

MEMSENSE

NANO IMU

Product Specification User's Guide

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TABLE OF CONTENTS

- 1.0 PURPOSE 1
 - 1.1 The NANO Inertial Measurement Unit 1
- 2.0 COMMUNICATIONS..... 2
 - 2.1 Commands..... 2
 - 2.2 Sample Format..... 2
 - 2.3 Measurement 4
- 3.0 MECHANICAL 5
 - 3.1 Dimensions 5
 - 3.2 Coordinate System..... 6
- 4.0 HARDWARE 7
 - 4.1 Connections 7
 - 4.2 Pin Function Description..... 7
 - 4.3 I²C/SMBus Slave Connection Description 8
 - 4.4 RS422 Connection Description 9
- 5.0 ELECTRICAL SPECIFICATIONS AND OPTIONS..... 10
 - 5.1 Part Numbers..... 10
 - 5.2 USB Data Acquisition (DAQ) Module Options..... 10
 - 5.3 Specifications 11
- 6.0 TERMS, CONDITIONS AND WARRANTY 12

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 I²C, RS422 or LVDS protocols and custom algorithms provide high performance, temperature compensated, 3D data in real time (see Section 5.1 for part numbering specifications).

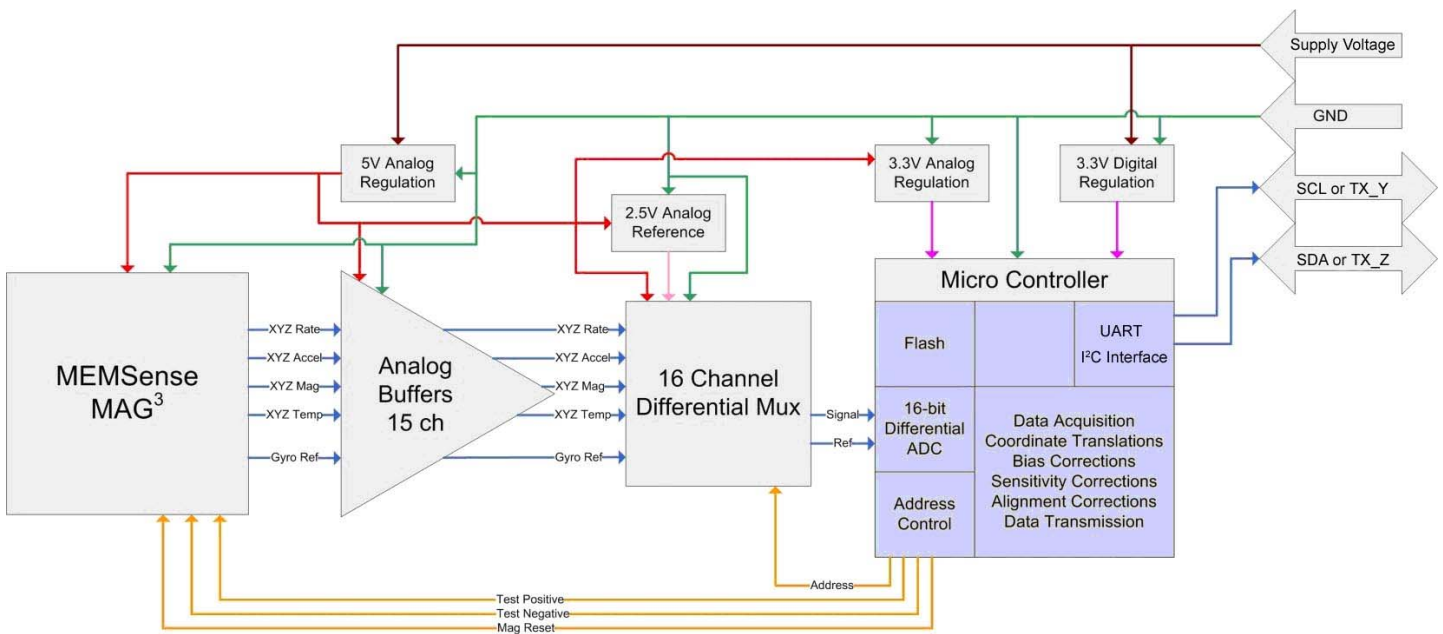


Figure 1 - nIMU Functional Block Diagram

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:

