H3-IMU
Product Specification User's Guide

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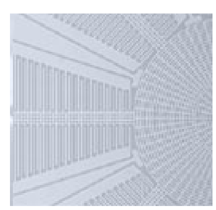

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H3-IMU
Product Specification User's Guide

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PSD-1001	**E**	**June 29, 2011**

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Document Change History

Rev	Status	Description	Date
A	Obsolete	Original	5/5/2010
B	Obsolete	Updated specification table. Reduced maximum sample rate to 800 Hz to support future feature additions.	11/15/2010
C	Obsolete	Updated RS422 connection section. Added sample rate and temperature information to part numbering table.	5/3/2011
D	Obsolete	Updated the HP accelerometer noise specifications.	**5/18/2011**
E	Released	Updated the HP accelerometer noise specifications. Added 3000 deg/sec gyro specifications. Updated USB DAQ Section.	**6/29/2011**

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1.0 Purpose

1.1 The High Performance Inertial Measurement Unit

This user's guide documents the features and use of the H3-IMU Series of products. The H3-IMU provides serial digital outputs of triaxial acceleration, angular rate and magnetic field data. Custom algorithms provide high performance, temperature compensated data in real time via the RS-422 protocol at sample rates up to 800 Hz. Two performance options are available the HN for normal applications or the HP which dramatically reduces the accelerometer bias offset and noise. The H3-IMU also supports 2 external analog inputs and 2 external digital inputs that allow other sensors, digital components or switches to be integrated from your application. The H3 is available in a custom package measuring 2.000 in. × 1.110 in. × 0.645 in. height. The H3-IMU is provided with a 15 pin Bi-Lobe connector. Table 2 details the pin-out of the connector configuration. (see Section 5.1 for part numbering specifications).

