

3DM-DH3+™

Downhole Orientation Sensor and Data Logger



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Revised: 3 September 2015

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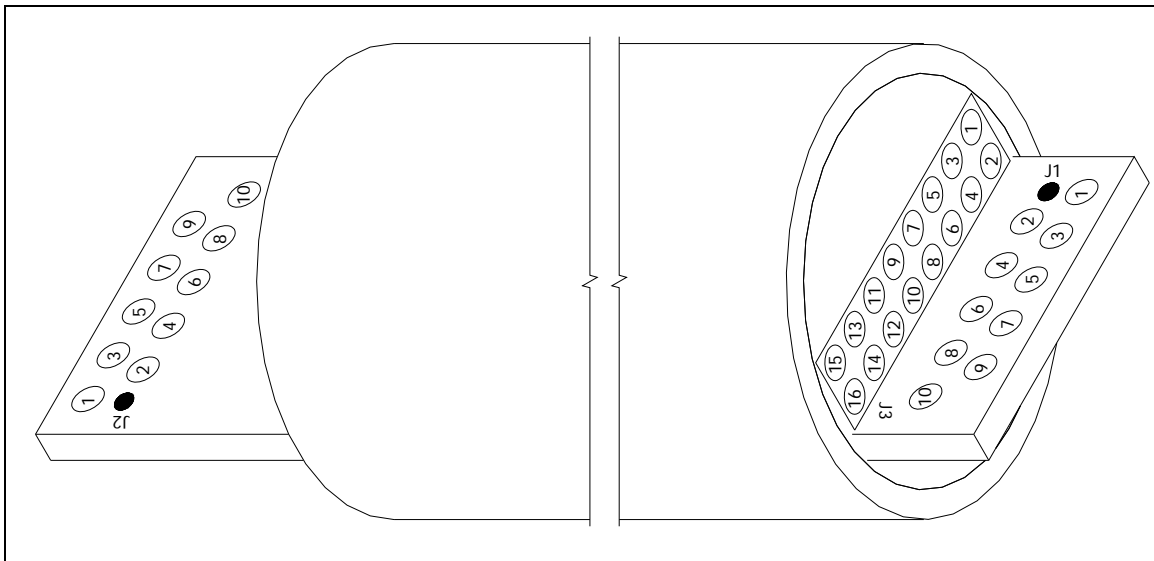
Overview

The 3DM-DH3+ is an orientation sensor and data logger incorporating acceleration sensors, magnetic field sensors, and non-volatile memories for data-logging and for configuration. Its form-factor and rated temperature range are optimized for down-hole drilling applications. Interface to the 3DM-DH3+ is accomplished via an RS-422 serial connection. This document contains the information necessary to develop supporting software and hardware for interfacing to, configuring, and using the 3DM-DH3+.

Physical Interface

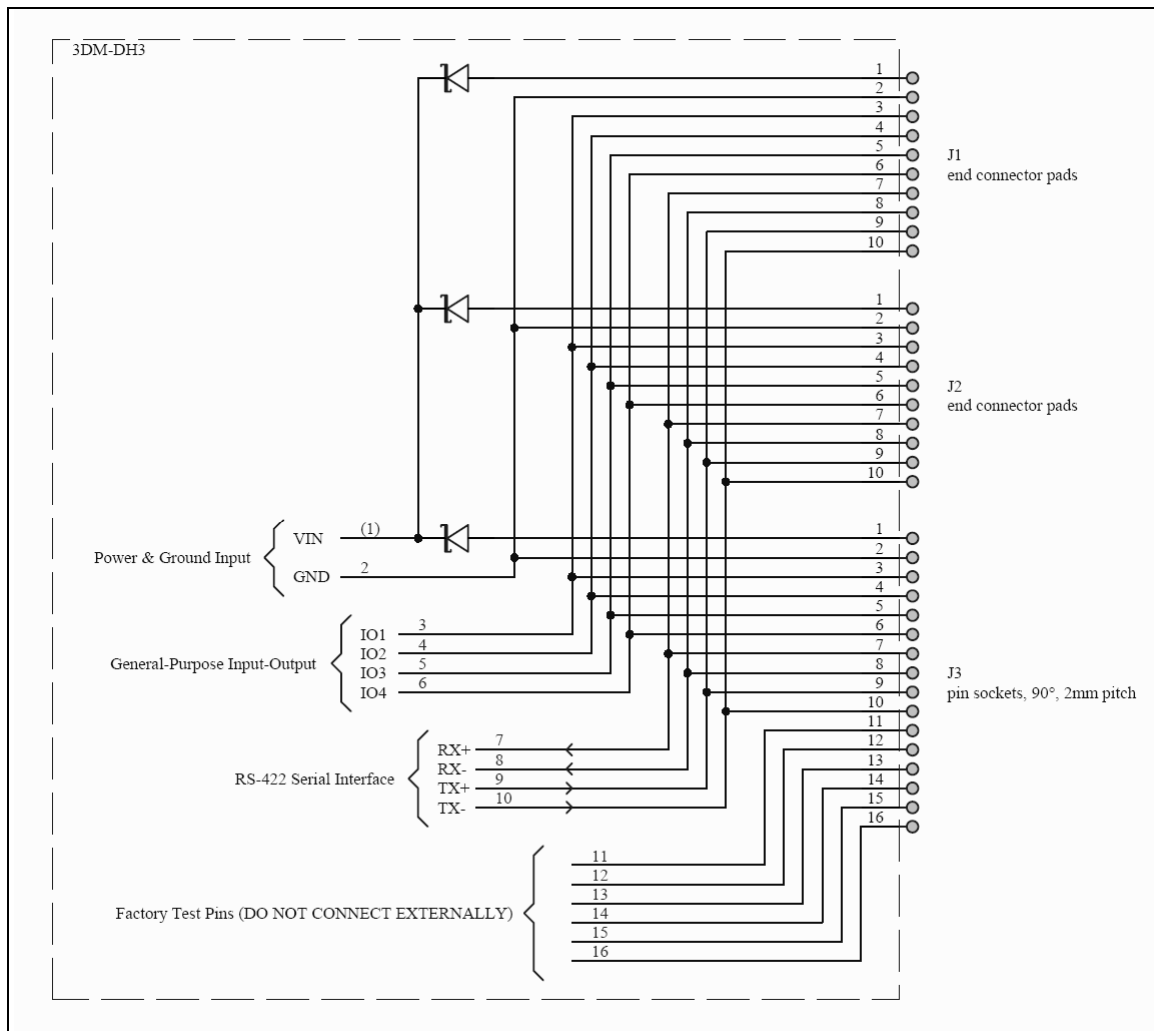
The following diagrams and descriptions illustrate the physical interface to the 3DM-DH3+.

Connector Pin-Outs



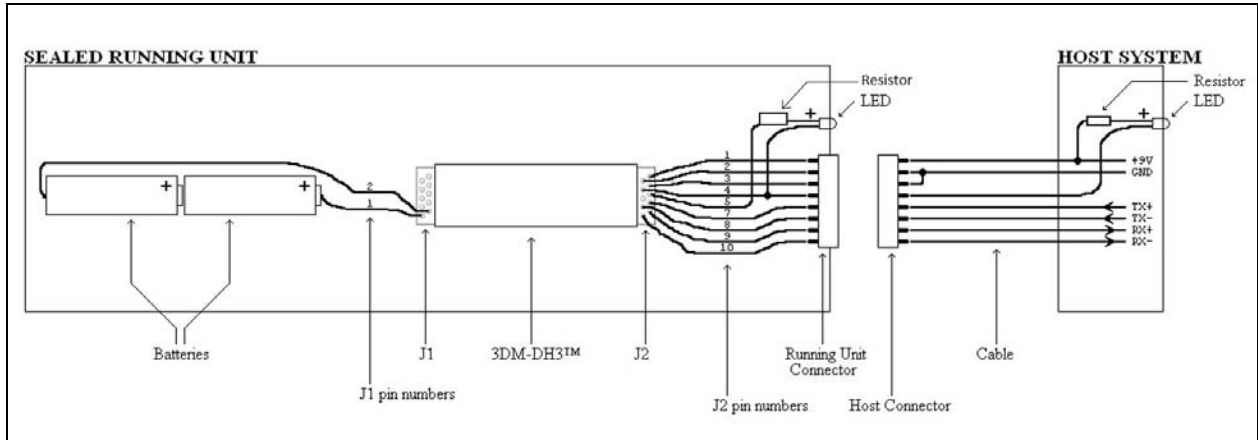
The 3DM-DH3+ has three connectors to the outside world: J1, J2, and J3. J1 and J2 are simply exposed PCB pads for wires to be soldered directly into. J3 is a 2mm pitch pin-socket header. The pin locations of all three connectors are shown above.

