MEMSENSE

W2 IMU

Product Specification & User Guide

Document Number: DOC00298

Document Revision – C

888.668.8743

For pricing or any further information, please contact Omni Instruments Ltd.

omni INSTRUMENTS
Measurement and data acquisition solutions

UK / Europe Office
Tel: +44 845 9000 601
Fax: +44 845 9000 602
info@omni.uk.com
www.omniinstruments.co.uk

Australian Office
Tel: +61 282 442 363
Fax: +61 294 751 278
info@omniinstruments.com.au
www.omniinstruments.com.au

USA / Canada Office
Tel: +1 866 849 3441
Fax: +1 866 625 8055
info@omniinstruments.net
www.omniinstruments.net

Wireless IMU
Product Specification & User Guide

Document Number:	Release / Revision	Release / Revision Date:
DOC00298	C	October 14, 2014

Document Owner:

Design Engineering

Information provided in this document is believed to be accurate, however it is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

Document Change History

Rev	Status	Description	Date
A	Superseded	New Document	8/29/2013
B	Superseded	Changed the magnetometer sensitivity. This new spec only applies to rev B or later product.	11/20/2013
C	Released	Corrected units on magnetometer noise density.	10/14/2014

Information provided in this document is believed to be accurate, however it is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

TABLE OF CONTENTS

Information provided in this document is believed to be accurate, however it is not guaranteed. MEMSense, LLC reserves the right to change product specifications at anytime without notice.

1.0 Introduction

The W2 IMU is the second generation Memsense wireless IMU that provides wireless serial digital outputs of triaxial acceleration, angular rate and magnetic field as well as temperature and barometric pressure via the Bluetooth™ wireless protocol. The inertial outputs are compensated over temperature for bias, scale factor, and cross-sensitivity. The accelerometers and gyroscope within the W2 IMU can be configured to different dynamic ranges over the wireless connection with a simple command structure. The available ranges for the gyroscopes are ±250, ±500, or ± 2000 °/sec and ±2g, ±4g, ±6g, ±8g, and ±16g for the accelerometers.

With the Bluetooth™ capability, the IMU can communicate with a wide variety of hosts, such as PCs, tablets, phones, and embedded systems. The range of transmission can be affected by the environment, but typical range capabilities are on the order of 60 feet.

An integrated rechargeable battery allows for up to 5 hours of power and can be charged via micro USB which makes the W2 IMU a convenient option for inertial measurement applications.

The device measures 1.58" × 1.32" × 0.60" and can be either screw mounted or easily strapped down with the built-in strap bars. Multiple Wireless IMUs can be utilized simultaneously allowing inertial motion capture of multi-segmented objects common in human motion analysis. The miniature size, wireless multiple device connection and configurability of the W2 IMU makes it an exceptional sensor choice for applications such as human motion analysis, biomechanics, or animation.

