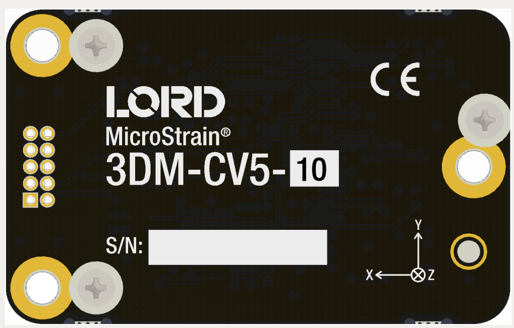
LORD Data Communications Protocol Manual

3DM™-CV5™-10

Inertial Measurement Unit



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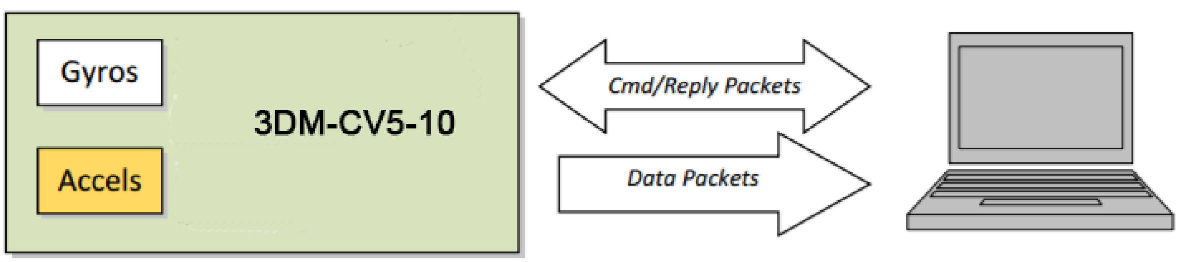
1. API Introduction

The 3DM-CV5-10 programming interface is comprised of a compact set of setup and control commands and a very flexible user-configurable data output format. The commands and data are divided into two command sets and one data set corresponding to the internal architecture of the device. The command sets consist of a set of "Base" commands (a set that is common across many types of devices) and a set of unified "3DM" (3D Motion) commands that are specific to the LORD Sensing inertial product line. The data set represents the one type of data that the 3DM-CV5-10 is capable of producing: "IMU" (Inertial Measurement Unit) data.

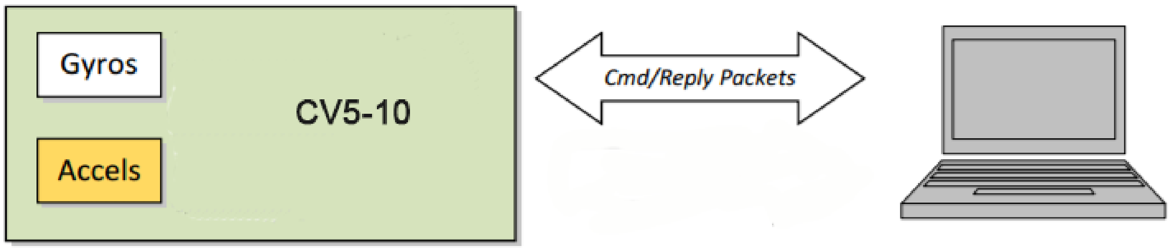
Base commands	Ping, Idle, Resume, Get ID Strings, etc.
3DM commands	Poll IMU Data, Estimation Filter Data, etc.
IMU data	Acceleration Vector, Gyro Vector, etc.

The protocol is packet based. All commands, replies, and data are sent and received as fields in a message packet. Commands are all confirmed with an ack/nack (with a few exceptions). The packets have a descriptor type field based on their contents, so it is easy to identify if a packet contains IMU data, commands, or replies.



2. Basic Programming

The 3DM-CV5-10 is designed to stream IMU data packets over a common interface as efficiently as possible. To this end, programming the device consists of a configuration stage where the data messages and data rates are configured. The configuration stage is followed by a data streaming stage where the program starts the incoming data packet stream.



In this section there is an overview of the packet, an overview of command and reply packets, an overview of how an incoming data packet is constructed, and then an example setup command sequence that can be used directly with the 3DM-CV5-10 either through a COM utility or as a template for software development.

2.1 MIP Packet Overview

This is an overview of the 3DM-CV5-10 packet structure. The packet structure used is the LORD "MIP" packet. A reference to the general packet structure is presented in the MIP Packet Reference section. An overview of the packet is presented here.

The MIP packet "wrapper" consists of a four byte header and two byte checksum footer:

Header				Packet Payload			Checksum	
SYNC1 "u"	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Length byte	Field Descriptor byte	Field Data	MSB	LSB
0x75	0x65	0x80	0x0E	0x0E	0x03	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x83	0xE1

Payload Length byte. This specifies the length of the packet payload. The packet payload may contain one or more fields and thus this byte also represents the sum of the lengths of all the fields in the payload.

Descriptor Set. Descriptors are grouped into different sets. The value 0x80 identifies this packet as an AHRS data packet. Fields in this packet will be from the AHRS data descriptor set.

Start of Packet (SOP) "sync" bytes. These are the same for every MIP packet and are used to identify the start of the packet.

2 byte Fletcher checksum of all the bytes in the packet.

The packet payload section contains one or more fields. Fields have a length byte, descriptor byte, and data. The diagram below shows a packet payload with a single field.

Header				Packet Payload			Checksum	
SYNC1 "u"	SYNC2 "e"	Descriptor Set byte	Payload Length byte	Field Length byte	Field Descriptor byte	Field Data	MSB	LSB
0x75	0x65	0x80	0x0E	0x0E	0x06	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x86	0x08

Field Length byte. This represents a count of all the bytes in the field including the length byte, descriptor byte and field data.

Descriptor byte. This byte identifies the contents of the field data. This descriptor indicates that the data is a mag vector (set: 0x80, descriptor: 0x06)

Field data. The length of the data is Field Length – 2. This data is 12 bytes long (14 – 2) and represents the floating point magnetometer vector value from the AHRS data set.

Below is an example of a packet payload with two fields (gyro vector and mag vector). Note the payload length byte of 0x1C which is the sum of the two field length bytes 0x0E + 0x0E:

Header				Packet Payload (2 Fields)						Checksum	
SYNC1 "u"	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length byte*	*Field 1 Length*	*Field 1 Descriptor*	*Field 1 Data*	*Field 2 Length*	*Field 2 Descriptor*	*Field 2 Data*	*MSB*	*LSB*
0x75	0x65	0x80	0x1C	0x0E	0x05	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x0E	0x06	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0xE0	0xC6

2.2 Command Overview

The basic command sequence begins with the host sending a command to the device. A command packet contains a field with the command value and any command arguments.

The device responds by sending a reply packet. The reply contains at minimum an ACK/NACK field. If any additional data is included in a reply, it appears as a second field in the packet.

2.2.1 Example "Ping" Command Packet

Below is an example of a "Ping" command packet from the Base command set. A "Ping" command has no arguments. Its function is to determine if a device is present and responsive:

Header				Packet Payload			Checksum	
SYNC1 "u	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length byte*	*Field Byte Length*	*Field Descriptor Byte*	*Field Data*	*MSB*	*LSB*
0x75	0x65	0x01	0x02	0x02	0x01	N/A	0xE0	0xC6
Copy-Paste version of command: "7565 0102 0201 E0C6"								

The packet header has the "ue" starting sync bytes characteristic of all MIP packets. The descriptor set byte (0x01) identifies the payload as being from the Base command set. The length of the payload portion is 2 bytes. The payload portion of the packet consists of one field. The field starts with the length of the field which is followed by the descriptor byte (0x01) of the field. The field descriptor value is the command value. Here the descriptor identifies the command as the "Ping" command from the Base command descriptor set. There are no parameters associated with the ping command, so the field data is empty. The checksum is a two byte Fletcher checksum (see the MIP Packet Reference for instructions on how to compute a Fletcher two byte checksum).

2.2.2 Example "Ping" Reply Packet

The "Ping" command will generate a reply packet from the device. The reply packet will contain an ACK/NACK field. The ACK/NACK field contains an "echo" of the command byte plus an error code. An error code of 0 is an "ACK" and a non-zero error code is a "NACK":

Header				Packet Payload			Checksum	
SYNC1 "u	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length byte*	*Field Byte Length*	*Field Descriptor Byte*	*Field Data*	*MSB*	*LSB*
0x75	0x65	0x01	0x04	0x04	0xF1	Command Echo: 0x01 Error code: 0x00	0xD5	0x6A
Copy-Paste version of reply:... "7565 0104 04F1 0100 D56A"								

The packet header has the "ue" starting sync bytes characteristic of all MIP packets. The descriptor set byte (0x01) identifies the payload fields as being from the Base command set. The length of the payload portion is 4 bytes. The payload portion of the packet consists of one field. The field starts with the length of the field which is followed by the descriptor byte (0xF1) of the field. The field descriptor byte identifies the reply as the "ACK/NACK" from the Base command descriptor set. The field data consists of an "echo" of the original command (0x01) followed by the error code for the command (0x00). In this case the error is zero, so the field represents an "ACK". Some examples of non-zero error codes that might be sent are "timeout", "not implemented", and "invalid parameter in command". The checksum is a two byte Fletcher checksum (see the MIP Packet Reference for instructions on how to compute a Fletcher two byte checksum).

The ACK/NACK descriptor value (0xF1) is the same in all descriptor sets. The value belongs to a set of reserved global descriptor values.

The reply packet may have additional fields that contain information in reply to the command. For example, requesting Device Status will result in a reply packet that contains two fields in the packet payload: an ACK/NACK field and a device status information field.

2.3 Data Overview

The IMU data packet is generated by the device. When the device is powered up, it may be configured to immediately stream the data packet out to the host or it may be "idle" and waiting for a command to either start continuous data or to get data by "polling". Either way, the data packet is generated by the device in the same way.