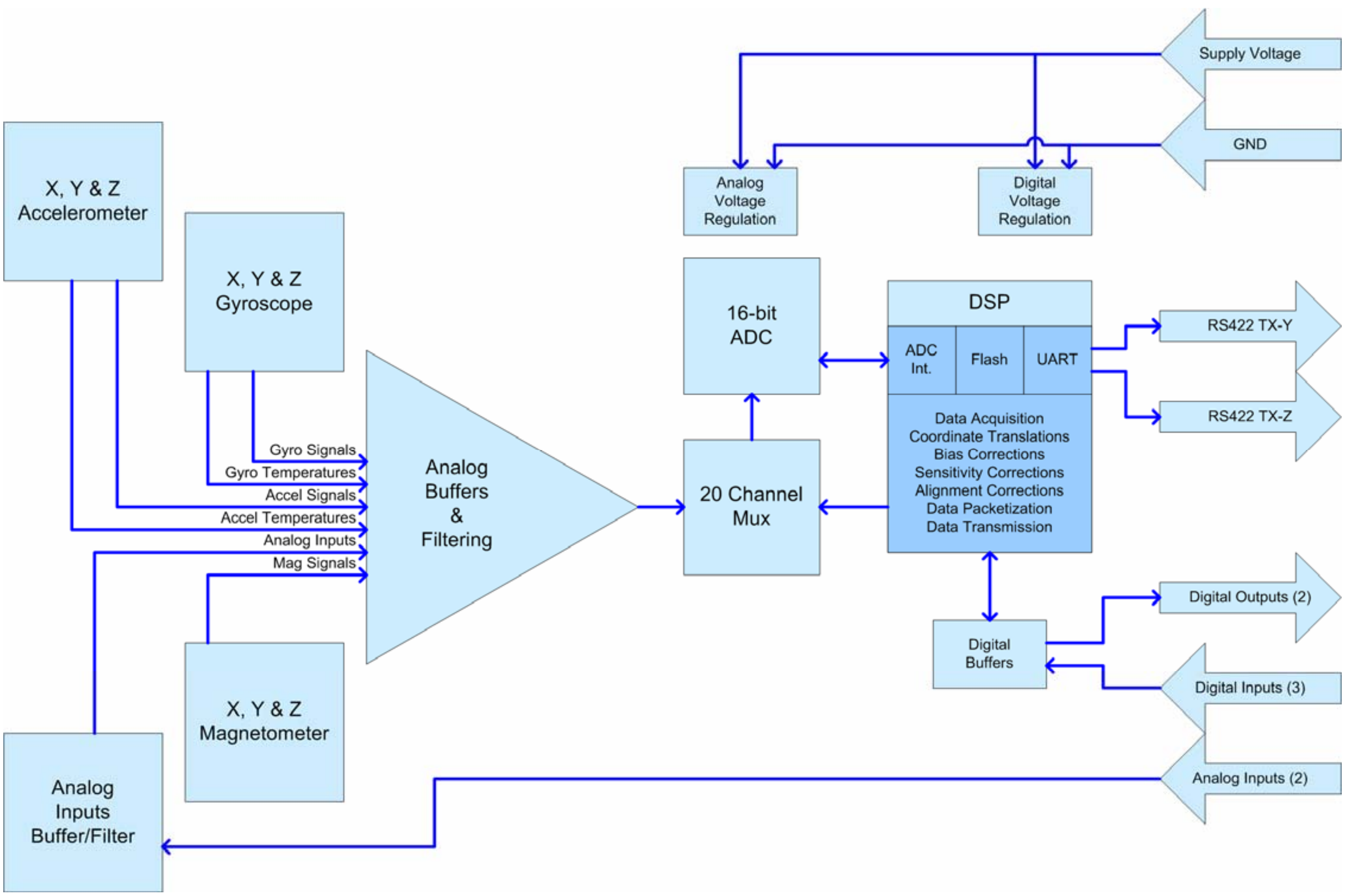

Figure 1 - H3-IMU Functional Block Diagram

2.0 Communications

2.1 Commands

The H3-IMU does not currently offer a command structure or API that allows modification of device characteristics at runtime.

2.2 Sample Format

Data samples are formatted as shown in Table 1. Each data channel (i.e. accelerometer, magnetometer, gyro) is represented by a signed (2's complement) 2-byte short (16-bit) integer that must be converted to its corresponding engineering unit before use (see Section 2.3). An individual data packet is collectively referred to as a *sample*.

Table 1 - Sample byte order/format

BYTE	ELEMENT	BYTE	ELEMENT
0	Synchronization byte (FF)	20	Gyroscope Z (LSB)
1	Synchronization byte (FF)	21	Accelerometer X (2/5/10g) (MSB)
2	Synchronization byte (FF)	22	Accelerometer X (2/5/10g) (LSB)
3	Synchronization byte (FF)	23	Accelerometer Y (2/5/10g) (MSB)
4	Message size	24	Accelerometer Y (2/5/10g) (LSB)
5	Device ID	25	Accelerometer Z (2/5/10g) (MSB)
6	Message ID	26	Accelerometer Z (2/5/10g) (LSB)
7	Pulse Marker / External Digital Inputs	27	Magnetometer X (MSB)
8	Reserved Future Use	28	Magnetometer X (LSB)
9	Product ID	29	Magnetometer Y (MSB)
10	Frame Counter (MSB)	30	Magnetometer Y (LSB)
11	Frame Counter	31	Magnetometer Z (MSB)
12	Frame Counter (LSB)	32	Magnetometer Z (LSB)
13	Serial Number (MSB)	33	External Analog In 1 (MSB)
14	Serial Number (LSB)	34	External Analog In 1 (LSB)
15	Gyroscope X (MSB)	35	External Analog In 2 (MSB)
16	Gyroscope X (LSB)	36	External Analog In 2 (LSB)
17	Gyroscope Y (MSB)	37	Temperature Gyro (MSB)
18	Gyroscope Y (LSB)	38	Temperature Gyro Z (LSB)
19	Gyroscope Z (MSB)	39	8-bit Checksum

Message Header   Message Payload   Message Checksum

Graphically, the sample has the format shown in Figure 2:

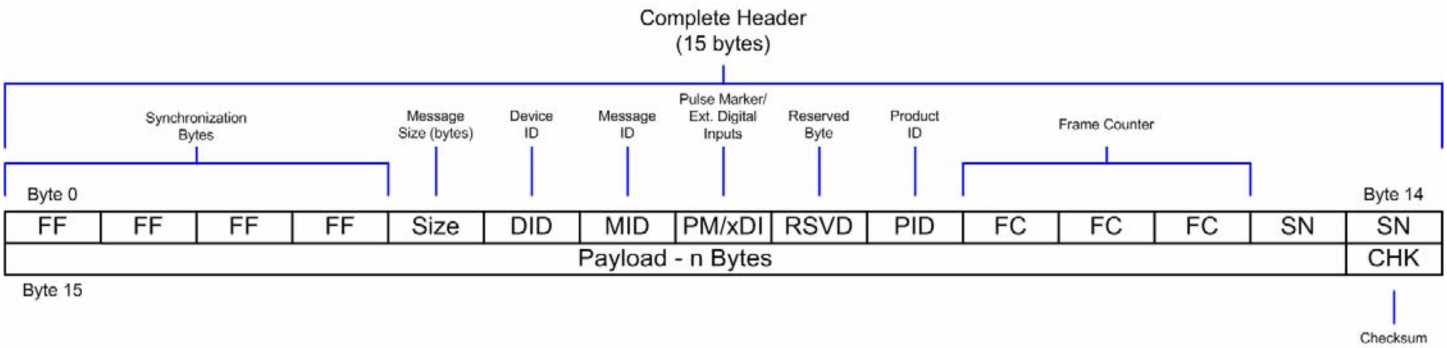

Figure 2 - Sample structure

All samples begin with four (4) synchronization bytes, where each byte is encoded with 0xFF hex. Synchronization bytes aid in the identification of the beginning of samples as they arrive from the device. There are two cases in which synchronization is necessary: 1) initial synchronization of data once the device is powered and 2) re-synchronization if data is lost or errors are encountered. The complete structure of a sample is as follows (*Note: all byte offsets are zero (0) based*):