Connector Pin Functions



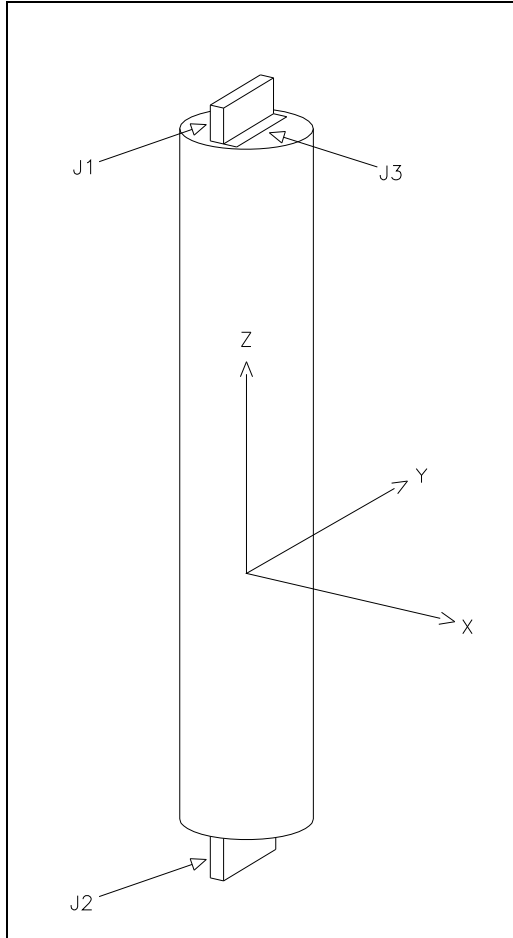
The above diagram shows the pin functions of the 3DM-DH3+ connectors. Note that J1 and J2 provide identical electrical connections, allowing external connections to be wired to either end of the 3DM-DH3+ at the system designer's choice. The primary purpose of J3 is factory test. Please **DO NOT CONNECT ANYTHING** to pins 11 through 16 of J3.

Recommended Hardware Configuration



The above diagram shows the recommended configuration of the 3DM-DH3+ with its supporting hardware. Below is a list of specific guidelines for the hardware configuration.

- It is recommended that batteries be connected to J1 rather than J2 to achieve the best sensor accuracy in data logging mode.
- External power (provided by the host system) should *not* be connected to the same connector as the battery so as to allow “diode-OR” switching between battery power and external power. Refer to the [Connector Pin Functions](#) diagram to see the diodes internal to the 3DM-DH3+ that allow power-source “OR-ing”.
- All other connections can be made to either J1 or J2 at the user’s discretion (recall that J1 and J2 provide duplicate and identical connectivity).
- Keep batteries at least 3.0 inches away from the J1 connector edge.
- If batteries must be on the J2 side of the 3DM-DH3+, keep them at least 6.5 inches away from the J2 connector edge.
- Avoid use of any ferromagnetic materials in the vicinity of the 3DM-DH3+ during its data acquisition operations.
- Recommended battery is [Tadiran](#) model TLH-5903 lithium 3.6V battery. Use two in series (nominally 7.2V total).
- Notice that when the host connector is connected, J2 pins 2 & 3 will be shorted together on the 3DM-DH3+. This is important for enabling communications with the 3DM-DH3+ as described in the [Operating Modes](#) section below.
- Both LEDs are optional but highly recommended for providing visual indications of various 3DM-DH3+ operations.
- The resistor in series with the LED on the host system side should be approximately 750 ohms if using +9V power to the 3DM-DH3+ as recommended.
- The resistor in series with the LED in the running unit should be approximately 300 ohms to match the +5 V available at IO3 (pin 5 of the connector).

Measurement Coordinate System

The above diagram shows the orientation of the 3DM-DH3+'s body-fixed coordinate system.

NOTE: Conventionally the 3DM-DH3+ should be oriented with J1 & J3 on the bottom in the end system (opposite what's shown above), such that the z-axis points down and inclination angle is near zero with the 3DM-DH3+ in its nominal orientation.

Operating Modes

The 3DM-DH3+ has three basic modes of operation as described below.

Communications Mode

If the 3DM-DH3+ is wired as suggested in [Recommended Hardware Configuration](#) above, then plugging in the host system connector will place the 3DM-DH3+ into Communications Mode. Specifically, whenever the IO1 pin (pin 3 of J1, J2, or J3) is externally connected to ground (pin 2 of J1, J2, or J3) the 3DM-DH3+ will be in Communications Mode, and whenever the IO1 pin is open-circuited the 3DM-DH3+ will be in either Data Logging Mode or Deep Sleep Mode, as described below. In Communications Mode (and only in Communications Mode) the 3DM-DH3+ enables its RS-422 communications channel, and will act on and respond to any serial commands it receives. The specifics of the serial commands are detailed in the remainder of this document. NOTE: Be sure to connect an external power source to the 3DM-DH3+ whenever it is operating in Communications Mode because this mode pulls more current than other modes and will quickly degrade battery life if running from the battery.

Data Logging Mode

Data Logging Mode is enabled by setting the *SR* (the sample rate control) value to something other than zero, as described in the [Set Logging Mode](#) command section below. With *SR* at a non-zero value, the 3DM-DH3+ will be in Data Logging Mode whenever the host system connector is disconnected (IO1 pin open-circuited). In Data Logging Mode, the 3DM-DH3+ will acquire sensor data at a rate defined by the *SR* value, and will store averaged data into non-volatile data logging memory at a rate defined by the *DR* (decimation ratio) control value. When in Data Logging Mode, the 3DM-DH3+ is in a reduced-power operating state. Actual power consumption in this mode will depend on the chosen sample rate, as defined in the [Power Consumption](#) section.

Deep Sleep Mode

Deep Sleep Mode is enabled by setting the *SR* value to zero, as described in the [Set Logging Mode](#) command section below. With the *SR* value at zero, the 3DM-DH3+ will be in Deep Sleep Mode whenever the host system connector is disconnected (i.e. whenever the IO1 pin is open-circuited). In Deep Sleep Mode, the 3DM-DH3+ is entirely shut down except for the internal elapsed time counter, and total power consumption is extremely low. Information on the total current consumed in Deep Sleep Mode is given in the [Power Consumption](#) section.

Introduction to the 3DM-DH3+ Data Communications Protocol

The 3DM-DH3+ Data Communications Protocol is a set of serial commands and responses designed specifically for MicroStrain's orientation sensors. For the most part, the communications protocol consists of simple single byte binary commands with fixed length binary data records as replies. Most replies include an "echo" byte and a checksum to do simple data integrity checks. All communications with the sensor are accomplished using a standard serial "COM" port.

The standard serial protocol is described below in [Communications Commands](#).

Serial Port Configuration

All communications with the 3DM-DH3+ are accomplished via an RS-422 serial interface. The serial COM port settings are shown in the table below:

COM Port Serial Settings	
Baud Rate	115.2K
Parity:	None
Data Bits:	8
Stop Bits:	1

Communications Commands

The host computer controls what data the 3DM-DH3+ will output 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-DH3+ to transmit a data record of a fixed number of bytes.

Below is a summary of all commands available for the 3DM-DH3+. Each of the commands is described in detail in the [Command Reference](#) section.

Command Set Summary

Command	Definition
0x13	Read Elapsed Consumption Value
0x14	Write Elapsed Consumption Value
0x15	Read Event Capture Data
0x16	Clear Event Capture Data
0x17	Set Logging Mode
0x18	Get Data Logging Summary
0x19	Read Logged Data Record
0x1A	Read Logged Data Record as Angles
0x1B	Get Immediate Sensor Data as Angles
0x1F	Erase All Logged Data
0x20	Stop/Start/Reset/Read TimeCount
0xC7	Get Immediate Sensor Data
0xE0	Write Byte to EEPROM
0xE8	Read Byte from EEPROM
0xE9	Read Firmware Version Number
0xEA	Read Device ID String
0xFB	Change User Test Mode
0xFE	Reset Device

Command Reference

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 contain the data requested.

The 16 bit checksum is equal to the sum of all preceding bytes with rollover from 65535 to 0.

All multi-byte quantities are transmitted in big endian order (MSB first, LSB last). Floating point values are 32 bit, and conform to the [IEEE-754](#) format.

