NANO IMU
Product Specification User’s Guide

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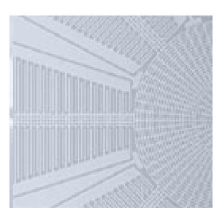

MEMSENSE

NANO IMU
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Design Engineering

Document Change History

Rev	Status	Description	Date
2.12	Obsolete	Original	12/15/2008
A	Obsolete	Created from PSD-0822_Rev-2.12. Changed to the new MEMSense document format	2/4/2009
B	Obsolete	Added section 5.2 USB DAQ Options and Table 5. Changed specifications table from 5 to 6. Removed the last page – Template Change tracking table.	9/29/2009
C	Obsolete	Changed title page photo. Changed Figure 1. Changed Table 6 "Supply Voltage" parameter name.	11/30/2009
D	Released	**Added pull up resistor recommendation to the I2c/SMBus section**	**11/15/2010**

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1.0 Purpose

1.1 The NANO Inertial Measurement Unit

This user's guide documents the features and use of the nIMU Series of products. The nIMU provides serial digital outputs of 3D acceleration, 3D rate of turn (rotational), and 3D magnetic field data. Digital outputs are factory configured to the I^2C or RS422 protocols and custom algorithms provide high performance, temperature compensated, 3D data in real time (see Section 5.1 for part numbering specifications).

