nIMU
Nano Inertial Measurement Unit
Series Documentation

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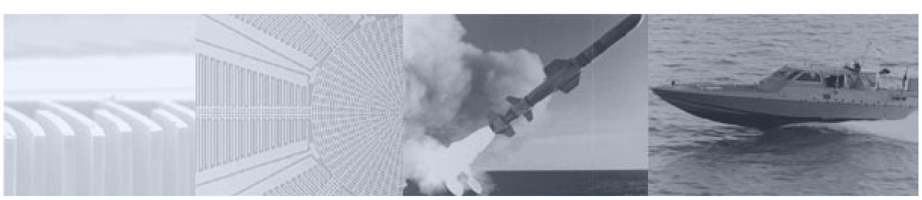

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MEMSENSE

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1 INTRODUCTION

1.1 The nIMU Micro Inertial Measurement Unit

This manual 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 protocol and custom algorithms provide high performance, temperature compensated, 3D data in real time (see Section A.1 for part numbering specifications). 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. Figures 1.1 depicts the physical dimensions of the part and its features.

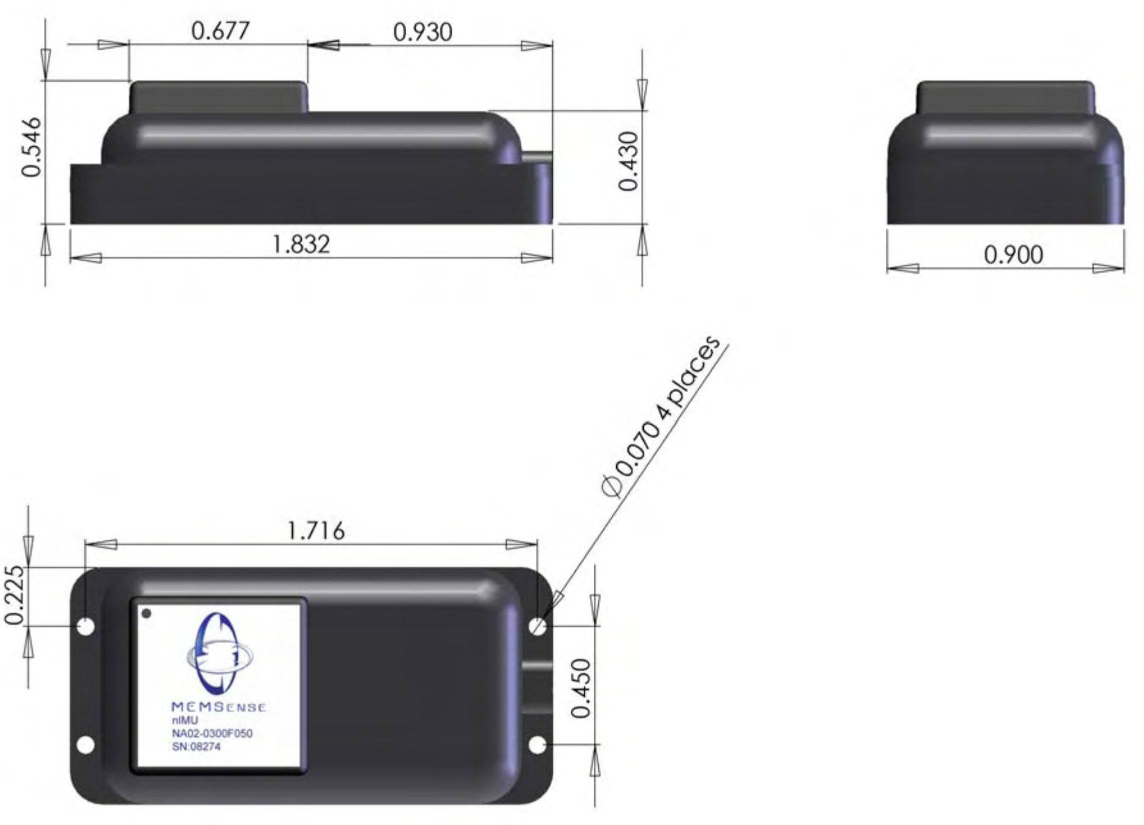

Figure 1.1 – Physical dimensions in inches

2 HARDWARE

2.1 Connections

The nIMU ships with a 4 inch cable terminated with a JST disconnectable crimp style connector as shown in Figure 2.1 below. The mating connector is a JST as shown in Figure 2.2 below. The user must ensure the circuit interfacing the IMU is configured to match the pin description as given in Section 2.2.