1. Synchronization bytes: bytes 0-3 with each byte encoded as 0xFF hex.
2. Message size: byte 4, size, in bytes, of entire data message, including complete header.
3. Device ID: byte 5.
4. Message ID: byte 6, type of message. Currently, only data messages are transmitted by the device with MID 0x14 hex (20 decimal).
5. Pulse Marker / External Digital Inputs: byte 7, bit3 of byte 7 is the pulse marker. If this bit is high a pulse output should be correlated to the frame otherwise the bit is 0. Bits 0-2 map to external digital inputs 1-3 respectively. Bits 4-7 are not used.
6. Byte 8 is reserved for future use.
7. Product ID: byte 9, product identification number.
8. Frame Counter: bytes 10- 12, The frame counter is a 23 bit unsigned integer with a maximum count of 16,777,216.
9. Serial Number: bytes 13 & 14 serial number of each H3-IMU.
10. Payload: byte 15, the payload size can be calculated as follows:

    payload_size = message_size – 13(header) – 1(Checksum byte)

11. Checksum byte: 8-bit checksum byte.
    a. Sum sample contents (header + payload). DO NOT include the checksum byte.
    b. The summed value should equal the checksum if the message is valid.
    c. *Note: If greater precision (larger than 8-bit) addition is used to calculate the checksum, the checksum will be the remainder of a divide by 256*.

2.3 Measurement

Accelerometer, gyro and magnetometer data is temperature compensated on the H3-IMU. The payload element of the data packet contains accelerometer, gyro and magnetometer samples, which must be converted to values that represent usable data (e.g. rotational rate, G-force, gauss). The data is transmitted as signed (2's complement) 16-bit integers. The following function must be used for conversion of sample values:

Equation 1: result = *raw_payload_value* x *digital_sensitivity*

where result is the converted value in the appropriate units (e.g. deg/sec), raw_payload_value is the raw component-specific value from the payload (e.g. accelerometer X), and Digital_Sensitivity is the sensitivity expressed in engineering unit per bits. Digital sensitivity values are listed in the Specification Table 5 on page 11 (NOTE: You must use the value specific to the dynamic range of the device you have purchased). For example, if you have purchased a ±300 deg/s, ±2 G H3-IMU, the corresponding equations for the X component would be:

$$value\_x = raw\_payload\_value\_x_{gyro} \times 1.3733 \times 10^{-2} \; {}^{\circ}/s \text{ /bit}$$

$$value\_x = raw\_payload\_value\_x_{accel} \times 9.1553 \times 10^{-5} \text{ G/bit}$$

where raw_payload_value_x is taken from the sample payload corresponding to the x-components of the gyro and accelerometer, respectively. The resulting values have units of degrees/sec and G's, respectively.

Although the sensor data is temperature compensated, a customer's application may require the use of temperature information, therefore a temperature value obtained from each gyro is provided. The temperature data provided in the payload requires a different conversion process. The data is transmitted as signed (2's complement) 16-bit integers. The following function must be used for conversion of temperature sample values:

[**Equation 2:** result_deg_C = ($raw\_payload\_value\_x_{temperature}$ x *digital_sensitivity*) + 25]

where result is the converted value in degrees Celsius, raw_payload_value is the raw component-specific value from the payload in bits and the digital sensitivity is the temperature sensitivity expressed in degrees C per bit (digital sensitivities are listed on page 11 in the Specification table).

In the cases where a custom dynamic range has been ordered, the digital sensitivity can be found by the following equation:

Equation 3: $digital\_sensitivity = dynamic\_range \times 4.57764 \times 10^{-5}$

where digital sensitivity is expressed in engineering units per bit and dynamic range is the unipolar range for the specific sensor axis (e.g. ±0075 º/s then 75 º/s should be used for the dynamic range in Equation 3).

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3.0 Mechanical

3.1 Dimensions

The H3-IMU is available in a custom package measuring 2.000 in. length × 1.500 in. width × 0.645 in. height. Holes are located near the center of each side allowing #3-48 machine screws to be utilized to mount the IMU to a PCB or chassis. The use of two 1/16 in. alignment pins is also supported on each side of the lower housing. Figure 3 depicts the physical dimensions of the part and its features.