Read Elapsed Consumption Value (0x13)

Function:	Returns an approximation of the elapsed current consumed, in units of mA·hours. <i>ElapsedCurrent</i> = approximate elapsed current in mA·hours NOTE: Use of this feature is described in the Elapsed Current Consumption Feature section of this document.		
Command Byte:	0x13		
Command Data:	None		
Response:	5 bytes defined as follows		
Byte 1	<i>Header</i> = 0x13		
Bytes 2-3	<i>ElapsedCurrent</i>	[unsigned]	
Bytes 4-5	<i>Checksum</i>	[unsigned]	

Write Elapsed Consumption Value (0x14)

Function:	Modifies the value of the elapsed consumption count. <i>ElapsedCurrent</i> = approximate elapsed current in mA·hours NOTE: Use of this feature is described in the Elapsed Current Consumption Feature section of this document.		
Command Byte:	0x14		
Command Data:	5 bytes defined as follows		
Byte 1	0xBA (Confirms user intent)		
Byte 2	0x29 (Confirms user intent)		
Byte 3	0x94 (Confirms user intent)		
Bytes 4-5	<i>ElapsedCurrent</i>		[unsigned]
Response:	5 bytes defined as follows		
Byte 1	<i>Header</i> = 0x14		
Bytes 2-3	<i>ElapsedCurrent</i>		[unsigned]
Bytes 4-5	<i>Checksum</i>		[unsigned]

Read Event Capture Data (0x15)

Function:	Reads the following diagnostic event count values: <i>PORcount</i> = # of Power On Reset events <i>BORcount</i> = # of Brown Out Reset events <i>WDTcount</i> = # of Watchdog Reset events <i>SRSTcount</i> = # of Soft Reset events <i>STKFcount</i> = # of Stack Full Reset events <i>STKUcount</i> = # of Stack Underflow Reset events <i>HRSTcount</i> = # of Hard Reset events NOTE: This command can be used to help determine the cause of problems in the event of system malfunction (such as intermittent power connection, battery failure, etc). To make optimal use of this feature, use the Clear Event Capture Data command (below) to reset the event count values whenever you install new batteries.	
Command Byte:	0x15	
Command Data:	None	
Response:	11 bytes defined as follows	
Byte 1	<i>Header</i> = 0x15	
Byte 2	<i>PORcount</i>	[unsigned]
Byte 3	<i>BORcount</i>	[unsigned]
Byte 4	<i>WDTcount</i>	[unsigned]
Byte 5	<i>SRSTcount</i>	[unsigned]
Byte 6	<i>STKFcount</i>	[unsigned]
Byte 7	<i>STKUcount</i>	[unsigned]
Byte 8	<i>HRSTcount</i>	[unsigned]
Byte 9	0x00 (reserved for future use)	
Bytes 10-11	<i>Checksum</i>	[unsigned]

Clear Event Capture Data (0x16)

Function:	Clears the diagnostic event count values to zero. Event count values can be read using the Read Event Capture Data command (above).	
Command Byte:	0x16	
Command Data:	5 bytes defined as follows	
Byte 1	0x46 (Confirms user intent)	
Byte 2	0xB1 (Confirms user intent)	
Byte 3	0xE9 (Confirms user intent)	
Byte 4	0x00 (Confirms user intent)	
Byte 5	0x9E (Confirms user intent)	
Response:	11 bytes defined as follows	
Byte 1	<i>Header</i> = 0x16	
Byte 2	<i>PORcount</i>	[unsigned]
Byte 3	<i>BORcount</i>	[unsigned]
Byte 4	<i>WDTcount</i>	[unsigned]
Byte 5	<i>SRSTcount</i>	[unsigned]
Byte 6	<i>STKFcount</i>	[unsigned]
Byte 7	<i>STKUcount</i>	[unsigned]
Byte 8	<i>HRSTcount</i>	[unsigned]
Byte 9	0x00 (reserved for future use)	
Bytes 10-11	<i>Checksum</i>	[unsigned]

Set Logging Mode (0x17)

Function:	<p>Changes the Logging Mode settings as follows.</p> <p>The Sample Rate of the 3DM-DH3+ is the rate at which raw sensor data is acquired in Data Logging Mode. Sample Rate is controlled by the <i>SR</i> control byte.</p> $\text{Sample Rate in Hz} = 64 \div (SR + 1)$ <p>The Logging Rate of the 3DM-DH3+ is the rate at which it stores averaged sensor data in Data Logging Mode. Logging Rate is controlled by the <i>DR</i> control byte.</p> $\text{Logging Rate in Hz} = \text{Sample Rate} \div DR$ <p>NOTE: A <i>DR</i> value of zero is not allowed. If 0 is written to <i>DR</i>, it is automatically changed to 1.</p> <p>NOTE: If <i>SR</i> is zero, then data logging is disabled.</p> <p>NOTE: The “Configuring the 3DM-DH3+” section describes in detail how to set up the 3DM-DH3+ for data logging.</p>		
Command Byte:	0x17		
Command Data:	4 bytes defined as follows		
Byte 1	0x51 (Confirms user intent)		
Byte 2	0xD6 (Confirms user intent)		
Byte 3	<i>SR</i>		[unsigned]
Byte 4	<i>DR</i>		[unsigned]
Response:	5 bytes defined as follows		
Byte 1	<i>Header</i> = 0x17		
Byte 2	<i>SR</i>		[unsigned]
Byte 3	<i>DR</i>		[unsigned]
Bytes 4-5	<i>Checksum</i>		[unsigned]

Get Data Logging Summary (0x18)

Function:	Returns information about the Logged Data presently stored in non-volatile memory, and about the current Logging Mode settings. <i>SampleRate</i> = indicates Sample Rate per above. <i>DecimationRatio</i> = indicates Decimation Ratio per above. <i>NumRecords</i> = indicates the number of Data Records that are currently stored in non-volatile Data-Logging Memory.	
Command Byte:	0x18	
Command Data:	None	
Response:	9 bytes defined as follows	
Byte 1	<i>Header</i> = 0x18	
Bytes 2-5	<i>NumRecords</i>	[unsigned]
Byte 6	<i>SampleRate</i>	[unsigned]
Byte 7	<i>DecimationRatio</i>	[unsigned]
Bytes 8-9	<i>Checksum</i>	[unsigned]

Read Logged Data Record (0x19)

Function:	Reads back a logged Data Record from non-volatile Data-Logging Memory. Response data variables are described in detail in the Reading & Interpreting Sensor Data section. NOTE: The 3DM-DH3+ can store 32,768 data records. The address range (<i>RecordAddress</i>) is 0x000000 to 0x007FFF.		
Command Byte:	0x19		
Command Data:	4 bytes defined as follows		
Byte 1	0x00 (This byte must be zero)		
Bytes 2-4	<i>RecordAddress</i>		[unsigned]
Response:	44 bytes defined as follows		
Byte 1	<i>Header</i> = 0x19		
Bytes 2-5	<i>TimeStamp</i>		[unsigned]
Byte 6	<i>EventLog</i>		
Bytes 7-10	<i>A_x</i>		[float]
Bytes 11-14	<i>A_y</i>		[float]
Bytes 15-18	<i>A_z</i>		[float]
Bytes 19-20	<i>AccelTemp</i>		[signed]
Bytes 21-24	<i>H_x</i>		[float]
Bytes 25-28	<i>H_y</i>		[float]
Bytes 29-32	<i>H_z</i>		[float]
Bytes 33-34	<i>MagTemp</i>		[signed]
Bytes 35-42	reserved for future use (current firmware returns zeros)		
Bytes 43-44	<i>Checksum</i>		[unsigned]

Read Logged Data Record as Angles (0x1A)

Function:	<p>Reads back a logged Data Record from non-volatile Data-Logging Memory. Response data variables are described in detail in the Reading & Interpreting Sensor Data section.</p> <p>NOTE: The 3DM-DH3+ can store 32,768 data records. The address range (<i>RecordAddress</i>) is 0x000000 to 0x007FFF.</p> <p><i>Available in firmware v0x00000008 or higher</i></p>		
Command Byte:	0x1A		
Command Data:	4 bytes defined as follows		
Byte 1	0x00 (This byte must be zero)		
Bytes 2-4	<i>RecordAddress</i>		[unsigned]
Response:	40 bytes defined as follows		
Byte 1	<i>Header</i> = 0x1A		
Bytes 2-5	<i>TimeStamp</i>		[unsigned]
Byte 6	<i>EventLog</i>		
Bytes 7-10	<i>Inclination</i>		[float]
Bytes 11-14	<i>Azimuth</i>		[float]
Bytes 15-18	<i>GTF</i>		[float]
Bytes 19-22	<i>MTF</i>		[float]
Bytes 23-26	<i>DipAngle</i>		[float]
Bytes 27-28	<i>AccelTemp</i>		[signed]
Bytes 29-30	<i>MagTemp</i>		[signed]
Bytes 31-34	<i>G-TOT</i>		[float]
Bytes 35-38	<i>H-TOT</i>		[float]
Bytes 39-40	<i>Checksum</i>		[unsigned]

