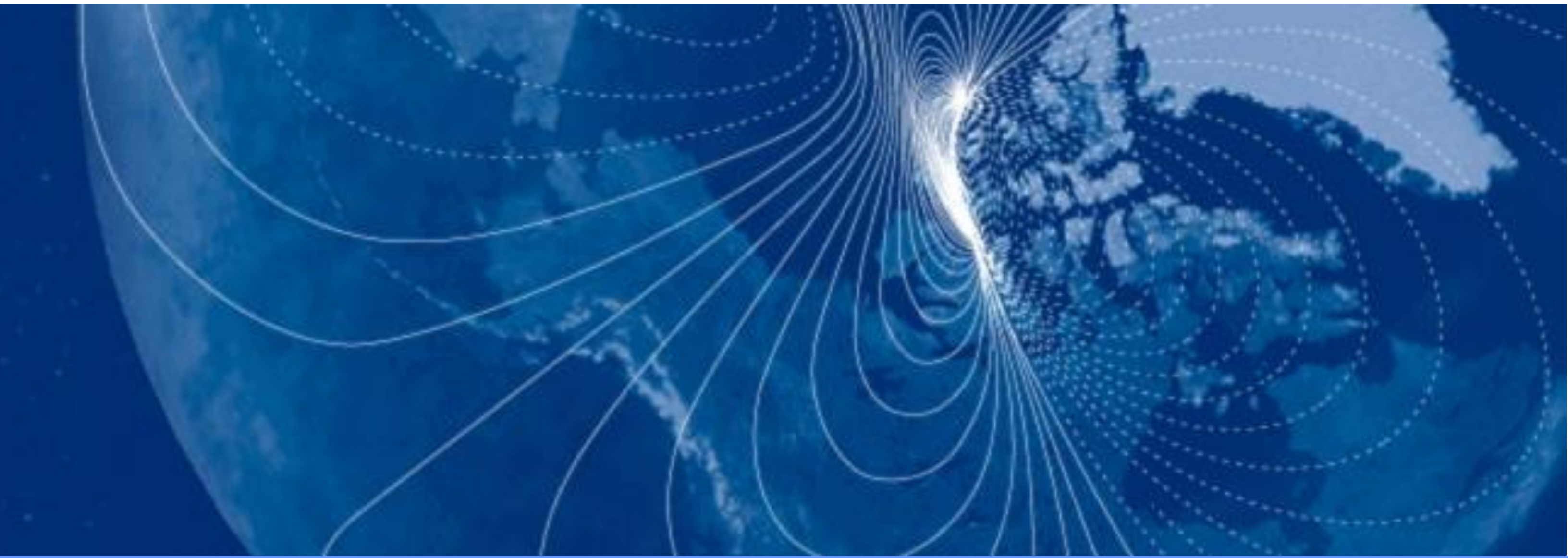

User Manual

Headway

Sensor Based Orientation System for UAVs,

ocean gliders, robots and buoys

Headway 11302022

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PRODUCT OVERVIEW

Headway (PNI Part number 14714)

PNI's Headway module is the *first* complete sensor-based orientation system for UAVs, ocean gliders, robots, and buoys. It incorporates PNI's SENtral-A2 sensor fusion coprocessor, PNI's RM3100 magnetic sensor, an accelerometer, and a gyroscope. The sensor fusion coprocessor comes super-charged with the latest, military grade algorithms, including continuous hard and soft-iron magnetic auto-calibration, and important magnetic anomaly compensation. The module requires ***no*** external calibration.

The Headway is a panel mountable printed-circuit assembly with a connector for cable interfacing. Its small form factor, UART interface and ASCII protocol makes system integration straightforward. Physical and virtual sensor outputs are available along with meta events to enable even tighter system integration with the host system. For quick evaluation and test, a GUI application can be obtained by contacting support@pnisensor.zendesk.com