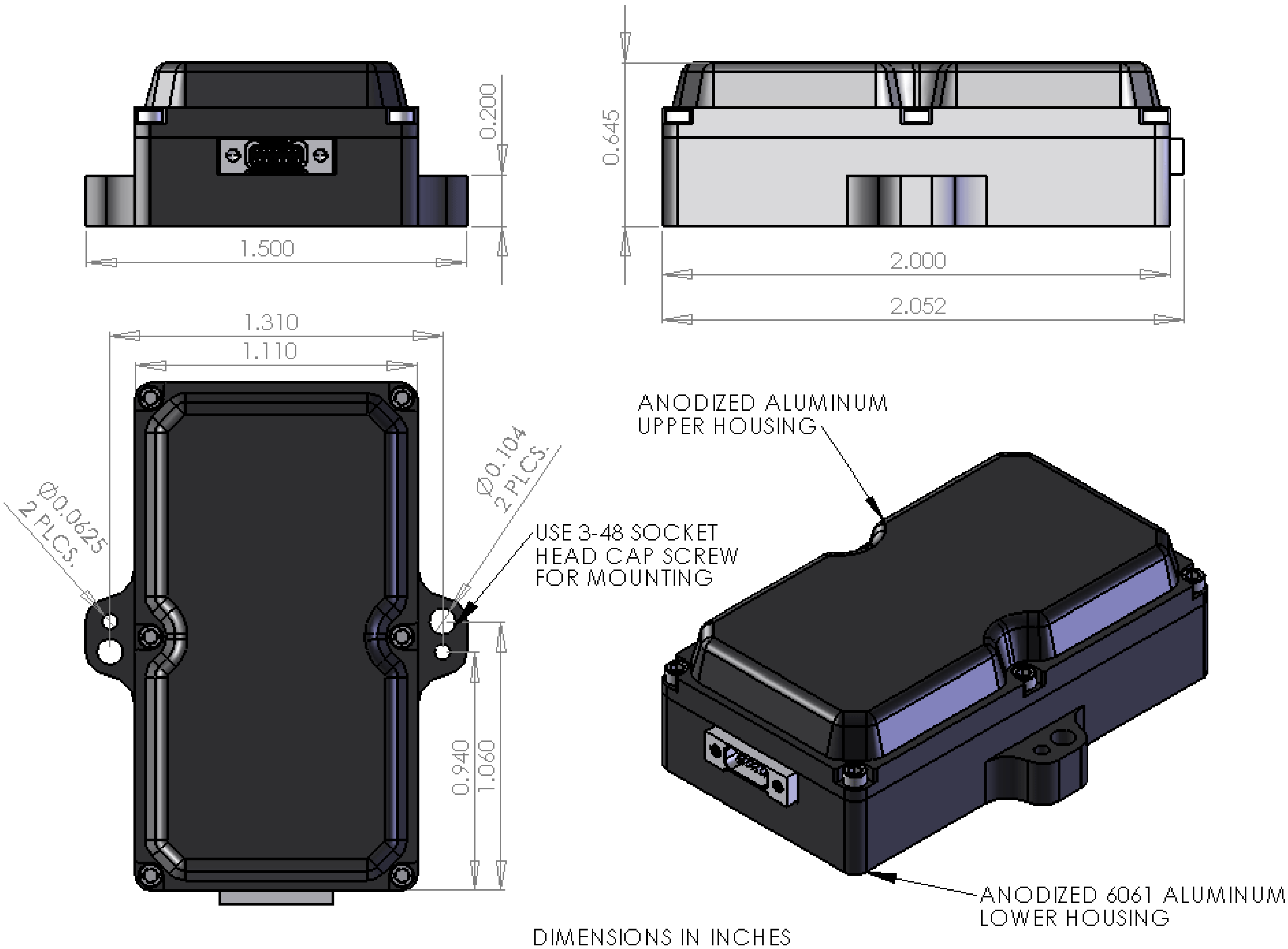

Figure 3 - Physical Dimensions

3.2 Coordinate System

The coordinate system for the IMU follows the right hand rule convention. The sign convention for the accelerometers is configured to produce a positive signal when the IMU is accelerated in the opposite direction of the axis arrow. As an example, the IMU pictured in Figure 4 below (given the X and Y axis are parallel to the earth's surface) will produce 0 *gs* for the X and Y axes and a positive 1 *g* for the Z-axis. As a further example, if the IMU were moved backwards (left side of the page) the X-axis accelerometer would produce a positive output. A counterclockwise rotation of the IMU about any of the depicted axis will produce a positive angular rate output for the corresponding axis.