Get Immediate Sensor Data as Angles (0x1B)

Function:	The 3DM-DH3+ will acquire new sensor readings and output a data record containing the resulting data as orientation angles, along with ancillary data. Response data variables are described in detail in the Reading & Interpreting Sensor Data section. <i>Available in firmware v0x00000008 or higher</i>
Command Byte:	0x1B
Command Data:	None
Response:	40 bytes defined as follows
Byte 1	<i>Header</i> = 0x19
Bytes 2-5	<i>TimeStamp</i> [unsigned]
Byte 6	<i>EventLog</i>
Bytes 7-10	<i>Inclination</i> [float]
Bytes 11-14	<i>Azimuth</i> [float]
Bytes 15-18	<i>GTF</i> [float]
Bytes 19-22	<i>MTF</i> [float]
Bytes 23-26	<i>DipAngle</i> [float]
Bytes 27-28	<i>AccelTemp</i> [signed]
Bytes 29-30	<i>MagTemp</i> [signed]
Bytes 31-34	<i>G-TOT</i> [float]
Bytes 35-38	<i>H-TOT</i> [float]
Bytes 39-40	<i>Checksum</i> [unsigned]

Erase All Logged Data (0x1F)

Function:	Erases all contents of non-volatile Data-Logging Memory. NOTE: This command will take between 10 and 45 seconds to process. The 3DM-DH3+ will send its response only when the command has processed completely. If an LED is connected to the IO2 output pin as described in the Physical Interface section, then the LED will blink while the command is processing.	
Command Byte:	0x1F	
Command Data:	3 bytes defined as follows	
Byte 1	0xB3 (Confirms user intent)	
Byte 2	0x94 (Confirms user intent)	
Byte 3	0xE6 (Confirms user intent)	
Response:	3 bytes defined as follows	
Byte 1	<i>Header</i> = 0x1F	
Bytes 2-3	<i>Checksum</i>	[unsigned]

Stop/Start/Reset/Read TimeCount (0x20)

Function:	Starts, Stops, Resets, or Reads the Elapsed Time Counter . NOTE: The specific action is controlled by <i>ControlByte</i> . <i>ControlByte</i> = 0x00 -- Stop & Read Elapsed Time Counter <i>ControlByte</i> = 0x51 -- Start & Read Elapsed Time Counter <i>ControlByte</i> = 0xA9 -- Reset & Read Elapsed Time Counter <i>ControlByte</i> = other -- Read Elapsed Time Counter $\text{Elapsed Time} = \text{TimeCount} \times 15.625\text{ms}$	
Command Byte:	0x20	
Command Data:	4 bytes defined as follows	
Byte 1	0x11 (Confirms user intent)	
Byte 2	0xD9 (Confirms user intent)	
Byte 3	0x2B (Confirms user intent)	
Byte 4	<i>ControlByte</i>	
Response:	7 bytes defined as follows	
Byte 1	<i>Header</i> = 0x20	
Bytes 2-5	<i>TimeCount</i>	[unsigned]
Bytes 6-7	<i>Checksum</i>	[unsigned]

Get Immediate Sensor Data (0xC7)

Function:	The 3DM-DH3+ will acquire new sensor readings and output a data record containing the resulting acceleration vector and magnetic field vector, along with ancillary data. Response data variables are described in detail in the Reading & Interpreting Sensor Data section.	
Command Byte:	0xC7	
Command Data:	None	
Response:	44 bytes defined as follows	
Byte 1	<i>Header</i> = 0xC7	
Bytes 2-5	<i>TimeStamp</i>	[unsigned]
Byte 6	<i>EventLog</i>	
Bytes 7-10	<i>A_x</i>	[float]
Bytes 11-14	<i>A_y</i>	[float]
Bytes 15-18	<i>A_z</i>	[float]
Bytes 19-20	<i>AccelTemp</i>	[signed]
Bytes 21-24	<i>H_x</i>	[float]
Bytes 25-28	<i>H_y</i>	[float]
Bytes 29-32	<i>H_z</i>	[float]
Bytes 33-34	<i>MagTemp</i>	[signed]
Bytes 35-42	reserved for future use (current firmware returns zeros)	
Bytes 43-44	<i>Checksum</i>	[unsigned]

Write Byte to EEPROM (0xE0)

Function:	The specified byte will be written to EEPROM of the 3DM-DH3+ at the specified address. EEPROM details are given in the “ Configuring the 3DM-DH3+ ” section.	
Command Byte:	0xE0	
Command Data:	6 bytes defined as follows	
Byte 1	0xC1	
Byte 2	0x29	
Byte 3	0x00	
Byte 4-5	16 bit address of EEPROM byte to be written to	[unsigned]
Byte 6	Data Byte to be written to EEPROM	
Response:	4 bytes defined as follows	
Byte 1	<i>Header</i> = 0xE0	
Byte 2	verification Data Byte (as read back from EEPROM)	
Bytes 3-4	<i>Checksum</i>	

Read Byte from EEPROM (0xE8)

Function:	The 3DM-DH3+ will output the value of the Data Byte stored in EEPROM at the specified address. EEPROM details are given in the “ Configuring the 3DM-DH3+ ” section.
Command Byte:	0xE8
Command Data:	3 bytes defined as follows
Byte 1	0x00
Byte 2-3	16 bit address of EEPROM word to be read
Response:	4 bytes defined as follows
Byte 1	<i>Header</i> = 0xE8
Byte 2	Data Byte read from EEPROM
Bytes 3-4	<i>Checksum</i>

Read Firmware Version Number (0xE9)

Function:	Reads the version number of the firmware that’s running on the 3DM-DH3+.
Command Byte:	0xE9
Command Data:	None
Response:	7 bytes defined as follows
Byte 1	<i>Header</i> = 0xE9
Bytes 2-5	Firmware Version Number [unsigned]
Bytes 6-7	<i>Checksum</i>

Read Device ID String (0xEA)

Function:	Reads one of the following Device Identification Strings: <i>StringNum</i> = 0x00 → Model Number <i>StringNum</i> = 0x01 → Serial Number <i>StringNum</i> = 0x02 → Model Name <i>StringNum</i> = 0x03 → Device Options
Command Byte:	0xEA
Command Data:	1 byte defined as follows
Byte 1	<i>StringNum</i>
Response:	19 bytes defined as follows
Byte 1	<i>Header</i> = 0xEA
Byte 2	<i>StringNum</i>
Bytes 3-18	Device ID String [ASCII]
Bytes 19-20	<i>Checksum</i>

Change User Test Mode (0xFB)

Function:	<p>Controls the built-in user test functions for verifying accelerometer and magnetometer sensor functionality. Individual bits of the <i>TestMode</i> byte control the user test modes as follows:</p> <p>If bit 2 is set, an offset signal of approximately 0.25 gauss is applied to all three magnetometer axes, the direction of which is controlled by bit 3 (1=positive offset, 0=negative offset).</p> <p>If bit 4 is set, a positive offset signal of approximately 1G is applied to all three accelerometer axes.</p> <p>All other bits are to be written as zeros for compatibility with possible future firmware enhancements.</p> <p>NOTE: Whenever the 3DM-DH3+ enters Data Logging Mode or Deep Sleep Mode it automatically clears the user test mode to zero (removes offsets) to prevent accidentally leaving test modes engaged while performing data logging operations.</p>
Command Byte:	0xFB
Command Data:	3 bytes defined as follows
Byte 1	0xC1 (Confirms user intent)
Byte 2	0x29 (Confirms user intent)
Byte 3	<i>TestMode</i>
Response:	4 bytes defined as follows
Byte 1	<i>Header</i> = 0xFB
Byte 2	<i>TestMode</i>
Bytes 3-4	<i>Checksum</i>

Reset Device (0xFE)

Function:	<p>Initiates a Reset of the 3DM-DH3+ internal processor. This command should not be necessary in normal operation.</p> <p>NOTE: Whenever the 3DM-DH3+ powers up or is reset by any means (brown-out, power interruption, watchdog time-out, etc) it emits the ASCII text string “3DM-DH3+” as the processor begins code execution. The Reset Device command performs an actual reset of the internal processor, so the ‘response’ is not actually a response to the command, but is the same ASCII text string that the 3DM-DH3+ emits on power-up or other reset events.</p>
Command Byte:	0xFE
Command Data:	2 bytes defined as follows
Byte 1	0x9E (Confirms user intent)
Byte 2	0x3A (Confirms user intent)
Response:	8 bytes defined as follows
Bytes 1-8	“3DM-DH3+” as ASCII text

Configuring the 3DM-DH3+

Sample Rate & Decimation Ratio

In [Data Logging Mode](#), the 3DM-DH3+ acquires sensor data at a specified Sample Rate, and averages the acquired sensor data by a specified Decimation Ratio. The Sample Rate and Decimation Ratio are most easily controlled by the user through the [Set Logging Mode](#) command.