HEADWAY SYSTEM OVERVIEW

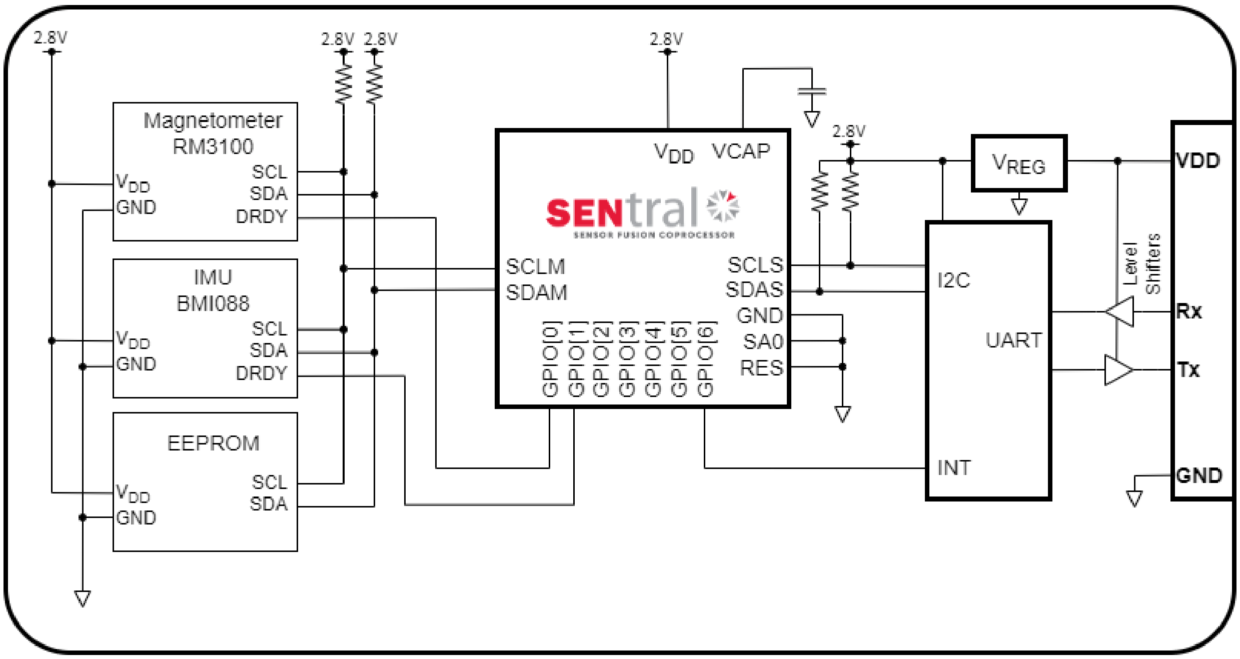


Figure 1-1: Headway Module Block Diagram

The block diagram, above, shows sensors for the Headway UART version. Headway modules incorporate a combination sensor that combines the gyroscope and accelerometer into a single device.

For more information on the SENtral-A2 Motion Processor please contact support@pnisensor.zendesk.com

HEADWAY UART VERSION SPECIFICATIONS

PERFORMANCE CHARACTERISTICS

Table 2-1: Performance Characteristics

Parameter	Typical
Heading Accuracy	2° rms
Output Data Rate	200 Hz

ELECTRICAL CHARACTERISTICS

Table 2-2: Absolute Maximum Ratings

Parameter	Symbol	Minimum	Maximum	Units
Supply Voltage	V_{IN}	-0.3	+6	VDC
Storage Temperature	T_{STORE}	-50°	+150°	C

CAUTION:

Stresses beyond those listed above may cause permanent damage to the device. These are stress ratings only. Operation of the device at these or other conditions beyond those indicated in the operational sections of the specifications is not implied.

Table 2-3: Operating Conditions

Parameter		Conditions	Value
V_{IN}	Supply Voltage		2.9 to 5.5 VDC (1)
I_{IN}	Supply Current	max. sample rate	9.5 mA typical
		Sleep Mode	0.38 mA typical
I_{OH}	High-level output current (Tx)	V_{IN} = 3.3 V	-7mA max
		V_{IN} = 5 V	-8mA max
I_{OL}	Low-level output current (Tx)	V_{IN} = 3.3 V	7mA max
		V_{IN} = 5 V	8mA max
V_{IH}	High-level input voltage (Rx)	V_{IN} = 3 V to 3.3 V	1.39 V min
		V_{IN} = 3.6 V	1.48 V min