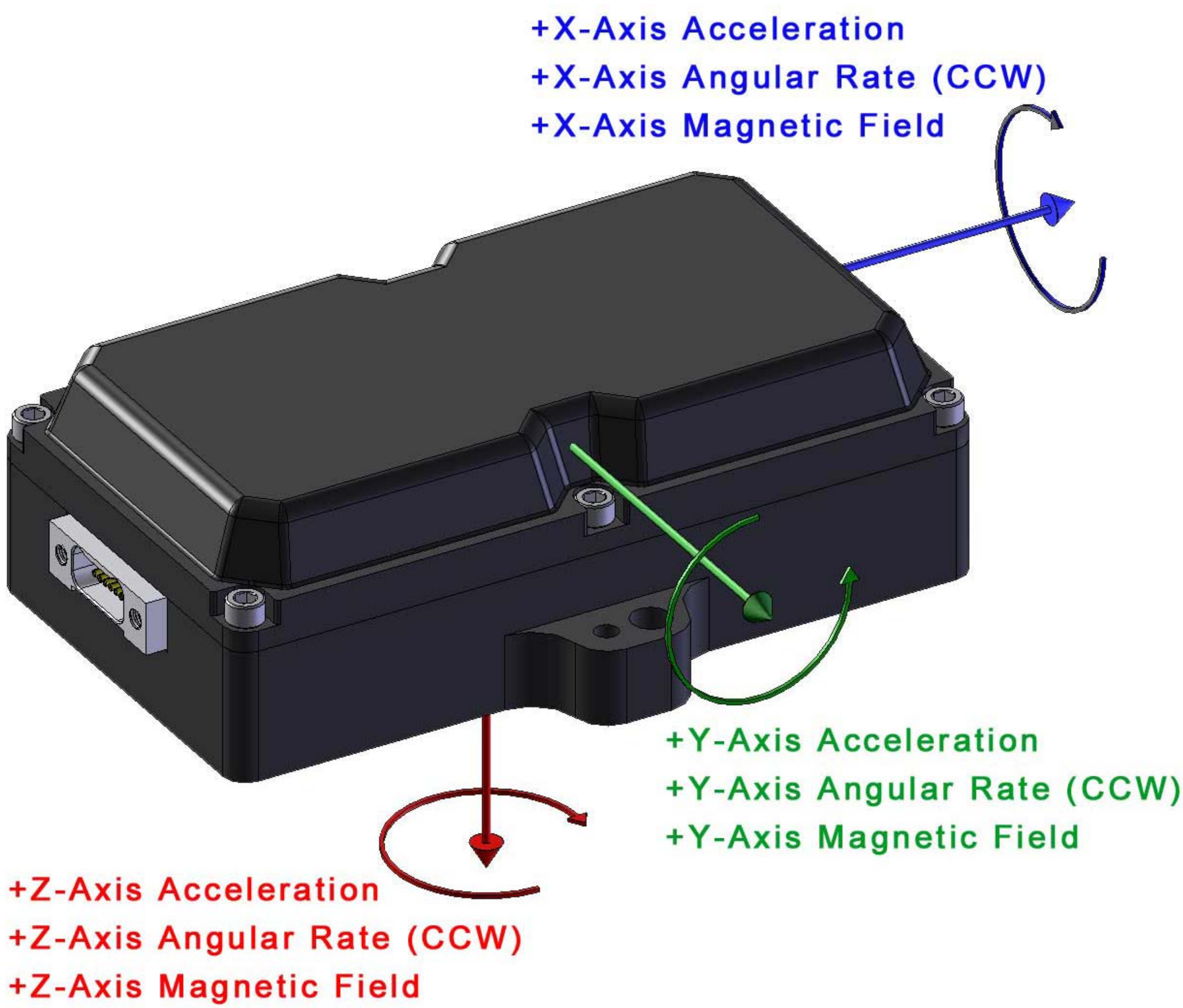

Figure 4 - H3-IMU coordinate system, side view

4.0 Hardware

4.1 Connections

The H3-IMU's output connector is a dual row metal shell 15-pin Nano connector produced by Omnetics that meets all MIL-DTL-32139 specifications. The mating connector is a dual row Bi-Lobe Nano connector with an Omnetic part number of 28000-015.

4.2 Pin Function Description

The pin functions for the IMU and mating connector are listed in Table 2 below:

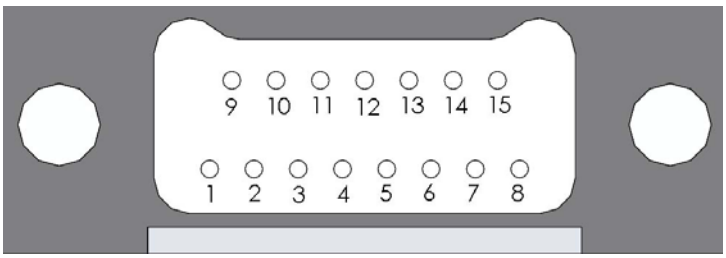

Figure 5 – Omnetics Bi-Lobe Nano interface connector A29100-015

Table 2 – H3-IMU Connector Interface Pin Functions.

Pin No.	Signal Name	Description	Wire Color
1	VSUPPLY	Supply Voltage Input	Black 1
2	GND	Supply Voltage Return	Brown 1
3	ASPIN2	Analog External Input 2	Red 1
4	DSPIN2	Digital External Input 2 (Not Implemented in Revision A)	Orange 1
5	DSPOUT1	Digital Sensor Encode Pulse Output	Yellow 1
6	DSPOUT2	Pulse Output at 1 Second Intervals	Green 1
7	TX_Z	RS422 Inverting Output	Blue 1
8	TX_Y	RS422 Non-Inverting Output	Purple 1
9	GND	Supply Voltage Return	Grey 1
10	ASPIN1	Analog External Input 1	White 1
11	DSPIN1	Digital External Input 1 (Not Implemented in Revision A)	Black 2
12	DSPIN3	Digital External Input 3 (Not Implemented in Revision A)	Brown 2
13	NC	No Connect, Internal Use Only	Red 2
14	RX_B	RS422 Inverting Input (Not Implemented in Revision A)	Orange 2
15	RX_A	RS422 Non-Inverting Input (Not Implemented in Revision A)	Yellow 2

4.3 RS422 Connection Description

The H3-IMU RS422 connection is factory configured to 230400 Baud. The RS422 connection is configured as an 8-bit UART with one start bit, eight data bits, and one stop bit. Data is sent from the H3-IMU via the YZ differential driver pair and should be terminated with a 120 ohm resistor. The sample rate for standard H3 IMUs is set to 250 samples per second and can be increased up to 800 samples per second in custom units. The H3-IMU is not currently configured to receive data.