The **Sample Rate** of the 3DM-DH3+ is the rate at which raw sensor data is acquired in Data Logging Mode. Sample Rate is controlled by the *SR* control byte. When *SR* is zero, sampling is disabled. For any other value of *SR* the Sample Rate is as follows:

$$\text{Sample Rate in Hz} = 64 \div (SR + 1)$$

Sample Rate can be from 0.25Hz on the slow side up to 8Hz on the fast side. Sample Rates greater than 8Hz ($SR < 7$) will yield unpredictable results, so do not set *SR* to any value less than 7 and greater than 0. The Sample Rates shown in the below table are just a few of the values achievable.

<i>SR</i> data byte [dec]	<i>SR</i> data byte [hex]	Sample Period [sec]	Sample Rate [Hz]
7	0x07	0.125	8
15	0x0F	0.25	4
31	0x1F	0.5	2
63	0x3F	1	1
127	0x7F	2	0.5
191	0xBF	3	0.3333
255	0xFF	4	0.25

The **Decimation Ratio** of the 3DM-DH3+ is the number of sensor acquisitions it averages before storing a record in Data Logging Memory. The **Logging Rate** of the 3DM-DH3+ is the rate at which it stores records into Data Logging Memory. Decimation Ratio and Logging Rate are controlled by the *DR* control byte as follows.

$$\text{Decimation Ratio} = DR$$

$$\text{Logging Rate in Hz} = \text{Sample Rate} \div DR = 64 \div ((SR + 1) \times DR)$$

A Decimation Ratio of zero is not allowed. If you set *DR* to 0, the 3DM-DH3+ will automatically change it to 1.

One example:

if $SR = 15$ and $DR = 8$, then

Sample Rate = $64 \div (15 + 1) = 4$ Hz (i.e. 4 samples acquired per second)

Decimation Ratio = 8 (i.e. 8 samples averaged for every point logged)

Logging Rate = $4 \div 8 = 0.5$ Hz (i.e. 1 point logged every 2 seconds)

The two main considerations in choosing SR & DR are battery life and logging memory capacity. Current consumption in Data Logging Mode is highly dependant on the operating Sample Rate as described in the [Power Requirements & Battery Life](#) section. You should set SR such that battery capacity will be sufficient for the duration of the expected data logging task. Logging memory capacity of the 3DM-DH3+ is 32,768 data records. Divide that by the configured Logging Rate to determine the amount of time that the 3DM-DH3+ can log data before it fills its memory.

NOTE: Whenever the Data Logging Memory is full, the 3DM-DH3+ will not allow SR to be any value other than zero. While in Data Logging Mode, if the Data Logging Memory becomes full, the 3DM-DH3+ will automatically stop sampling, set SR to zero, exit Data Logging Mode and enter Deep Sleep Mode.

NOTE: The Decimation Ratio (DR) setting applies to immediate sensor readings as well as to Data Logging Mode readings. For example, if $DR = 8$ then whenever you request immediate sensor readings (using the [Get Immediate Sensor Data](#) or [Get Immediate Sensor Data as Angles](#) commands) the 3DM-DH3+ will perform 8 sensor acquisitions and return the average of them. Increasing the value of DR will therefore significantly increase the response time to these commands.

Elapsed Time Counter

The Elapsed Time Counter keeps track of elapsed time while the 3DM-DH3+ is running, and is used during Data Logging Mode to store a Time Stamp along with each logged data record. User control of the Elapsed Time Counter is achieved using the [Start/Stop/Reset/Read TimeCount](#) command. Additionally, the Elapsed Time Counter will start running automatically (if not already running) whenever the 3DM-DH3+ enters Deep Sleep Mode or Data Logging Mode. The Elapsed Time Counter value (*TimeCount*) is a 32-bit unsigned long integer. The relationship between *TimeCount* and the actual elapsed time is defined below.

$$\text{Elapsed Time} = \text{TimeCount} \times 15.625\text{ms}$$

One example:

If *TimeCount* = 0x00000F00 = 3840

Elapsed Time = $3840 \times 15.625\text{ms} = 60\text{seconds}$

If *TimeCount* reaches 4,294,967,295 (0xFFFFFFFF) it will overflow to zero on its next increment. This is equivalent to a little over two years of elapsed time.

Configuration Memory (EEPROM)

dec addr	hex addr	name of variable	data type*	bytes	default value	byte value at addr+3	byte value at addr+2	byte value at addr+1	byte value at addr	description
0	0x00	<i>accelC_x</i>	float	4	0	0x00	0x00	0x00	0x00	<i>accelC</i> : Accelerometer User Offset Vector
4	0x04	<i>accelC_y</i>	float	4	0	0x00	0x00	0x00	0x00	
8	0x08	<i>accelC_z</i>	float	4	0	0x00	0x00	0x00	0x00	
12	0x0C	<i>accelMt_{xx}</i>	float	4	1	0x3F	0x80	0x00	0x00	<i>accelMt</i> : Accelerometer Tare Matrix (3x3 matrix)
16	0x10	<i>accelMt_{xy}</i>	float	4	0	0x00	0x00	0x00	0x00	
20	0x14	<i>accelMt_{xz}</i>	float	4	0	0x00	0x00	0x00	0x00	
24	0x18	<i>accelMt_{yx}</i>	float	4	0	0x00	0x00	0x00	0x00	
28	0x1C	<i>accelMt_{yy}</i>	float	4	1	0x3F	0x80	0x00	0x00	
32	0x20	<i>accelMt_{yz}</i>	float	4	0	0x00	0x00	0x00	0x00	
36	0x24	<i>accelMt_{zx}</i>	float	4	0	0x00	0x00	0x00	0x00	
40	0x28	<i>accelMt_{zy}</i>	float	4	0	0x00	0x00	0x00	0x00	
44	0x2C	<i>accelMt_{zz}</i>	float	4	1	0x3F	0x80	0x00	0x00	
48	0x30	<i>magC_x</i>	float	4	0	0x00	0x00	0x00	0x00	<i>magC</i> : Magnetometer Hard Iron Offset Vector
52	0x34	<i>magC_y</i>	float	4	0	0x00	0x00	0x00	0x00	
56	0x38	<i>magC_z</i>	float	4	0	0x00	0x00	0x00	0x00	
60	0x3C	<i>magMs_{xx}</i>	float	4	1	0x3F	0x80	0x00	0x00	<i>magMs</i> : Magnetometer Soft Iron Compensation Matrix (3x3 matrix)
64	0x40	<i>magMs_{xy}</i>	float	4	0	0x00	0x00	0x00	0x00	
68	0x44	<i>magMs_{xz}</i>	float	4	0	0x00	0x00	0x00	0x00	
72	0x48	<i>magMs_{yx}</i>	float	4	0	0x00	0x00	0x00	0x00	
76	0x4C	<i>magMs_{yy}</i>	float	4	1	0x3F	0x80	0x00	0x00	
80	0x50	<i>magMs_{yz}</i>	float	4	0	0x00	0x00	0x00	0x00	
84	0x54	<i>magMs_{zx}</i>	float	4	0	0x00	0x00	0x00	0x00	
88	0x58	<i>magMs_{zy}</i>	float	4	0	0x00	0x00	0x00	0x00	
92	0x5C	<i>magMs_{zz}</i>	float	4	1	0x3F	0x80	0x00	0x00	
96	0x60	<i>magMt_{xx}</i>	float	4	1	0x3F	0x80	0x00	0x00	<i>magMt</i> : Magnetometer Tare Matrix (3x3 matrix)
100	0x64	<i>magMt_{xy}</i>	float	4	0	0x00	0x00	0x00	0x00	
104	0x68	<i>magMt_{xz}</i>	float	4	0	0x00	0x00	0x00	0x00	
108	0x6C	<i>magMt_{yx}</i>	float	4	0	0x00	0x00	0x00	0x00	
112	0x70	<i>magMt_{yy}</i>	float	4	1	0x3F	0x80	0x00	0x00	
116	0x74	<i>magMt_{yz}</i>	float	4	0	0x00	0x00	0x00	0x00	
120	0x78	<i>magMt_{zx}</i>	float	4	0	0x00	0x00	0x00	0x00	
124	0x7C	<i>magMt_{zy}</i>	float	4	0	0x00	0x00	0x00	0x00	
128	0x80	<i>magMt_{zz}</i>	float	4	1	0x3F	0x80	0x00	0x00	
132	0x84	SR	unsigned	1	0				0x00	Sample Rate Control
133	0x85	DR	unsigned	1	1				0x01	Decimation Ratio Control
134	0x86	<i>accelADCconfig</i>	unsigned	1	3				0x03	(DO NOT CHANGE)
135	0x87	<i>magADCconfig</i>	unsigned	1	32				0x20	(DO NOT CHANGE)
136	0x88	(unused)		120						(reserved for future use)