2.2 Pin Function Description

The pin functions for the IMU and mating connector are listed in Table 2.2.1 and 2.2.2 below.

INTERFACE PIN FUNCTIONS – IMU Connector

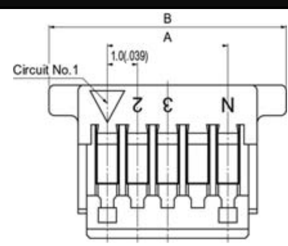

Figure 2.1 SHR-04V-S-B

Port No.	UART	I^2C
1	GND	GND
2	RX	SCL
3	TX	SDA
4	VDD	VDD

Table 2.2.1 Pin functions for *SHR-04V-S-B* manufactured by JST.

INTERFACE PIN FUNCTIONS – Mating Connector

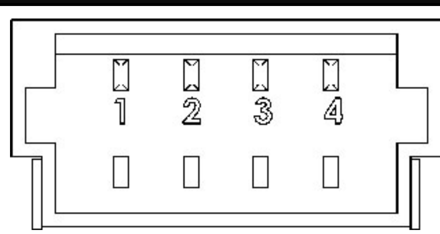

Figure 2.2 SM04B-SRSS-TB

Port No.	UART	I^2C
1	GND	GND
2	RX	SCL
3	TX	SDA
4	VDD	VDD

Table 2.2.2 – Matting Connector: JST SM04B-SRSS-TB

2.3 UART Mode 1 Asynchronous Connection Description

The nIMU UART connection supports standard 16550 UART speeds but defaults to 57600 Baud from the factory. The UART 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 TX driver. Data is received by the nIMU via the RX input if the device is operating in full duplex mode. *Note: If the user is directly communicating with one nIMU, the TX output must be crossed with the RX input as shown in Figure 2.6.*

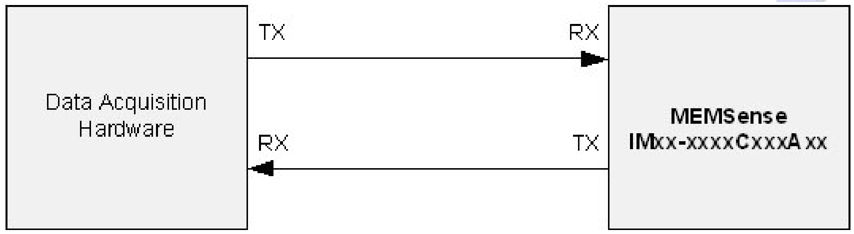

Figure 2.3 – 56k Full-duplex asynchronous connection diagram

2.4 I²C/SMBus Slave Connection Description

See the SiLabs C8051F06x Data Sheet for additional information on the nIMU I2C/SMBus connection. The nIMU I2C/SMBus interface is compliant with the SMBus Specification version 1.1 and compatible with the I2C serial bus. Each slave device operates at ~380 kHz SCL rate during slave transmitting. 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 bus address. 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. Once a master has acquired a list of known slave addresses (either provided or queried), it may read a sample from any of the nIMU's. A read is initiated by a master device. The master sends a start, followed by the target slave nIMU. If the nIMU ACK's the master, the master changes from a Master Transmitter to a Master Receiver, while the nIMU goes from a Slave Receiver to a Slave Transmitter.