2.3.1 Example Data Packet:

Below is an example of a MIP data packet which has one field that contains the scaled accelerometer vector.

Header				Packet Payload			Checksum	
SYNC1 "u	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length byte*	*Field Byte Length*	*Field Descriptor Byte*	*Field Data: Accel vector (12 bytes, 3 float - X, Y, Z)*	*MSB*	*LSB*
0x75	**0x65**	**0x80**	**0x0E**	**0x0E**	**0x04**	**0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F**	**0x92**	**0xC0**
Copy-Paste version: "7565 800E 0E04 3E7A 63A0 BB8E 3B29 7FE5 BF7F 92C0"								

The packet header has the "ue" starting sync bytes characteristic of all MIP packets. The descriptor set byte (0x80) identifies the payload field as being from the IMU data set. The length of the packet payload portion is 14 bytes (0x0E). The payload portion of the packet starts with the length of the field. The field descriptor byte (0x04) identifies the field data as the scaled accelerometer vector from the IMU data descriptor set. The field data itself is three single precision floating point values of 4 bytes each (total of 12 bytes) representing the X, Y, and Z axis values of the vector. The checksum is a two byte Fletcher checksum (see the MIP Packet Reference for instructions on how to compute a Fletcher two byte checksum).

The format of the field data is fully and unambiguously specified by the descriptor. In this example, the field descriptor (0x04) specifies that the field data holds an array of three single precision IEEE-754 floating point numbers in big-endian byte order and that the values represent units of "g's" and the order of the values is X, Y, Z vector order. Any other specification would require a different descriptor (see the Data Reference section of this manual).

Data polling commands generate two individual reply packets: An ACK/NACK packet and a data packet. Enable/Disable continuous data commands generate an ACK/NACK packet followed by the continuous stream of data packets.

2.4 Example Setup Sequence

Setup involves a series of command/reply pairs. The example below demonstrates actual setup sequences that you can send directly to the 3DM-CV5-10 either programmatically or by using a COM utility. In most cases only minor alterations will be needed to adapt these examples for your application.

2.4.1 Continuous Data Example Command Sequence

Most applications will operate with the 3DM-CV5-10 sending a continuous data stream. To reduce the amount of streaming data, if present during the configuration, the device is placed into the idle state while performing the device initialization; when configuration is complete, the required data streams are enabled to bring the device out of idle mode. Finally, the configuration is saved so that it will be loaded on subsequent power-ups, eliminating the need to perform the configuration again.

1. **Put the Device in Idle Mode**

Send the "Set To Idle" command to put the device in the idle state (reply is ACK/NACK), disabling the data-streams. This is not required but reduces the parsing burden during initialization and makes visual confirmation of the commands easier.

	MIP Packet Header				Command/Reply Fields			Checksum	
	SYNC1 "u	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length*	*Field Length*	*Cmd. Descriptor*	*Field Data*	*MSB*	*LSB*
Command: *Set to Idle*	0x75	0x65	0x01	0x02	0x02	0x02	N/A	0xE1	0xC7
Reply: *ACK/NACK*	0x75	0x65	0x01	0x04	0x04	0xF1	Cmd echo: **0x02** Error code: **0x00**	0xD6	0x6C
Copy-Paste version of the command: "7565 0102 0202 E1C7"									

2. **Configure the IMU Data-stream Format**

Send a "Set IMU Message Format" command (reply is ACK/NACK). This example requests GPS correlation timestamp, scaled gyro, and scaled accelerometer information at 100 Hz (1000Hz base rate divided by a rate decimation of 10 on the 3DM-CV5-10 = 100 Hz.) This will result in a single IMU data packet sent at 100Hz containing the IMU GPS correlation timestamp followed by the scaled gyro field and the scaled accelerometer field. This is a very typical configuration for a base level of inertial data. If different rates were requested, then each packet would only contain the data quantities that fall in the same decimation frame (see the Multiple Rate Data section). If the stream was not disabled in the previous step, the IMU data would begin stream immediately.

Please note, this command will not append the requested descriptors to the current IMU data-stream configuration, it will overwrite it completely.

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	MIP Packet Header				Command/Reply Fields			Checksum	
	SYNC1 "u	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length*	*Field Length*	*Cmd. Descriptor*	*Field Data*	*MSB*	*LSB*
Command: *New IMU Message Format*	0x75	0x65	0x0C	0x0D	0x0D	0x08	Function: **0x01** Desc. count: **0x03** GPS TS Desc.: **0x12** Rate Dec: **0x000A** Accel Desc.: **0x04** Rate Dec: **0x000A** Ang Rate Desc: **0x05** Rate Dec: **0x000A**	0x45	0xF2
Reply: *ACK/NACK*	0x75	0x65	0x0C	0x04	0x04	0xF1	Cmd echo: **0x08** Error code: **0x00**	0xE7	0xBA
Copy-Paste version of the command: "7565 0C0D 0D08 0103 1200 0A04 000A 0500 0A45 F2"									

3. Resume the Device: (Optional)

Sending the "Resume" command is another method of re-enabling transmission of enabled data streams (reply is ACK/NACK).

	MIP Packet Header				Command/Reply Fields			Checksum	
	SYNC1 "u	*SYNC2 "e"*	*Descriptor Set byte*	*Payload Length*	*Field Length*	*Cmd. Desc.*	*Field Data*	*MSB*	*LSB*
Command: *Resume*	0x75	0x65	0x01	0x02	0x02	0x06	N/A	0xE5	0xCB
Reply: *ACK/NACK*	0x75	0x65	0x01	0x04	0x04	0xF1	Cmd echo: 0x06 Error code: 0x00	0xDA	0x74
Copy-Paste version of the command: "7565 0102 0206 E5CB"									

2.4.2 Polling Data Example Sequence

Polling for data is less efficient than processing a continuous data stream, but may be more appropriate for certain applications. The main difference from the continuous data example is the inclusion of the Poll data commands in the data loop:

1. **Put the Device in Idle Mode (Disabling the data-streams)**
   Same as continuous streaming (*see Put the Device in Idle Mode on page 12*).

2. **Configure the IMU data-stream format**
   Same as continuous streaming (*see Configure the IMU data-stream format on page 12*).

3. **Resume the Device**
   Same as continuous streaming (*see Resume the Device (Optional) on page 13*).

Send Individual Data Polling Commands

Send an individual Poll IMU Data command in your data collection loop. After the ACK/NACK is sent by the device, a single data packet will be sent according to the settings in the previous steps. Note that the ACK/NACK has the same descriptor set value as the command, but the data packet has the descriptor set value for the type of data (IMU or Estimation Filter):

	MIP Packet Header				Command/Reply Fields			Checksum	
	SYNC1 "u	*SYNC2 "e"*	*Desc. Set*	*Payload Length*	*Field Length*	*Cmd. Desc.*	*Field Data*	*MSB*	*LSB*
Command: *Poll IMU Data*	0x75	0x65	0x0C	0x04	0x04	0x01	Option: 0x00 Desc Count: 0x00	0xEF	0xDA
Reply Field 1: *ACK/NACK*	0x75	0x65	0x0C	0x04	0x04	0xF1	Cmd echo: 0x01 Error code: 0x00	0xE0	0xAC
IMU Data Packet Field 1: *Gyro Vector*	0x75	0x65	0x80	0x1C	0x0E	0x04	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0x41	0xBB
IMU Data Packet Field 2: *Accel Vector*					0x0E	0x03	0x3E 7A 63 A0 0xBB 8E 3B 29 0x7F E5 BF 7F	0xAD	0xDC
Copy-Paste version of the command: "7565 0C04 0401 0000 EFDA"									

You may specify the format of the data packet on a per-polling-command basis rather than using the pre-set data format (see the Poll IMU Data)

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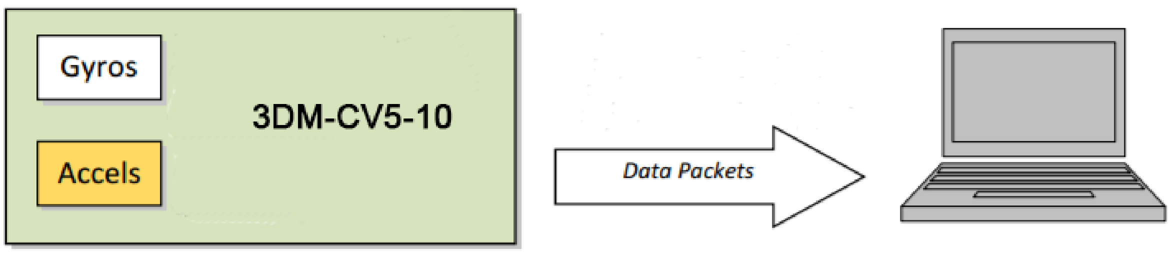
The polling command has an option to suppress the ACK/NACK in order to keep the incoming stream clear of anything except data packets. Set the option byte to 0x01 for this feature.

2.5 Parsing Incoming Packets

Setup is usually the easy part of programming the 3DM-CV5-10. Once you start continuous data streaming, parsing and processing the incoming data packet stream will become the primary focus. Polling for data may seem to be a logical solution to controlling the data flow, and this may be appropriate for some applications, but if your application requires the precise delivery of inertial data, it is often necessary to have the data stream drive the process rather than having the host try to control the data stream through polling.



The “descriptor set” qualifier in the MIP packet header is a feature that greatly aids the management of the incoming packet stream by making it easy to sort the packets into logical sub-streams and route those streams to appropriate handlers. The first step is to parse the incoming character stream into packets.

It is important to take an organized approach to parsing continuous data. The basic strategy is this: parse the incoming stream of characters for the packet starting sequence “ue” and then wait for the entire packet to come in based on the packet length byte which arrives after the “ue” and descriptor set byte. Make sure you have a timeout on your wait loop in case your stream is out of sync and the starting “ue” sequence winds up being a “ghost” sequence. If you timeout, restart the parsing with the first character after the ghost “ue”. Once the stream is in sync, it is rare that you will hit a timeout unless you have an unreliable communications link. After verifying the checksum, examine the “descriptor set” field in the header of the packet. This tells you immediately how to handle the packet.