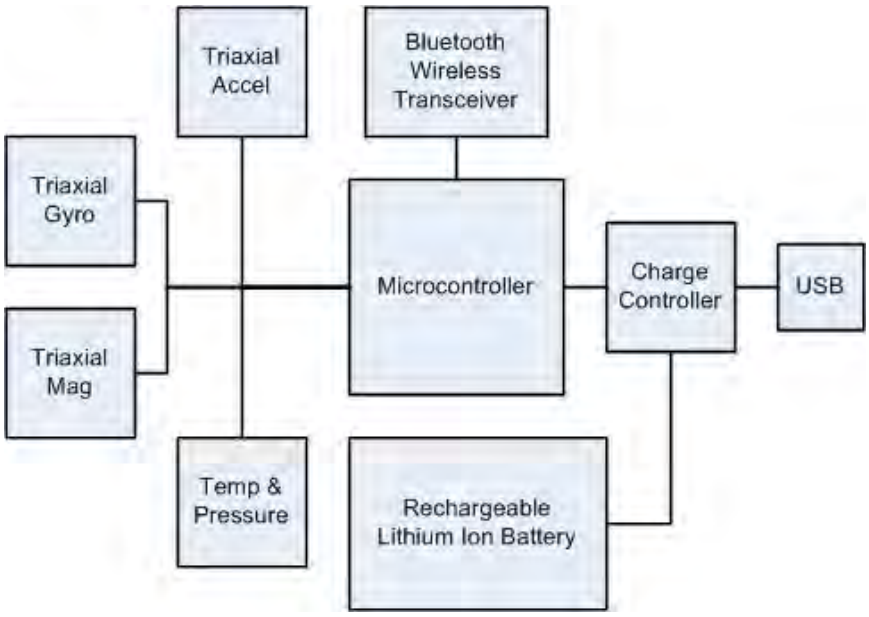

Figure 1 - Wireless IMU Functional Block Diagram

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

2.0 Communications

2.1 Bluetooth Communications

The W2 IMU incorporates a wireless serial port module with a unique Bluetooth address. The address of each IMU is “W2IMU-<device SN> and can be found by a host system thru a discovery. Authentication with the W2 IMU requires a passkey with a PIN of “1234”.

The serial port settings are shown in Table 1 Serial Port Settings. The IMU starts sending sample packets once a Bluetooth connection has been established with a host.

Interference from other devices which use the same frequency range (2.4GHz) as Bluetooth such as 802.11 wireless networks can cause occasional packet loss. Other potential interference sources include “noisy” devices such as microwaves and fluorescent lights.

Table 1 - Serial port settings

PARAMETER	SETTING
Bits per second	115200
Data bits	8
Parity	None
Stop bits	1
Flow Control	No

2.2 Modes

The W2 IMU operates in two communications modes, data and configuration. The default communication mode is the Data Mode where the IMU outputs data described in the sample format section. The default settings for the W2 IMU are contained in Table 2. While operating in the Data Mode the IMU can be switched into the Configuration Mode by transmitting zzz/r via the wireless connection. Once the IMU is in the Configuration Mode, commands can be sent that configure the gyroscope and accelerometer dynamic ranges as well as the sample rate. Table 3 details the available configuration commands for the W2 IMU. A power reset clears changes not saved to the IMU and returns operation to the Data Mode.

Table 2 - W2 IMU Default Settings

SETTING	DEFAULT VALUE
Accelerometer Dynamic Range	6
Gyroscope Dynamic Range	500
Output Sample Rate	150

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

Table 3 - Configuration Mode Commands

COMMAND	DESCRIPTION
zzz\r	Enter Configuration Mode from Data Mode
i\r	Request current settings information
g<space> <Dynamic Range>\r	Change Gyroscope Dynamic Range to 250, 500, or 2000
a<space> <Dynamic Range>\r	Change Accelerometer Dynamic Range to 2, 4, 6, 8 or 16
s<space> <Sample Rate>\r	Change output Sample Rate to 100, 125, or 150
d\r	Save current settings to Defaults.
x\r	Exit Configuration Mode to Data Mode

Note: "\r" denotes a carriage return.

Gyroscope Default Dynamic Range Example

A command sequence for changing the default gyroscope dynamic range to 2000 °/s is provided below.

STEP	COMMAND/INFO	DESCRIPTION
1	zzz\r	Enter Configuration Mode
2	g 2000\r	Change Gyroscope Dynamic Range to 2000
	Serial Number = 16274	IMU returns current settings
	Gyro Range = 2000	
	Accel Range = 6	
	Sample Rate = 150	
3	d\r	Save the change to defaults.
4	x\r	Exit Configuration Mode

Accelerometer Default Dynamic Range Example

A command sequence for changing the default accelerometer dynamic range to 16 g is provided below.

STEP	COMMAND/INFO	DESCRIPTION
1	zzz\r	Enter Configuration Mode
2	a 16\r	Change Accelerometer Dynamic Range to 16
	Serial Number = 16274	IMU returns current settings
	Gyro Range = 500	
	Accel Range = 16	
	Sample Rate = 150	
3	d\r	Save the change to defaults.
4	x\r	Exit Configuration Mode

Sample Rate Default Example

A command sequence for changing the default sample rate to 100 Hz is provided below.