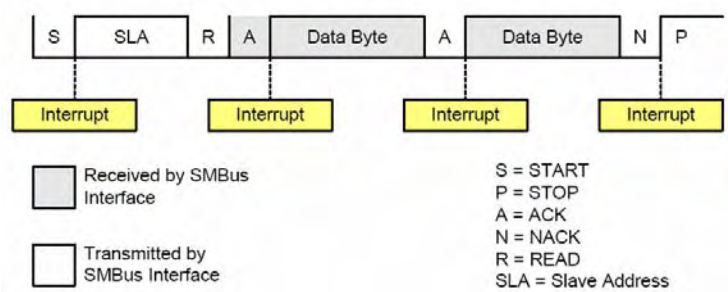

Figure 2.4 – Master Receiver Sequence

The master device may either parse out the initial message structure for the message size (X), and read X bytes from the slave, NACK the final byte and send a stop, or wait for a stop from the slave nIMU (sent as soon as the checksum has been shifted out. A master-receiver sequence is shown in figure 2.3. Slave device SCL and SDA ports are open drain, and pull-ups are the responsibility of the acquisition system. Both lines are 5 v tolerant with a V_{IH} minimum of 2.1 v. A typical I2C/SMBus connection is shown in figure 2.4. Care must be taken to minimize line capacitance.

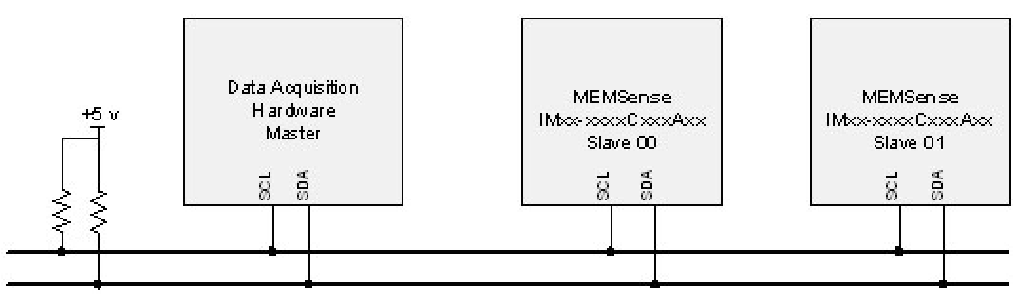

Figure 2.4 – I²C/SMBus connection diagram

3 FIRMWARE

3.1 Commands

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

3.2 Sample Format

Data samples are formatted as shown in Tables 3.1 and 3.2. 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 4.1). An individual data packet is collectively referred to as a *sample*.

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

Table 3.2: Sample byte order/format

Graphically, the sample has the format shown in Figure 3.2:

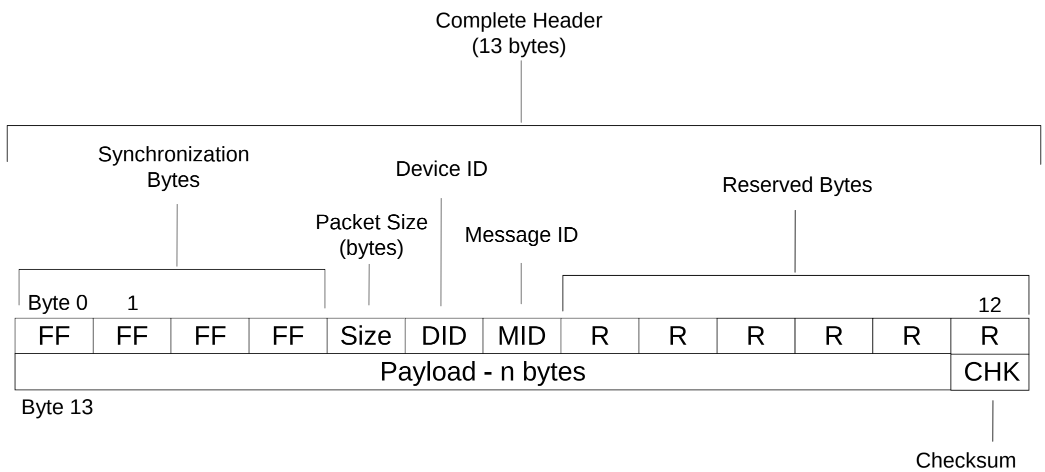

Figure 3.2: Sample structure

All samples begin with four (4) synchronization bytes, where each byte is encoded with FF 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 FF hex.
2. Packet size: size, in bytes, of entire data packet, including complete header.
3. Device ID: useful only when 2 or more devices exist on the same data bus.
4. Message ID: type of message. Currently, only data messages are transmitted by the device with MID 0x14 hex (20 decimal).
5. Reserved bytes: six (6) bytes are reserved for internal/future use.
6. Payload: payload always starts at byte 13. The payload size can be calculated as follows:

   payload_size = message_size – 13(header) – 1(last reserved byte)

