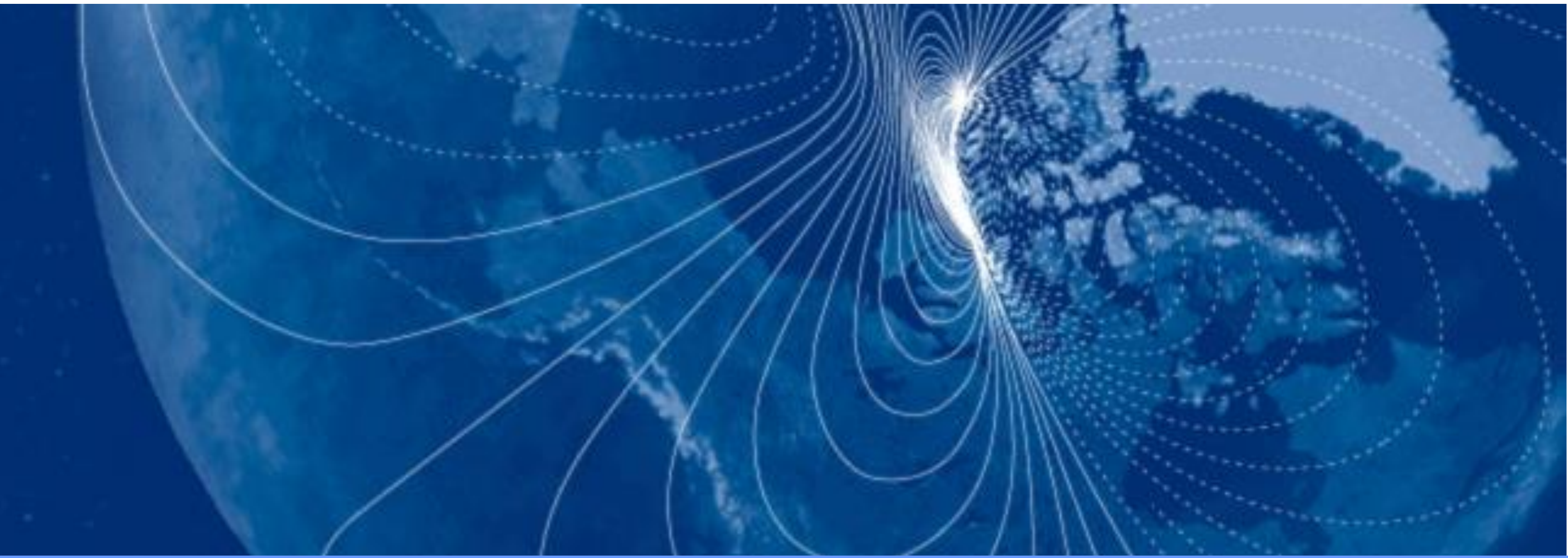

User Manual

NaviGuider

Sensor Based Orientation System for UAVs,

ocean gliders, robots and buoys

NaviGuider 11302022

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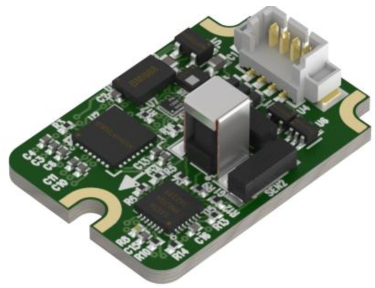
PRODUCT OVERVIEW



NaviGuider (PNI Part number 14703)

PNI's NaviGuider 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 NaviGuider 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