STEP	COMMAND/INFO	DESCRIPTION
1	zzz\r	Enter Configuration Mode
2	s 100\r	Change Sample Rate to 100
	Serial Number = 16274	IMU returns current settings
	Gyro Range = 500	
	Accel Range = 6	
	Sample Rate = 100	
3	d\r	Save the change to defaults.
4	x\r	Exit Configuration Mode

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

2.3 Sample Format

An individual data packet is collectively referred to as a *sample.* Data samples are formatted as shown in Table 4, Sample byte order format. Each data channel is represented by a signed 2's complement, 2-byte short (16-bit) integer that represents the output level of the signal. To convert this value to its corresponding engineering unit see Section 2.4.

Table 4 - Sample Byte Order Format

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

All samples begin with four (4) synchronization bytes, where each byte contains 0xFF. The details on the structure of a sample are as follows (*Note: all byte offsets are zero (0) based*):

BYTES	ELEMENT	DESCRIPTION
0 - 3	Synchronization bytes	each byte encoded as 0xFF hex
4	Message size	Size in bytes of entire data packet including complete header
5	Product ID	3 for Wireless IMU
6	Message ID	Type of message. Data messages with MID = 0x14 hex (20 decimal).
7 - 8	Sample Counter	Represents a 16-bit counter of value of the number of samples with a rollover value of 65,535. Each count represents $(\text{sample rate})^{-1}$.
9	Gyro Range/Sample Rate	Bits 7–4 identify gyro range: 0000 – 250 °/s; 0001 – 500 °/s; 0010 – 2000 °/s Bits 3–0 identify sample rate: 0000 – 100Hz; 0001 – 125Hz; 0010 – 150Hz
10	Accelerometer Range	Bits 7–4 identify accel range: 0000 – 2 *g*; 0001 – 4*g*; 0010 – 8*g*; 0011 – 16 *g*
11 - 12	Serial Number	Unique number identifying each device
13 - 36	Payload	The payload size calculated as follows: payload size = message size – 13(header) – 1(Checksum byte)
37	Checksum byte	8-bit checksum byte. Sum sample contents (header + payload). DO NOT include the checksum byte. The summed value should equal the checksum if the message is valid. If larger than 8-bit addition is used to calculate the checksum, the checksum will be the remainder of a divide by 256.

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

2.4 Measurements

The gyroscope, accelerometer, and magnetometer values may be converted to rotational rate, acceleration, and gauss respectively. The data is transmitted as signed (2's complement) 16-bit integers. The following function must be used for conversion of raw values:

Equation 1: $\text{result} = \text{raw\_payload} \times \text{digital sensitivity}$

where the result is the converted value in the appropriate units (e.g. °/s), "raw value" is the raw component-specific value from the payload (e.g. accelerometer X), and "digital sensitivity" is the digital sensitivity of the sensors configuration found in Table 7. Candidate ranges are as shown in Table 5, Sensor Dynamic Ranges. For example, a ±500 deg/s, ±6 G W2 IMU, the corresponding equations

for the X component would be:

$$\text{X Gyro Value} = \text{Raw Payload Value} \times 2.2888^{-2}$$

$$\text{X Accelerometer Value} = \text{Raw Payload Value} \times 2.7466^{-4}$$

where the "raw payload value" 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.

Table 5 – Sensor Dynamic Ranges

Sensor	Ranges				
Gyroscope	±250 °/s		±500 °/s		±2000 °/s
Accelerometer	±2 *g*	±4 *g*	±6 *g*	±8 *g*	±16 *g*
Magnetometer	±4 gauss				
Pressure Sensor	260 – 1260 mbar				

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

Equation 2: $\text{Temperature Degrees C} = \text{Raw Payload Value} \times 1.8165 \times 10^{-2} + 25$

where the result is the converted value in degrees Celsius and "raw value" is the raw value from the payload.

The pressure sensor output is a 24 bit value and is located in bytes 33 – 35. The conversion of the raw output to millibar is accomplished using equation 3 below.