		V_{IN} = 4.5 V to 5 V	2.03 V min
		V_{IN} = 5.5 V	2.11 V min
V_{IL}	Low-level input voltage (Rx)	V_{IN} = 3 V to 3.6 V	0.65 V Max
		V_{IN} = 4.5 V to 5.5 V	0.8 V Max
V_{OH}	High-level output voltage (Tx)	V_{IN} = 2.9 V to 5.5V I_{OH} = -20uA	V_{IN} - 0.1V min
		V_{IN} = 3 V I_{OH} = -3mA I_{OH} = -5.5mA	2.7 V min 2.49 V min (2)
		V_{IN} = 3.3 V, I_{OH} = -5.5mA	2.8 V min
		V_{IN} = 4.5 V, I_{OH} = -4mA	4.1V min
		V_{IN} = 4.5 V, I_{OH} = -8mA	3.95V min
		V_{IN} = 5 V, I_{OH} = -8mA	4.5 V min
V_{OL}	Low-level output voltage (Tx)	V_{IN} = 2.9 V to 5.5V I_{OH} = 20uA	0.1V max
		V_{IN} = 3 V, I_{OH} = 3mA	0.15 V max
		V_{IN} = 3 V, I_{OH} = 3mA	0.252 V max
		V_{IN} = 4.5 V, I_{OH} = 3mA	0.2 V max
		V_{IN} = 4.5 V, I_{OH} = 3mA	0.35 V max
T_O	Operating Temperature		
Operating Current	Idle (no Sensors Enabled)	V_{IN} = 5 V	12.4 mA
	Rotation Vector (max ODR)		17.8 mA
	Geo-Mag Rot (min ODR)		12.9 mA
	All Sensors (Max ODR)		20.4 mA

TTL-compliant logic levels guaranteed for V_{IN} = 3.0V to 5.5V with R_X load ≤ 3mA or V_{IN} = 3.3V to 5.5V with loads ≤ 8mA. CMOS-compliance is guaranteed the entire V_{IN} voltage range.

High load currents at low V_{IN} voltages may prevent device from producing TTL-compliant voltages.

INTERFACE

Table 3-1 Communication Format

Parameter	Value
Communication Interface	TTL/CMOS serial UART
Communication Protocol	ASCII
UART Configuration	115200 Baud 8-bit data 1-stop bit No parity bits

The Headway pin-out is given in Table 3-2. See Table 2-3 for the operating voltage range.

Table 3-2: Headway Module Pin Assignments

Pin Name	Description	Pin#
GND	Ground	1
V_{IN}	Supply Voltage	2
TX	UART Transmit Output	3
RX	UART Receive Input	4

Headway UART mating connector is 4-pin Molex PicoBlade, housing part number 0510210400, or pigtail cable assembly part numbers 218112040X, where X = 0 through 3.

A 1.8 Meter USB-Serial cable, shown in **Error! Reference source not found.** below, is available from PNI Sensor as part number 14480

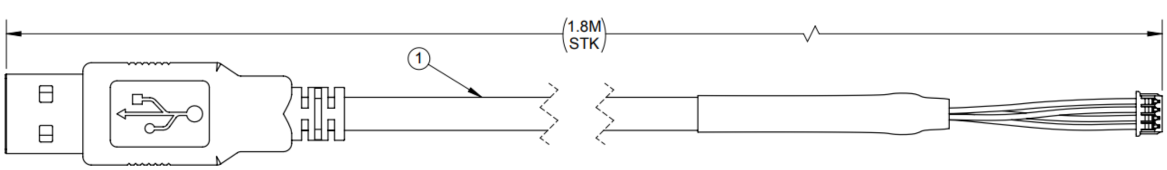


Figure 3-1 PNI 14480 USB-serial evaluation Cable

OPERATION

The Headway has two distinct modes of execution: Boot Mode, Main Execution Mode.

The Boot Mode is transparent to the user and happens automatically upon power-up, after which the module enters Idle state of the Execution Mode.