NAVIGUIDER SYSTEM OVERVIEW

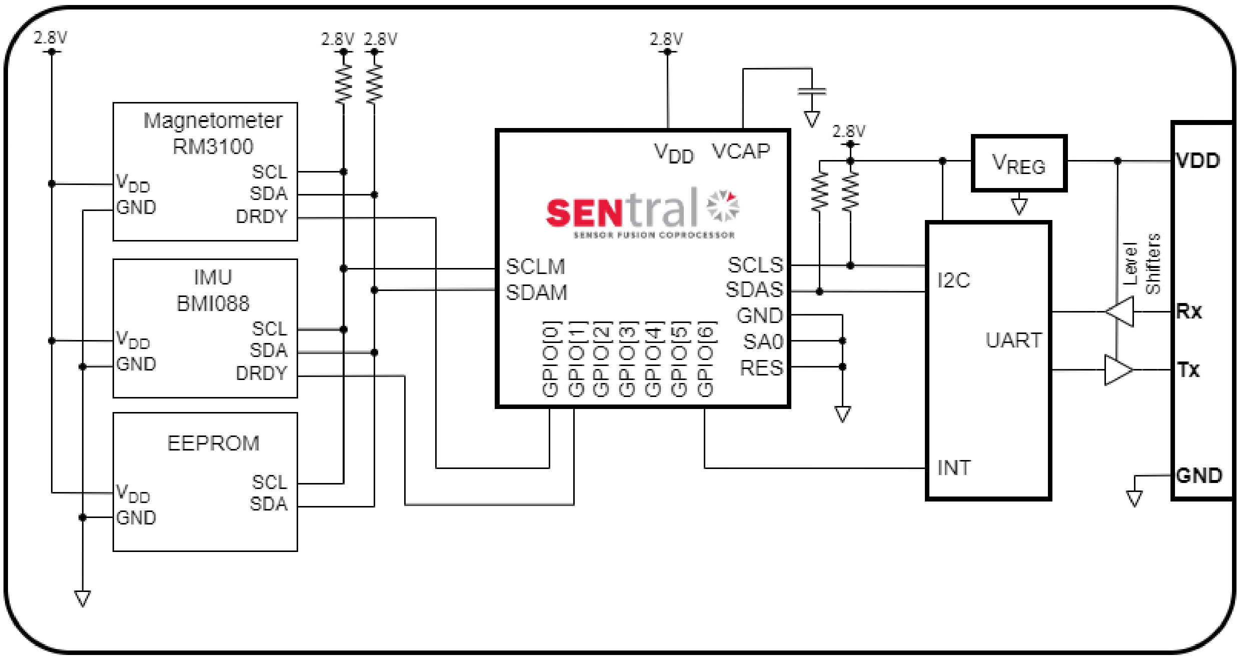


Figure 1-1: NaviGuider Module Block Diagram

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

NAVIGUIDER SPECIFICATIONS

PERFORMANCE CHARACTERISTICS

Table 2-1: Performance Characteristics

Parameter	Typical
Heading Accuracy	2° rms
Tilt Accuracy	1° 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°	+85°	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 NaviGuider pin-out is given in Table 3-2. See Table 2-3 for the operating voltage range.

Table 3-2: NaviGuider 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

NaviGuider 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 Figure 2-1 below, is available from PNI Sensor as part number 14480

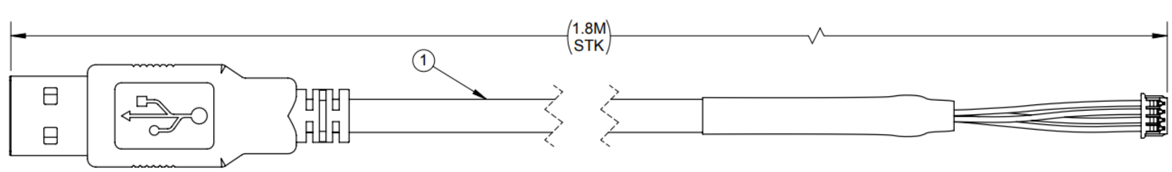


Figure 2-1 PNI 14480 USB-serial evaluation Cable

OPERATION

The NaviGuider 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

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 NaviGuider 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
O	One-Shot Orientation Sensor*

M#[CR]	Mounting Options
	# is limited to 1-16. See Figure 4-1 for specific mounting options
	[CR] = carriage return (0x0D).