Equation 3: $\text{Pressure mbar} = {}^{\text{RawPayloadValue}}/_{4096}$

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

3.0 LED Indication

The green LED on the IMU will indicate when the device is powered-on and when the Bluetooth connection has been established. When the IMU is powered-on and is **not** connected, the LED will blink slowly at a rate of approximately every 2 seconds. When a connection has been established, the blink cycle rate will increase to approximately once every second. A rapid 3 blink sequence followed by a 3 second off period indicates that the battery is low and should be charged. There is approximately 10 minutes of operation possible once the battery low indication is initiated. When the IMU is charging the inverse of the above described patterns will be indicated.

4.0 Mechanical

4.1 Dimensions

The W2 IMU has four evenly spaced mounting holes that allow for the use of 4- 40, Socket Head Cap Screws. Two evenly spaced slots near the edges provide for mounting with a strap.

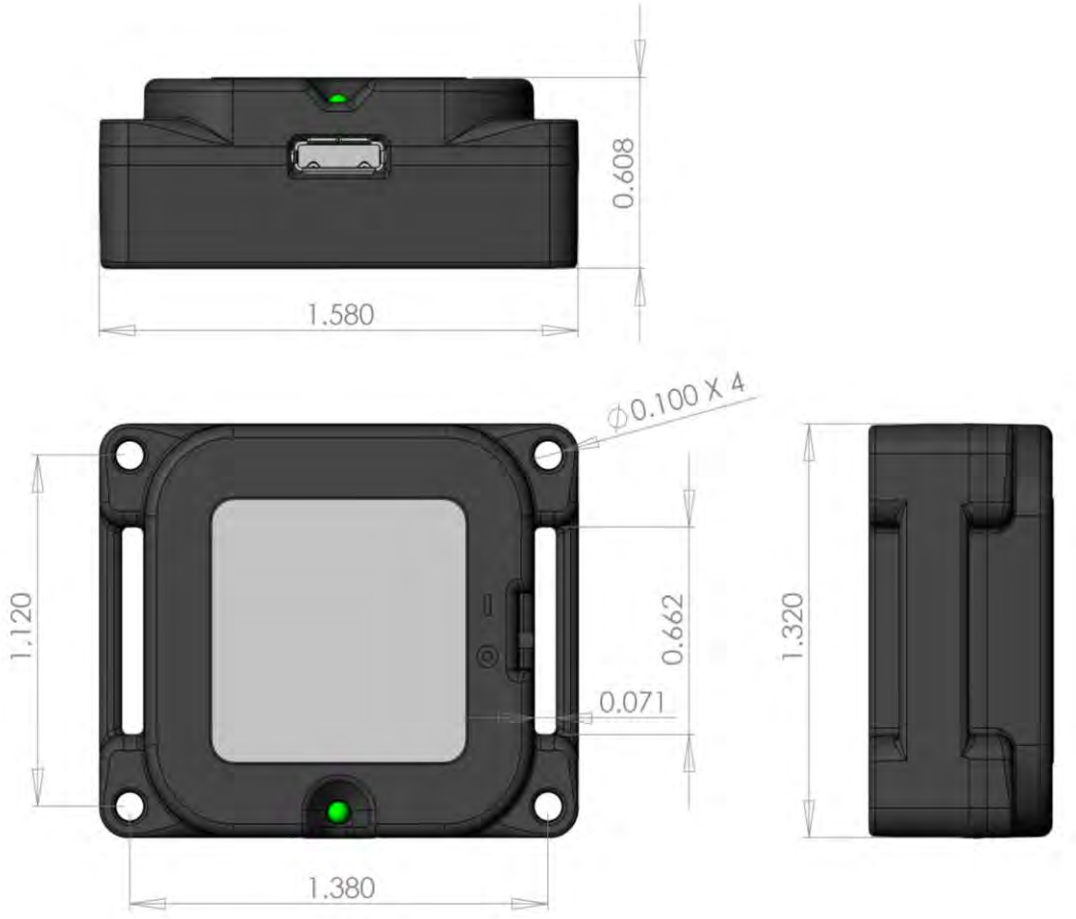

Figure 2 - Physical dimensions (inches)

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

4.2 Coordinate System

The coordinate system for the Wireless IMU follows the right hand rule convention. The sign convention for the accelerometers is configured to produce a positive signal when the Wireless IMU is accelerated in the opposite direction of the axis. As an example, with the Wireless IMU pictured in Figure 3 Wireless IMU Coordinate System, if the Z axis is pointed straight down towards the earth, it will produce 0 *g* for the X and Y axes and a positive 1 *g* for the Z-axis. A counterclockwise rotation of the IMU about any of the depicted axis will produce a positive angular rate output for the corresponding axis.