7. 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.*

4 OPERATION

4.1 Measurements

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 from voltages 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:

$$\text{result} = \text{raw\_payload\_value} \times \left(\frac{\frac{\text{device\_range}}{2} \times 1.5}{32768} \right)$$

where result is the converted value in the appropriate units (e.g. deg/sec), raw_payload_data is the raw component-specific data from the payload (e.g. accelerometer X), and device_range is the maximum possible range for the component (e.g. ±2 G accelerometer). Candidate ranges are as shown in Table 3.1 (NOTE: you must use the ranges specific to 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:

$$\text{value\_x} = \text{raw\_payload\_value\_x} \times \left(\frac{\frac{600}{2} \times 1.5}{32768} \right)$$

$$\text{value\_x} = \text{raw\_payload\_value\_x} \times \left(\frac{\frac{4}{2} \times 1.5}{32768} \right)$$

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.

Component	Resulting Units	Range
Gyro	Degrees/sec	±300/±1200
Accelerometer	G (9.8 m/s^2)	±2/±5
Magnetometer	Gauss	±1.9

Table 4.1 – Component ranges

4.2 Coordinate System

The coordinate system for the IMU follows the left 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 4.2 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.

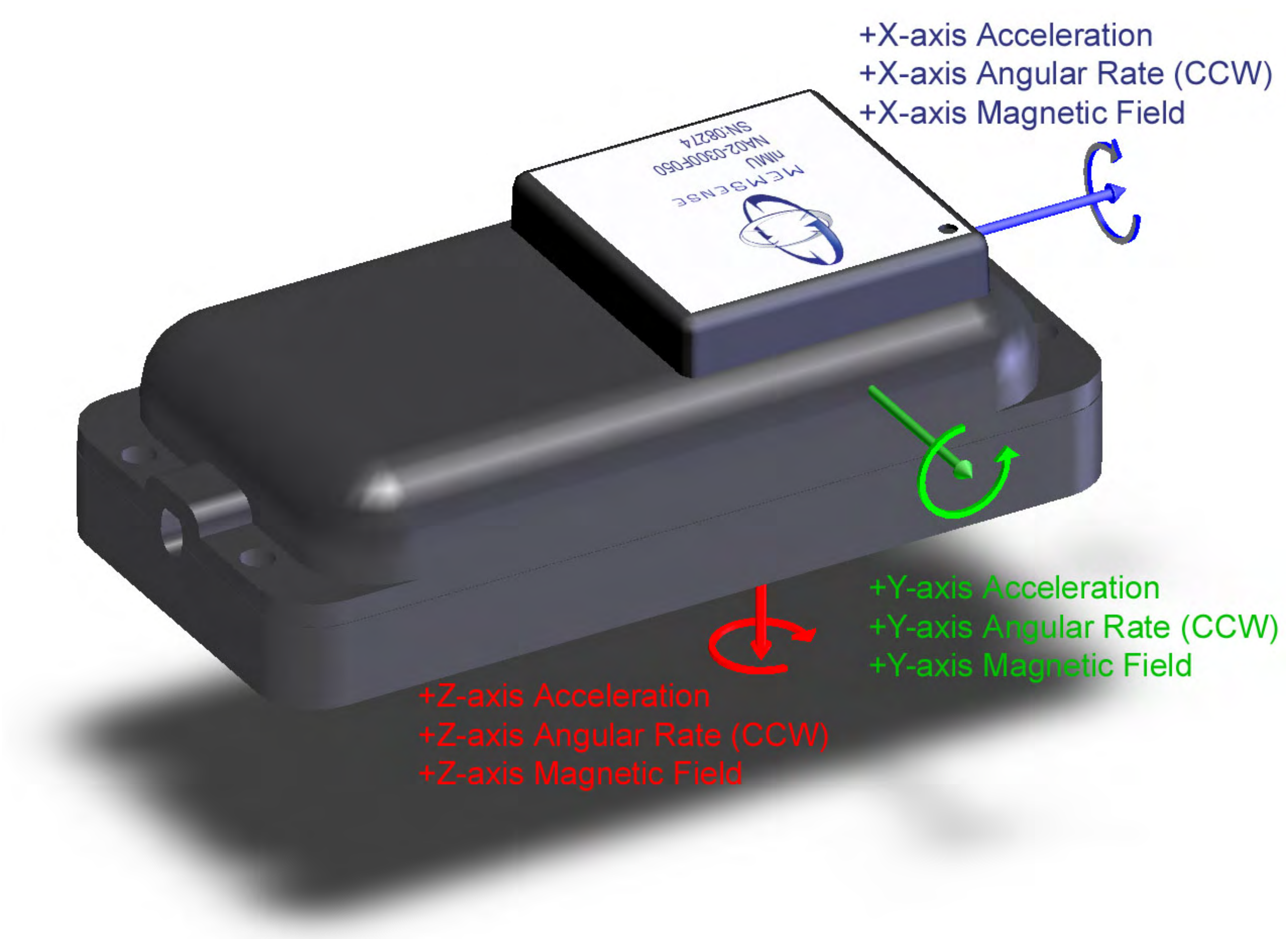

Figure 4.2: nIMU coordinate system, side view

MEMSENSE

5 APPENDIX A

5.1 Part Numbering

Part	Accel.(g)	Angular Rate (°/s)	Bandwidth (Hz.)
NA02-0300F050	**2**	**300**	**50**
NA05-0300F050	**5**	**300**	**50**
NA02-1200F050	**2**	**1200**	**50**
NA05-1200F050	**5**	**1200**	**50**

5.2 Specifications