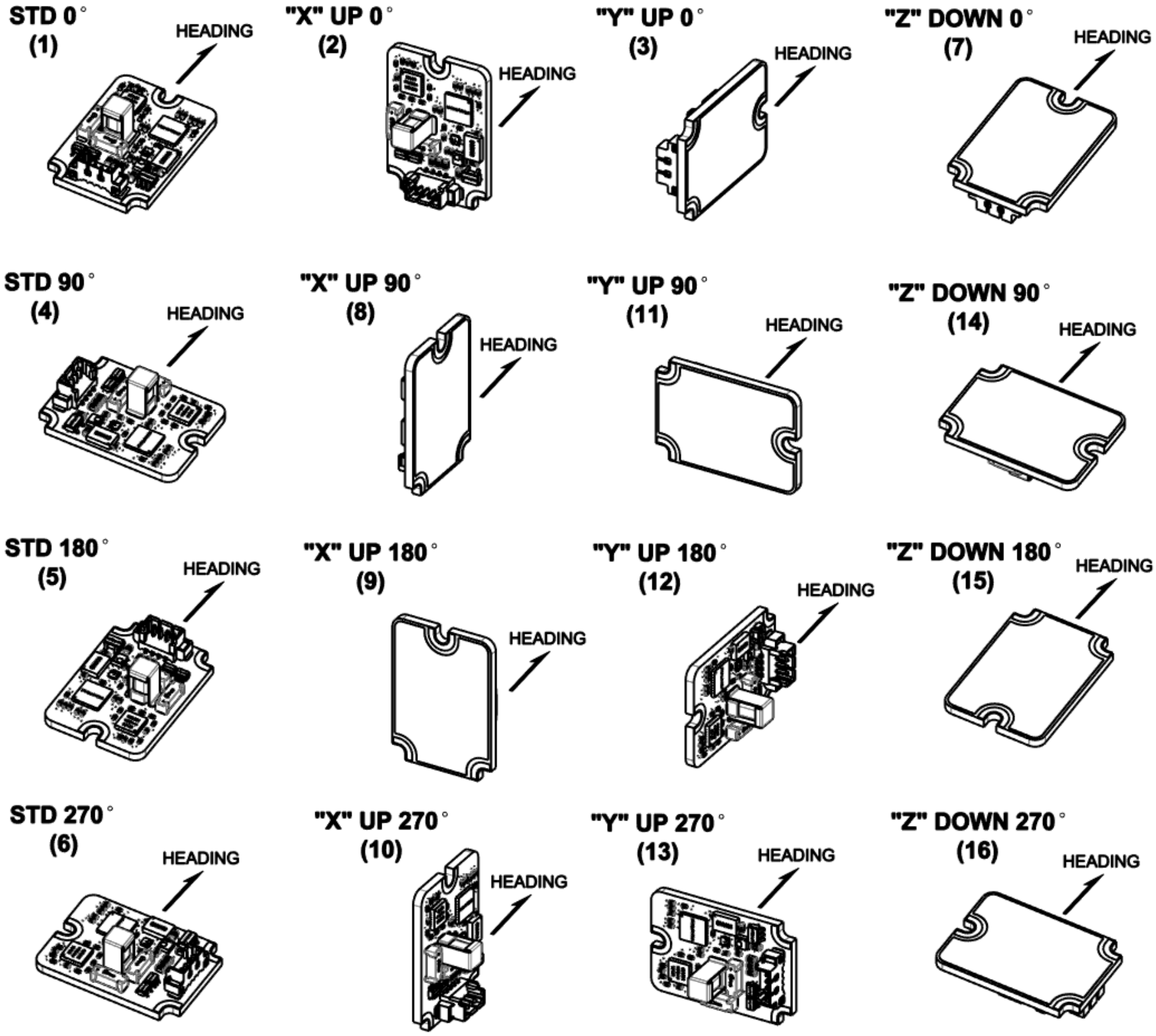
J3	Set module to NED orientation
J4	Set module to ENU orientation (Default)
Sensor Selection and Rates	
s #,#[CR]	Start Sensor at given rate. where: 1st # = Sensor ID. See Table 4-2 Summary of Supported Virtual Sensors and Meta Events 2nd # = Data rate (Aggregate data rate should not exceed 1200 Hz) [CR] = carriage return (0x0D).
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.
S	Save factory calibration parameters
X	Restart system
J1	Stop autocal (this will reset the current autocal values)
J0	Start autocal
A#[CR]	Change Application Mode to number # # = desired application mode 0-5. 0 is custom, higher numbers merge faster. [CR] = carriage return (0x0D). If A0[CR] is selected, custom mode will be entered. In this case 5 knobs will be requested. Enter a number followed by [CR] for each of these knobs. For reference the default A3 setting would have values 1,2,2,1,80.**
A[CR]	Report the current Application Mode
?	Display commands menu
Tests	
B	Run RM3100 Self tests