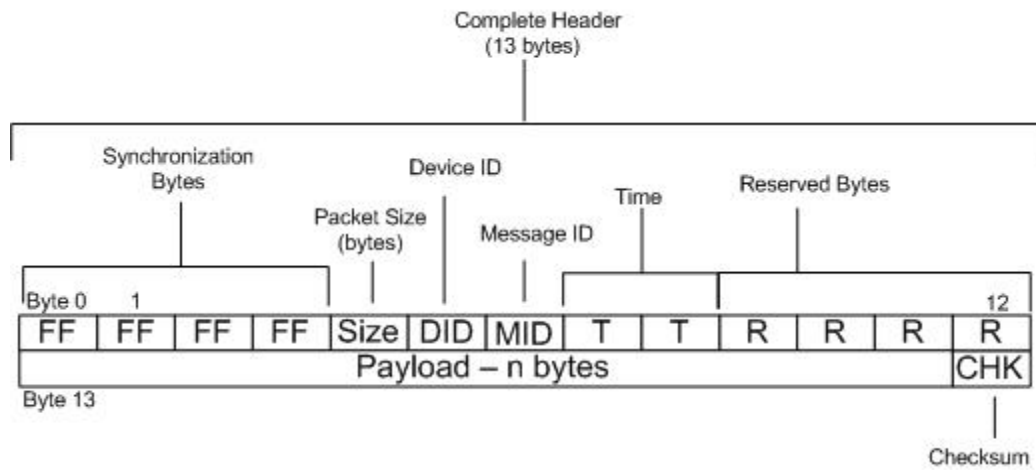


Figure 2 - Sample structure

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:

$$\text{payload_size} = \text{message_size} - 13(\text{header}) - 1(\text{Checksum byte})$$

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:

$$\text{Equation 1: } \text{result} = \text{raw_payload_value} \times \text{digital_sensitivity}$$

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:

$$\begin{aligned} \text{value_x} &= \text{raw_payload_value_x}_{\text{gyro}} \times 1.3733 \times 10^{-2} \text{ } ^\circ/\text{s/bit} \\ \text{value_x} &= \text{raw_payload_value_x}_{\text{accel}} \times 9.1553 \times 10^{-5} \text{ G/bit} \end{aligned}$$

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:

$$\text{[Equation 2: } \text{result_deg_C} = (\text{raw_payload_value_x}_{\text{temperature}} \times \text{digital_sensitivity}) + 25]$$

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:

$$\text{Equation 3: } \text{digital_sensitivity} = \text{dynamic_range} \times 4.57764 \times 10^{-5}$$

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 °/s then 75 °/s should be used for the dynamic range in Equation 3).

3.0 Mechanical

3.1 Dimensions

The Nano IMU 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.