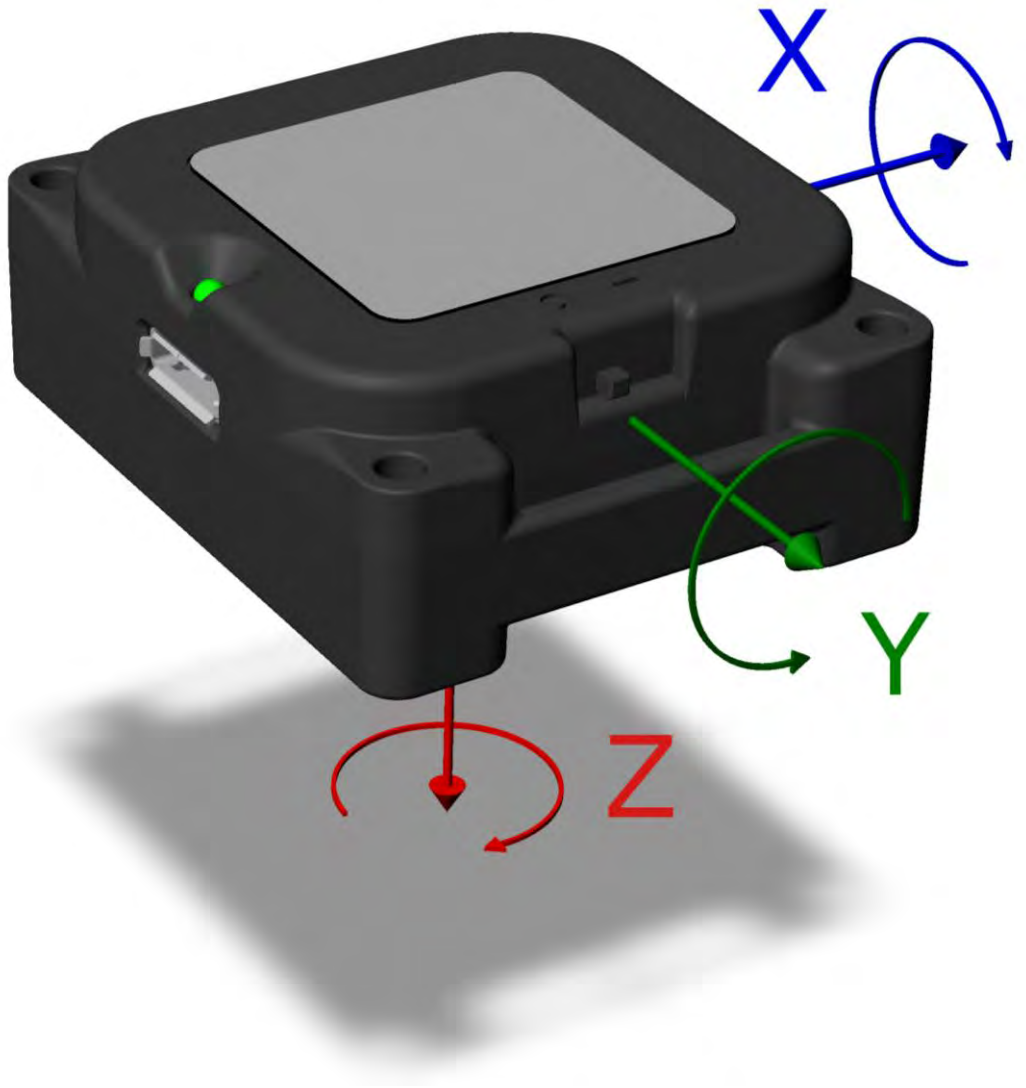

Figure 3 - Wireless IMU coordinate system

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

5.0 Electrical Specifications and Options

5.1 Part Numbering

Table 6 - Standard part number.

