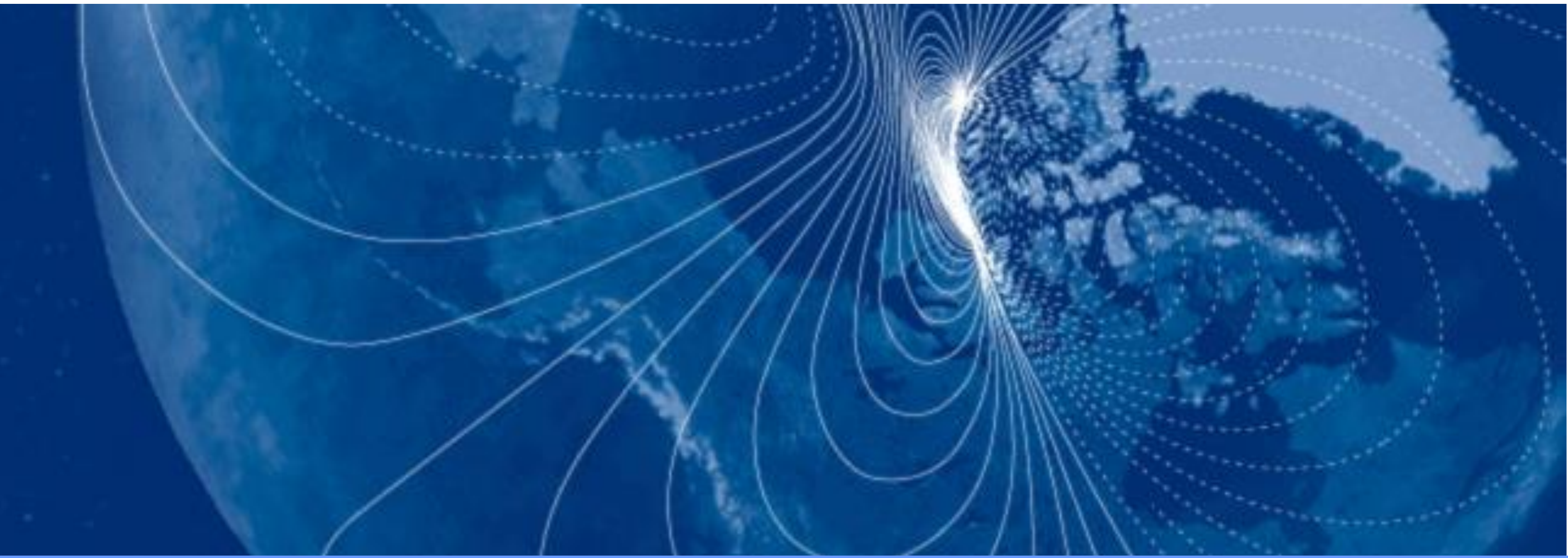

User Manual

NaviGuider I2C

Sensor Based Orientation System for UAVs,

ocean gliders, robots and buoys

NaviGuider 11302022

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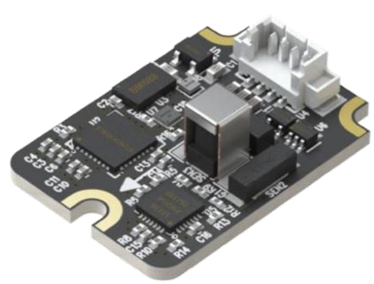
1 PRODUCT OVERVIEW

NaviGuider I2C (PNI Part number 14709)

PNI's NaviGuiderI2C 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 I2C module is a castellated (SMD) printed-circuit board assembly that can be soldered to a host's printed-circuit board assembly and interfaced via I2C. It provides reliable orientation, accurate heading, pitch and roll and motion tracking while consuming less than 6 mA of power. 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, we recommend evaluating the NaviGuider (PNI Part number 14703) with a GUI application which can be obtained by contacting support@pnisensor.zendesk.com



NaviGuider (PNI Part number 14703)

