 9 component coordinate transformation matrix which describes the orientation of the 3DM-GX1® with respect to the fixed earth coordinate system. The earth fixed coordinate system has X pointing North, Y pointing East, and Z pointing down. The M matrix is derived from the Accel and MagField vectors, and therefore does not incorporate any gyroscopic stabilization. If the 3DM-GX1® is exposed to linear accelerations, or magnetic interference, M will contain artifacts. To obtain a matrix with unit determinant, the individual components values must be divided by the constant 8192.

```
         / M_11,  M_12,  M_13 \
M =     |  M_21,  M_22,  M_23  |  /  8192
         \ M_31,  M_32,  M_33 /
```

M satisfies the following equation:

$$V\_3DM_i = M_{ij} \cdot V\_E_j$$

Where: V_3DM is a vector expressed in the 3DM-GX1®'s local coordinate system.

V_E is the same vector expressed in the stationary, earth-fixed coordinate system

StabM

This is a gyroscopically stabilized 9 component coordinate transformation matrix which describes the orientation of the 3DM-GX1® with respect to the fixed earth coordinate system. The earth fixed coordinate system has X pointing North, Y pointing East, and Z pointing down. The StabM matrix is derived from the StabAccel and StabMagField vectors. The StabM matrix will provide an accurate estimate of orientation even if the 3DM-GX1® is exposed to transient linear accelerations, or transient magnetic interference. To obtain a matrix with unit determinant, the individual components values must be divided by the constant 8192.

```
               / StabM_11,  StabM_12,  StabM_13 \
StabM =       |  StabM_21,  StabM_22,  StabM_23  |  /  8192
               \ StabM_31,  StabM_32,  StabM_33 /
```

StabM satisfies the following equation:

$$V\_3DM_i = StabM_{ij} \cdot V\_E_j$$

Where: V_3DM is a vector expressed in the 3DM-GX1®'s local coordinate system.

V_E is the same vector expressed in the stationary, earth-fixed coordinate system

Q

This is a 4 component quaternion which describes the orientation of the 3DM-GX1® with respect to the fixed earth coordinate system. The earth fixed coordinate system has X pointing North, Y pointing East, and Z pointing down. The Q quaternion is derived from the Accel and MagField vectors, and therefore does not incorporate any gyroscopic stabilization. If the 3DM-GX1® is exposed to linear accelerations, or magnetic interference, Q will contain artifacts. To obtain a unit quaternion, the individual components values must be divided by the constant 8192.

$$Q = \begin{pmatrix} Q\_0 \\ Q\_1 \\ Q\_2 \\ Q\_3 \end{pmatrix} / 8192$$

Q satisfies the following equation:

$$V\_3DM = Q \bullet V\_E \bullet Q^{-1}$$

Where: V_3DM is a vector expressed in the 3DM-GX1®'s local coordinate system.

V_E is the same vector expressed in the stationary, earth-fixed coordinate system

• indicates a quaternion product

By convention, Q_0 is the scalar term.

StabQ

This is a gyroscopically stabilized 4 component quaternion which describes the orientation of the 3DM-GX1® with respect to the fixed earth coordinate system. The earth fixed coordinate system has X pointing North, Y pointing East, and Z pointing down. The StabQ quaternion will provide an accurate estimate of orientation even if the 3DM-GX1® is exposed to transient linear accelerations, or magnetic interference. To obtain a unit quaternion, the individual components values must be divided by the constant 8192.

$$StabQ = \begin{pmatrix} StabQ\_0 \\ StabQ\_1 \\ StabQ\_2 \\ StabQ\_3 \end{pmatrix} / 8192$$

Q satisfies the following equation:

$$V\_3DM = StabQ \bullet V\_E \bullet StabQ^{-1}$$

Where: V_3DM is a vector expressed in the 3DM-GX1®'s local coordinate system.

V_E is the same vector expressed in the stationary, earth-fixed coordinate system

• indicates a quaternion product

By convention, Q_0 is the scalar term.