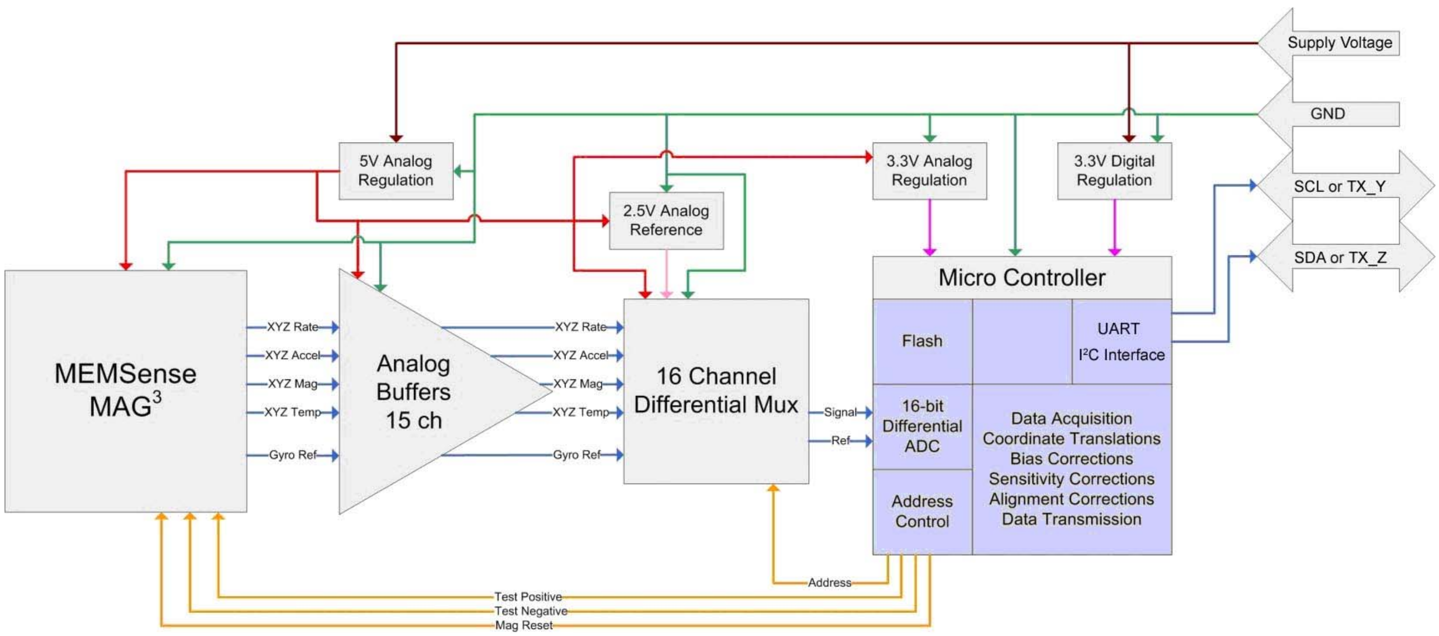

Figure 1 - nIMU Functional Block Diagram

2.0 Communications

2.1 Commands

The nIMU 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)	21	Accelerometer Y (2/5/10g) (MSB)
1	Synchronization byte (FF)	22	Accelerometer Y (2/5/10g) (LSB)
2	Synchronization byte (FF)	23	Accelerometer Z (2/5/10g) (MSB)
3	Synchronization byte (FF)	24	Accelerometer Z (2/5/10g) (LSB)
4	Message size	25	Magnetometer X (MSB)
5	Device ID	26	Magnetometer X (LSB)
6	Message ID	27	Magnetometer Y (MSB)
7	Sample Timer (MSB)	28	Magnetometer Y (LSB)
8	Sample Timer (LSB)	29	Magnetometer Z (MSB)
9-12	Reserved	30	Magnetometer Z (LSB)
13	Gyro X (MSB)	31	Temperature Gyro X (MSB)
14	Gyro X (LSB)	32	Temperature Gyro X (LSB)
15	Gyro Y (MSB)	33	Temperature Gyro Y (MSB)
16	Gyro Y (LSB)	34	Temperature Gyro Y (LSB)
17	Gyro Z (MSB)	35	Temperature Gyro Z (MSB)
18	Gyro Z (LSB)	36	Temperature Gyro Z (LSB)
19	Accelerometer X (2/5/10g) (MSB)	37	8-bit Checksum
20	Accelerometer X (2/5/10g) (LSB)		

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

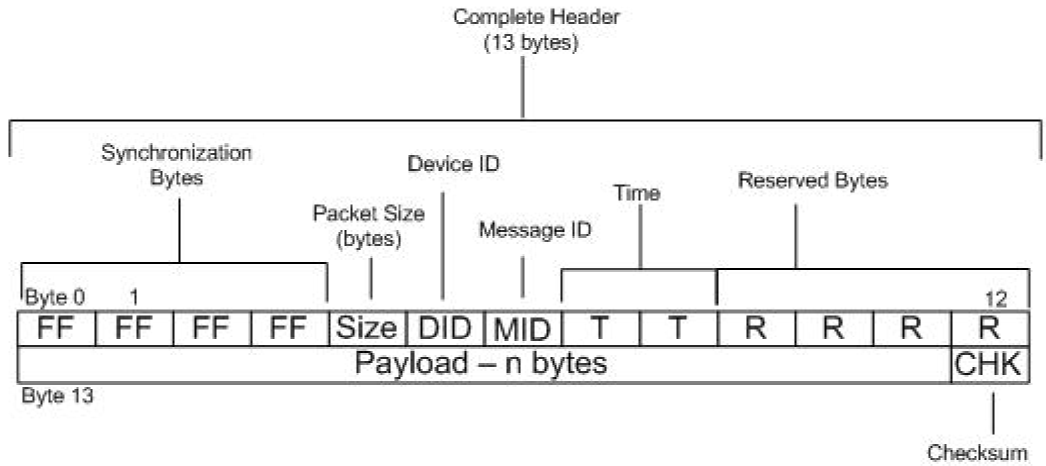

Figure 2 - Sample structure

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/discarded 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. Packet size: size, in bytes, of entire data packet, including complete header.
3. Device ID.
4. Message ID: type of message. Currently, only data messages are transmitted by the device with MID 0x14 hex (20 decimal).
5. Sample Timer: bytes 7 (MSB) and 8 (LSB) when combined represent a 16-bit timer value of the time at which the ADC started the conversion for the X Gyro with a scale of 2.1701×10^{-6} seconds/count.
6. Reserved bytes: four (4) bytes are reserved for internal/future use.
7. Payload: payload always starts at byte 13. The payload size can be calculated as follows:

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

8. 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 nIMU. 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 nIMU, the corresponding equations for the X component would be:

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

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

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 = ($raw\_payload\_value\_x_{temperature} \times digital\_sensitivity$) + 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).