Based on the value of the descriptor set field in the packet header, pass the packet to either a command handler (if it is a Base command or 3DM command descriptor set) or a data handler (if it is an IMU Filter data set). Replies to commands generally happen sequentially after a command so the incidence of these is under program control.

For multi-threaded applications, it is often useful to use queues to buffer packets bound for different packet handler threads. The depth of the queue can be tuned so that no packets are dropped while waiting for their associated threads to process the packets in the queue. See Advanced Programming Models section for more information on this topic.

Once you have sorted the different packets and sent them to the proper packet handler, the packet handler may parse the packet payload fields and handle each of the fields as appropriate for the application. For simple applications, it is perfectly acceptable to have a single handler for all packet types. Likewise, it is perfectly acceptable for a single parser to handle both the packet type and the fields in the packet. The ability to sort the packets by type is just an option that simplifies the implementation of more sophisticated applications.

2.6 Multiple Rate Data

The IMU Message Format command allows you to set different data rates for different data quantities. This is a very useful feature because some data, such as accelerometer and gyroscope data, usually requires higher data rates (>100 Hz). The ability to send data at different rates reduces the parsing load on the user program and decreases the bandwidth requirements of the communications channel. Multiple rate data is scheduled on a common sampling rate clock. This means that if there is more than one data rate scheduled, the schedules coincide periodically. For example, if you request Accelerometer data at 100 Hz and Delta Theta data at 50 Hz, the Delta Theta schedule coincides with the Accelerometer schedule 50% of the time. When the schedules coincide, then the two data quantities are delivered in the same packet. In other words, in this example, you will receive data packets at 100 Hz and every packet will have an accelerometer data field and EVERY OTHER packet will also include a Delta Theta data field:

Packet 1	*Packet 2*	*Packet 3*	*Packet 4*	*Packet 5*	*Packet 6*	*Packet 7*	*Packet 8*	...
Accel	Accel Delta Theta	Accel	Accel Delta Theta	Accel	Accel Delta Theta	Accel	Accel Delta Theta	Accel

If a timestamp is included at 100 Hz, then the timestamp will also be included in every packet in this example. It is important to note that *the data in a packet with a timestamp is always synchronous with the timestamp.* This assures that multiple rate data is always synchronous.

Packet 1	*Packet 2*	*Packet 3*	*Packet 4*	*Packet 5*	*Packet 6*	...
Accel Timestamp	Accel Delta Theta Timestamp	Accel Timestamp	Accel Delta Theta Timestamp	Accel Timestamp	Accel Delta Theta Timestamp	Accel

2.7 Communications Bandwidth Management

Because of the large amount and variety of data that is available from the 3DM-CV5-10, it is quite easy to overdrive the bandwidth of the communications channel. This can result in dropped packets. The 3DM-CV5-10 does not do analysis of the bandwidth requirements for any given output data configuration, it will simply drop a packet if its internal serial buffer is being filled faster than it is being emptied. It is up to the programmer to analyze the size of the data packets requested and the available bandwidth of the communications channel. Often the best way to determine this is empirically by trying different settings and watching for dropped packets. Below are some guidelines on how to determine maximum bandwidth for your application.

2.7.1 UART Bandwidth Calculation

Below is an equation for the maximum theoretical UART baud rate for a given message configuration. Although it is possible to calculate the approximate bandwidth required for a given setup, there is no guarantee that the system can support that setup due to internal processing delays. The best approach is to try a setting based on an initial estimate and watch for dropped packets. If there are dropped packets, increase the baud rate, reduce the data rate, or decrease the size or number of packets.

$$\mathrm{n}(\mathrm{k} \times f_{mr}) + \mathrm{n} \sum (S_f \times \ f_{dr})$$

Where:

S_f = size of data field in bytes

f_{dr} = field of data rate in Hz

f_{mr} = maximum date rate in Hz

n = size of UART word = 10 bits

k = size of MIP wrapper = 6 bytes

which becomes:

$$60 f_{mr} + 10 \sum (S_f \times \ f_{dr})$$

Example:

For an IMU message format of Accelerometer Vector (14 byte data field) + Internal Timestamp (six byte data field), both at 100 Hz, the theoretical minimum baud rate would be:

$$= 60 \times 100 + 10((14 \times \ 100) + (6 \times 100))$$

$$= 26000 \text{ BAUD}$$

In practice, if you set the baud rate to 115200 the packets come through without any packet drops. If you set the baud rate to the next available lower rate of 19200, which is lower than the calculated minimum, you get regular packet drops. The only way to determine a packet drop is by observing a timestamp in sequential packets. The interval should not change from packet to packet. If it does change then packets were dropped.

3. Command and Data Summary

Below is a summary of the commands and data available in the programming interface. Commands and data are denoted by two values. The first value denotes the “descriptor set” that the command or data belongs to (Base command, 3DM command,IMU data) and the second value denotes the unique command or data “descriptor” in that set. The pair of values constitutes a “full descriptor”.

3.1 Commands

3.1.1 Base Command Set (0x01)

Ping	(0x01, 0x01)
Set to Idle	(0x01, 0x02)
Get Device Information	(0x01, 0x03)
Get Device Descriptor Sets	(0x01, 0x04)
Device Built-In Test (BIT)	(0x01, 0x05)
Resume	(0x01, 0x06)
GPS Time Update	(0x01, 0x72)
Device Reset	(0x01, 0x7E)

3.1.2 3DM Command Set (0x0C)

Poll IMU Data	(0x0C, 0x01)
Get IMU Data Rate Base	(0x0C, 0x06)
IMU Message Format	(0x0C, 0x08)
Enable/Disable Device Continuous Data Stream	(0x0C, 0x11)
Device Startup Settings	(0x0C, 0x30)
Accel Bias	(0x0C, 0x37)
Gyro Bias	(0x0C, 0x38)
Capture Gyro Bias	(0x0C, 0x39)
Coning and Sculling Enable	(0x0C, 0x3E)
Change UART Baud rate	(0x0C, 0x40)
Advanced Low-Pass Filter Settings	(0x0C, 0x50)
Device Status*	(0x0C, 0x64)

**Advanced commands*

3.2 Data

3.2.1 IMU Data Set (0x08)

Scaled Accelerometer Vector	(0x80, 0x04)
Scaled Gyro Vector	(0x80, 0x05)

Delta Theta Vector (0x80, 0x07)
Delta Velocity Vector (0x80, 0x08)
GPS Correlation Timestamp (0x80, 0x12)

4. Command Reference

4.1 Base Commands

The Base command set is common to many LORD Sensing devices. With the Base command set it is possible to identify many properties and do basic functions on a device even if you do not recognize its specialized functionality or data. The commands work the same way on all devices that implement this set.

4.1.1 Ping (0x01, 0x01)

Description	Send "Ping" command Device responds with ACK if present.								
Field Format	*Field Length*		*Field Descriptor*			*Field Data*			
Command	0x02		0x01			N/A			
Reply: ACK/ NACK	0x04		0xF1			U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)			
Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Ping	0x75	0x65	0x01	0x02	0x02	0x01		0xE0	0xC6
Reply: ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Command echo: 0x01 Error code: 0x00	0xD5	0x6A
Copy-Paste version of the command: "7565 0102 0201 E0C6"									

4.1.2 Set To Idle (0x01, 0x02)

Description	Place device into idle mode Command has no parameters. Device responds with ACK if successfully placed in idle mode. This command will suspend streaming (if enabled) or wake the device from sleep (if sleeping) to allow it to respond to status and setup commands. You may restore the device mode by issuing the Resume command.								
Field Format	*Field Length*		*Field Descriptor*		*Field Data*				
Command	0x02		0x02		N/A				
Reply : ACK/ NACK	0x04		0xF1		U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)				
Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Set to Idle	**0x75**	**0x65**	**0x01**	**0x02**	**0x02**	**0x02**		**0xE1**	**0xC7**
Reply: ACK/NACK	**0x75**	**0x65**	**0x01**	**0x04**	**0x04**	**0xF1**	**Command echo: 0x02 Error code: 0x00**	**0xD6**	**0x6C**
Copy-Paste version of the command: “7565 0102 0201 E0C6”									

4.1.3 Get Device Information (0x01, 0x03)

Description	Get the device ID strings and firmware version.					
Field Format	*Field Length*	*Field Descriptor*	*Field Data*			
Command	0x02	0x03	N/A			
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)			
Reply Field 2: Array of Descriptors	0x52	0x81	*Binary Offset*	*Description*	*Data Type*	*Units*
			0	Firmware version	U16	N/A
			2	Model Name	String(16)	N/A
			18	Model Number	String(16)	N/A
			34	Serial Number	String(16)	N/A

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Get Device Info	**0x75**	**0x65**	**0x01**	**0x02**	**0x02**	**0x03**		**0xE2**	**0xC8**
Reply Field 1: ACK/NACK	**0x75**	**0x65**	**0x01**	**0x58**	**0x04**	**0xF1**	**Command echo: 0x03** **Error code: 0x00**		
Reply Field 2: Device Info Field					**0x54**	**0x81**	**FW Version: 0x05FE** " 3DM-GX5-45" " 6232-4270" " 6232-00122" " " " 5g, 150d/s"	**0x##**	**0x##**
Copy-Paste version of the command: "7565 0102 0203 E2C8"									

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4.1.4 Get Device Descriptor Sets (0x01, 0x04)

Description

Get the set of descriptors that this device supports

Reply has two fields: “ACK/NACK” and “Descriptors”. The “Descriptors” field is an array of 16 bit values. The MSB specifies the descriptor set and the LSB specifies the descriptor.

Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x02	0x04	N/A
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2: Array of Descriptors	2 x <Number of descriptors> + 2	0x82	see below

Reply Field 2 field data:

Binary Offset	*Description*	*Data Type*
0	Firmware version	U16
1	Model Name	U16
...	etc.	...

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Get Device Info	0x75	0x65	0x01	0x02	0x02	0x04		0xE3	0xC9
Reply Field 1: ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Command echo: 0x01 Error code: 0x00		
Reply Field 2: Array of Descriptors					<n*2>	0x82	0x0101 0x0102 0x0103 ... 0x0C01 0x0C02 ... nth descriptor: 0x0C72	0x##	0x##

Copy-Paste version of the command: “7565 0102 0204 E3C9”

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4.1.5 Device Built-In Test (0x01, 0x05)

Description

Run the device Built-In Test (BIT). The Built-In Test command always returns a 32 bit value. A value of 0 means that all tests passed. A non-zero value indicates that not all tests passed. The failure flags are device dependent. The flags for the 3DM-CV5-10 are defined below.

3DM-CV5-10 BIT Error Flags:

Byte	Byte 1 (LSB)	Byte 2	Byte 4 (MSB)
Device	Processor Board	Sensor Board	Kalman Filter
Bit 1 (LSB)	WDT Reset (Latching, Reset after first commanded BIT)	IMU Communication Fault	Solution Fault
Bit 2	Reserved	Magnetometer Fault (if applicable)	Reserved
Bit 3	Reserved	Pressure Sensor Fault (if applicable)	Reserved
Bit 4	Reserved	Reserved	Reserved
Bit 5	Reserved	Reserved	Reserved
Bit 6	Reserved	Reserved	Reserved
Bit 7	Reserved	Reserved	Reserved
Bit 8 (MSB)	Reserved	Reserved	Reserved

Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x02	0x05	N/A
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2: Array of BIT Errors	0x06	0x83	U32 - BIT Error Flags

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command *Built-In Test*	0x75	0x65	0x01	0x02	0x02	0x05	N/A	0xE4	0xCA

Reply Field 1: ACK/NACK	0x75	0x65	0x01	0x0A	0x04	0xF1	Echo cmd: 0x05 Error code: 0x00		
Reply Field 2: BIT Error Flags					0x06	0x83	BIT Error Flags: 0x00000000	0x68	0x7D
Copy-Paste version of the command: "7565 0102 0205 E4CA"									

4.1.6 Resume (0x01, 0x06)

Description	Place device back into the mode it was in before issuing the Set To Idle command. If the Set To Idle command was not issued, then the device is placed in default mod- e.Command has no parameters. Device responds with ACK if stream successfully enabled.		
Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x02	0x06	N/A
Reply: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Resume	**0x75**	**0x65**	**0x01**	**0x02**	**0x02**	**0x06**		**0xE5**	**0xCB**
Reply: ACK/NACK	**0x75**	**0x65**	**0x01**	**0x04**	**0x04**	**0xF1**	**Command echo: 0x01** **Error code: 0x00**	**0xDA**	**0x74**

Copy-Paste version of the command: "7565 0102 0206 E5CB"

4.1.7 GPS Time Update (0x01, 0x72)

Description

This message updates the internal GPS Time as reported in the Filter Timestamp.

This command enables synchronization of the IMU Timestamp with an external GPS receiver. When combined with a PPS input applied to pin 7 of the I/O connector, the GPS Correlation Timestamp in the inertial data output is synchronized with the external GPS clock. It is recommended that this update command be sent once per second. See the GPS Correlation Timestamp command for more information.

Possible function selector values:

0x01 - Apply new settings
0x02 - Read back current settings
0x06 - Apply new settings with no ACK/NACK reply

Possible field selector values:

0x01 - GPS Week Number

4.1.7 GPS Time Update (0x01, 0x72)

	0x02 - GPS Seconds		
Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x08	0x72	U8 - Function Selector U8 - GPS Time Field Selector U32 - New Time Value
Reply: ACK/NACK	0x04	0xF1	U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2 (function = 2, selector = 1)	0x06	0x84	U32 - Current GPS Week Value
Reply Field 2 (function = 2, selector = 2)	0x06	0x85	U32 - Current GPS Seconds Value

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: GPS Time Update	0x75	0x65	0x01	0x08	0x08	0x72	Fctn (Apply): 0x01 Field (Week): 0x00 Val: 0x00000698	0xFD	0x32
Reply : ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Cmd echo: 0x72 Error code: 0x00	0x46	0x4C

Copy-Paste version of the command: "7565 0108 0872 0101 0000 0698 FD32"

4.1.8 Device Reset (0x01, 0x7E)

Description	Resets the device. Device responds with ACK if it recognizes the command and then immediately resets.		
Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x02	0x7E	N/A
Reply Field 1:	0x04	0xF1	U8 - Echo the command byte

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ACK/ NACK						U8 - Error code (0: ACK, non-zero: NACK)		
Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Ping	0x75	0x65	0x01	0x02	0x02	0x7E		0x5D	0x43
Reply Field 1: ACK/NACK	0x75	0x65	0x01	0x04	0x04	0xF1	Command echo: 0x7E Error code: 0x00	0x52	0x64
Copy-Paste version of the command: "7565 0102 027E 5D43"									

4.2 3DM Commands

The 3DM command set is common to the LORD Sensing Inertial sensors that support the MIP packet protocol. Because of the unified set of commands, it is easy to migrate code from one inertial sensor to another.

4.2.1 Poll IMU Data (0x0C, 0x01)

Description	Poll the device for an IMU message with the specified format This function polls for an IMU message using the provided format. The resulting message will maintain the order of descriptors sent in the command and any unrecognized descriptors are ignored. If the format is not provided, the device will attempt to use the stored format (set with the Set IMU Message Format command.) If no format is provided and there is no stored format, the device will respond with a NACK. The reply packet contains an ACK/NACK field. The polled data packet is sent separately as an IMU Data packet. Possible Option Selector Values: 0x00 - Normal ACK/NACK Reply. 0x01 - Suppress the ACK/NACK reply.		
Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	4 + 3*N	0x01	U8 - Option Selector U8 - Number of Descriptors (N) N*(U8 - Descriptor, U16 Reserved)
Reply: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Poll IMU data (use stored format)	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0x01**	**Option: 0x00 Desc count: 0x00**	**0xEF**	**0xDA**
Command: Poll IMU data (use specified format)	**0x75**	**0x65**	**0x0C**	**0x0A**	**0x0A**	**0x01**	**Option: 0x00 Desc count: 0x02 1st Descriptor: 0x04 Reserved: 0x0000 2nd Descriptor: 0x05 Reserved: 0x0000**	**0x06**	**0x27**

Reply: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Command echo: 0x01 Error code: 0x00	0xE0	0xAC
Copy-Paste versions of the commands: *Stored format: "7565 0C04 0401 0000 EFDA"* *Specified format: "7565 0C0A 0A01 0002 0400 0005 0000 0627"*									

4.2.2 Get IMU Data Base Rate (0x0C, 0x06)

Description	Get the base rate for the IMU data in Hz. Returns the value used for data rate calculations. See the IMU Message Format command.		
Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x02	0x06	None
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2: IMU Base Rate	0x04	0x83	U16 - IMU data base rate (Hz)

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Get IMU Base Rate	0x75	0x65	0x0C	0x02	0x02	0x06		0xF0	0xF7
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x08	0x04	0xF1	Command echo: 0x06 Error code: 0x00		
Reply Field 2: IMU Base Rate					0x04	0x83	Base rate (Hz): 0x0x0064	0xD4	0x6B
Copy-Paste version of the command: "7565 0C02 0206 F0F7"									

4.2.3 IMU Message Format (0x0C, 0x08)

Description

Set, read, or save the format of the IMU message packet. This command sets the format for the IMU data packet when in standard mode. The resulting data messages will maintain the order of descriptors sent in the command. The command has a function selector and a descriptor array as parameters.

Possible Function Selector Values:

0x01 - Use new settings
0x02 - Read back current settings.
0x03 - Save current settings as startup settings
0x04 - Load saved startup settings
0x05 - Reset to factory default settings

The rate decimation field is calculated as follows for IMU messages:

Rate Decimation = IMU Base Rate / Desired Data Rate

You should always retrieve the Base Rate from the Get IMU Data Base Rate command for computing the desired rate decimation. Base rates vary from device to device. The IMU base rate for the 3DM-CV5 is 500.

The device checks that all descriptors are valid prior to executing this command. If any of the descriptors are invalid for the IMU descriptor set, a NACK will be returned and the message format will be unchanged. The descriptor array only needs to be provided if the function selector is = 1 (Use new settings). For all other functions it may be empty (Number of Descriptors = 0).

Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	4 + 3*N	0x08	U8 - Function Selector U8 - Number of Descriptors (N) N*(U8 - Descriptor, U16 - Rate Decimation)
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2 : Function = 2	3 + 3*N	0x80	U8 - Number of Descriptors (N) N*(U8 - Descriptor, U16 - Rate Decimation)

Example	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: IMU Message	**0x75**	**0x65**	**0x0C**	**0x0A**	**0x0A**	**0x08**	**Function: 0x01 Desc count: 0x02**	**0x22**	**0xA0**

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Format (use new settings)							1st Descriptor: 0x04 Rate Dec: 0x000A 2nd Descriptor: 0x05 Rate Dec: 0x000A		
Reply Field : ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x01 Error code: 0x00	0xE7	0xBA
Command: IMU Message Format (read back current settings)	0x75	0x65	0x0C	0x04	0x04	0x08	Function: 0x02 Desc count: 0x00	0xF8	0xF3
Reply Field 1: ACK/NACK	0x75	0x65	0x0C	0x0D	0x04	0xF1	Echo cmd: 0x08 Error code: 0x00		
Reply Field 2 : Current IMU Message Format					0x09	0x80	Desc count: 0x02 1st Descriptor: 0x03 Rate Dec: 0x000A 2nd Descriptor: 0x04 Rate Dec: 0x000A	0x98	0x0F
Copy-Paste version of the commands: Use New Settings:"7565 0C0A 0A08 0102 0400 0A05 000A 22A0" Read Current Settings: "7565 0C04 0408 0200 F8F3"									

4.2.4 Enable/Disable Continuous Data Stream (0x0C, 0x11)

Description

Control the streaming of IMU and Estimation Filter data. If disabled, the data from the selected device is not continuously transmitted. Upon enabling, the most current data will be transmitted (i.e. no stale data is transmitted.) The default for the device is all streams enabled. For all functions except 0x01 (use new setting), the new enable flag value is ignored.