RUN MODE

To access the full sensor suite, the device must be in run mode (AKA Run State of the Execution mode). This is achieved by sending the character ‘r’. If you are unsure of the current execution state, begin by first sending a Reset command followed by a Run command, i.e. “Rr”.

A list of the ASCII Serial commands are given in Table 4-1 on the next page. These are the UART commands used by the Headway modules.

Following that table is Table 4-2 which lists the available virtual sensors and meta events with their respective IDs. The IDs are used with the start command to start and stop specific sensors. The IDs are also used in the non-verbose mode of the output data stream to identify the data packets.

Table 4-1 Summary of Simple Serial Character Commands

Note: *Commands are CASE Sensitive!*

Char	Description
Configuration and Status	
n	Display sensor information
v	Display Version
M#[CR]	Mounting Options # is limited to 1-16. See Figure 4-1 for specific mounting options
J3	Set module to NED orientation
J4	Set module to ENU orientation (Default)
Sensor Selection and Rates	
s	Start Sensor at given rate Format: s #,#[CR] where: 1st # = Sensor ID. See Table 4-2 Summary of Supported Virtual Sensors and Meta Events 2nd # = Data rate (Aggregate data rate should not exceed 1200 Hz) [CR] = carriage return (0x0D) this is one command that does require it.
Display Controls	
m0	Meta event reporting off
m1	Meta event reporting on
m[CR]	Toggle meta event reporting(on/off) Default (On)
D0	sensor Data display off
D1	sensor Data display on
D[CR]	Toggle sensor Data display (on/off) Default (On)
V0	Verbose Mode off
V1	Verbose Mode on
V[CR]	Toggle Verbose Mode (on/off) Default (On)

Additional Controls	
P	Power Down (Low power mode) - Everything is turned low power (~500 uW) until next UART event to wake up.
Additional Controls	
S	Save factory calibration parameters
X	Restart system
J1	Stop autocal
J0	Start autocal
?	Display commands menu
Tests	
B	Run RM3100 Self tests

Figure 4-1: Mounting Options

Ascending Index from Left to Right, then Top to Bottom
(Mounting Option #1 is Top Left, #16 is Bottom Right)