Euler

This is the set of three Euler angles (Pitch, Roll, and Yaw) which describe the orientation of the 3DM-GX1® with respect to the fixed earth. These angles are calculated according to the “ZYX” or “Aircraft” coordinate system. Users should be aware that there are other valid formulations of Euler Angles that will yield different results. The earth fixed coordinate system has X pointing North, Y pointing East, and Z pointing down. The Euler quantities are derived from the Accel and MagField vectors, and therefore do not incorporate any gyroscopic stabilization. If the 3DM-GX1® is exposed to linear accelerations, or magnetic interference, artifacts will be present. The Roll and Yaw angles have a range of –32768 to +32767 representing –180 to +180 degrees. The Pitch angle has a range of –16384 to +16383 representing –90 to +90 degrees. To obtain angles in units of degrees, the integer outputs should be multiplied by the scaled factor (360/65536).

The user should be aware that the Euler angle formulation in general contains a mathematical singularity at Pitch = +90 or –90 degrees. In practice, poor numerical results will be present if the Pitch angle exceeds +/-70 degrees. In applications where the Pitch angle cannot be guaranteed to exceed these values, it is recommended that the orientation matrix output be utilized instead.

StabEuler

This is the set of three gyro-stabilized Euler angles (Pitch, Roll, and Yaw) which describe the orientation of the 3DM-GX1® with respect to the fixed earth. These angles are calculated according to the “ZYX” or “Aircraft” coordinate system. Users should be aware that there are other valid formulations of Euler Angles that will yield different results. The earth fixed coordinate system has X pointing North, Y pointing East, and Z pointing down. The StabEuler quantities are derived from the StabAccel and StabMagField vectors, and therefore are gyro-stabilized. StabEuler will provide an accurate estimate of orientation even if the 3DM-GX1® is exposed to transient linear accelerations, or magnetic interference. The Roll and Yaw angles have a range of –32768 to +32767 representing –180 to +180 degrees. The Pitch angle has a range of –16384 to +16383 representing –90 to +90 degrees. To obtain angles in units of degrees, the integer outputs should be multiplied by the scaled factor (360/65536).

The user should be aware that the Euler angle formulation in general contains a mathematical singularity at Pitch = +90 or –90 degrees. In practice, poor numerical results will be present if the Pitch angle exceeds +/-70 degrees. In applications where the Pitch angle cannot be guaranteed to exceed these values, it is recommended that the orientation matrix output be utilized instead.

Temp

This is the temperature of the interior of the 3DM-GX1® enclosure.

Temperature (ºC) = ((Temp * 5/65536) – 0.5) 100

MagField_Minimum – (X, Y and Z components)

To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ MagGainScale), i.e.,

$$\text{Magnetic Field Vector (Gauss)} = \begin{pmatrix} \text{MagField\_Minimum\_X} \\ \text{MagField\_ Minimum\_Y} \\ \text{MagField\_ Minimum\_Z} \end{pmatrix} / \ 32768000/\text{MagGainScale})$$

MagGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #232. Its value is also listed in the Certification of Calibration document.

MagField_Maximum – (X, Y and Z components)

To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ MagGainScale), i.e.,

$$\text{Magnetic Field Vector (Gauss)} = \begin{pmatrix} \text{MagField\_Maximum\_X} \\ \text{MagField\_ Maximum\_Y} \\ \text{MagField\_ Maximum\_Z} \end{pmatrix} / \ 32768000/\text{MagGainScale})$$

MagGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #232. Its value is also listed in the Certification of Calibration document.

Calibration type indicator byte

2D = 1; 3D =0

Magnitude_Z

A value in units of milliGauss.

Hard_Iron_Offset – (X, Y and Z components)

To complete the conversion to physical units, these values must be divided by the scale constant, (32768000/ MagGainScale), i.e.,

$$\text{Magnetic Field Vector (Gauss)} = \begin{pmatrix} \text{Hard\_Iron\_Offset\_X} \\ \text{Hard\_Iron\_Offset \_Y} \\ \text{Hard\_Iron\_Offset \_Z} \end{pmatrix} / \ 32768000/\text{MagGainScale})$$

MagGainScale is a constant whose value is stored in the 3DM-GX1®'s non-volatile memory at EEPROM address #232. Its value is also listed in the Certification of Calibration document.