* Float data types are [32-bit IEEE-754 format](#).

The Configuration Memory (EEPROM) is user-accessible non-volatile memory that stores configuration data. It is accessed using the [Write Byte to EEPROM](#) and [Read Byte from EEPROM](#) commands. The functions of the various configuration data variables are described below.

Acceleration Measurement Compensation (*accelC*, *accelMt*)

The factory calibration parameters are used by the 3DM-DH3+'s firmware to transform the raw accelerometer outputs into an initial acceleration measurement (A') in units of (g) and given in terms of the body-fixed coordinate system. The following equation is then used to compute the final acceleration measurement output by the system (A).

$$A = accelMt \times (A' - accelC)$$

Where: A = Acceleration measurement output by the 3DM-DH3+ to the host
 $accelMt$ = Accelerometer Tare Matrix
 $accelC$ = Accelerometer User Offset Vector
 A' = Initial acceleration measurement made by the system using the factory calibration.

The quantities $accelMt$ and $accelC$ provide a means by which the user can modify the final acceleration output of the system. The factory defaults of these quantities are such that $A = A'$. This is appropriate for most applications.

Accelerometer User Offset Vector (*accelC*)

The Accelerometer User Offset Vector is a 3 element vector that is subtracted from every acceleration measurement that the device makes. This provides a means by which bias errors in the accelerometer sensors can be compensated for.

In normal operations, $accelC$ should be set to (0,0,0). The factory calibration of the accelerometers compensates for all systematic sources of bias shift (e.g., temperature change).

In some unusual circumstances, the bias of the accelerometers may permanently shift, possibly as a result of exposing the device to large mechanical shocks. In such cases, it is possible to compensate for this shift in sensor bias by entering appropriate values for $accelC$. In most such cases, however, it is preferable to return the unit to the factory for complete system re-calibration.

Accelerometer Tare Matrix (*accelMt*)

The Accelerometer Tare Matrix is a 3x3 coordinate transformation matrix. The factory default is the identity matrix. Valid entries include any orthonormal matrix (i.e., transpose = inverse, and determinant = 1). The tare matrix provides a means by which the local body-fixed coordinate system (that the acceleration output is expressed in terms of) can be re-oriented.

One common situation where *accelMt* is useful is in applications where the 3DM-DH3+ must be aligned within some larger apparatus. This can be done in one of two ways. First, the 3DM-DH3+ is can be physically mounted to the apparatus using a mounting system that ensures proper alignment. Second, the 3DM-DH3+ can be physically mounted in an arbitrary manner, and then mathematically “aligned”. This mathematical alignment would involve altering the values of *accelMt*. Consult the factory for advice on how to implement a mathematical alignment procedure.

Note: In almost all cases, the values of *accelMt* and *magMt* should be the same.

Magnetic Field Measurement Compensation (*magC*, *magMs*, *magMt*)

The factory calibration parameters are used by the 3DM-DH3+’s firmware to transform the raw magnetometer outputs into an initial magnetic field measurement (H') in units of (Gauss) and given in terms of the local body-fixed coordinate system. The following equation is then used to compute the final magnetic field measurement output by the system (H).

$$H = magMt \times magMs \times (H' - magC)$$

Where: H = Magnetic Field measurement output by the 3DM-DH3+ to the host
magMs = Magnetometer Soft Iron Compensation Matrix
magMt = Magnetometer Tare Matrix
magC = Magnetometer Hard Iron Offset Vector
 H' = Initial magnetic field measurement made by the system using the factory calibration.

The quantities *magMt*, *magMs* and *magC* provide a means by which the user can modify the final magnetic field output of the system. The factory defaults of these quantities are such that $H = H'$. This is appropriate for most applications.

Magnetometer Hard Iron Offset Vector (*magC*)

The Magnetometer User Offset Vector is a 3 element vector that is subtracted from every magnetic field measurement that the device makes. This provides a means by which bias errors in the magnetometer sensors can be compensated for.

In normal operations, *magC* should be set to (0,0,0). The factory calibration of the magnetometers compensates for all systematic sources of bias shift (e.g., temperature change).

In some unusual circumstances, the bias of the magnetometers may permanently shift. In such cases, it is possible to compensate for this shift in sensor bias by entering appropriate values for *magC*. In cases where the bias shift is due to a true shift in the sensor’s bias, it is generally preferable to return the unit to the factory for complete system re-calibration.

A more common cause of apparent bias shifts in the magnetometers is the presence in the local area of a source of hard iron interference. Such interference is caused by anything near the sensor that is itself a magnet (even a very weak one). In such cases, the magnetic field measurements will appear to be corrupted by a bias shift in the magnetometers. In reality, the sensors have not experienced a true bias shift, but rather, the nearby magnet is altering the actual magnetic environment in that the sensors are exposed to.

In either case, the bias shift (true or apparent) can be compensated for by entering the appropriate values into the *magC* vector.

In applications where hard iron interference is suspected or known to be present, consult the factory for advice on how to compute the optimal values for *magC*.

Magnetometer Soft Iron Compensation Matrix (*magMs*)

The Magnetometer Soft Iron Compensation Matrix is a 3x3 matrix. Unlike *magMt*, it is not required to be orthonormal. Its determinant does not need to be unity.

The purpose of *magMs* is to allow the user to compensate for the presence of soft iron interference. Such interference is caused by the presence of nearby objects which are made of ferromagnetic material (typically containing iron or nickel). Any material which is not itself a magnet (i.e., generating its own magnetic field) but which a conventional magnetic will stick to, is ferromagnetic.

In some cases, soft iron interference can be adequately compensated for through the use of the *magMs* matrix. Consult the factory for additional detail, and advice on implementing soft iron compensation.

Magnetometer Tare Matrix (*magMt*)

The Magnetometer Tare Matrix is a 3x3 coordinate transformation matrix. The factory default is the identity matrix. Valid entries include any orthonormal matrix (i.e., transpose = inverse, and determinant = 1). The tare matrix provides a means by which the local body-fixed coordinate system (that the magnetic field output is expressed in terms of) can be re-oriented.

One common situation where *magMt* is useful is in applications where the 3DM-DH3+ must be aligned within some larger apparatus. This can be done in one of two ways. First, the 3DM-DH3+ is can be physically mounted to the apparatus using a mounting system that ensures proper alignment. Second, the 3DM-DH3+ can be physically mounted in an arbitrary manner, and then mathematically “aligned”. This mathematical alignment would involve altering the values of *magMt*. Consult the factory for advice on how to implement a mathematical alignment procedure.

Note: In almost all cases, the values of *accelMt* and *magMt* should be the same.

Other Configuration Data Variables

The function of the *SR* & *DR* configuration bytes is described in the [Sample Rate & Decimation Ratio](#) section above. These bytes can be read and written directly just like any other EEPROM data byte. However, the *SR* & *DR* values are more directly and easily modified using the [Set Logging Mode](#) command as described previously.

The *accelADCconfig* & *magADCconfig* configuration bytes define configuration of the A/D converters that acquire data from the accelerometer and magnetometer sensors respectively. These are set by the factory and should not be changed by the user.