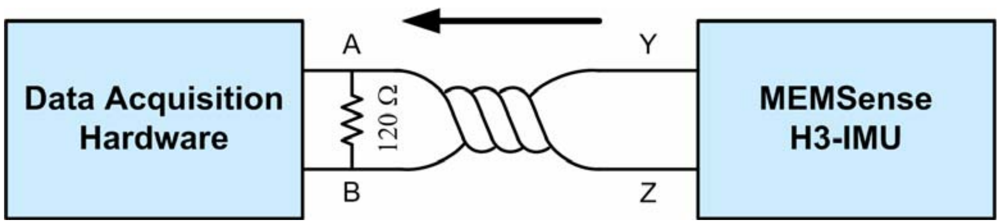

Figure 6– RS422 Full-duplex direct connection diagram

4.4 Digital Sensor Encode Pulse Output

The H3-IMU's pin 5 output contains a digital pulse train that indicates timing for when each sensor signal is encoded. The rising edge of the pulse is when the encode begins while the falling edge indicates the completion of the encode for the associated signal. The time between encodes is 5 µs. Figure 7 below details the pulse waveform for pin 5.

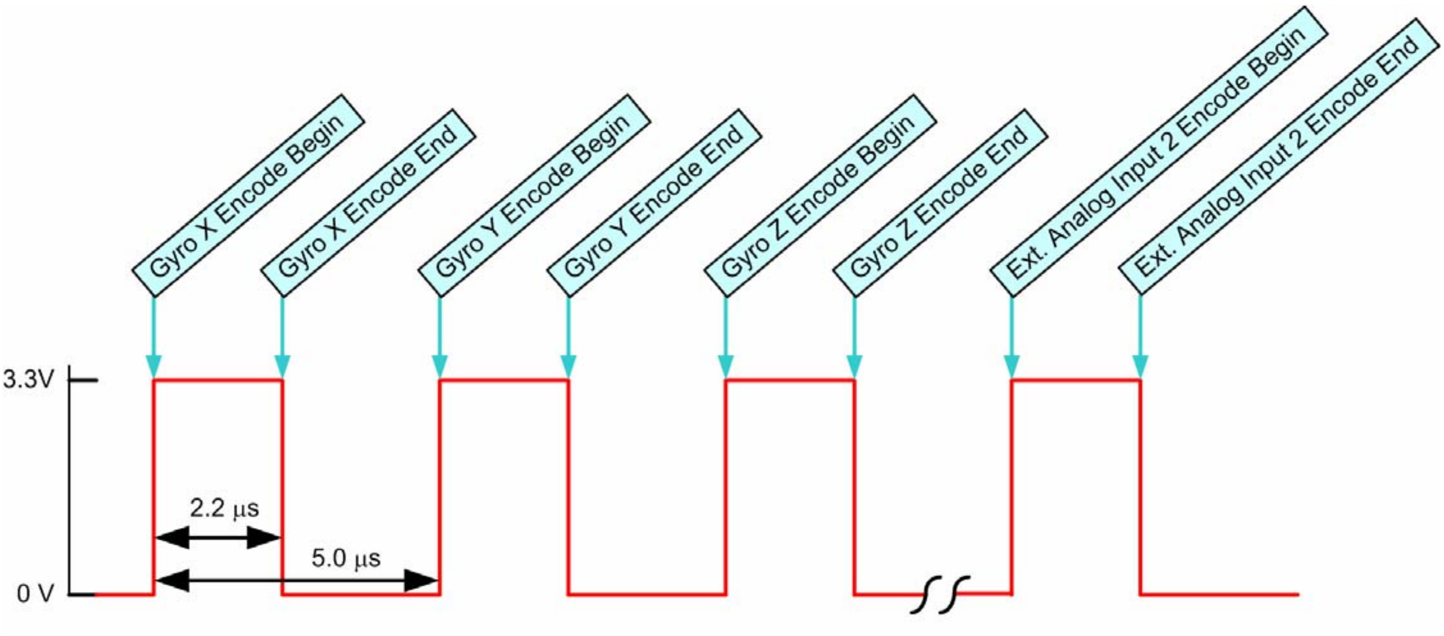

Figure 7 - Digital Sensor Encode Output Waveform

Table 3 - H3-IMU Sensor Signal Encode Orders

HN SIGNAL ENCODE ORDER		HP SIGNAL ENCODE ORDER	
Order	Sensor Signal	Order	Sensor Signal
1	Gyroscope X	1	Gyroscope X
2	Gyroscope Y	2	Gyroscope Y
3	Gyroscope Z	3	Gyroscope Z
4	Accelerometer X	4	Accelerometer X
5	Accelerometer Y	5	Accelerometer Y
6	Accelerometer Z	6	Accelerometer Z
7	Magnetometer X	7	Magnetometer X
8	Magnetometer Y	8	Magnetometer Y
9	Magnetometer Z	9	Magnetometer Z
10	Gyroscope X Temperature	10	Gyroscope X Temperature
11	Gyroscope Y Temperature	11	Gyroscope Y Temperature
12	Gyroscope Z Temperature	12	Gyroscope Z Temperature
13	External Analog In 1	13	Accelerometer X Temperature
14	External Analog In 2	14	Accelerometer Y Temperature
		15	Accelerometer Z Temperature
		16	External Analog In 1
		17	External Analog In 2