Command Set Summary

Command	Definition
0x00	**Null Command (not implemented)**
0x01	**Send Raw Sensor Bits**
0x02	**Send Gyro-Stabilized Vectors**
0x03	**Send Instantaneous Vectors**
0x04	**Send Instantaneous Quaternion**
0x05	**Send Gyro-Stabilized Quaternion**
0x06	**Capture Gyro Bias**
0x07	**Send Temperature**
0x08	**Read EEPROM Value**
0x09	**Write EEPROM Value**
0x0A	**Send Instantaneous Orientation Matrix**
0x0B	**Send Gyro-Stabilized Orientation Matrix**
0x0C	**Send Gyro-Stabilized Quaternion & Vectors**
0x0D	**Send Instantaneous Euler Angles**
0x0E	**Send Gyro-Stabilized Euler Angles**
0x0F	**Tare Coordinate System**
0x10	**Set Continuous Mode**
0x11	**Remove Tare**
0x12	**Send Gyro-Stabilized Quaternion & Instantaneous Vectors**
0x24	**Write System Gains**
0x25	**Read System Gains**
0x27	**Self Test**
0x28	**Read EEPROM Value with Checksum**
0x29	**Write EEPROM Value with Checksum**
0x31	**Send Gyro-Stabilized Euler Angles & Accel & Rate Vector**
0x40	**Initialize Hard Iron Field Calibration**
0x41	**Collect Hard Iron Field Calibration Data**
0x42	**Compute Hard Iron Field Calibration**
0xF0	**Send Firmware Version Number**
0xF1	**Send Device Serial Number**
	Default

Command Set Detail

All commands are one byte in length. Several commands require that the host transmit additional data bytes following the command byte to fully define the action to be taken. All commands generate a response of a fixed number of bytes.

The response to most commands begins with a header byte (which has the same value as the corresponding command byte), and ends with a 16 bit checksum. The intervening bytes comprise a series of 16 bit signed integers that correspond to the requested data.

The checksum is evaluated as the sum of all preceding 16 bit integers and the header byte. (When generating checksums, the header byte is treated as a 16 bit integer with an MSB of 0x00.) This means that the individual data byte pairs must be assembled into 16 bit integers prior to evaluating the checksum. For example, the checksum in the response to the "Send Instantaneous Quaternion" command (0x04) would be evaluated as:

Checksum = 0x0004 + Q_0 + Q_1 + Q_2 + Q_3 + TimerTicks

The Data Packet Format of each command follows.

Send Raw Sensor Bits

Function:	The 3DM-GX1® will transmit the raw sensor output voltages
Command Byte:	0x01
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x01
Byte 2	RawMag_1 MSB
Byte 3	RawMag_1 LSB
Byte 4	RawMag_2 MSB
Byte 5	RawMag_2 LSB
Byte 6	RawMag_3 MSB
Byte 7	RawMag_3 LSB
Byte 8	RawAccel_1 MSB
Byte 9	RawAccel_1 LSB
Byte 10	RawAccel_2 MSB
Byte 11	RawAccel_2 LSB
Byte 12	RawAccel_3 MSB
Byte 13	RawAccel_3 LSB
Byte 14	RawAngRate_1 MSB
Byte 15	RawAngRate_1 LSB
Byte 16	RawAngRate_2 MSB
Byte 17	RawAngRate_2 LSB
Byte 18	RawAngRate_3 MSB
Byte 19	RawAngRate_3 LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Send Gyro-Stabilized Vectors

Function:	The 3DM-GX1® will transmit the gyro-stabilized magnetic field and acceleration vectors, and the bias-corrected angular rate vector
Command Byte:	0x02
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x02
Byte 2	StabMagField_X MSB
Byte 3	StabMagField_X LSB
Byte 4	StabMagField_Y MSB
Byte 5	StabMagField_Y LSB
Byte 6	StabMagField_Z MSB
Byte 7	StabMagField_Z LSB
Byte 8	StabAccel_X MSB
Byte 9	StabAccel_X LSB
Byte 10	StabAccel_Y MSB
Byte 11	StabAccel_Y LSB
Byte 12	StabAccel_Z MSB
Byte 13	StabAccel_Z LSB
Byte 14	CompAngRate_X MSB
Byte 15	CompAngRate_X LSB
Byte 16	CompAngRate_Y MSB
Byte 17	CompAngRate_Y LSB
Byte 18	CompAngRate_Z MSB
Byte 19	CompAngRate_Z LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Send Instantaneous Vectors