3.0 Mechanical

3.1 Dimensions

The nIMU is available in a custom package measuring 1.832 in. length × 0.546 in. height × 0.900 in. width. Holes are located in each corner allowing #0-80 machine screws to be utilized to mount the IMU to a PCB or chassis. Figure 3 depicts the physical dimensions of the part and its features.

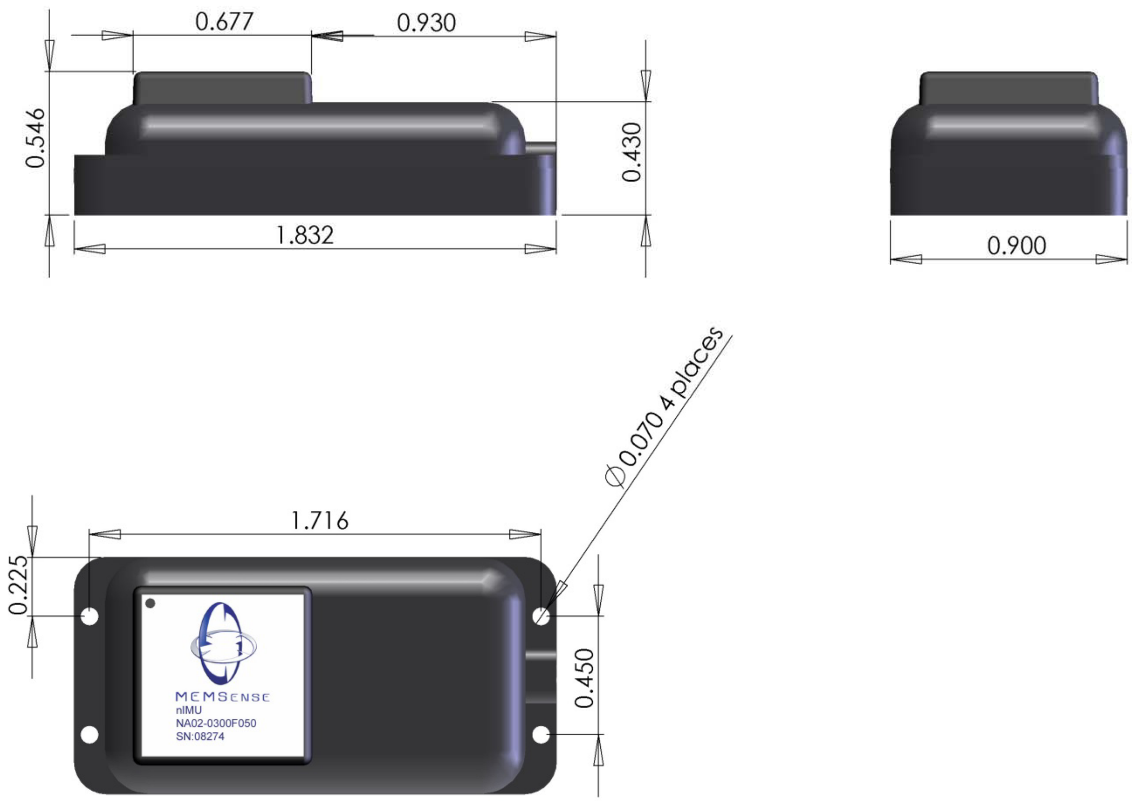

Figure 3 - Physical Dimensions in inches

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 forward (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.