* The one-shot orientation sensor is a version of sensor 3 (orientation) that happens as a "one-shot" command. This is for the convenience of customers to have a sensor type without additional buffer parsing. Whenever the user inputs the command 'O', the orientation sensor will output a single set of values. These values are timestamp, sensor type (3, or "Orientation" in verbose mode), Azimuth, Pitch, Roll, Calibration Score, Distortion Flag (meta event 5). If this command is made without first enabling sensor 3, the system will default to update the one-shot register at 30hz, and show no additional Orientation sensor updates to buffer (use D[CR] command to display normal Orientation sensor).
** Setting A0 is custom mode, this allows custom changes to sensor knobs. Summary of knobs:
Time constants (first 3 custom knobs): Recommended values 0.1-100 (float), Lower numbers will merge faster. TC1 controls overall merge rate. TC2 controls mag merge rate. TC3 controls accel merge rate.
Dynamic accel (4th custom knob): Recommended values 1-20 (uint), Higher numbers will reduce accel merging during dynamic motion.
Still Delay (5th custom knob): Recommended values 10-1000 (uint), Higher numbers will result in a longer period of time after unit is set down before merging stops.

Figure 4-1: Mounting Options (M#[CR] command)

Index of each mounting option shown in parenthesis



NAVIGUIDER BOARD SUPPORTED VIRTUAL SENSORS

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

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

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] LFCR
```

Verbose Mode (On) -default

```
Timestamp,event name[,Value][,Value]...[,Value] LFCR
```

Example:

Verbose Mode (Off)

```
246511934, 14, -0.020935, 0.006653, -0.690308, 0.723145, -2.496170 LFCR
```

Verbose Mode (On) -default