Function:	The 3DM-GX1® will transmit the instantaneous magnetic field, acceleration, angular rate vectors
Command Byte:	0x03
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x03
Byte 2	MagField_X MSB
Byte 3	MagField_X LSB
Byte 4	MagField_Y MSB
Byte 5	MagField_Y LSB
Byte 6	MagField_Z MSB
Byte 7	MagField_Z LSB
Byte 8	Accel_X MSB
Byte 9	Accel_X LSB
Byte 10	Accel_Y MSB
Byte 11	Accel_Y LSB
Byte 12	Accel_Z MSB
Byte 13	Accel_Z LSB
Byte 14	AngRate_X MSB
Byte 15	AngRate_X LSB
Byte 16	AngRate_Y MSB
Byte 17	AngRate_Y LSB
Byte 18	AngRate_Z MSB
Byte 19	AngRate_Z LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Send Instantaneous Quaternion

Function:	The 3DM-GX1® will transmit the instantaneous orientation quaternion
Command Byte:	0x04
Command Data:	None
Response:	13 bytes defined as follows
Byte 1	Header byte = 0x04
Byte 2	Q_0 MSB
Byte 3	Q_0 LSB
Byte 4	Q_1 MSB
Byte 5	Q_1 LSB
Byte 6	Q_2 MSB
Byte 7	Q_2 LSB
Byte 8	Q_3 MSB
Byte 9	Q_3 LSB
Byte 10	TimerTicks MSB
Byte 11	TimerTicks LSB
Byte 12	Checksum MSB
Byte 13	Checksum LSB

Send Gyro-Stabilized Quaternion

Function:	The 3DM-GX1® will transmit the gyro-stabilized orientation quaternion
Command Byte:	0x05
Command Data:	None
Response:	13 bytes defined as follows
Byte 1	Header byte = 0x05
Byte 2	StabQ_0 MSB
Byte 3	StabQ_0 LSB
Byte 4	StabQ_1 MSB
Byte 5	StabQ_1 LSB
Byte 6	StabQ_2 MSB
Byte 7	StabQ_2 LSB
Byte 8	StabQ_3 MSB
Byte 9	StabQ_3 LSB
Byte 10	TimerTicks MSB
Byte 11	TimerTicks LSB
Byte 12	Checksum MSB
Byte 13	Checksum LSB

Capture Gyro Bias

Function:	The 3DM-GX1® will capture the current gyroscope outputs and store these values as the gyro bias estimate.
Command Byte:	0x06
Command Data:	None
Response:	5 bytes defined as follows
Byte 1	Header byte = 0x06
Byte 2	TimerTicks MSB
Byte 3	TimerTicks LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Send Temperature

Function:	The 3DM-GX1® will transmit the current temperature
Command Byte:	0x07
Command Data:	None
Response:	7 bytes defined as follows
Byte 1	Header byte = 0x07
Byte 2	Temp MSB
Byte 3	Temp LSB
Byte 4	TimerTicks MSB
Byte 5	TimerTicks LSB
Byte 6	Checksum MSB
Byte 7	Checksum LSB

Read EEPROM Value

Note: This is NOT the preferred command to read EEPROM; normally you should use Read EEPROM Value with Checksum (0x28).

Function:	The 3DM-GX1® will transmit the 2 byte signed integer value stored in EEPROM at the specified address.
Command Byte:	0x08
Command Data:	1 Bytes defined as follows
Byte 1	Address
Response:	Responds with value at specified memory location
Byte 1	data MSB
Byte 2	data LSB

Write EEPROM Value

Note: This is NOT the preferred command to write EEPROM; normally you should use Write EEPROM Value with Checksum (0x29).