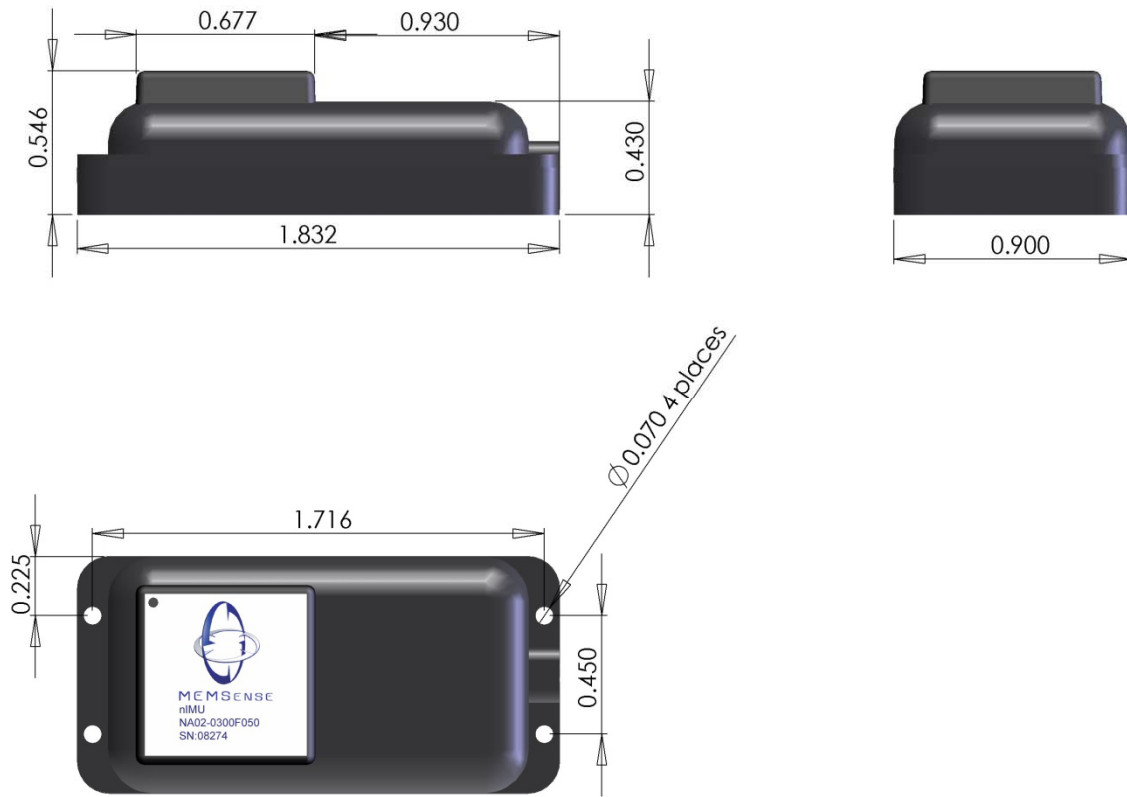


Figure 3 - Physical Dimensions in inches

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 *g*s 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.

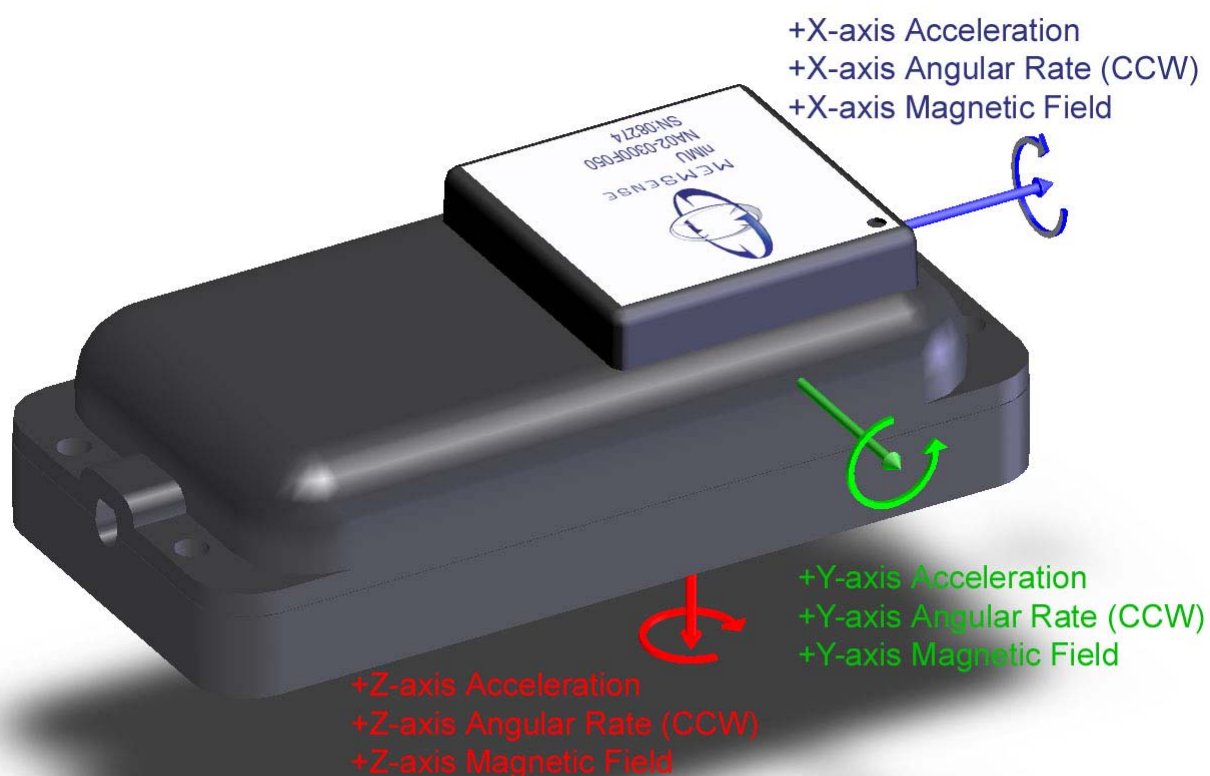


Figure 4 - nIMU coordinate system, side view

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.