```
246511934, Rotation Vector, -0.020935, 0.006653, -0.690308, 0.723145, -2.496170 LFCR
```

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 Azimuth (Yaw/Heading), Pitch, and Roll are in degrees Accuracy is the magnetometer autocalibration score, approximately in degrees RMS heading. Autocal score of 180 indicates the system is not yet calibrated.

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

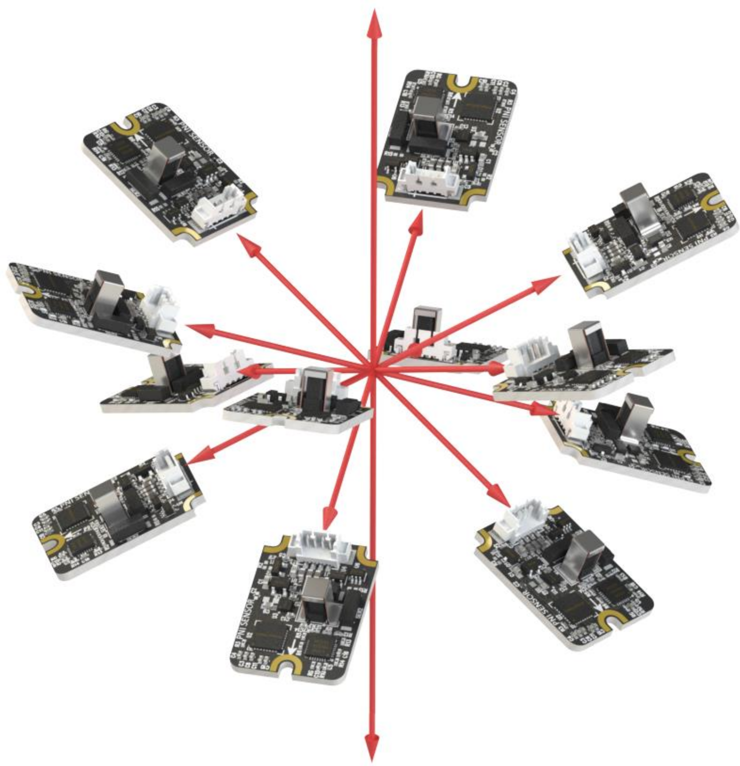
Payload size: 3

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

MAGNETIC AUTOMATIC CALIBRATION

An important part of the NaviGuider system is the ability to automatically calibrate the magnetometers. This allows the system to adapt to changes in environment, including transient magnetic fields, new hardware changes, and temperature changes. While this calibration is automatic, for the system to perform an accurate calibration, it is still necessary for the sensors to see a wide range of positions. Order does not matter, nor timing, but the wider the range of positions the better the magnetic calibration is likely to perform. Figure 5-1 shows a wide distribution of magnetometer points, showing different points of heading at different pitch angles.

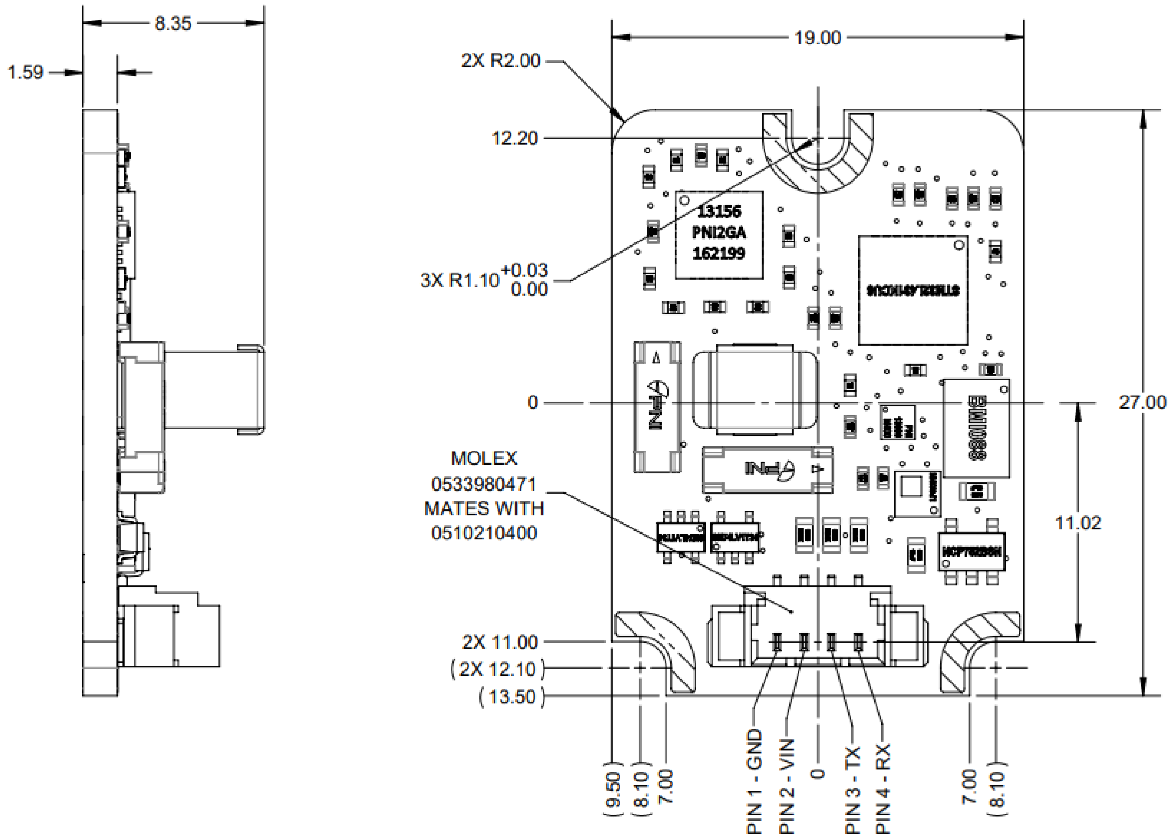
Figure 5-1:Example of a widely distributed autocalibration data set



A set of motions similar to an iPhone “figure 8” pattern would also be acceptable, if perhaps slightly less accurate. The mag score (the 4th value in the Orientation sensor) starts at 180 degrees when not calibrated, and will change to a lower value when calibrated. Changes will only be made when the system believes that it universally improves magnetic accuracy. The score may go down during continued motion, indicating that the system is improving accuracy. Calibration score approximately corresponds to RMS heading accuracy; however, this accuracy is entirely self-contained, and therefore is only an approximate value, not an absolute indicator of system accuracy. Scores less than the specified accuracy (2 degrees for NaviGuider), should provide acceptable accuracy. If the system is rigidly attached to a magnetic distortion, such as placement in a new system, it will adapt to that system after some movement.

MECHANICAL DRAWINGS

Figure 6-1:NaviGuider



Revised March 2016: for the most recent version of this document visit our website at www.pnicorp.com

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Revision Control Block

Revision	Description of Change	Effective Date	Approval
V1.0	Released (Preliminary-C)	11/29/2022	BO
V1.1	Changed image of Naviguider (Black to Green), updated Mech drawing of PCA	12/23/2022	HN
V1.2	Fixed Figure/Table Numbering links and a type on page 16	01/05/2023	HN
V1.3	Updates to include additional features	3/8/2023	JT