Possible function selector values:

- 0x01 - Apply new settings
- 0x02 - Read back current settings
- 0x03 - Save current settings as startup settings
- 0x04 - Load saved startup settings
- 0x05 - Load factory default settings

The device selector can be:

- 0x01 - IMU
- 0x03 - Estimation Filter

The enable flag can be either:

- 0x00 - Disable the selected stream
- 0x01 - Enable the selected stream *(default)*

Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x05	0x11	U8 - Function Selector U8 - Device Selector U8 - New Enable Flag
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)
Reply Field 2: (function = 2)	0x04	0x85	U8 - Device Selector U8 - Current Device Enable Flag

Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: IMU Stream ON	**0x75**	**0x65**	**0x0C**	**0x05**	**0x05**	**0x11**	**Function (Apply): 0x01 Device (IMU): 0x01 Stream (ON): 0x01**	**0x04**	**0x1A**
Command: IMU Stream	**0x75**	**0x65**	**0x0C**	**0x05**	**0x05**	**0x11**	**Function (Apply): 0x01 Device (IMU): 0x01**	**0x03**	**0x19**

OFF							Stream (OFF): 0x00		
Reply: ACK/NACK	0x75	0x65	0x0C	0x04	0x04	0xF1	Echo cmd: 0x11 Error code: 0x00	0xF0	0xCC
Copy-Paste version of the 1st command: "7565 0C05 0511 0101 0104 1A"									

4.2.5 Device Startup Settings (0x0C, 0x30)

Description	Read, Save, Load, or Reset to Default the values for all device settings. Possible function selector values: 0x03 - Save current settings as startup settings** 0x04 - Load saved startup settings 0x05 - Reset to factory default settings							
Notes	***When a save current settings command is issued a brief data disturbance may occur as all settings are written to non-volatile memory.*							
Field Format	*Field Length*		*Field Descriptor*		*Field Data*			
Command	0x03		0x30		U8 - Function selector			
Reply: ACK/ NACK	0x04		0xF1		U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)			
Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Save All	**0x75**	**0x65**	**0x0C**	**0x03**	**0x03**	**0x30**	Fctn (Save): **0x03**	**0x1F**	**0x45**
Reply: ACK/NACK	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0xF1**	Echo cmd: **0x30** Error code: **0x00**	**0x0F**	**0x0A**
Copy-Paste version of the command: “7565 0C03 0330 031F 45”									

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<table>
<tr><th colspan="10">4.2.6 Accel Bias (0x0C, 0x37) Advanced</th></tr>
<tr><td>Description</td><td colspan="9">Set the value, or read the current value of the IMU7 Accelerometer Bias Vector. For all functions except 0x01 and 0x06 (apply new settings), the new vector value is ignored. The bias value is subtracted from the scaled accelerometer value prior to output.

Possible function selector values:
0x01 - Apply new settings
0x02 - Read back current settings
0x03 - Save current settings as startup settings
0x04 - Load saved startup settings
0x05 - Load factory default settings
0x06 - Apply new settings with no ACK/NACK reply</td></tr>
<tr><td>Field Format</td><td colspan="2">Field Length</td><td colspan="2">Field Descriptor</td><td colspan="5">Field Data</td></tr>
<tr><td>Command</td><td colspan="2">0x0F</td><td colspan="2">0x37</td><td colspan="5">U8 - Function selector
float - X Accel Bias Value
float - Y Accel Bias Value
float - Z Accel Bias Value</td></tr>
<tr><td>Reply Field 1: ACK/ NACK</td><td colspan="2">0x04</td><td colspan="2">0xF1</td><td colspan="5">U8 - echo the command byte
U8 - error code (0: ACK, non-zero: NACK)</td></tr>
<tr><td>Reply Field 2: Function = 2</td><td colspan="2">0x0E</td><td colspan="2">0x9A</td><td colspan="5">float - Current X Accel Bias Value
float - Current Y Accel Bias Value
float - Current Z Accel Bias Value</td></tr>
<tr><td rowspan="2">Examples</td><td colspan="4">MIP Packet Header</td><td colspan="3">Command/Reply Fields</td><td colspan="2">Checksum</td></tr>
<tr><td>Sync1</td><td>Sync2</td><td>Desc. Set</td><td>Payload Length</td><td>Field Length</td><td>Field Desc.</td><td>Field Data</td><td>MSB</td><td>LSB</td></tr>
<tr><td>Command: Accel Bias</td><td>0x75</td><td>0x65</td><td>0x0C</td><td>0x0F</td><td>0x0F</td><td>0x37</td><td>Fctn (Apply): 0x01
Field (Bias): 0x00000000
0x00000000
0x00000000</td><td>0x3C</td><td>0x75</td></tr>
<tr><td>Reply Field : ACK/NACK</td><td>0x75</td><td>0x65</td><td>0x0C</td><td>0x04</td><td>0x04</td><td>0xF1</td><td>Echo cmd: 0x37
Error code: 0x00</td><td>0x16</td><td>0x18</td></tr>
<tr><td colspan="10">Copy-Paste version of the command: "7565 0C0F 0F37 0100 0000 0000 0000 0000 0000 003C 75”</td></tr>
</table>

<table>
<tr><th colspan="10">4.2.7 Gyro Bias (0x0C, 0x38) Advanced</th></tr>
<tr><td>Description</td><td colspan="9">Set the value, or read the current value of the IMU7 Gyro Bias Vector. For all functions except 0x01 and 0x06 (apply new settings), the new vector value is ignored. The bias value is subtracted from the scaled Gyro value prior to output.

Possible function selector values:
0x01 - Apply new settings
0x02 - Read back current settings
0x03 - Save current settings as startup settings
0x04 - Load saved startup settings
0x05 - Load factory default settings
0x06 - Apply new settings with no ACK/NACK reply</td></tr>
<tr><td>Field Format</td><td colspan="2">Field Length</td><td colspan="2">Field Descriptor</td><td colspan="5">Field Data</td></tr>
<tr><td>Command</td><td colspan="2">0x0F</td><td colspan="2">0x38</td><td colspan="5">U8 - Function selector
float - X Gyro Bias Value
float - Y Gyro Bias Value
float - Z Gyro Bias Value</td></tr>
<tr><td>Reply Field 1: ACK/ NACK</td><td colspan="2">0x04</td><td colspan="2">0xF1</td><td colspan="5">U8 - echo the command byte
U8 - error code (0: ACK, non-zero: NACK)</td></tr>
<tr><td>Reply Field 2: Function = 2</td><td colspan="2">0x0E</td><td colspan="2">0x9B</td><td colspan="5">float - Current X Gyro Bias Value
float - Current Y Gyro Bias Value
float - Current Z Gyro Bias Value</td></tr>
<tr><td rowspan="2">Examples</td><td colspan="4">MIP Packet Header</td><td colspan="3">Command/Reply Fields</td><td colspan="2">Checksum</td></tr>
<tr><td>Sync1</td><td>Sync2</td><td>Desc. Set</td><td>Payload Length</td><td>Field Length</td><td>Field Desc.</td><td>Field Data</td><td>MSB</td><td>LSB</td></tr>
<tr><td>Command: Gyro Bias</td><td>0x75</td><td>0x65</td><td>0x0C</td><td>0x0F</td><td>0x0F</td><td>0x38</td><td>Fctn (Apply): 0x01
Field (Bias): 0x00000000
0x00000000
0x00000000</td><td>0x3D</td><td>0x83</td></tr>
<tr><td>Reply Field : ACK/NACK</td><td>0x75</td><td>0x65</td><td>0x0C</td><td>0x04</td><td>0x04</td><td>0xF1</td><td>Echo cmd: 0x38
Error code: 0x00</td><td>0x17</td><td>0x1A</td></tr>
<tr><td colspan="10">Copy-Paste version of the command: “7565 0C0F 0F38 0100 0000 0000 0000 0000 0000 003D 83”</td></tr>
</table>

4.2.8 Capture Gyro Bias (0x0C, 0x39)

Description	This command will cause the 3DM-CV5-15 to sample its sensors for the specified number of milliseconds. The resulting data will be used to initialize its orientation, and to estimate its gyro bias error. The estimated gyro bias error will be automatically written to the Gyro Bias vector. The bias vector is not saved as a startup value. If you wish to save this vector, use the Gyro Bias command. Possible sampling time values: Total sampling time in units of milliseconds. Range of values: 1000 to 3000.		
Notes	Note: The 3DM-CV5-10 must be stationary during the execution of the Capture Gyro Bias operation.		
Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x04	0x39	U16 - Sampling Time (milliseconds)
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command byte U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2: Function = 2	0x0E	0x9B	float - Current X Gyro Bias Value float - Current Y Gyro Bias Value float - Current Z Gyro Bias Value

Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Capture Gyro Bias	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0x39**	Sampling Time: **0x2710**	**0x5E**	**0xE0**
Reply Field 1: ACK/NACK	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0xF1**	Echo cmd: **0x39** Error code: **0x00**		
Reply Field 2: Bias Vector					**0x0E**	**0x9B**	Field (Bias): **0x00000000** **0x00000000** **0x00000000**	**0xCF**	**0x19**
Copy-Paste version of the command: "7565 0C04 0439 2710 5EE0"									