Function:	The 3DM-GX1® will write the specified integer value to EEPROM at the specified address
Command Byte:	0x09
Command Data:	5 Bytes defined as follows
Byte 1	0x71
Byte 2	Address
Byte 3	data MSB
Byte 4	data LSB
Byte 5	0xAA
Response:	Responds with 2 bytes defined as follows
Byte 1	data MSB
Byte 2	data LSB

Send Instantaneous Orientation Matrix

Function:	The 3DM-GX1® will transmit the instantaneous orientation matrix
Command Byte:	0x0A
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x0A
Byte 2	M_11 MSB
Byte 3	M_11 LSB
Byte 4	M_21 MSB
Byte 5	M_21 LSB
Byte 6	M_31 MSB
Byte 7	M_31 LSB
Byte 8	M_12 MSB
Byte 9	M_12 LSB
Byte 10	M_22 MSB
Byte 11	M_22 LSB
Byte 12	M_32 MSB
Byte 13	M_32 LSB
Byte 14	M_13 MSB
Byte 15	M_13 LSB
Byte 16	M_23 MSB
Byte 17	M_23 LSB
Byte 18	M_33 MSB
Byte 19	M_33 LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Send Gyro-Stabilized Orientation Matrix

Function:	The 3DM-GX1® will transmit the gyro-stabilized orientation matrix
Command Byte:	0x0B
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x0B
Byte 2	StabM_11 MSB
Byte 3	StabM_11 LSB
Byte 4	StabM_21 MSB
Byte 5	StabM_21 LSB
Byte 6	StabM_31 MSB
Byte 7	StabM_31 LSB
Byte 8	StabM_12 MSB
Byte 9	StabM_12 LSB
Byte 10	StabM_22 MSB
Byte 11	StabM_22 LSB
Byte 12	StabM_32 MSB
Byte 13	StabM_32 LSB
Byte 14	StabM_13 MSB
Byte 15	StabM_13 LSB
Byte 16	StabM_23 MSB
Byte 17	StabM_23 LSB
Byte 18	StabM_33 MSB
Byte 19	StabM_33 LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Send Gyro-Stabilized Quaternion & Vectors

Function:	The 3DM-GX1®will transmit the gyro-stabilized orientation quaternion, the instantaneous magnetic field and acceleration vectors, and the bias corrected angular rate vector.
Command Byte:	0x0C
Command Data:	None
Response:	31 bytes defined as follows
Byte 1	Header byte = 0x0C
Byte 2	StabQ_0 MSB
Byte 3	StabQ_0 LSB
Byte 4	StabQ_1 MSB
Byte 5	StabQ_1 LSB
Byte 6	StabQ_2 MSB
Byte 7	StabQ_2 LSB
Byte 8	StabQ_3 MSB
Byte 9	StabQ_3 LSB
Byte 10	MagField_X MSB
Byte 11	MagField_X LSB
Byte 12	MagField_Y MSB
Byte 13	MagField_Y LSB
Byte 14	MagField_Z MSB
Byte 15	MagField_Z LSB
Byte 16	Accel_X MSB
Byte 17	Accel_X LSB
Byte 18	Accel_Y MSB
Byte 19	Accel_Y LSB
Byte 20	Accel_Z MSB
Byte 21	Accel_Z LSB
Byte 22	CompAngRate_X MSB
Byte 23	CompAngRate_X LSB
Byte 24	CompAngRate_Y MSB
Byte 25	CompAngRate_Y LSB
Byte 26	CompAngRate_Z MSB
Byte 27	CompAngRate_Z LSB
Byte 28	TimerTicks MSB
Byte 29	TimerTicks LSB
Byte 30	Checksum MSB
Byte 31	Checksum LSB

Send Instantaneous Euler Angles

Function:	The 3DM-GX1® will transmit the instantaneous Euler Angles
Command Byte:	0x0D
Command Data:	None
Response:	11 bytes defined as follows
Byte 1	Header byte = 0x0D
Byte 2	Roll MSB
Byte 3	Roll LSB
Byte 4	Pitch MSB
Byte 5	Pitch LSB
Byte 6	Yaw MSB
Byte 7	Yaw LSB
Byte 8	TimerTicks MSB
Byte 9	TimerTicks LSB
Byte 10	Checksum MSB
Byte 11	Checksum LSB

Send Gyro-Stabilized Euler Angles

Function:	The 3DM-GX1® will transmit the gyro-stabilized Euler Angles
Command Byte:	0x0E
Command Data:	None
Response:	11 bytes defined as follows
Byte 1	Header byte = 0x0E
Byte 2	Roll MSB
Byte 3	Roll LSB
Byte 4	Pitch MSB
Byte 5	Pitch LSB
Byte 6	Yaw MSB
Byte 7	Yaw LSB
Byte 8	TimerTicks MSB
Byte 9	TimerTicks LSB
Byte 10	Checksum MSB
Byte 11	Checksum LSB