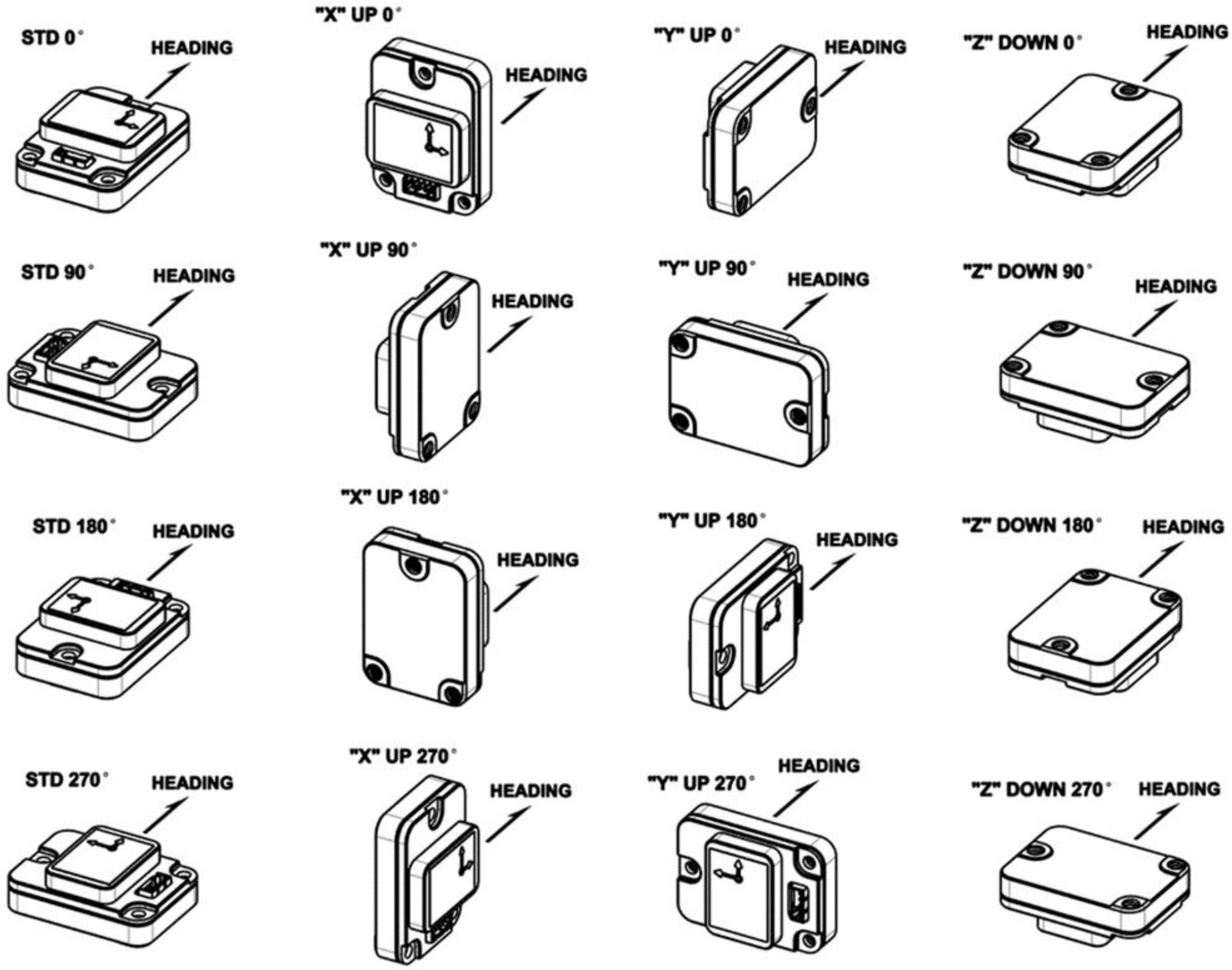


Table 4-2 Summary of Supported Virtual Sensors and Meta Events

Sensor ID	Description	Type
1	Accelerometer (uncalibrated)	Continuous
2	Magnetometer	Continuous
3	Orientation	Continuous
4	Gyroscope (temperature compensated)	Continuous
6	Pressure	Continuous
7	Temperature	Continuous
9	Gravity	Continuous
10	Linear Acceleration	Continuous
11	Rotation Vector (9DOF)	Continuous
14	Magnetometer Uncalibrated	Continuous
15	Game Rotation Vector (6DOF accelerometer + gyroscope)	Continuous
16	Gyroscope Uncalibrated	Continuous
17	Significant Motion	One shot
20	Geomagnetic Rotation Vector (6DOF accelerometer + magnetometer)	Continuous
254	Meta Events Used in HEADWAY-A2 UART	
	4	Error
	5	Magnetic Transient
	6	Cal Status Changed
	7	Stillness Changed
	9	Calibration Stable
	15	Self-Test (BIST) Results

VIRTUAL SENSOR AND META EVENT INFORMATION

Listed below are the interface specifications for the most used Virtual Sensors and Meta Events that occur in the host readable FIFO stream. When the host enables these virtual sensors, the Virtual sensors' output data is posted to the host readable FIFO at prescribed rates.

UART Output Format:

Verbose Mode (Off)

`Timestamp,SensorID[,Value][,Value]...[,Value]` $^{L}{}_{F}{}^{C}{}_{R}$

Verbose Mode (On) -default

`Timestamp,`*`event name`*`[,Value][,Value]...[,Value]` $^{L}{}_{F}{}^{C}{}_{R}$

Example:

Verbose Mode (Off)

`246511934, 14, -0.020935, 0.006653, -0.690308, 0.723145, -2.496170` $^{L}{}_{F}{}^{C}{}_{R}$

Verbose Mode (On) -default

`246511934, Rotation Vector, -0.020935, 0.006653, -0.690308, 0.723145, -2.496170` $^{L}{}_{F}{}^{C}{}_{R}$

Notes:

Each line ends with a Linefeed and Carriage return, ($^{L}{}_{F}{}^{C}{}_{R}$).