The remaining 120 bytes of EEPROM is unused, but reserved for future use. Please contact MicroStrain® if you wish to make use of any portion of this unused non-volatile memory space.

Power-Up Configuration

When you first apply power to a previously un-powered 3DM-DH3+ (i.e. when you first install batteries, or when you apply external power while no batteries are connected) it can be useful to perform the following Power-Up Configuration steps.

Clear Elapsed Time Counter

At initial power-up, the 3DM-DH3+ will recover the Elapsed Time Counter (*TimeCount*) value from the most recently logged data record. This prevents the *TimeCount* value from being inadvertently cleared to zero in the event of a brief power interruption during Data Logging Mode. If, on initial power-up, no valid logged data records exist, then the *TimeCount* value will start at zero. If you want to be sure that the Elapsed Time Counter starts at zero regardless of the contents of the data logging memory, then you must clear it manually using the [Start/Stop/Reset/Read TimeCount](#) command. Note also that when the 3DM-DH3+ powers up into Communications Mode, the Elapsed Time Counter is stopped. It will start automatically when the 3DM-DH3+ enters Data Logging or Deep Sleep modes, or until you start it manually using the [Start/Stop/Reset/Read TimeCount](#) command at any time.

Erase Data Logging Memory

The 3DM-DH3+'s Data Logging Memory is non-volatile, meaning that the memory is maintained even when it has no power supply (battery or otherwise). If you allow the 3DM-DH3+ to start logging data when its Data Logging Memory already contains records from previous acquisitions, then it will simply append new records starting at the address above the previously logged records. If you want to start logging at address 0 (allowing the greatest logging duration), then you must first erase the data logging memory using the [Erase All Logged Data](#) command. This is also a good idea if you're at all unsure of the contents of the Data Logging Memory. A good time to erase the Data Logging Memory is at initial power-up.

Clear Event Capture Data

The 3DM-DH3+ captures various types of power-up and reset events and keeps a count of each type in non-volatile memory for diagnostic purposes in the event of power interruption or other fault conditions that might be encountered during operation. In order to make use of this feature, you should periodically clear the captured events using the [Clear Event Capture Data](#) command. A good time to do this is right after you install batteries in the 3DM-DH3+, since this is typically the only time it gets powered up from a completely un-powered state.

Perform Dummy Data Read

In addition to keeping a count of power-up and reset events as described above, the 3DM-DH3+ also provides an *EventLog* in the first acquired data record following the event. Applying power to the 3DM-DH3+ is one event that gets reported in the *EventLog* byte. To prevent this *EventLog* from appearing in your logged data, simply read a data record from the 3DM-DH3+ using the [Get Immediate Sensor Data](#) command, and just ignore the results.

Clear Elapsed Current Consumption Value

The 3DM-DH3+ keeps track of its approximate elapsed current consumption whenever it's running on batteries (Data Logging Mode and Deep Sleep Mode). The Elapsed Current Consumption count is kept in non-volatile memory to prevent temporary power interruption from affecting its value. To make use of the Elapsed Current Consumption feature you must set its value to zero immediately after installing fresh batteries by using the [Write Elapsed consumption Value](#) command. Details of this feature are given in the [Elapsed Current Consumption Feature](#) section of this document.

Reading & Interpreting Sensor Data

3DM-DH3+ sensor data can be read using any of the following options:

1. The [Get Immediate Sensor Data](#) command returns real-time sensor data as acceleration and magnetic field vectors.
2. The [Get Immediate Sensor Data as Angles](#) command returns real-time sensor data as orientation angles.
3. The [Read Logged Data Record](#) command returns previously logged sensor data as acceleration and magnetic field vectors.
4. The [Read Logged Data Record as Angles](#) command returns previously logged sensor data as orientation angles.

Numbers 1 & 3 above return data records in the following format:

Byte 1	<i>Header</i>	
Bytes 2-5	<i>TimeStamp</i>	[unsigned]
Byte 6	<i>EventLog</i>	
Bytes 7-10	<i>A_x</i>	[float]
Bytes 11-14	<i>A_y</i>	[float]
Bytes 15-18	<i>A_z</i>	[float]
Bytes 19-20	<i>AccelTemp</i>	[signed]
Bytes 21-24	<i>H_x</i>	[float]
Bytes 25-28	<i>H_y</i>	[float]
Bytes 29-32	<i>H_z</i>	[float]
Bytes 33-34	<i>MagTemp</i>	[signed]
Bytes 35-42	reserved for future use (current firmware returns zeros)	
Bytes 43-44	<i>Checksum</i>	[unsigned]

Numbers 2 & 4 above return data records in the following format:

Byte 1	<i>Header</i>	
Bytes 2-5	<i>TimeStamp</i>	[unsigned]
Byte 6	<i>EventLog</i>	
Bytes 7-10	<i>Inclination</i>	[float]
Bytes 11-14	<i>Azimuth</i>	[float]
Bytes 15-18	<i>GTF</i>	[float]
Bytes 19-22	<i>MTF</i>	[float]
Bytes 23-26	<i>DipAngle</i>	[float]
Bytes 27-28	<i>AccelTemp</i>	[signed]
Bytes 29-30	<i>MagTemp</i>	[signed]
Bytes 31-34	<i>G-TOT</i>	[float]
Bytes 35-38	<i>H-TOT</i>	[float]
Bytes 39-40	<i>Checksum</i>	[unsigned]

The individual data values from the above tables are as follows:

Time Stamp

The Time Stamp value (*TimeStamp*) indicates the relative time at which the returned data was acquired. Specifically, *TimeStamp* represents the value of the [Elapsed Time Counter](#) at the moment the data record was acquired.

Event Log

The Event Log byte (*EventLog*) indicates if an erroneous event, such as power interruption, has occurred since the previous acquisition. Specific events are associated with specific bits in the Event Log byte, as illustrated in the below table.

bit 7 (MSb)	power-on reset (POR)
bit 6	brown-out reset (BOR)
bit 5	watchdog time-out (WDT)
bit 4	soft reset
bit 3	stack-full reset
bit 2	stack-underflow reset
bit 1	hard reset
bit 0 (LSb)	(reserved for future use)

Consider the following examples to illustrate the function of the Event Log feature.

EXAMPLE 1:

Data is being read directly from the 3DM-DH3+ periodically using the Get Immediate Sensor Data command. Most data records have an *EventLog* value of 0x00 (default value). However, one data record is read in that has an *EventLog* value of 0x70 (0b10000000). This indicates that at some time between the previous read (with *EventLog* = 0x00) and the current read (with *EventLog* = 0x70), a power-on reset occurred, indicating that the power supply was temporarily interrupted.

EXAMPLE 2:

A large set of data has been captured by the 3DM-DH3+ in Data Logging Mode. That data is read back using the Read Logged Data Record command. Analysis of the data shows that most data records have *EventLog* value of 0x00 (default value). However, data record # 8002 (record address 0x1F42) has an *EventLog* value of 0x60 (0b01100000). This indicates that at some time after the capture of record # 8001, and before the capture of record #8002, two events happened: 1) a brown-out reset (power supply drops to unacceptably low but non-zero value), and 2) a watchdog time-out (firmware malfunction causes the watchdog timer to trigger a reset of the processor).

The Event Log feature is provided for diagnostic purposes in the event of power interruption or other erroneous behavior. In normal operation you should only see the following *EventLog* values:

<i>EventLog</i> = 0x00	default value. indicates that no erroneous event has occurred since the previous data record was read or logged.
<i>EventLog</i> = 0x70	power-on reset. in normal operation you'll see this value for the first data-record read or logged after initially installing batteries or connecting power.
<i>EventLog</i> = 0xFF	empty data record. when reading from logged data memory this indicates an empty data record location.

Acceleration and Magnetic Field Vectors (A & H)

The acceleration vector, *A*, quantifies the acceleration that the 3DM-DH3+ is exposed to. It is given in units of (g) where $1g = 9.8067 \text{ m/sec}^2$. *A* is a 3-D vector expressed in terms of the 3DM-DH3+'s body-fixed coordinate system, consisting of the three components A_x, A_y, A_z . Note that *A* is sensitive both to the acceleration of gravity as well as to linear accelerations.

The magnetic Field vector, *H*, quantifies the strength and direction of the magnetic field that the 3DM-DH3+ is exposed to. It is given in units of (Gauss). *H* is a 3-D vector expressed in terms of the 3DM-DH3+'s body-fixed coordinate system, consisting of the three components H_x, H_y, H_z . Note that *H* is sensitive both to the earth's geomagnetic field as well as to any other source of magnetic field.