Tare Coordinate System

Function:	The 3DM-GX1® will tare its coordinate system such that the local body fixed coordinate system will be aligned with Earth-Fixed reference coordinate system (X north, Y east, Z down). All rotations will thereafter be referenced to this new body-fixed coordinate system. Note that this command takes several seconds, during which time, the device must be stationary
Command Byte:	0x0F
Command Data:	3 bytes defined as follows
Byte 1	0xC1
Byte 2	0xC3
Byte 3	0xC5
Response:	5 bytes defined as follows
Byte 1	Header byte = 0x0F
Byte 2	TimerTicks MSB
Byte 3	TimerTicks LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Set Continuous Mode

Function:	This command enables/disable continuous communications mode. To enable continuous mode, set Command Data Byte 2 to the desired command byte. To disable continuous mode, set Command Data Byte 2 to 0x00.
Command Byte:	0x10
Command Data:	2 Bytes defined as follows
Byte 1	0x00
Byte 2	Command Byte to which continuous response is desired
Response:	7 bytes defined as follows
Byte 1	Header byte = 0x10
Byte 2	0x00
Byte 3	Command Byte
Byte 4	TimerTicks MSB
Byte 5	TimerTicks LSB
Byte 6	Checksum MSB
Byte 7	Checksum LSB

Remove Tare

Function:	Any previous tare matrix will be removed (replaced by the identity matrix). This will realign the body fixed coordinates to their factory default alignment.
Command Byte:	0x11
Command Data:	3 bytes defined as follows
Byte 1	0xC1
Byte 2	0xC3
Byte 3	0xC5
Response:	5 bytes defined as follows
Byte 1	Header byte = 0x11
Byte 2	TimerTicks MSB
Byte 3	TimerTicks LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Send Gyro-Stabilized Quaternion & Instantaneous Vectors

Function:	The 3DM-GX1® will transmit the gyro-stabilized orientation quaternion and the Instantaneous MagField, Accel, and AngRate Vectors. Note, this differs from the 0x0C command only in that the AngRate vector is sent rather than CompAngRate
Command Byte:	0x12
Command Data:	None
Response:	31 bytes defined as follows
Byte 1	Header byte = 0x12
Byte 2	StabQ_0 MSB
Byte 3	StabQ_0 LSB
Byte 4	StabQ_1 MSB
Byte 5	StabQ_1 LSB
Byte 6	StabQ_2 MSB
Byte 7	StabQ_2 LSB
Byte 8	StabQ_3 MSB
Byte 9	StabQ_3 LSB
Byte 10	MagField_X MSB
Byte 11	MagField_X LSB
Byte 12	MagField_Y MSB
Byte 13	MagField_Y LSB
Byte 14	MagField_Z MSB
Byte 15	MagField_Z LSB
Byte 16	Accel_X MSB
Byte 17	Accel_X LSB
Byte 18	Accel_Y MSB
Byte 19	Accel_Y LSB
Byte 20	Accel_Z MSB
Byte 21	Accel_Z LSB
Byte 22	AngRate_X MSB
Byte 23	AngRate_X LSB
Byte 24	AngRate_Y MSB
Byte 25	AngRate_Y LSB
Byte 26	AngRate_Z MSB
Byte 27	AngRate_Z LSB
Byte 28	TimerTicks MSB
Byte 29	TimerTicks LSB
Byte 30	Checksum MSB
Byte 31	Checksum LSB

Write System Gains

Function:	This will update the system gain values currently used by the 3DM-GX1®'s filtering algorithm. These gains consist of the Accelerometer Proportional Gain, Magnetometer Proportional Gain, and the Bias Tracking Gain. Note that only the RAM values will be updated, not the non-volatile EEPROM values. The system will revert back the values stored in EEPROM if the power is cycled, or if any other EEPROM values are written to (causing all EEPROM values to be re-read).
Command Byte:	0x24
Command Data:	6 Bytes defined as follows
Byte 1	Accelerometer Proportional Gain MSB
Byte 2	Accelerometer Proportional Gain LSB
Byte 3	Magnetometer Proportional Gain MSB
Byte 4	Magnetometer Proportional Gain LSB
Byte 5	Bias Tracking Gain MSB
Byte 6	Bias Tracking Gain LSB
Response:	5 bytes defined as follows
Byte 1	Header byte = 0x24
Byte 2	TimerTicks MSB
Byte 3	TimerTicks LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Read System Gains