4.2.9 Coning and Sculling Enable (0x0C, 0x3E)

Description	Set, read, or save the Coning and Sculling Compensation Enable. This function sets the Coning and Sculling Compensation Enable. For all functions except 0x01 (use new setting), the new parameter values are ignored. Possible function selector values: 0x01 - Apply new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Load factory default settings The enable flag can be either: 0x00 - Disable the Coning and Sculling compensation 0x01 - Enable the Coning and Sculling compensation (default)

Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x10	0x3E	U8 - Function selector U8 - New Coning and Sculling enable setting
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2: Function = 2	0x03	0x9E	U8 - Current Coning and Sculling enable setting

Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Enable Settings	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0x3E**	Fctn (Apply): **0x01** Enable: **0x01**	**0x2E**	**0x94**
Reply Field : ACK/NACK	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0xF1**	Echo cmd: **0x38** Error code: **0x00**	**0x1D**	**0x26**

Copy-Paste version of the command: "7565 0C04 043E 0101 2E94"

4.2.10 UART Baud Rate (0x0C, 0x40)

Description	Change, read, or save the baud rate of the main communication channel (UART1). For all functions except 0x01 (use new settings), the new baud rate value is ignored. Possible function selector values: 0x01 - Apply new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Supported baud rates are: 9600, 19200, 115200 *(default)*, 230400, 460800, 921600
Notes	*The ACK/NACK packet is sent at the current baud rate and then there is a 0.25 second delay before the device will respond to commands at the new BAUD rate.*

Field Format	*Field Length*	*Field Descriptor*	*Field Data*
Command	0x07	0x40	U8 - Function selector U8 - New baud rate
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - Echo the command descriptor U8 - Error code (0: ACK, non-zero: NACK)
Reply Field 2: Function = 2	0x06	0x87	U8 - Current baud rate

Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Set Baud Rate	**0x75**	**0x65**	**0x0C**	**0x07**	**0x07**	**0x40**	Fctn (USE): **0x01** Baud (115200): **0x0001C200**	**0xF8**	**0xDA**
Reply Field : ACK/NACK	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0xF1**	Echo cmd: **0x40** Error code: **0x00**	**0x1F**	**0x2A**

Copy-Paste version of the command: “7565 0C07 0740 0100 01C2 00F8 DA”

4.2.11 Advanced Low-Pass Filter Settings (0x0C, 0x50)

Description	Advanced configuration for low-pass filter settings. The scaled data quantities are **by default** filtered through a single-pole IIR low-pass filter which is configured with a -3dB cutoff frequency of half the reporting frequency (set by decimation factor in the IMU Message Format command) to prevent aliasing on a per data quantity basis. This advanced configuration command allows for the cutoff frequency to be configured independently of the data reporting frequency as well as allowing for a complete bypass of the digital low-pass filter. Possible function selector values: 0x01 - Apply new settings 0x02 - Read back current settings 0x03 - Save current settings as startup settings 0x04 - Load saved startup settings 0x05 - Reset to factory default settings Possible data descriptors: 0x04 - Scaled accel data 0x05 - Scaled gyro data 0x06 - Scaled mag data (if applicable) 0x17 - Scaled pressure data Possible filter enable values: 0x01 - Apply low-pass filter 0x00 - Do not apply low-pass filter Manual filter bandwidth configuration: 0x01 - Use user specified -3 dB cutoff frequency 0x00 - Automatically configure -3 dB cutoff frequency to half reporting rate -3 dB Cutoff Frequency: Cutoff Frequency value specified must be no greater than 250 Hz. ***This value in a write command is ignored if Automatic Bandwidth is selected.* Reserved Byte: This byte is reserved for internal use and should be left in the 0x00 state			
Field Format	*Field Length*	*Field Descriptor*	*Field Data*

Command	0x09	0x50	U8 - Function selector U8 - Data Descriptor U8 - Low-Pass Filter Enable/Disable U8 - Manual/Auto -3 dB Cutoff Frequency Configuration U16 - -3 dB Cutoff Frequency U8 - Reserved Byte
Reply Field 1: ACK/ NACK	0x04	0xF1	U8 - echo the command descriptor U8 - error code (0: ACK, non-zero: NACK)
Reply Field 2: Function = 2	0x08	0x8B	U8 - Data Descriptor U8 - Filter (0x01: Enabled, 0x00: Disabled) U8 - Cutoff Frequency (0x00: Auto, 0x01: Manual) U16 - -3 dB Cutoff Frequency Hz U8 - Reserved

Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command	**0x75**	**0x65**	**0x0C**	**0x09**	**0x09**	**0x50**	Fctn (Apply): **0x01** Scaled Accel: **0x04** Enable Filter: **0x01** Automatic Cutoff Configuration: **0x00** -3dB Cutoff Frequency (ignored for automatic cutoff configuration) **0x0000** Reserved: **0x00**	**0x4C**	**0x6D**
Reply Field : ACK/NACK	**0x75**	**0x65**	**0x0C**	**0x04**	**0x04**	**0xF1**	Echo cmd: **0x50** Error code: **0x00**	**0x2F**	**0x4A**
Copy-Paste version of the command: "7565 0C09 0950 0104 0100 0000 004E 80"									

<table>
<tr><th colspan="7">4.2.12 Device Status (0x0C, 0x64)</th></tr>
<tr><td>Description</td><td colspan="6">Get the device-specific status for the 3DM-CV5-10.

Reply has two fields: “ACK/NACK” and “Device Status Field”. The device status field may be one of two selectable formats - basic and diagnostic.

The reply data for this command is device specific. The reply is specified by two parameters in the command. The first parameter is the model number (which for the 3DM-CV5-10 is always = 6259 (0x1873). That is followed by a status selector byte which determines the type of data structure returned. In the case of the 3DM-CV5-10, there are two selector values - one to return a basic status structure and a second to return an extensive diagnostics status structure. A list of available values for the selector values and specific fields in the data structure are as follows:

Possible Status Selector Values:

0x01 - Basic Status Structure
0x02 - Diagnostic Status Structure</td></tr>
<tr><td>Notes</td><td colspan="6">The reply field for this command is tightly tied to the model number. Make sure you check the model number in the reply and match it to the correct structure for the data field for the specific device model number. This reply data descriptor 0x0C,0X90 is an exception to the rule for MIP descriptors that the structure of descriptor data is the same for all devices. In this case, it is the same for all devices with the same model number but not necessarily the same for devices with different model numbers.</td></tr>
<tr><td>Field Format</td><td>Field Length</td><td>Field Descriptor</td><td colspan="4">Field Data</td></tr>
<tr><td>Command</td><td>0x02</td><td>0x64</td><td colspan="4">U16-Device Model Number: set = 6259 (0x1873))
U8-Status Selector</td></tr>
<tr><td>Reply Field 1: ACK/ NACK</td><td>0x04</td><td>0xF1</td><td colspan="4">U8 - echo the command byte
U8 - error code (0: ACK, non-zero: NACK)</td></tr>
<tr><td rowspan="5">Reply Field 2: Basic Device Status Field</td><td rowspan="5">0x0F</td><td rowspan="5">0x90</td><td>Binary Offset</td><td>Description</td><td>Data Type</td><td>Units</td></tr>
<tr><td>0</td><td>Echo of the Device Model Num-ber</td><td>U16</td><td>N/A</td></tr>
<tr><td>2</td><td>Echo of the selector byte</td><td>U8</td><td>N/A</td></tr>
<tr><td>3</td><td>Status Flags (Reserved)</td><td>U32</td><td>N/A</td></tr>
<tr><td>9</td><td>System Timer (since start-up)</td><td>U32</td><td>millisecond</td></tr>
<tr><td>Reply Field 2:</td><td>0x35</td><td>0x90</td><td>Binary</td><td>Description</td><td>Data</td><td>Units</td></tr>
</table>

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			Offset		Type	
Diagnostic Device Status Field			0	Echo of the Device Model Number	U16	N/A
			2	Echo of the selector byte	U8	N/A
			3	Status Flags (Reserved)	U32	N/A
			9	System Timer (since start-up)	U32	millisecond
			13	IMU Stream Enabled	U8	1 - on 0 - off
			14	Estimation Filter Stream Enabled	U8	1 - on 0 - off
			15	Outgoing IMU Stream Dropped Packet Count	U32	count
			19	Outgoing Estimation Filter Stream Dropped Packet Count	U32	count
			23	Number of bytes written to com port	U32	count
			27	Number of bytes read from com port	U32	count
			31	Number of overruns when writing to com port	U32	count
			35	Number of overruns when reading com port	U32	count
			39	Number of IMU message parsing errors	U32	count
			43	Total IMU messages read	U32	count
			47	Last IMU message read (System Timer)	U32	millisecond

Examples	MIP Packet Header				Command/Reply Fields			Checksum	
	Sync1	*Sync2*	*Desc. Set*	*Payload Length*	*Field Length*	*Field Desc.*	*Field Data*	*MSB*	*LSB*
Command: Get Device Status (return Basic Status structure: selector = 1)	**0x75**	**0x65**	**0x0C**	**0x05**	**0x05**	**0x64**	Model # (6259): **0x1873** Status selector (basic status): **0x01**		

Reply Field 1: ACK/NACK	**0x75**	**0x65**	**0x0C**	**0x15**	**0x04**	**0xF1**	Echo cmd: **0x64** Error code: **0x00**		
Reply Field 2: Device Status (Basic Status structure)					**0x0F**	**0x90**	Echo Model # (6259): **0x1873** Echo selector: **0x01** Additonal data: **...**	**0x##**	**0x##**

4.3 Error Codes

Error Name	*Error Value*	*Description*
MIP Unknown Command	0x01	The command descriptor is not supported by this device
MIP Invalid Checksum	0x02	An otherwise complete packet has a bad checksum
MIP Invalid Parameter	0x03	One or more parameters in the packet are invalid. This can refer to a value that is outside the allowed range for a command or a value that is not the expected size or type
MIP Command Failed	0x04	Device could not complete the command
MIP Command Timeout	0x05	Device could not complete the command within the expected time