Part	Accel. (g)	Rate (°/s)
W2-IMU	±2, ±4, ±6, ±8, and ±16	±250, ±500, and ±2000

5.2 W2 IMU Accessories

The W2 IMU ships with a 3-foot micro USB cable used for charging and an ESD protective carrying case. The use of any Bluetooth transceiver is possible however the optimal range will be achieved with transceivers using non-chip based antennas.

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

5.3 Specifications

Table 7 - W2 IMU Specifications

PARAMETER	SPECIFICATION					UNITS	CONDITIONS
Operational Requirements							
Charge Voltage	4.9 to 5.5					VDC	
Charge Current	250 (300)					mA	Typical, (IMU On)
Charge Time	1.5					hours	Typical
Run Time	4.5					hours	
Devices/Node	6					Max	
Wireless Range	30					m	Clear line of sight
Physical Properties							
Alignment Error	±1					%	
Mass	25					grams	
Acceleration	2	4	6	8	16		
Dynamic Range	± 2	± 4	±6	±8	±16	g	
Bias (In Run)	±0.20	±0.34	±0.34	±0.56	±1.06	mg	Typical
Offset	±40	± 40	±40	±40	±40	mg	Maximum
Noise Density	0.2 (0.4)	0.3 (0.6)	0.5 (0.8)	0.6 (0.9)	1.6 (2.8)	mg/Hz$^{-1/2}$	Typical (Max)
Digital Sensitivity	9.1553 x 10^{-5}	1.8311 x 10^{-4}	2.7466 x 10^{-4}	3.6621 x 10^{-4}	7.3242 x 10^{-4}	g/bit	
Bandwidth	50	50	50	50	50	Hz	-3dB point, Note 1
Angular Rate	250		500		2000		
Dynamic Range	± 250		±500		± 2000	°/s	
Bias (In Run)	±0.03		±0.03		±0.06	°/s	
Offset	±1.5		±1.5		±1.5	°/s	Max
Noise Density	0.04 (0.07)		0.04 (0.07)		0.05 (0.09)	°/s/Hz$^{-1/2}$	Typical (Max), 1σ
Digital Sensitivity	1.1444 x 10^{-2}		2.2888 x 10^{-2}		9.1553 x 10^{-2}	°/s/bit	
Bandwidth	50		50		50	Hz	-3dB point, Note 1
Magnetic Field							
Dynamic Range	±4					gauss	
Offset	+/-0.05					gauss	
Noise Density	X and Y Axes		Z Axis				
	0.4 (0.8)		0.5 (1.0)			mgauss/Hz$^{-1/2}$	Typical (Max), 1σ
Digital Sensitivity	1.8311 x 10^{-4}					gauss/bit	
Temperature							
Digital Sensitivity	1.8165 x10^{-2}					°C/bit	
Pressure							
Digital Sensitivity	2.44 x10^{-4}					mBar/bit	
Absolute Max Ratings							
Acceleration Powered	2000 max					g	Any axis 0.5ms
Charging Voltage	-0.3 (min) +6.0 (max)					VDC	
Operating Temperature	0 to +50					°C	
Storage Temperature	-20 to +60					°C	
Storage Temperature	0 to +30					°C	Long-Term
Typical Values at 25°C and 0 °/s unless otherwise noted							

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.

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.

LIMITATION OF LIABILITIES - In no event shall Seller be liable to Buyer or any third party for consequential, indirect, punitive, special, or incidental damages (including but not limited to loss of profits) arising from or relating to the sale, delivery or use of the Products. Seller’s total cumulative liability under this Agreement to Buyer or any third party (including indemnity obligations), whether in contract or tort or otherwise, will not exceed the amount paid by Buyer to Seller for the Product sold hereunder giving rise to such liability.

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.

Information provided in this document is believed to be accurate, however is not guaranteed. MEMSense LLC reserves the right to change product specifications at anytime without notice.