The timestamp is a Uint32 type that will wrap on overflow. The units are uncalibrated picoseconds

The formats of the Sensor payloads are given in the following section

KEY for the following Sensor and Event listings

SENSOR_TYPE ID#:	This is the SENSOR_TYPE ID value written to ParamIO page 3 to select a particular virtual sensor.
Sample_Rate:	A zero sample rate disables the virtual sensor.
Reporting Type:	**Wake-up type** Virtual sensors will interrupt the host even in AP_Suspend mode
	Continuous mode will report data to the host continuously at the sample rate
	ON-Change mode will only report data to the host if the data value(s) have changed.
Payload size:	Number of Comma Separated Values **not including the Time Stamp and SENSOR_TYPE ID** in each report sentence sent to the host interface FIFO. All payloads end with a Carriage Return [CR], 0X0D.
Payload Values:	The range and type of each data value is listed along with a short description
Description:	Describes the operation of this virtual sensor or event

Accelerometer

SENSOR_TYPE ID#:	**1**
Sample Rate:	Set by user, 0-400Hz
Reporting Type:	Continuous
Payload size:	4
Payload Values:	X, Y, Z, Accuracy
Description:	Acceleration sensor, no autocalibration performed
	Values X, Y, and Z units are m/s^2

Magnetometer

SENSOR_TYPE ID#:	**2**
Sample Rate:	Set by user, 0-125Hz
Reporting Type:	Continuous
Payload size:	4
Payload Values:	X, Y, Z, Accuracy
Description:	Magnetometer sensor, auto-calibration performed X, Y, and Z values are in micro-Tesla (uT)

Orientation

SENSOR_TYPE ID#:	**3**
Sample Rate:	0-400Hz
Reporting Type:	Continuous
Payload size:	4
Payload Values:	Yaw, Pitch, Roll, Accuracy
Description:	A 9DOF calculation from Accel, Mag and Gyro sensors Values X, Y, and Z are in degrees

Gyroscope

SENSOR_TYPE ID#:	**4**
Sample Rate:	Set by user, 0-400Hz
Reporting Type:	Continuous
Payload size:	4
Payload Values:	X, Y, Z, Accuracy
Description:	Device specific output data from Gyroscope sensor, bias removed X, Y, & Z units are radians per second (rad/s)

Pressure

SENSOR_TYPE ID#: **6**

Sample Rate: 0-50Hz

Reporting Type: Continuous

Payload size: 1

Payload Values: Pressure values are in Pascals

Description: Output data from Pressure sensor

Temperature

SENSOR_TYPE ID#: **7**

Sample Rate: 0-50Hz

Reporting Type: Continuous

Payload size: 1

Payload Values: Temperature values are in degrees Celsius

Description: Output data from Temperature sensor

Acceleration components (2 types)

SENSOR_TYPE ID#: **9** **Gravity**

10 **Linear Acceleration**

Sample Rate: 0-400Hz

Reporting Type: Continuous

Payload size: 5

Payload Values: X, Y, Z, Accuracy

Description: Gravity and linear acceleration components of acceleration sensor

Values X, Y, and Z units are m/s^2

Quaternions (3 types)

SENSOR_TYPE ID#: **11** **Rotation Vector (9-DOF Accel/Mag/Gyro)**

15 **Game Rotation (6-DOF Accel/Gyro)**

	20	**Geo-magnetic Rotation (6-DOF Mag/Accel)**
Sample Rate:	0-400Hz	(Geo-magnetic Rotation maximum rate is 125Hz)
Reporting Type:	Continuous	
Payload size:	5	
Payload Values:	Q_X, Q_Y, Q_Z, Q_W, Accuracy	

Description: Quaternion Output data from Rotation Vector Virtual Sensors.

A rotation vector sensor reports the orientation of the device relative to the East-North-Up (ENU)coordinates frame. The ENU coordinate system is defined as a direct orthonormal basis where when body is aligned with Earth frame:

X points east and is tangential to the ground.

Y points north and is tangential to the ground.

Z points towards the sky and is perpendicular to the ground.