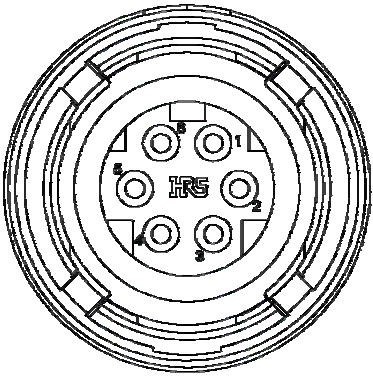
INTERFACE PIN FUNCTIONS – IMU Connector			
	Port No.	I ² C	RS422/LVDS
	1	SDA	Not Used
	2	VDD	VDD
	3	Not Used	TX_Y
	4	Not Used	TX_Z
	5	GND	GND
	6	SCL	Not Used

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

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

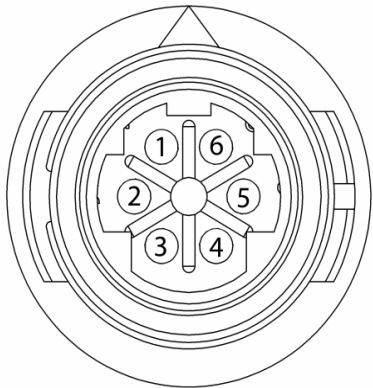
INTERFACE PIN FUNCTIONS – Mating Connector			
	Port No.	I ² C	RS422/LVDS
	1	SDA	Not Used
	2	VDD	VDD
	3	Not Used	RX_A
	4	Not Used	RX_B
	5	GND	GND
	6	SCL	Not Used

Figure 6 - HR30-6J-6P

4.3 I²C/SMBus Slave Connection Description

The nIMU I²C/SMBus interface is compliant with the SMBus Specification version 1.1 and compatible with the I²C 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.

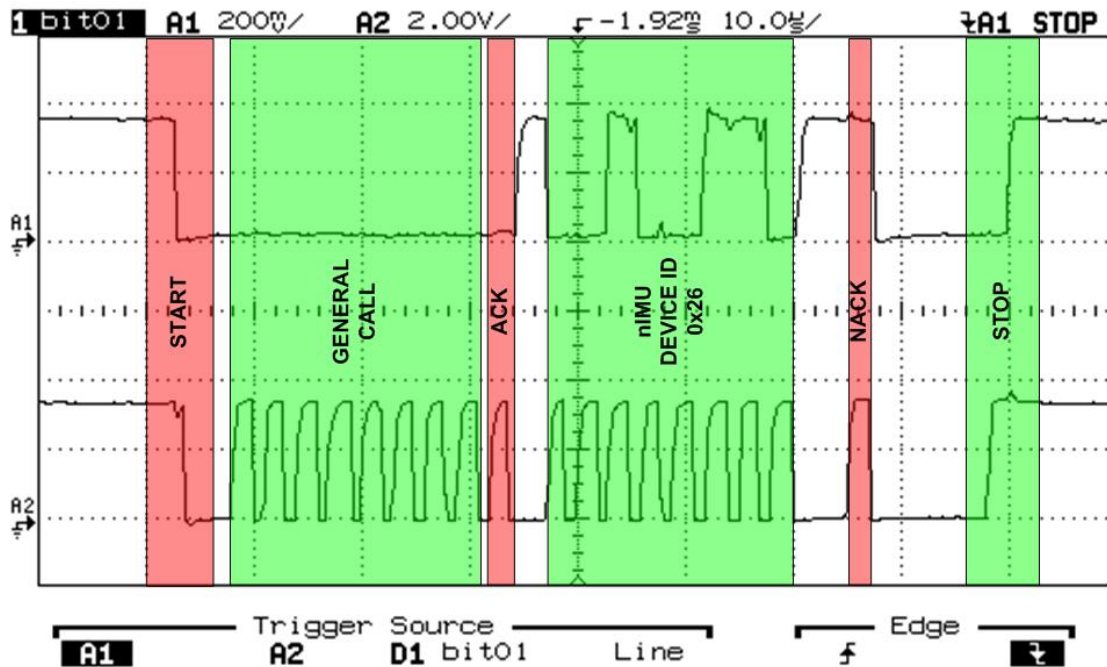


Figure 7 - Master/nIMU General Call Sequence

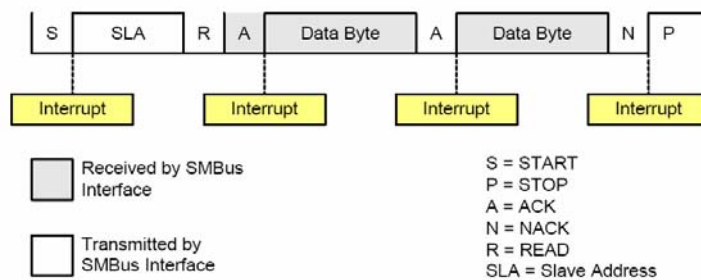


Figure 8 - Master Receiver Sequence

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 I²C/SMBus connection see the SiLabs [C8051F06x Data Sheet](#). A typical I²C/SMBus connection is shown in Figure 9 (below).

