3DM-G Data Communication Protocol (Comm spec REV 2.11)

Document last modified November December 11, 2003

This document describes the communications protocol associated with 3DM-G firmware version 1.3.00.

RS-232 Communications

There are two methods of serial communications with the 3DM-G device. The first is RS-232 mode. This the most convenient and reliable method for communications between a host computer and a single 3DM-G device (or multiple 3DM-G's each connected to a separate serial port).

RS-232 Signals Definition

Signal	Name	Direction	Function
TxD	**Transmit Data**	**Host to 3DM**	**Asynchronous Serial Data from Host**
RxD	**Receive Data**	**3DM 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

The second communications mode is an addressable half duplex RS-485 mode. This allows for multiple 3DM-G 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-G'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-G 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-G address

Example: Request Gyro-Stabilized Vectors from a 3DM-G 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 base 10. 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-G 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 bus. This allows the other 3DM-G units on the bus to ignore the bytes.

Response byte format

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 data transmitted by the 3DM-G can be controlled by the issuance of one or more single byte commands. Each command will generate a response of a fixed number of bytes. The 3DM-G will not transmit unsolicited data. The user can select what data the 3DM-G will transmit by selecting one or more of the commands as defined in the following sections.

Calculation Cycle

The 3DM-G's on-board processor operates with a 0.0065536 second clock tick interval. The processor continually reads the raw sensor outputs, scales them into physical units, performs gyro-stabilization, and (if requested by a user issued command) generates an estimate of its orientation. The time required to perform all the required calculations is called the calculation cycle. The duration of the calculation cycle can be one, two or three clock ticks, depending on what data the user requests. Two clock ticks are required to read the sensor outputs, scale them into physical units, and carry out the gyro-stabilization process. Therefore, if the user requests either Instantaneous Vectors, or Gyro-Stabilized Vectors, the maximum rate at which these can be calculated and transmitted is 76.29 Hz (1/(2*0.0065536 sec)). If the user requests either Quaternions, or the Orientation Matrix (Instantaneous or Gyro-Stabilized), an additional clock tick is required to perform the additional calculations. Therefore, the maximum rate at which these quantities can be calculated and transmitted is at 50.86 Hz (1/(3*0.0065536 sec)). Note that the calculation of the quaternions, or orientation matrix is only done when the users requests data to be transmitted. Therefore, calculation cycles of two clock ticks may be intermingled with calculation cycles of three clock ticks if the user only occasionally requests that the quaternion, for example, be transmitted.

In some applications, the user may only need the Instantaneous Vectors. In this case, the gyro-stabilization portion of the algorithm can be disabled by setting EEPROM location 122 to a value of 0. The calculation cycle time is then reduced by one clock tick. The Instantaneous Vectors can be calculated and transmitted at a maximum rate of 152.59 Hz (1/0.0065536 sec). Similarly, the Instantaneous Quaternions or Orientation Matrix can be calculated at a maximum rate of 76.29 Hz. When the gyro-stabilization algorithm is disabled, any command requesting gyro-stabilized data will return undefined data.

Polled Command Mode

The 3DM-G has two command modes. The first is Polled mode. This is the default. In polled mode, the 3DM-G will transmit a data packet each time a command byte is issued by the host computer. The 3DM-G will not transmit unsolicited data packets. The user may issue a command at any time. The 3DM-G 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-G (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)

The second command mode is continuous mode. 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-G 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-G 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” byte followed by the new desired command byte.

Normally, the 3DM-G starts in Polled Mode on power up. In some applications, it may be desirable to have the 3DM-G 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-G 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-g first transmits the response to the continuous mode command if continuous mode is active. The 3DM-G 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 in 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.

Data Quantities Available

The 3DM-G is capable of calculating and reporting data of various types. These can be accessed by selecting and sending the appropriate command byte (see following 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 4096 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 4096 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 4096 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 is exposed to. This quantity is derived from the magnetometer outputs, but has been scaled, and corrected for mechanical misalignment. It is expressed in terms of the 3DM-G'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, 8192, i.e.,

$$\text{Magnetic Field Vector (Earth Field Units}^{*}) = \begin{pmatrix} \text{MagField\_X} \\ \text{MagField\_Y} \\ \text{MagField\_Z} \end{pmatrix} / 8192$$

* The magnetometers are scaled with respect to one another, but not to an absolute standard. One "Earth Field Unit" is equivalent to Earth's geomagnetic field strength present in the factory during calibration.

Accel – (X, Y and Z components): This is a vector quantifying the direction and magnitude of the instantaneously measured acceleration that the 3DM is exposed to. This quantity is derived from the accelerometer outputs, but has been scaled into physical units, and corrected for mechanical misalignment. It is expressed in terms of the 3DM-G'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, 8192, i.e.,

$$\text{Acceleration Vector (G}^{*}) = \begin{pmatrix} \text{Accel\_X} \\ \text{Accel\_Y} \\ \text{Accel\_Z} \end{pmatrix} / 8192$$

* 1 G = 9.81m/sec^2

AngRate – (X, Y and Z components): This is a vector quantifying the rate of rotation of the 3DM-G. This quantity is derived from the rate gyroscope outputs, but has been scaled into physical units, and corrected for mechanical misalignment. It is expressed in terms of the 3DM-G'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, (GyroGainScale*8192*0.0065536), i.e.,

$$\text{Rotation Rate (rad/sec)} = \begin{pmatrix} \text{AngRate\_X} \\ \text{AngRate\_Y} \\ \text{AngRate\_Z} \end{pmatrix} / (\text{GyroGainScale}*8192*0.0065536)$$

GyroGainScale is a constant incorporated during gyroscope calibration to maximize resolution. For standard 3DM-G's, it is set to 64. Its value is stored in EEPROM location 130, and is also listed on the calibration documentation.