Magnetometer Uncalibrated

SENSOR_TYPE ID#: **14**

Sample Rate: Set by user, 0-125Hz

Reporting Type: Continuous

Payload size: 7

Payload Values: X, Y, Z, X offset, Y offset, Z offset, Accuracy

Description: Magnetometer sensor, auto-calibration not performed

X, Y, and Z values and offsets are in micro-Tesla (uT)

Gyroscope Uncalibrated

SENSOR_TYPE ID#: **16**

Sample Rate: Set by user, 0-125Hz

Reporting Type: Continuous

Payload size: 7

Payload Values: X, Y, Z, X bias, Y bias, Z bias, Accuracy

Description: Device specific output data from Gyroscope sensor, bias not removed

X, Y, & Z values and biases are radians per second (rad/s)

Meta Event

SENSOR_TYPE ID#: **254**

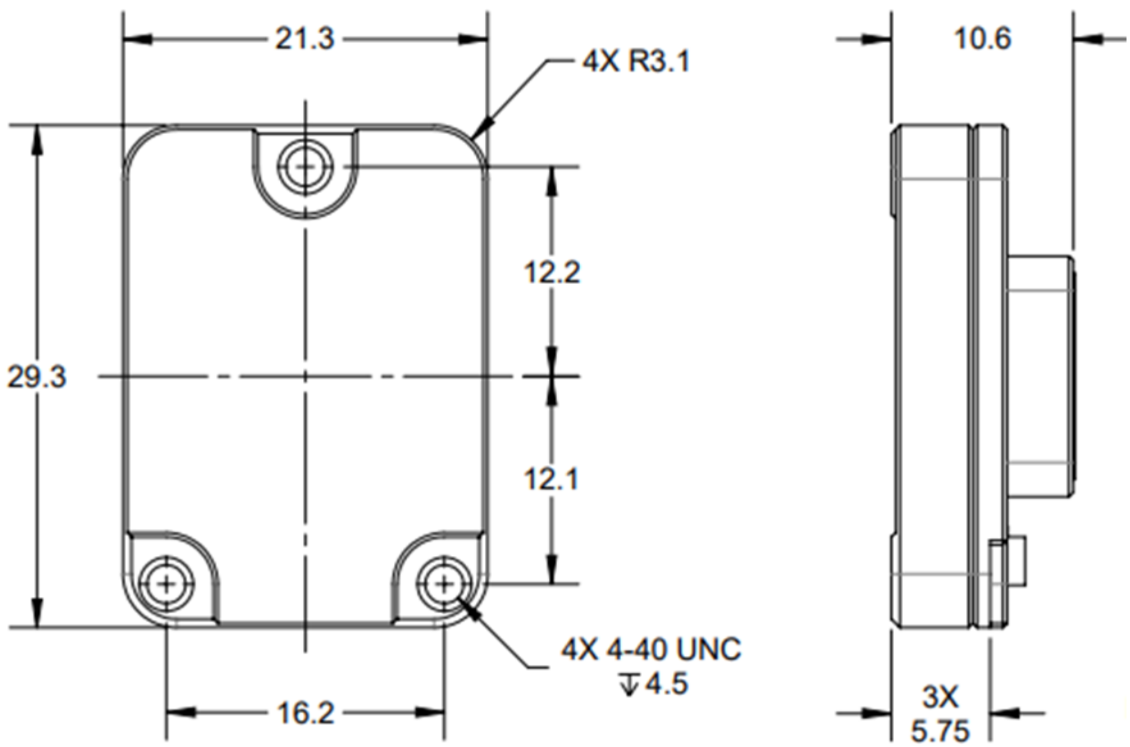
Reporting Type: On Change

Payload size: 3

Payload Values			
Value 1 – Meta Event type ID		Value 2	Value 3
4	Error	Error Register	Debug State
5	Magnetic Transient	1 = transient detected 0 = no transient detected	0
6	Cal Status Changed	Cal Status Value	Trans Component
7	Stillness Changed	1 = now still 0 = no longer still	0
9	Calibration Stable	1 = stable 0 = not stable	0
15	Self-Test (BIST) Results	Sensor ID	Test results 0 = pass

MECHANICAL DRAWINGS

Figure 5-1:Headway



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Revision Control Block

Revision	Description of Change	Effective Date	Approval
V1.0	Released	01/04/2023	HN