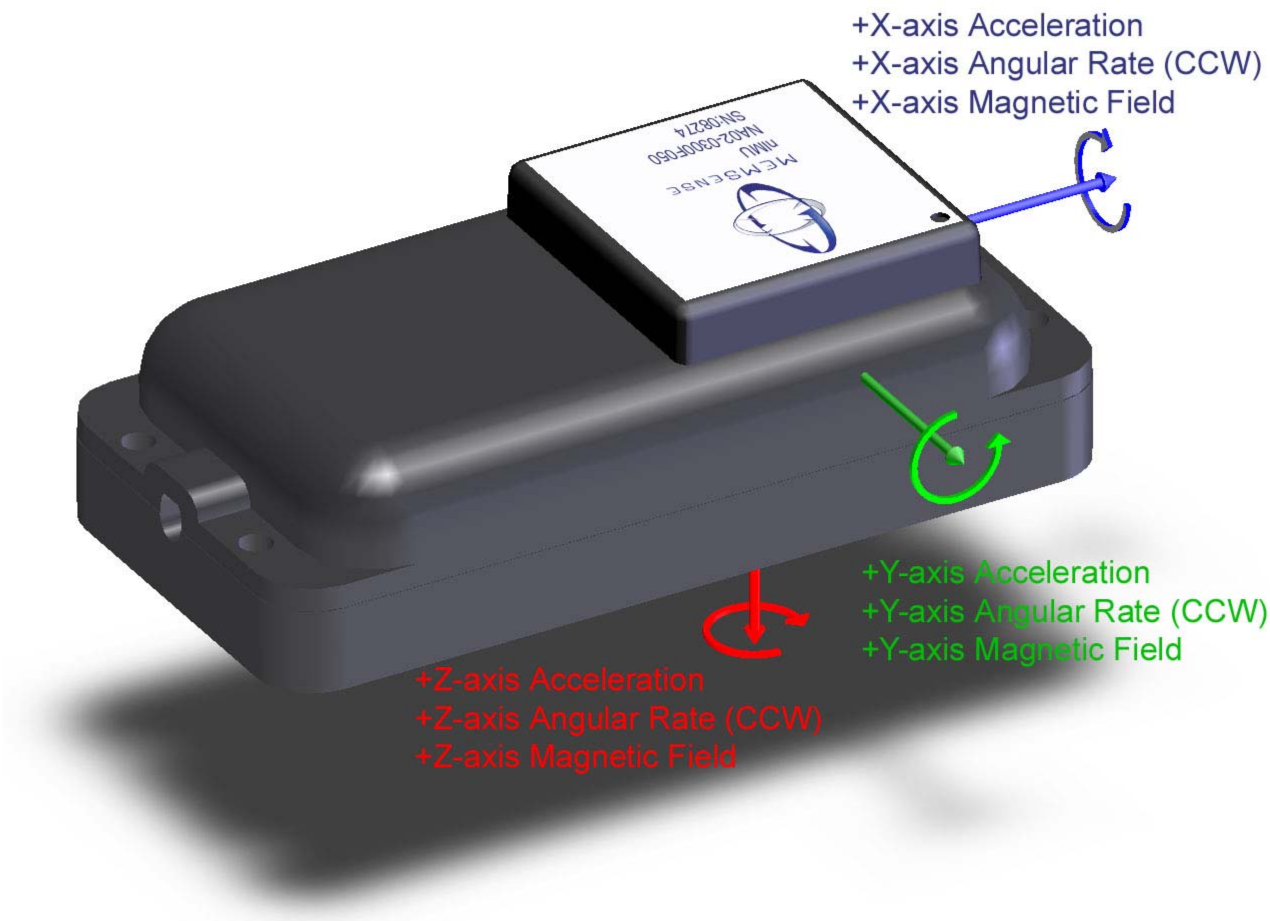

Figure 4 - nIMU coordinate system, side view

4.0 Hardware

4.1 Connections

The nIMU ships with a 6 inch cable terminated with a Hirose HR-30 series miniature plastic in-line connector. In addition, it contains a built-in lock/release mechanism, is lightweight and corrosion resistant.

4.2 Pin Function Description

The pin functions for the IMU and mating connector are listed in Table 2 and 3 below:

Table 2 - Pin functions for HR30-6P-6S manufactured by HIROSE.