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-G 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-G is stationary.

StabMagField – (X, Y and Z components): This is a gyroscopically stabilized analog of the MagField vector. 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, 8192, i.e.,

$$\text{Gyro-Stabilized Mag Field Vector (Earth Field Units}^*) = \begin{pmatrix} StabMagField\_X \\ StabMagField\_Y \\ StabMagField\_Z \end{pmatrix} / 8192$$

[*] The magnetometers are scaled with respect to one another, but not to an absolute standard. One "Earth Field Unit" is equivalent to Earth's geomagnetic field strength in the factory during calibration.

StabAccel – (X, Y and Z components): This is a gyroscopically stabilized analog of the Accel vector. 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, 8192, i.e.,

$$\text{Gyro-Stabilized Acceleration Vector (G}^*) = \begin{pmatrix} StabAccel\_X \\ StabAccel\_Y \\ StabAccel\_Z \end{pmatrix} / 8192$$

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

CompAngRate – (X, Y and Z components): This is a bias compensated analog of the AngRate vector. 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, (GainScale*8192*0.0065536), i.e.,

$$\text{Bias Compensated Rotation Rate (rad/sec)} = \begin{pmatrix} CompAngRate\_X \\ CompAngRate\_Y \\ CompAngRate\_Z \end{pmatrix} / (GyroGainScale*8192*0.0065536)$$

GyroGainScale is a constant parameter incorporated during gyroscope calibration to maximize resolution. For standard range 3DM-G's, it is set equal to 64. Its value is stored in EEPROM location 130, and is also listed on the calibration documentation.

The output bias of the rate gyroscopes are prone to drift over time, and with changes in temperature. The on-board processor continuously runs an algorithm that attempts to track the drift in the rate gyroscopes bias, and subtract that bias from their outputs. Therefore, the CompAngRate vector should be close to zero when the 3DM-G is stationary. The gyro bias can be manually zeroed, overridding the automatic bias compensation algorithm, by issuing the "Capture Gyro Bias" command at any time the 3DM-G is stationary.

TimerTicks **-** This is the value of the on-board clock tick counter sampled at the beginning of the current calculation cycle. 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

M - This is a 9 component coordinate transformation matrix which describes the orientation of the 3DM-G 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-G 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.

$$M = \begin{pmatrix} M\_11, & M\_12, & M\_13 \\ M\_21, & M\_22, & M\_23 \\ M\_31, & M\_32, & M\_33 \end{pmatrix} / \ 8192$$

M satisfies the following equation:

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

Where: V_3DM is a vector expressed in the 3DM-G'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-G 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-G is exposed to transient linear accelerations, or magnetic interference. To obtain a matrix with unit determinant, the individual components values must be divided by the constant 8192.

$$StabM = \begin{pmatrix} StabM\_11, & StabM\_12, & StabM\_13 \\ StabM\_21, & StabM\_22, & StabM\_23 \\ StabM\_31, & StabM\_32, & StabM\_33 \end{pmatrix} / \ 8192$$

StabM satisfies the following equation:

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

Where: V_3DM is a vector expressed in the 3DM-G'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-G 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-G 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-G's local coordinate system.
V_E is the same vector expressed in the stationary, earth-fixed coordinate system
• indicates a quaternion product

StabQ - This is a gyroscopically stabilized 4 component quaternion which describes the orientation of the 3DM-G 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-G 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.

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

Q satisfies the following equation:

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

Where: V_3DM is a vector expressed in the 3DM-G's local coordinate system.
V_E is the same vector expressed in the stationary, earth-fixed coordinate system
• indicates a quaternion product

Euler – This is the set of three Euler angles (Pitch, Roll, and Yaw) which describe the orientation of the 3DM-G 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-G 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 multiplied by the scaled factor (360/65536).

The user should be aware that the Euler angle forumlation 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-G 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-G 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 multiplied by the scaled factor (360/65536).

The user should be aware that the Euler angle forumlation 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-G unit.

$$\text{Temperature } (^{\circ}C) = \text{Temp} * 5/(4096*0.01) = \text{Temp} * 0.12207$$

Command Set Summary

Command	Definition

0x00	**Null Command**
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	**Send EEPROM Value**
0x09	**Program 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**
0x10	**Set Continuous Mode**
0xF0	**Send Firmware Version Number**
0xF1	**Send Device Serial Number**

Command Set Overview

All commands are one byte in length. All commands generate a response of a fixed number of bytes Three commands (0x080, 0x09, and 0x10) require that the host transmit additional data bytes following the command byte to fully define the action to be taken.

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

Data Packet Format

Send Raw Sensor Outputs

Function:	The 3DM-G 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-G 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-G 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-G 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-G 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-G 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-G 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

Send EEPROM Value

Function:	The 3DM-G 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

Program EEPROM Value

Function:	The 3DM-G 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-G 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-G 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 with Vectors

Function:	The 3DM-G 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-G 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-G 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

Set Continuous Mode

Function:	This command enables/disable continuous communications mode. To enable continuous mode, set the Command Data Byte to the desired command byte. To disable continuous mode, set the Command Data byte to 0x00.
Command Byte:	0x10
Command Data:	2 Bytes defined as follows
Byte 1	0x00
Byte 2	Command Data 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

Send Firmware Version Number

Function:	The 3DM-G 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-G 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