5. Data Reference

5.1 IMU Data

5.1.1 Scaled Accelerometer Vector (0x80, 0x04)

<table>
<tr><td>Description</td><td colspan="6">Scaled Accelerometer Vector</td></tr>
<tr><td>Notes</td><td colspan="6">This is a vector quantifying the direction and magnitude of the acceleration that the 3DM-CV5-10 is exposed to. This quantity is fully temperature compensated and scaled into physical units of g (1 g = 9.80665 m/sec^2). It is expressed in terms of the 3DM-CV5-10's local coordinate system.</td></tr>
<tr><td rowspan="5">Field Format</td><td>Field Length</td><td>Data Descriptor</td><td colspan="4">Message Data</td></tr>
<tr><td rowspan="4">14 (0x0E)</td><td rowspan="4">0x04</td><td>Binary Off-set</td><td>Description</td><td>Data Type</td><td>Units</td></tr>
<tr><td>0</td><td>X Accel</td><td>float</td><td>g</td></tr>
<tr><td>4</td><td>Y Accel</td><td>float</td><td>g</td></tr>
<tr><td>8</td><td>Z Accel</td><td>float</td><td>g</td></tr>
</table>

5.1.2 Scaled Gyro Vector (0x80, 0x05)

<table>
<tr><td>Description</td><td colspan="6">Scaled Gyro Vector</td></tr>
<tr><td>Notes</td><td colspan="6">This is a vector quantifying the rate of rotation (angular rate) of the 3DM-CV5-10. This quantity is fully temperature compensated and scaled into units of radians/second. It is expressed in terms of the 3DM-CV5-10’s local coordinate system.</td></tr>
<tr><td rowspan="5">Field Format</td><td>Field Length</td><td>Data Descriptor</td><td colspan="4">Message Data</td></tr>
<tr><td rowspan="4">14 (0x0E)</td><td rowspan="4">0x05</td><td>Binary Offset</td><td>Description</td><td>Data Type</td><td>Units</td></tr>
<tr><td>0</td><td>X Gyro</td><td>float</td><td>Radians/second</td></tr>
<tr><td>4</td><td>Y Gyro</td><td>float</td><td>Radians/second</td></tr>
<tr><td>8</td><td>Z Gyro</td><td>float</td><td>Radians/second</td></tr>
</table>

5.1.3 Delta Theta Vector (0x80, 0x07)

<table>
<tr><td>Description</td><td colspan="6">Time integral of angular rate.</td></tr>
<tr><td>Notes</td><td colspan="6">This is a vector which gives the time integral of angular rate over the interval set by the IMU message format command. It is expressed in terms of the 3DM-CV5-10’s local coordinate system in units of radians.</td></tr>
<tr><td rowspan="5">Field Format</td><td>Field Length</td><td>Data Descriptor</td><td colspan="4">Message Data</td></tr>
<tr><td rowspan="4">14 (0x0E)</td><td rowspan="4">0x07</td><td>Binary Offset</td><td>Description</td><td>Data Type</td><td>Units</td></tr>
<tr><td>0</td><td>X Delta Theta</td><td>float</td><td>radians</td></tr>
<tr><td>4</td><td>Y Delta Theta</td><td>float</td><td>radians</td></tr>
<tr><td>8</td><td>Z Delta Theta</td><td>float</td><td>radians</td></tr>
</table>

5.1.4 Delta Velocity Vector (0x80, 0x07)

<table>
<tr><td>Description</td><td colspan="6">Time integral of acceleration.</td></tr>
<tr><td>Notes</td><td colspan="6">This is a vector which gives the time integral of specific acceleration over the interval set by the IMU message format command. It is expressed in terms of the 3DM-CV5-10's local coordinate system in units of g*second where g is the standard gravitational constant. To convert Delta Velocity into the more conventional units of m/sec, simply multiply by the standard gravitational constant, 9.80665 m/sec^2.</td></tr>
<tr><td rowspan="5">Field Format</td><td>Field Length</td><td>Data Descriptor</td><td colspan="4">Message Data</td></tr>
<tr><td rowspan="4">14 (0x0E)</td><td rowspan="4">0x08</td><td>Binary Offset</td><td>Description</td><td>Data Type</td><td>Units</td></tr>
<tr><td>0</td><td>X Delta Velocity</td><td>float</td><td>g*seconds</td></tr>
<tr><td>4</td><td>Y Delta Velocity</td><td>float</td><td>g*seconds</td></tr>
<tr><td>8</td><td>Z Delta Velocity</td><td>float</td><td>g*seconds</td></tr>
</table>

5.1.5 GPS Correlation Timestamp (0x80, 0x12)

Description

GPS correlation timestamp.

Notes

This timestamp has three fields:

Double GPS TOW
U16 GPS Week number
U16 Timestamp flags

Timestamp Status Flags:

Bit0 - PPS Beacon Good If set, PPS signal is present
Bit1 - GPS Time Refresh (toggles with each refresh)
Bit2 - GPS Time Initialized (set with the first GPS Time Refresh) (*See GPS Time Update (0x01, 0x72) on page 27*)

This timestamp is formatted to match standard universal GPS Time format. It may be initialized with the GPS Time Update message. If a user-supplied PPS hardware signal is available, that, along with the user-supplied GPS Time Update message may be used to provide precise time synchronization with other parts of the user's system.

The GPS Time Initialized flag will only be asserted after an initial GPS Time Update message has been received.

The “PPS Beacon Good” flag in the Timestamp flags byte indicates if the PPS beacon coming from the GPS is present. If this flag is not asserted, it means that the IMU internal clock is being used for the PPS. The fractional portion of the GPS TOW represents the amount of time that has elapsed from the last PPS.

Field Format

Field Length	*Data Descriptor*	*Message Data*			
		Binary Offset	*Description*	*Data Type*	*Units*
14 (0x0E)	0x12	0	GPS Time of Week	Double	Seconds
		8	GPS Week Number	U16	N/A
		10	Timestamp Flags	U16	See Notes

6. MIP Packet Reference

6.1 Structure

Commands and Data are sent and received as fields in the LORD "MIP" packet format. Below is the general definition of the structure:

The packet always begins with the start-of-packet sequence "ue" (0x75, 0x65). The "Descriptor Set" byte in the header specifies which command or data set is contained in fields of the packet. The payload length byte specifies the sum of all the field length bytes in the payload section.

6.2 Payload Length Range

The payload section can be empty or can contain one or more fields. Each field has a length byte and a descriptor byte. The field length byte specifies the length of the entire field including the field length byte and field descriptor byte. The descriptor byte specifies the command or data that is contained in the field data. The descriptor can only be from the set of descriptors specified by the descriptor set byte in the header. The field data can be anything but is always rigidly defined. The definition of a descriptor is fundamentally described in a ".h" file that corresponds to the descriptor set that the descriptor belongs to.

LORD Sensing provides a "Packet Builder" functionality in the "MIP Monitor" software utility to simplify the construction of a MIP packet. Most commands will have a single field in the packet, but multiple field packets are possible. Extensive examples complete with checksums are given in the command reference section.

6.3 MIP Checksum Range

The checksum is a 2 byte Fletcher checksum and encompasses all the bytes in the packet:

6.4 16-bit Fletcher Checksum Algorithm (C Language)

```
for(i=0; i<checksum_range; i++)

    {

    checksum_byte1 += mip_packet[i];

    checksum_byte2 += checksum_byte1;

    }

checksum = ((u16) checksum_byte1 << 8) + (u16) checksum_byte2;
```

7. Advanced Programming

7.1 Multiple Commands in a Single Packet

MIP packets may contain one or more individual commands. In the case that multiple commands are transmitted in a single MIP packet, the 3DM-CV5-10 will respond with a single packet containing multiple replies. As with any packet, all commands must be from the same descriptor set (you cannot mix Base commands with 3DM commands in the same packet).

Note that the only difference in the packet headers of the single command packets compared to the multiple command packets is the payload length. Parsing multiple fields in a single packet involves subtracting the field length of the next field from the payload length until the payload length is less than or equal to zero.

7.2 Internal Diagnostic Functions

The 3DM-CV5-10 supports two device specific internal functions used for diagnostics and system status. These are Device Built In Test and Device Status. These commands are defined generically but the implementation is very specific to the hardware implemented on this device. Other LORD Sensing devices will have their own implementations of these functions depending on the internal hardware of the devices.

7.2.1 3DM-CV5-10 Internal Diagnostic Commands

- Device Built In Test (0x01, 0x05)
- Device Status (0x0C, 0x64)

7.3 Handling High Rate Data

The size of the data fields from an inertial device is substantially greater than on most other types of sensors. On top of that, in many applications it is desirable to receive that data with the lowest latency possible and thus the highest baud rate is selected. The result is that the port servicing requirements in terms of both speed and buffer size can be surprisingly large for inertial data. This can lead to a couple of common problems: runaway latency and dropped packets.

7.3.1 Runaway Latency

Most operating systems provide drivers that have ample buffers and take care of port servicing at the hardware level. Dropping packets or losing data is not usually an issue on these systems. What can be an issue is latency, that is, when the buffer is not emptied by the application in a timely manner. In the worst case, the buffer is being filled faster than it is emptied and the application operates with increasingly “old” data - which causes runaway latency. It is important to monitor the incoming data buffer to make sure you do not reach this condition.