INTERFACE PIN FUNCTIONS – IMU Connector

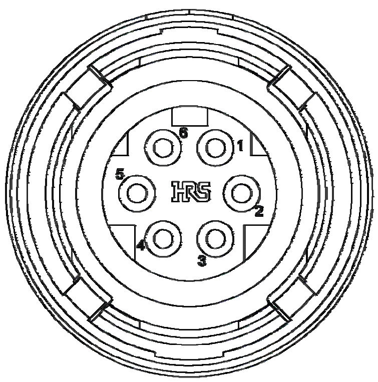

Figure 5 - HIROSE PN: HR30-6P-6S

Port No.	I^2C	RS422
1	SDA	Not Used
2	VDD	VDD
3	Not Used	TX_Y
4	Not Used	TX_Z
5	GND	GND
6	SCL	Not Used

Table 3 - Mating Connector: *Mates with Hirose HR30-6R-6P Male or HR30-6J-6P Inline Male)*

INTERFACE PIN FUNCTIONS – Mating Connector

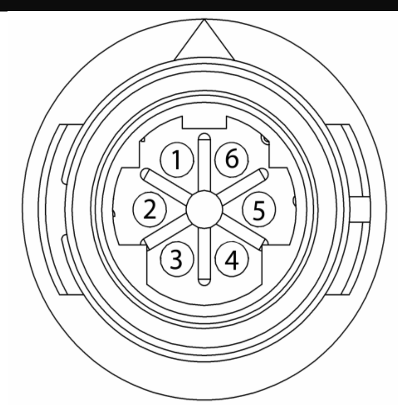

Figure 6 - *HR30-6J-6P*

Port No.	I^2C	RS422
1	SDA	Not Used
2	VDD	VDD
3	Not Used	RX_A
4	Not Used	RX_B
5	GND	GND
6	SCL	Not Used

4.3 I²C/SMBus Slave Connection Description

The nIMU I^2C/SMBus interface is compliant with the SMBus Specification version 1.1 and compatible with the I^2C serial bus. An SMBus master device can query nIMU slave devices by issuing a General Call (address + direction = 0000 000 0). Each slave nIMU, upon receiving a General Call, responds with its slave address (device ID).

If a slave nIMU is able to shift its 8-bit address onto the SMBus without encountering an error, it will then ignore future General Calls for 512 ms. A bus master can use this feature to issue General Calls until no slave devices respond, or 512 ms have elapsed.