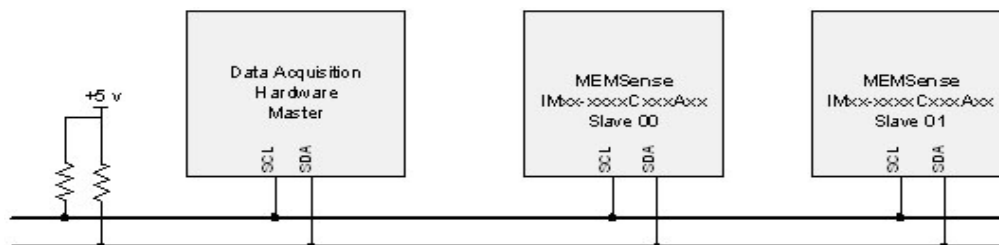


Figure 9 – I²C/SMBus connection diagram

4.4 RS422 and LVDS Connection Description

The nIMU RS422 and LVDS 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.

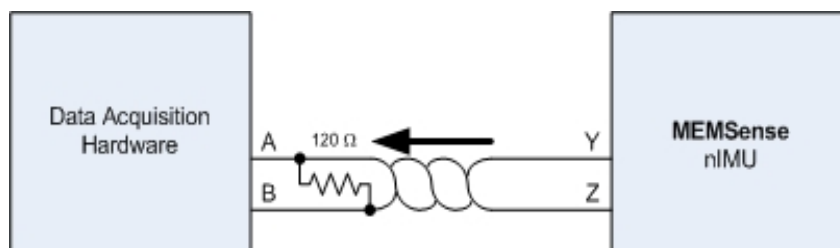


Figure 10– RS422 Full-duplex direct connection diagram

5.0 Electrical Specifications and Options

5.1 Part Numbers

Table 4 - Standard Part Numbers

Part	Accel.(g)	Angular Rate (°/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. I²C Protocol(s) available upon request.

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-N-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-N-8.5XR allows the use of an external power supply and has a maximum voltage of 8.5 volts. Each USB DAQ model number in Table 5 below is compatible with the Nano IMU and is available for order.

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 ² C	Custom - for I ² C 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	0 to 70 °C Maximum Typical (Maximum) Typical (Maximum), 1 σ See Equation 1 on page 9 -3dB point
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 Sensitivity	9.1553x10 ⁻⁵	2.2888x10 ⁻⁴	4.5776 x10 ⁻⁴		g/bit	
Bandwidth ¹	50	50	50		Hz	
Angular Rate	-0150F050	-0300F050	-0600F050	-1200F050		
Dynamic Range	± 150	± 300	± 600	± 1200	°/s	0 to 70 °C Maximum Maximum Best fit straight line Typical (Maximum), 1 σ See Equation 1 on page 9 -3dB point
Offset	+/-1.5	+/-1.5	+/-1.5	+/-1.5	°/s	
Cross-Axis Sensitivity	+/-1	+/-1	+/-1	+/-1	%	
Nonlinearity	0.1	0.1	0.1	0.1	% of FS	
Noise	0.36 (0.95)	0.56 (0.95)	0.56 (0.95)	0.56 (0.95)	°/s	
Digital Sensitivity	6.8664x10 ⁻³	1.3733x10 ⁻²	2.7465x10 ⁻²	5.4932x10 ⁻²	°/s/bit	
Bandwidth ¹	50	50	50	50	Hz	
Magnetic Field						
Dynamic Range	±1.9				gauss	Best fit straight line Typical (Maximum), 1 σ See Equation 1 on page 9 -3dB point
Drift	2700				ppm/°C	
Nonlinearity	0.5				% of FS	
Noise	0.00056(0.0015)				gauss	
Digital Sensitivity	8.6975x10 ⁻⁵				gauss/bit	
Bandwidth ¹	50				Hz	
Temperature						
Digital Sensitivity	1.8165 x 10 ⁻²				°C/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. I²C 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.

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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.