Function:	This will cause the 3DM-GX1® to transmit the values of the system gains it is currently using in its filtering algorithm. These gains consist of the Accelerometer Proportional Gain, Magnetometer Proportional Gain, and the Bias Tracking Gain. Note that only RAM values will be sent. These are not necessarily the same as the non-volatile EEPROM values since they may have been updated using the 0x25 command (see above)
Command Byte:	0x25
Command Data:	None
Response:	11 bytes defined as follows
Byte 1	Header byte = 0x25
Byte 2	Accelerometer Proportional Gain MSB
Byte 3	Accelerometer Proportional Gain LSB
Byte 4	Magnetometer Proportional Gain MSB
Byte 5	Magnetometer Proportional Gain LSB
Byte 6	Bias Tracking Gain MSB
Byte 7	Bias Tracking Gain LSB
Byte 8	TimerTicks MSB
Byte 9	TimerTicks LSB
Byte 10	Checksum MSB
Byte 11	Checksum LSB

Self Test

Function:	The sensor self-test feature will be enabled/disabled. The individual tests are controlled by the bits of the Self Test Byte. Clearing all bits disables all self-test features. -Setting bit 0 will cause a negative shift of all gyro outputs -Setting bit 1 will cause a positive shift of all gyro and accelerometer outputs - Setting bit 2 will cause a shift of all magnetometer outputs (sign undetermined) - Setting bit 3 will change the sign of all magnetometer shifts generated by setting bit 2 - Setting bits 4-7 has no effect
Command Byte:	0x27
Command Data:	1 Bytes defined as follows
Byte 1	Self Test Byte
Response:	5 Bytes defined as follows
Byte 1	0x27
Byte 2	TimerTicks MSB
Byte 3	TimerTicks LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Read EEPROM Value with Checksum

Note: This is the preferred command to read EEPROM; use this command normally instead of Read EEPROM Value (0x08).

Function:	The 3DM-GX1® will transmit the 2 byte signed integer value stored in EEPROM at the specified address. The EEPROM address is specified as a two byte integer.
Command Byte:	0x28
Command Data:	2 Bytes defined as follows
Byte 1	Address MSB
Byte 2	Address LSB
Response:	7 Bytes defined as follows
Byte 1	0x28
Byte 2	data MSB
Byte 3	data LSB
Byte 4	TimerTicks MSB
Byte 5	TimerTicks LSB
Byte 6	Checksum MSB
Byte 7	Checksum LSB

Write EEPROM Value with Checksum

Note: This is the preferred command to write EEPROM; use this command normally instead of Write EEPROM Value (0x09).

Function:	The 3DM-GX1® will write the specified integer value to EEPROM at the specified address. The EEPROM address is specified as a two byte integer.
Command Byte:	0x29
Command Data:	6 Bytes defined as follows
Byte 1	0x71
Byte 2	Address MSB
Byte 3	Address LSB
Byte 4	data MSB
Byte 5	data LSB
Byte 6	0xAA
Response:	7 Bytes defined as follows
Byte 1	0x29
Byte 2	data MSB
Byte 3	data LSB
Byte 4	TimerTicks MSB
Byte 5	TimerTicks LSB
Byte 6	Checksum MSB
Byte 7	Checksum LSB

Send Gyro-Stabilized Euler Angles & Accel & Rate Vector

Function:	The 3DM-GX1® will transmit the gyro-stabilized Euler Angles and the Instantaneous Acceleration Vector and the drift compensated Angular Rate vector
Command Byte:	0x31
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x31
Byte 2	Roll MSB
Byte 3	Roll LSB
Byte 4	Pitch MSB
Byte 5	Pitch LSB
Byte 6	Yaw MSB
Byte 7	Yaw LSB
Byte 8	Accel_X MSB
Byte 9	Accel_X LSB
Byte 10	Accel_Y MSB
Byte 11	Accel_Y LSB
Byte 12	Accel_Z MSB
Byte 13	Accel_Z LSB
Byte 14	CompAngRate_X MSB
Byte 15	CompAngRate_X LSB
Byte 16	CompAngRate_Y MSB
Byte 17	CompAngRate_Y LSB
Byte 18	CompAngRate_Z MSB
Byte 19	CompAngRate_Z LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Initialize Hard Iron Field Calibration