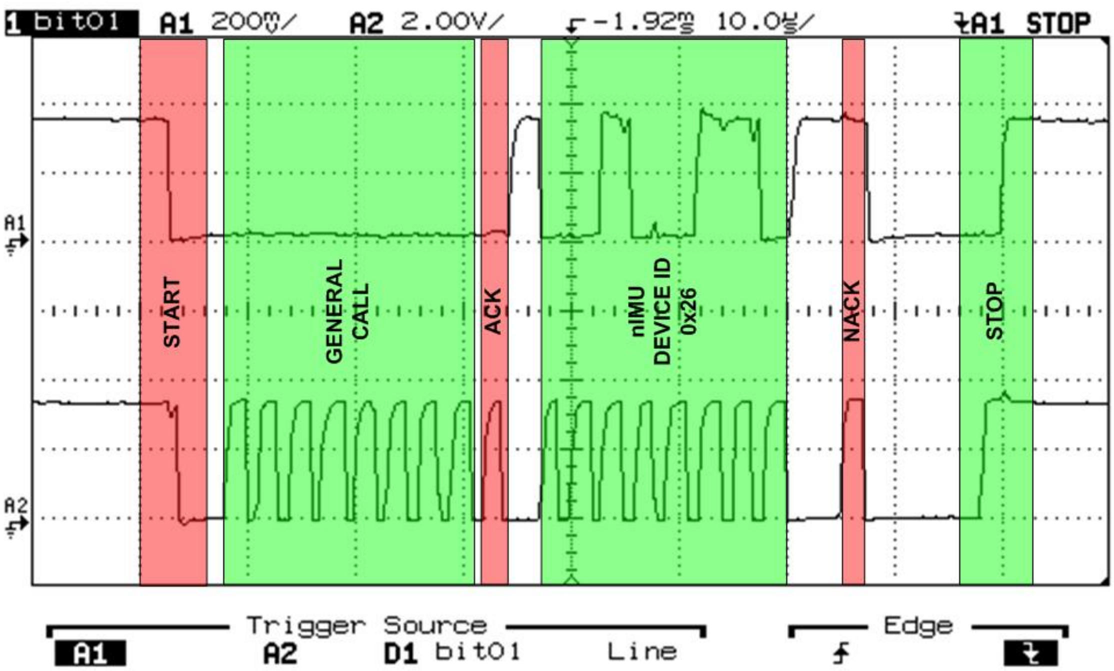

Figure 7 - Master/nIMU General Call Sequence

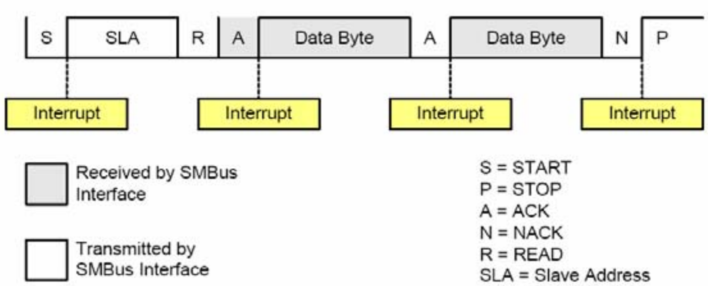

Figure 8 - Master Receiver Sequence

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The master device must parse out the initial message structure for the message size (X), read X bytes from the slave, NACK the final byte then send a stop. A master-receiver sequence is shown in Figure 8 (above). Slave device SCL and SDA ports are open drain. Pull-up resistors of 10k for 3.3 V and 15k for 5V are recommended on the SCL and SDA signals. Both lines are 5 V tolerant with a V_{IH} minimum of 2.1 V. Care must be taken to minimize line capacitance. For additional information on the nIMU I^2C/SMBus connection see the SiLabs C8051F06x Data Sheet. A typical I^2C/SMBus connection is shown in Figure 9 (below).

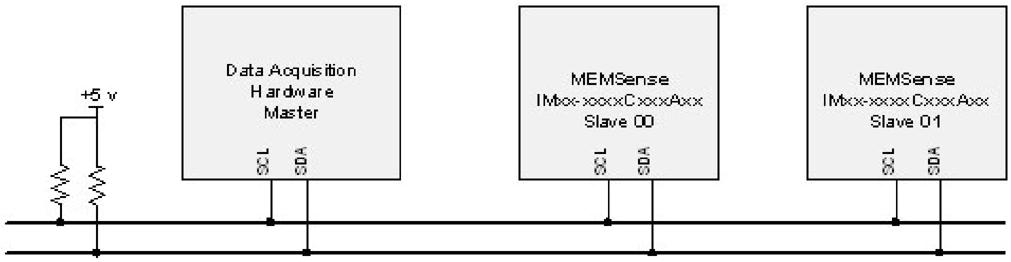

Figure 9 – I2C/SMBus connection diagram

4.4 RS422 Connection Description

The nIMU RS422 connection is factory configured to 115200 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 nIMU via the YZ differential driver pair and should be terminated with a 120 ohm resistor. The nIMU is not currently configured to receive data.

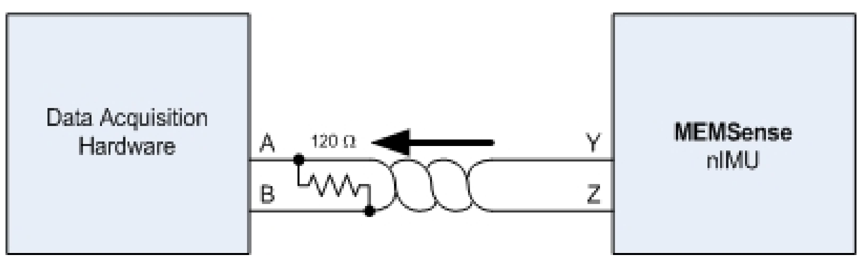

Figure 10– RS422 Full-duplex direct connection diagram

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5.0 Electrical Specifications and Options

5.1 Part Numbers

Table 4 - Standard Part Numbers

Part	Accel.(g)	Angular Rate (^{o}/s)	Bandwidth (Hz.)	Protocol
NA02-0150F050R	2	150	50	RS422
NA02-0300F050R	2	300	50	RS422
NA05-0300F050R	5	300	50	RS422
NA05-0600F050R	5	600	50	RS422
NA10-1200F050R	10	1200	50	RS422

1. I^2C Protocol(s) available upon request.

5.2 USB Data Acquisition (DAQ) Module Options

Every nIMU ordered comes standard with a USB DAQ Module that is powered via USB. No external power supply is required. A USB DAQ with leads to connect to an external power supply is also available; if this is your preference please let sales know when you place your order and they will substitute the externally power powered USB DAQ for no additional charge. The I^2C version of the nIMU is only available with the externally powered DAQ configuration.