PARAMETER	SPECIFICATION		UNITS	CONDITIONS
Operational Requirements				
Operating Input Voltage	5.4 to 7.0		VDC	unregulated
Supply Current	113		mA	typical
Power Supply Rejection	60		db	5.4 to 7.0 volts
Alignment Error	±1		%	
Mass	15		grams	
Acceleration	**NA02**	**NA05**		
Axis	X, Y, Z	X, Y, Z		
Dynamic Range	± 2	± 5	g	
Offset Vs Temp	±100	± 100	mg	0 to 70 °C
Nonlinearity	± 0.4 (± 1.0)	± 0.4 (± 1.0)	% of FS	Typical (Maximum)
Noise	4.87 (7.5)	4.87 (7.5)	mg	Typical (Maximum), 1 σ
Digital Sensitivity	152.6×10^{-6}	381.6×10^{-6}	g/bit	
Bandwidth [1]	50	50	Hz	Accelerometer -3dB point
Angular Rate	**-0300F050**	**-1200F050**		
Dynamic Range	± 300	± 1200	°/s	
Nonlinearity	0.1	0.1	% of FS	Best fit straight line
Turn On Time	35	35	ms	Power on to ± ½ °/s of Final
Rate Noise	0.56 (0.95)	0.56 (0.95)	°/s	Typical (Maximum), 1 σ
Digital Sensitivity	22.9×10^{-6}	122.1×10^{-3}	°/s/bit	
Bandwidth [1]	50	50	Hz	Gyroscope -3dB point
Magnetic Field				
Dynamic Range	±1.9		gauss	
Drift	2700		ppm/°C	
Nonlinearity	0.5		% of FS	Best fit straight line
Rate Noise Density	5.6×10^{-3}		gauss	
Digital Sensitivity	152.6×10^{-6}		guass/bit	
Bandwidth[1]	50		Hz	Magnetometer -3dB point
Absolute Maximum Ratings				
Acceleration Powered	2000 max		g	Any axis 0.5ms
Input Voltage	-0.3 (min) +12 (max)		VDC	
Operating Temperature[2]	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				

1. Other bandwidth configurations are available.
2. -40 to +85 °C operating temperature range is available.

5.3 Terms and Conditions, Warranty

DEFINITIONS - As used herein: “Seller” means Qualvox dba 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.

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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.