Function:	This will initialize the 3DM-GX1®'s Hard Iron field calibration algorithm. It will also erase any previous hard iron calibration, and return to the factory default calibration parameters
Command Byte:	0x40
Command Data:	2 Bytes defined as follows
Byte 1	0x71
Byte 2	0x3E
Response:	5 bytes defined as follows
Byte 1	Header byte = 0x40
Byte 2	TimerTicks MSB
Byte 3	TimerTicks LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Collect Hard Iron Calibration Data

Function:	The 3DM-GX1® will collect one data point for use in its Hard Iron field calibration algorithm.
Command Byte:	0x41
Command Data:	None
Response:	23 bytes defined as follows
Byte 1	Header byte = 0x41
Byte 2	MagField_X MSB
Byte 3	MagField_X LSB
Byte 4	MagField_Y MSB
Byte 5	MagField_Y LSB
Byte 6	MagField_Z MSB
Byte 7	MagField_Z LSB
Byte 8	MagField_Minimum_X MSB
Byte 9	MagField_Minimum_X LSB
Byte 10	MagField_Minimum_Y MSB
Byte 11	MagField_Minimum_Y LSB
Byte 12	MagField_Minimum_Z MSB
Byte 13	MagField_Minimum_Z LSB
Byte 14	MagField_Maximum_X MSB
Byte 15	MagField_Maximum_X LSB
Byte 16	MagField_Maximum_Y MSB
Byte 17	MagField_Maximum_Y LSB
Byte 18	MagField_Maximum_Z MSB
Byte 19	MagField_Maximum_Z LSB
Byte 20	TimerTicks MSB
Byte 21	TimerTicks LSB
Byte 22	Checksum MSB
Byte 23	Checksum LSB

Compute Hard Iron Field Calibration

Function:	The 3DM-GX1® will process previously collected hard iron field calibration data, and will write the corresponding calibration parameters to non-volatile memory
Command Byte:	0x42
Command Data:	5 Bytes defined as follows
Byte 1	0x71
Byte 2	0x3E
Byte 3	Calibration type indicator byte (2D = 1, 3D = 0)
Byte 4	Magnitude_Z MSB (units of milliGauss)
Byte 5	Magnitude_Z LSB
Response:	11 bytes defined as follows
Byte 1	Header byte = 0x42
Byte 2	Hard_Iron_Offset_X MSB
Byte 3	Hard_Iron_Offset_X LSB
Byte 4	Hard_Iron_Offset_Y MSB
Byte 5	Hard_Iron_Offset_Y LSB
Byte 6	Hard_Iron_Offset_Z MSB
Byte 7	Hard_Iron_Offset_Z LSB
Byte 8	TimerTicks MSB
Byte 9	TimerTicks LSB
Byte 10	Checksum MSB
Byte 11	Checksum LSB

Send Firmware Version Number

Function:	The 3DM-GX1® will transmit the firmware version number. After converting to decimal format the 5 digit number should be interpreted as version XX.X.XX
Command Byte:	0xF0
Command Data:	None
Response:	5 bytes defined as follows
Byte 1	Header byte = 0xF0
Byte 2	Version MSB
Byte 3	Version LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Send Serial Number

Function:	The 3DM-GX1® will transmit its serial number
Command Byte:	0xF1
Command Data:	None
Response:	5 bytes defined as follows
Byte 1	Header byte = 0xF1
Byte 2	Serial MSB
Byte 3	Serial LSB
Byte 4	Checksum MSB
Byte 5	Checksum LSB

Default

Function:	If an unrecognized command is received by the 3DM-GX1®, it will respond as follows
Command Byte:	Unrecognized Command Byte
Response:	5 Bytes defined as follows
Byte 1	Unrecognized Command Byte
Byte 2	0x00
Byte 3	0x01
Byte 4	0x02
Byte 5	Unrecognized Command Byte