5.0 Electrical Specifications and Options

5.1 Part Numbers

Table 4 - Standard Part Numbers

Part Number	Accel (g)	Angular Rate (°/s)	Bandwidth (Hz.)	Sample Rate (Hz.)	Protocol
HN02-0150F050R	2	150	50	250	RS422
HP02-0150F050R	2	300	50	250	RS422
HN02-0300F050R	2	150	50	250	RS422
HP02-0300F050R	2	300	50	250	RS422
HN05-0300F050R	5	300	50	250	RS422
HP05-0300F050R	5	300	50	250	RS422
HN05-0600F050R	5	600	50	250	RS422
HP05-0600F050R	5	600	50	250	RS422
HN10-1200F050R	10	1200	50	250	RS422
HP10-1200F050R	10	1200	50	250	RS422

1.) Custom Acceleration Ranges of ± 30g , ± 50g, ± 100g and ± 200g Also Available
2.) Custom Angular Rate Ranges Available up to ± 5400 °/s
3.) Commercial Temperature Range of 0°C to 70°C add a "C" to the last position of the Part Number
4.) Military Temperature Range of -40°C to 85°C add a "M" to the last position of the Part Number
5.) Custom Sample Rates can be ordered up to 800 Hz.
6.) Custom Bandwidth can be ordered contact sales for more information.

5.2 USB Data Acquisition (DAQ) Module Options

The USB DAQ is available to purchase with your IMU to facilitate simple data collection using a PC. The module converts the IMU RS422 output to USB signals and in the case of the USB-H-8.5UR model utilizes an internal charge pump to boost the USB 5 volt power up to 8.3 volts to power the IMU. Model number USB-H-8.5XR allows the use of an external power supply and has maximum voltage of 8.5 volts. Each USB DAQ model number in Table 5 below is compatible with the H3 IMU and is available for order.

Table 5 – USB DAQ Module Options

Model Number	Description	Max Voltage	Power Source	Protocol	Availability
USB-H-8.5UR	H3-IMU USB RS422 DAQ, USB power	8.5V	USB	RS422	Standard - with all H3-IMU's ordered
USB-H-8.5XR	H3-IMU USB RS422 DAQ, Ext. power	8.5V	External Power	RS422	Option available upon request

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5.3 Specifications

Table 6 - Specifications

PARAMETER	SPECIFICATION					UNITS	CONDITIONS
Operational Requirements							
Supply Voltage	5.4 to 9.0					VDC	
Supply Current	210					mA	Typical
Physical Properties							
Alignment Error	±1					%	
Mass	55					grams	
Acceleration – HN Option	**HN02**	**HN05**	**HN10**				
Dynamic Range	± 2	± 5	± 10			g	
Offset	± 30	± 30	± 30			mg	
Nonlinearity	± 0.4 (± 1.0)	± 0.4 (± 1.0)	± 0.4 (± 1.0)			% of FS	
Noise	0.6 (0.8)	1.1 (1.3)	2.1 (2.8)			mg	
Digital Scale Factor	9.1553E-05	2.2888E-04	4.5776E-04			g/bit	
Bandwidth [1]	50	50	50			Hz	
Acceleration – HP Option	**HP02**	**HP05**	**HP10**	**HP30**	**HP50**		
Dynamic Range	± 2	± 5	± 10	± 30	± 50	g	
1 Yr Bias Stability	± 0.5 (± 2.3)	± .75 (±5)	± 1.5 (±7.5)	± 4.5 (±22.5)	± 7.5 (±37.5)	mg	1 σ (Maximum)
Offset	< 8	< 10	< 12	< 22.5	< 37.5	mg	Maximum
Nonlinearity	± 0.3 (± 0.8)	± 0.3 (± 0.8)	± 0.3 (± 0.8)	± 0.3 (± 0.8)	± 0.3 (± 0.8)	% of FS	Typical (Maximum)
Noise	0.127 (0.170)	0.318 (0.424)	0.636 (0.849)	1.911 (2.548)	6.364 (8.486)	mg	Typical (Maximum), 1 σ
Digital Scale Factor	9.1553E-05	2.2888E-04	4.5776E-04	1.3733E-03	2.2888E-03	g/bit	
Bandwidth [1]	50	50	50	50	50	Hz	-3dB point
Angular Rate	**-0150F050**	**-0300F050**	**-0600F050**	**-1200F050**	**-3000F050**		
Dynamic Range	± 150	± 300	± 600	± 1200	± 3000	°/s	
Offset	+/-1.5	+/-1.5	+/-1.5	+/-2.0	+/-2.0	°/s	0 to 70 °C Maximum
Cross-Axis Sensitivity	+/-1	+/-1	+/-1	+/-1	+/-1	%	Maximum
Nonlinearity	0.1	0.1	0.1	0.1	0.1	% of FS	Best fit straight line
Noise	0.36 (0.95)	0.56 (0.95)	0.56 (0.95)	0.56 (0.95)	1.08 (1.24)	°/s	Typical (Maximum), 1 σ
Digital Scale Factor	6.8665E-03	1.3733E-02	2.7466E-02	5.4932E-02	1.3733E-01	°/s/bit	
Bandwidth [1]	50	50	50	50	50	Hz	-3dB point
Magnetic Field							
Dynamic Range	±1.9					gauss	
Offset	0.020					gauss	Maximum
Nonlinearity	0.5					% of FS	Best fit straight line
Noise	0.00056 (0.0015)					gauss	Typical (Maximum), 1 σ
Digital Scale Factor	8.6975E-05					gauss/bit	
Bandwidth [1]	50					Hz	-3dB point
Temperature							
Digital Sensitivity	1.8165E-02					°C /bit	
External Analog Inputs							
Voltage Range	0 to 5					VDC	
Input Impedance	8					MΩ	
Bandwidth	482					Hz	-3dB point
External Digital Inputs	Minimum	Maximum					
High Level Input Voltage	2.31	3.3				V	
Low Level Input Voltage	0	0.99				V	
Input Leakage Current	± 1					µA	
Absolute Max Ratings							
Acceleration Powered	2000 max					*g*	Any axis 0.5ms
Supply Voltage	-0.3 (min) +12 (max)					VDC	
Operating Temperature	0 to +70					°C	
Mil Operating Temperature	-40 to +85					°C	
Storage Temperature	-55 to +125					°C	
Typical Values at 25°C, Supply Voltage = 5.6 VDC, 0 °/s, unless otherwise noted.							