Table 5 – USB DAQ Module Options

Model Number	Description	Max Voltage	Power Source	Protocol	Availability
USB-N-8.5UR	nIMU USB RS422 DAQ, USB power	8.5V	USB	RS422	Standard - with all nIMU's ordered
USB-N-8.5XR	nIMU USB RS422 DAQ, Ext. power	8.5V	External Power	RS422	Option available upon request
USB-N-8.5XC	nIMU USB RS422 DAQ, Ext. power	8.5V	External Power	I^2C	Custom - for I^2C nIMU

5.3 Specifications

Table 6 - Specifications

PARAMETER	SPECIFICATION				UNITS	CONDITIONS
Operational Requirements						
Supply Voltage	5.4 to 9.0				VDC	unregulated
Supply Current	120/140				mA	Typical I2C/RS422
Physical Properties						
Alignment Error	±1				%	
Mass	20				grams	
Acceleration	**NA02**	**NA05**	**NA10**			
Dynamic Range	± 2	± 5	± 10		g	
Offset	±30	± 30	± 30		mg	0 to 70 °C Maximum
Nonlinearity	± 0.4 (± 1.0)	± 0.4 (± 1.0)	± 0.4 (± 1.0)		% of FS	Typical (Maximum)
Noise	0.6 (0.8)	1.1 (1.3)	2.1 (2.8)		mg	Typical (Maximum), 1 σ
Digital Sensitivity	$9.1553\text{x}10^{-5}$	$2.2888\text{x}10^{-4}$	$4.5776\ \text{x}10^{-4}$		g/bit	See Equation 1 on page 9
Bandwidth [1]	50	50	50		Hz	-3dB point
Angular Rate	**-0150F050**	**-0300F050**	**-0600F050**	**-1200F050**		
Dynamic Range	± 150	± 300	± 600	± 1200	°/s	
Offset	+/-1.5	+/-1.5	+/-1.5	+/-1.5	°/s	0 to 70 °C Maximum
Cross-Axis Sensitivity	+/-1	+/-1	+/-1	+/-1	%	Maximum
Nonlinearity	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)	°/s	Typical (Maximum), 1 σ
Digital Sensitivity	$6.8664\text{x}10^{-3}$	$1.3733\text{x}10^{-2}$	$2.7465\text{x}10^{-2}$	$5.4932\text{x}10^{-2}$	°/s/bit	See Equation 1 on page 9
Bandwidth [1]	50	50	50	50	Hz	-3dB point
Magnetic Field						
Dynamic Range	±1.9				gauss	
Drift	2700				ppm/°C	
Nonlinearity	0.5				% of FS	Best fit straight line
Noise	0.00056(0.0015)				gauss	Typical (Maximum), 1 σ
Digital Sensitivity	$8.6975\text{x}10^{-5}$				gauss/bit	See Equation 1 on page 9
Bandwidth[1]	50				Hz	-3dB point
Temperature						
Digital Sensitivity	$1.8165\ \text{x}\ 10^{-2}$				ºC/bit	
Absolute Max Ratings						
Acceleration Powered	2000 max				*g*	Any axis 0.5ms
Input Voltage	-0.3 (min) +12 (max)				VDC	
Operating Temperature	0 to +70				°C	
Storage Temperature	-55 to +125				°C	
Typical Values at 25°C, V_{supply} = 5.6 VDC, 0 °/s, unless otherwise noted. **Note: nIMU configurations are not subject to ITAR export controls.**						

1. Custom bandwidth configurations are available up to 70 Hz upon request.
2. Other configurations are available on a special order basis.
3. I^2C Protocol available upon request.
4. Contact MEMSense sales for more information relating to 1, 2 or 3 (above).

6.0 Electrical Specifications and Options

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.