7.3.2 Dropped Packets

Many applications do not use an operating system but are written from scratch or on top of proprietary application frameworks. These are most often embedded MCUs or small single board microcontrollers. On these systems, port handling is usually done in code at the hardware level. Collecting data from a port requires the use one of three techniques: register polling, hardware interrupts, or direct memory access (DMA). Register polling is very easy to do and is adequate for simple communications where data comes in very small chunks and at reasonable data rates. The problem with register polling is that you either waste time looping while waiting for a byte to come in at the port or you get too busy doing other tasks so that by the time you poll the port, the byte is lost because the next one overwrites it. This causes dropped packets. On these systems, it is imperative to utilize either a hardware interrupt or hardware DMA on the UART receiving data from the 3DM-

CV5-10. The DMA or UART interrupt service routine only takes processor time when a byte is ready and as long as the interrupts are preemptive, the processor will fetch every byte received. Using the interrupt routine to fill a ring buffer makes the most efficient use of an MCU and makes it easier to write your application main line code. This is essentially what drivers in operating systems do.

7.4 Creating Fixed Data Packet Format

The MIP packet structure and protocol provides a great deal of flexibility to the user for creating a custom data stream. It does this by allowing selectable data fields and individual data rates for each field. The side effect of this feature is that packets vary in size depending on what data is being delivered in any particular time frame. For example, if acceleration data is configured for 100 Hz and gyroscope data is configured for 25 Hz, every fourth packet is larger than the previous three because of the additional magnetometer data. In some applications, this is undesirable and there may be a requirement for a fixed packet structure so that each data packet is exactly the same. A fixed packet structure allows you to find data fields by fixed offsets rather than parsing the packet for each field.

A fixed packet structure is easily achieved with MIP packet protocol by simply making sure the data rate for each data quantity is the same. The order of the data fields in the packet reflect the order of the fields in the Message Format command and thus are completely under the control of the user. Once an acceptable data packet structure is determined, and all the rates are set to the same decimation, use the “Save current settings as startup settings” function selector in the message format command, and that format will be saved and used automatically on subsequent device startups.

8. Glossary

A

A/D Value
The digital representation of analog voltages in an analog-to-digital (A/D) conversion. The accuracy of the conversion is dependent on the resolution of the system electronics. Higher resolution produces a more accurate conversion.

Acceleration
In physics,acceleration is the change in the rate of speed (velocity) of an object over time.

Accelerometer
A sensor used to detect and measure magnitute and direction of an acceleration force (g-force) in reference to its sensing frame. For example, at rest perpendicular to the Earth's surface an accelerometer will measure 9.8 meters/second squared as a result of gravity. If the device is tilted the acceleration force will change slightly, indicating tilt of the device. When the accelerometer is moving it will measure the dynamic force (including gravity).

Adaptive Kalman Filter (AKF)
A type of Extended Kalman Filter (EKF) that contains an optimization algorithm that adapts to dynamic conditions with a high dependency on adaptive technology. Adaptive technology refers to the ability of a filter to selectively trust a given measurement more or less based on a trust threshold when compared to another measurement that is used as a reference. Sensors that have estimation filters that rely on adaptive control elements to improve their estimations are refered to as an AKF.

AHRS (Attitude and Heading Reference System)
A navigation device consisting of sensors on the three primary axes used to measure vehicle direction and orientation in space. The sensor measurements are typically processed by an onboard algorthim, such as an Estimation Filter, to produce a standardized output of attitude and heading.

Algorithm
In math and science, an algorithm is a step-by-step process used for calculations.

Altitude
the distance an object is above the sea level

Angular rate
The rate of speed of which an object is rotating. Also know as angular frequency, angular speed, or radial frequency. It is typically measured in radians/second.

API (Applications Programming Interface)
A library and/or template for a computer program that specifies how components will work together to form a user application: for example, how hardware will be accessed and what data structures and variables will be used.

ASTM (Association of Standards and Testing)
a nationally accepted organization for the testing and calibration of technological devices

Attitude
the orientaion of an object in space with reference to a defined frame, such as the North-East-Down (NED) frame

Azimuth
A horizontal arc measured between a fixed point (such as true north) and the vertical circle passing through the center of an object

B

Bias
A non-zero output signal of a sensor when no load is applied to it, typically due to sensor imperfections. It is also called offset.

C

Calibration
to standardize a measurement by determining the deviation standard and applying a correction, or calibration, factor

Complementary Filter (CF)
A term commonly used for an algorithm that combines the readings from multiple sensors to produce a solution. These filters typically contain simple filtering elements to smooth out the effects of sensor over-ranging or anomalies in the magnetic field.

Configuration
A general term applied to the sensor indicating how it is set up for data acquisition. It includes settings such as sampling rate, active measurements, measurement settings, offsets, biases, and calibration values

Convergance
when mathematical computations approach a limit or a solution that is stable and optimal.

D

Data Acquisition
the process of collecting data from sensors and other devices

Data Logging
the process of saving acquired data to the system memory, either locally on the device, or remotely on the host computer

Data rate
the rate at which sampled data is transmitted to the host

Delta-Theta
the time integral of angular rate expressed with refernce to the device local coordinate system, in units of radians

Delta-velocity
the time integral of velocity expressed with refernce to the device local coordinate system, in units of g*second where g is the standard gravitational constant

E

ECEF (Earth Centered Earth Fixed)
a reference frame that is fixed to the earth at the center of the earth and turning about earth's axis in the same way as the earth

Estimation Filter
A mathematical algorithm that produces a statistically optimum solution using measurements and references from multiple sources. Best known estimation filters are the Kalman Filter, Adaptive Kalman Filter, and Extended Kalman Filter.

Euler angles
Euler angles are three angles use to describe the orientation of an object in space such as the x, y and z or pitch; roll; and yaw. Euler angles can also represent a sequence of three elemental rotations around the axes of a coordinate system.

Extended Kalman Filter (EKF)
Used generically to describe any estimation filter based on the Kalman Filter model that can handle non-linear elements. Almost all inertial estimation filters are fundamentally EKFs.

G

GNSS (Global Navigation Statellite System)
a global network of space based statellites (GPS, GLONASS, BeiDou, Galileo, and others) used to triangulate position co-ordinates and provide time information for navigational purposes

GPS (Global Positioning System)
a U.S. based network of space based statellites used to triangulate position co-ordinates and provide time information for navigational purposes

Gyroscope
a device used to sense angular movements such as rotation

H

Heading
an object's direction of travel with reference to a co-ordinate frame, such as lattitude and longitude

Host (computer)
The host computer is the computer that orchestrates command and control of attached devices or networks.

I

IMU
Inertial Measurement System

Inclinometer
device used to measure tilt, or tilt and roll

Inertial
pertaining to systems that have inertia or are used to measure changes in inertia as in angular or linear accelerations

INS (Inertial Navigation System)
systems that use inertial measurements exclusively to determine position, velocity, and attitude, given an initial reference

K

Kalman Filter
a linear quadratic estimation algorithm that processes sensor data or other input data over time, factoring in underlying noise profiles by linearizing the current mean and covariance to produces an estimate of a system’s current state that is statistically more precise than what a single measurement could produce

L

LOS (Line of Sight)
Describes the ideal condition between transmitting and receiving devices in a wireless network. As stated, it means they are in view of each other with no obstructions.

M

Magnetometer
A type of sensor that measures the strength and direction of the local magnetic field with refernce to the sensor frame. The magnetic field measured will be a combination of the earth's magnetic field and any magnetic field created by nearby objects.

MEMS (Micro-Electro-Mechanical System)
The technology of miniaturized devices typically made using micro fabrication techniques such as nanotechnology. The devices range in size from one micron to several millimeters and may include very complex electromechanical parts.

N

NED (North-East-Down)
A geographic reference system

O

OEM
acronym for Original Equipment Manufacturer

Offset
A non-zero output signal of a sensor when no load is applied to it, typically due to sensor imperfections. Also called bias.

Orientation
The orientaion of an object in space with reference to a defined frame. Also called attitude.

P

Pitch
In navigation pitch is what occurs when vertical force is applied at a distance forward or aft from the center of gravity of the platform, causing it to move up or down with respect to the sensor or platform frame origin.

Position
The spatial location of an object

PVA
acronym for Position, Velocity, Attitude

Q

Quaternion
Mathematical notation for representing orientation and rotation of objects in three dimensions with respect to the fixed earth coordinate quaternion. Quaternions convert the axis-angle representation of the object into four numbers and to apply the corresponding rotation to a position vector representing a point relative to the origin.

R

Resolution
In digital systems, the resolution is the number of bits or values available to represent analog voltages or information. For example, a 12-bit system has 4096 bits of resolution and a 16-bit system has 65536 bits.

RMS
acronym for Root Mean Squared

Roll
In navigation roll is what occurs when a horizontal force is applied at a distance right or left from the center of gravity of the platform, causing it to move side to side with respect to the sensor or platform frame origin.

RPY
acronym for Roll, Pitch, Yaw

RS232
a serial data communications protocol

RS422
a serial data communications protocol

S

Sampling
the process of taking measurements from a sensor or device

Sampling rate
rate at which the sensors are sampled

Sampling Rate
the frequency of sampling

Sensor
a device that physically or chemically reacts to environmental forces and conditions and produces a predictable electrical signal as a result

Sigma
In statistics, sigma is the standard deviation from the mean of a data set.

Space Vehicle Information
refers to GPS satellites

Streaming
typically when a device is sending data at a specified data rate continuously without requiring a prompt from the host

U

USB (Universal Serial Bus)
A serial data communications protocol

UTC (Coordinated Universal Time)
The primary time standard for world clocks and time. It is similar to Greenwich Mean Time (GMT).

V

Vector
a measurement with direction and magnitude with refernce from one point in space to another

Velocity
The rate of change of position with respect to time. Also called speed.

W

WAAS (Wide Area Augmentation System)
An air navigation aid developed to allow aircraft to rely on GPS for all phases of flight, including precision approaches to any airport.

WGS (World Geodetic System)
a protocol for geo-referencing such as WGS-84

Y

Yaw
In navigation yaw is what occurs when rotational force is applied at a distance forward or aft from the center of gravity of the platform, causing it to move around the center axis of a sensor or platform frame origin.