Orientation Angles (Inclination, Azimuth, GTF, MTF, DipAngle)

The inclination angle, *Inclination*, gives the angle in degrees between the vertical direction, and the sensor's Z axis. When the sensor's Z axis is pointing vertically down, the inclination angle is 0°. When it is pointing horizontally in any azimuth, the inclination is 90°. When it is pointing up, the inclination is 180°.

The azimuth angle, *Azimuth*, gives the compass heading in degrees of sensor's Z axis. This value is not valid when the inclination is near zero. By convention, the range of the azimuth is adjusted to 0° to +360°.

Gravity toolface, *GTF*, quantifies the rotation in degrees of the sensor about its Z axis. GTF will equal zero when $G_x = 0$ and $G_y > 0$. Positive rotation of the sensor about its Z axis will cause the GTF to increase. By convention, the range of GTF is adjusted to 0° to +360°. The physical interpretation of GTF is the following. The sensor can be rotated about its Z axis without changing its inclination and azimuth. This rotation is quantified by GTF. GTF=0 where the Y axis points as close to vertically up as possible. Note that when the inclination angle approaches 0° or 180°, GTF becomes undefined.

Magnetic toolface, *MTF*, quantifies the rotation in degrees of the sensor about its Z axis (analogous to GTF). Positive rotation of the sensor about its Z axis will cause the MTF to increase. By convention, the range of MTF is adjusted to 0° to +360°. The physical interpretation of MTF is the following. The sensor can be rotated about its Z axis without changing its inclination and azimuth. This rotation is quantified by MTF. MTF=0 where the Y axis points as close as possible to the horizontal component of magnetic North. MTF is undefined when inclination = 90° and azimuth = 0° or 180° (i.e. when the Z axis is horizontal and pointing straight toward either magnetic North or magnetic South).

The dip angle, *DipAngle*, quantifies the angle in degrees between the geomagnetic field vector and the gravity vector. At the magnetic North Pole, the dip angle is 90°. At the magnetic South Pole, the dip angle is -90°. At the magnetic equator, the dip angle is 0°. The dip angle does not depend on the orientation of the sensor. The dip angle can be used as a check on the accuracy of the system. If the reported dip angle is significantly different than expected, then it is likely that either magnetic interference or linear acceleration was present during the measurement, or the device is not operating correctly. The dip angle can also be used to verify that the magnetic based outputs (azimuth & magnetic toolface) are accurate. These values decrease significantly in accuracy as the dip angle exceeds ±80°.

Accelerometer & Magnetometer Temperatures

The values *AccelTemp* and *MagTemp* represent the temperatures of the accelerometer sensor and magnetometer sensor (respectively) at the moment the data record was acquired. They are defined as follows:

$$\text{Accelerometer Temperature in } ^\circ\text{C} = \text{AccelTemp} \div 4$$

$$\text{Magnetometer Temperature in } ^\circ\text{C} = \text{MagTemp} \div 4$$

These temperatures are available to the user for diagnostic purposes. Specifically, the temperature of the 3DM-DH3+ must not exceed the range -40°C to +125°C during operation. If the value of *AccelTemp* or *MagTemp* indicate that this temperature range has been exceeded, then it's quite possible the 3DM-DH3+ will have sustained temperature-related damage, and so any corresponding and subsequently acquired data should be treated as suspect.

G-TOT & H-TOT

G-TOT and *H-TOT* provides the magnitudes of the measured acceleration and magnetic field vectors respectively. *G-TOT* is expressed in units of (g) where 1g = 9.8067 m/sec²g.

$$G-TOT = \text{sqrt}(A_x^2 + A_y^2 + A_z^2).$$

H-TOT is expressed in units of (Gauss).

$$H-TOT = \text{sqrt}(H_x^2 + H_y^2 + H_z^2).$$

Power Requirements & Battery Life

If connected as described in the [Recommended Hardware Configuration](#) section, the 3DM-DH3+ will run from battery power when operating in either Data Logging Mode or Deep Sleep Mode, but will run from externally supplied power when operating in Communications Mode. This is important because the 3DM-DH3+ consumes significantly more power in Communications Mode. Do not allow the 3DM-DH3+ to run from battery power in Communications Mode or battery life will be significantly reduced. Also, to ensure that battery power is not being drained while operating from external power, be sure the externally supplied voltage is at least 0.7V greater than the greatest possible battery voltage, and that the battery and external power are wired to opposite connectors (battery to J1 and external power to J2, or vice-versa). Voltage requirements, recommended batteries, and approximate current consumption values are given below.

Voltage Requirements

The 3DM-DH3+ can operate from battery voltages as low as 6.0V, but for reasons described above the external voltage source (for Communications Mode operation) must be at least 0.7V greater than the maximum possible battery voltage. When using the recommended batteries, an external supply voltage of 9.0V will be sufficient to guarantee that batteries will not be drained while external power is connected. The maximum voltage recommended for use with the 3DM-DH3+ is 10.0V.

Recommended Batteries

MicroStrain® recommends the use of two [Tadiran](#) model TLH-5903 batteries wired in series as described in the [Recommended Hardware Configuration](#) section of this document. These batteries have a capacity of approximately 2A·hour nominally when operating at a temperature of +25°C. Capacity can be reduced by a factor of two or more during operation at temperature extremes under real-world loading. Refer to the manufacturer's datasheet for details. Note that the discharge curve of these batteries is such that battery capacity cannot be determined based on a measurement of battery voltage. For example, a battery that measures 3.6V might have 100% of its life remaining, or might have 30% or less of its life remaining; there's no way to tell anything about remaining capacity without knowing the battery's history. The [Elapsed Current Consumption Feature](#) can be useful in tracking battery usage.

NOTE: The recommended batteries are rated for operation over the full specified temperature range of the 3DM-DH3+ (-40°C to +125°C), but battery voltage drops significantly at very low temperatures. Therefore the recommended operating temperature range for the complete system (3DM-DH3+ + recommended batteries) is -10°C to +125°C.

Current Consumption

The 3DM-DH3+ will consume different amounts of current in different operating modes. Approximate current consumption values for the various operating modes are given below.

In Deep Sleep Mode

The 3DM-DH3+ will consume approximately 50 μ A in deep sleep mode at a temperature of +25°C. This approximate current consumption value can vary significantly as a function of temperature. If the 3DM-DH3+ is stored at normal room temperature in Deep Sleep Mode with a fresh set of the recommended batteries, the batteries should last more than 2 years.

In Data Logging Mode

Current consumption of the 3DM-DH3+ in Data Logging Mode will depend on the sample rate at which it is configured to operate. The 3DM-DH3+ consumes approximately 2000 μ A·sec for each sample taken. So the average current consumption is given by the following equation:

$$I_{\text{average}} = 2\text{mA} \cdot \text{sec} \times F_{\text{sample}}$$

For example, if the 3DM-DH3+ is configured to sample at 4Hz, then $I_{\text{average}} = 2\text{mA} \cdot \text{sec} \times 4\text{Hz} = 8\text{mA}$.

In Communications Mode

As stated previously, Communications Mode is not optimized for low power operation, and the 3DM-DH3+ should be operating from externally provided power rather than from battery power while in Communications Mode. Approximate current consumption in Communications Mode will be in the vicinity of 40mA to 50mA when operating at approximately +25°C. Current consumption may vary significantly as a function of temperature.

Elapsed Current Consumption Feature

The 3DM-DH3+ includes a feature to help track current consumption. This feature can be used to help gage approximate remaining battery life. It does not monitor the battery directly, but instead approximates elapsed current consumption based on time operating in various modes. Specifically, it keeps a count of *ElapsedCurrent* in units of mA·hours and increments it automatically at a rate determined by the operating mode so as to approximate the current being drawn in that mode. You can read the *ElapsedCurrent* value at any time using the [Read Elapsed Consumption Value](#) command. The *ElapsedCurrent* value is stored in non-volatile memory, so you must clear it to zero using the [Write Elapsed Consumption Value](#) command when installing new batteries in order to track current consumed from those batteries. Note that the Elapsed Current Consumption feature does *not* track current consumption in Communications Mode because it is assumed that power is provided by an external source (not the batteries) when operating in Communications Mode. If you operate the 3DM-DH3+ in Communications Mode without an external power source, then battery life will be quickly degraded, and the *ElapsedCurrent* value will no longer be accurate.