1.) Other bandwidth configurations are available upon request.
2.) Other configurations are available on a special order basis. Contact sales for more information.
3.) Custom correction temperature profiles are available. Contact sales for more information.

6.0 Terms, Conditions and Warranty

DEFINITION *:* As used herein: “Seller” means MEMSense, 2693D Commerce Road, Rapid City, SD 57702. “Buyer” means the party purchasing Product(s) from the Seller. “Product” means all articles, materials, work or services offered by the Seller and described in the accompanying quotation, acknowledgement, invoice, or other Seller form. “Order” means any purchase Order or contract issued by the Buyer for Products provided by the Seller.

WARRANTY : Seller warrants that the Products will be free from defects in material and workmanship and conform in all material respects to their applicable specifications for a period of one (1) year from the date of delivery (“Warranty Period”), when operated under normal conditions and in accordance with their applicable specifications. For any breach of this warranty, Seller will, at its option and expense and as its sole obligation, and as Buyer’s exclusive remedy, repair or replace any defective Product returned to Seller during the Warranty Period, provided that an examination by Seller discloses to Seller’s reasonable satisfaction that a defect is covered by this warranty. This warranty does not apply to any Products that have been (i) subject to misuse, neglect, or abuse, (ii) improperly installed or maintained, or (iii) repaired or altered by anyone other than Seller. The warranty period for Products repaired or replaced under this warranty shall be limited to the components repaired or replaced and shall run for a period of one hundred and eighty (180) days from the date of delivery or the balance of the original one (1) year Warranty Period (excluding the time the Products were out of service and in Seller’s plant), whichever is longer. EXCEPT AS STATED IN THIS SECTION, SELLER MAKES NO WARRANTIES, EXPRESS OR IMPLIED, AND SPECIFICALLY DISCLAIMS ANY IMPLIED WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, TITLE, AND NON-INFRINGEMENT OF THIRD PARTY RIGHTS.

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DELAYS - Seller shall not be liable for delay in delivery or for failure to manufacture, due to causes beyond its reasonable control, including but not limited to acts of God, acts of any government, acts of civil or military authority, acts of Buyer, application of US Government priorities, Government delays in granting Export Licenses, fires, strikes, floods, war, terrorism, riot or civil commotion, delays in transportation, difficulty in obtaining necessary labor or materials. In the event of any such delay, date of delivery shall be extended for a period of time equal to that lost by reason of the delay.

TAXES - Prices do not include sales or excise tax, VAT, duties or other governmental charges resulting from this transaction or the manufacture, sale, ownership, possession, or use of the Products, all of which must be paid by Buyer. Buyer shall provide Seller a tax exemption certificate acceptable to the taxing authorities.

SHIPMENT - Title to all purchased material and risk of loss therefore is passed from Seller to Buyer at the time of shipment from Seller’s facility. Unless otherwise agreed upon in writing, all purchased material will be shipped uninsured. Seller may request partial shipment and invoice therefore.

EXPORT LICENSE – Buyer will comply with all applicable export and import control laws and regulations in its use of the Products and Buyer will not export or re-export the Products or any technical data or confidential information derived from or pertaining to the Products without all required United States and foreign government licenses.