NAVIGUIDER I2C SYSTEM OVERVIEW

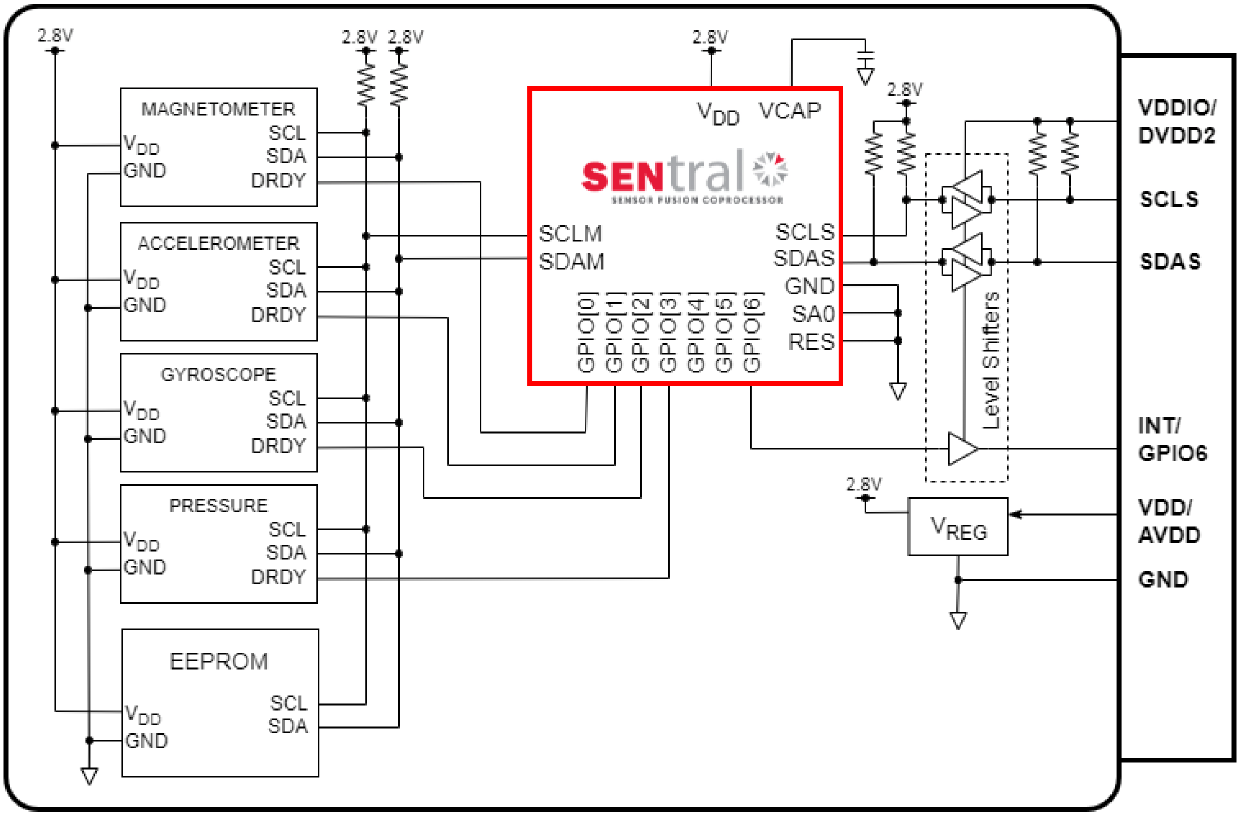


Figure 1-1: **NaviGuider I2C module block diagram**

PNI's SENtral-A2 sensor fusion coprocessor and its embedded algorithms perform the following functions:

Kalman Update fuses data from PNI's RM3100 magnetic sensor, 3-axis gyroscope, and 3-axis accelerometer, plus data from the magnetic anomaly determination algorithms and continuous auto-calibration blocks to generate intelligent Quaternion updates. The Kalman update involves an advanced multi-state Kalman algorithm.

Continuous Hard and Soft-Iron Auto-Calibration. The NaviGuider is the only product in the market that auto-calibrates for both hard-iron and soft-iron magnetic distortions. While others may calibrate for hard-iron distortion, soft-iron distortion is more difficult to correct for. Soft-iron distortion can be caused by ferrous shielding materials and batteries commonly found in electronic systems which can contribute up to 90° of error. Additionally, since a host system's magnetic signature can change over time and temperature, continuous auto-calibration algorithms ensure long-term accuracy.

Magnetic Anomaly Determination establishes if a transient magnetic distortion is present and accounts for it to ensure accurate heading in magnetically harsh environments.

2 NAVIGUIDER I2C SPECIFICATIONS

PERFORMANCE CHARACTERISTICS

Table 2-1: Performance Characteristics

Parameter	Typical
Heading Accuracy	2° rms
Temperature Accuracy	±1.5C
Output Data Rate	200 Hz

Below are the specifications for the installed pressure sensors.

Table 2-2 Pressure and Temperature Scale Factors

Product	Scale Factor	Range
Pressure	(1/128) Pa/LSB	30000 – 110000 Pa (300-1100 hPa)
Temperature	0.002°C/LSB	-40 - 85°C

ELECTRICAL CHARACTERISTICS

Table 2-3: Absolute Maximum Ratings

Parameter	Symbol	Minimum	Maximum	Units
Supply Voltage	DV_{DD} DV_{DIO} AV_{DD} V_{DD}	-0.3	+6	VDC
Input Pin Voltage	V_{IN}	– 0.5	+7	VDC
Storage Temperature	T_{STORE}	-40°	+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 2-4: Operating Conditions

Parameter		Symbol	Min.	Typ.	Max.	Units
IO voltage sense input		DV_{DD} DV_{DIO}	1.65		4.5	VDC
Analog Supply Voltage – Sensors		AV_{DD} V_{DD}	3.0		5.5	VDC
High Level Input Voltage		V_{IH}	$0.7*V_{DD}$		V_{DD}	VDC
Low Level Input Voltage		V_{IL}	0		$0.3*V_{DD}$	VDC
High Level Output Current, $V_{OH} = 0.75xV_{DDIO}$		I_{OH}			-0.5	mA
Low Level Output Current, $V_{OL} = 0.3V$		I_{OL}	0.5			mA
I^2C Interface Data Rate[1]	Host Bus				3400	kbits/sec
Operating Temperature		T_{OP}	-40	+25	+85	C
Operating Current	Idle[2]			0.22		mA
	Rotation Vector (max ODR)			6.36		mA
	All Motion Sensors (Max ODR)			8.55		mA

Footnote:

1. The NaviGuider I2C's co-processor's I^2C Host Interface supports Standard, Fast, Fast Plus, and High-Speed Modes. High Speed Mode (3400 kHz) is supported with a reduced range of V_{DD} and bus capacitance. The co-processor's I^2C sensor bus interface supports Standard, Fast, and Fast Plus Modes. Pass-Through state, which connects the sensor bus and host bus, supports Standard and Fast Modes.
2. Idle current after reset will be higher. It is recommended to cycle run mode once to achieve stated idle current.

3 INTERFACE

The NaviGuider I2C pin-out is given in Table 3-1. See Table 2-4 for the operating voltage range. A discussion of the communication interface follows the table.

Table 3-1: NaviGuider I2C Module Pin Assignments

Pin Name	Description	Pin Number(s)
DV_{DD} DV_{DIO}	IO voltage sense input	2
AV_{DD} V_{DD}	Supply Voltage	7
GND	Ground	8,11
SCLS	I^2C host bus SCL clock line	3
SDAS	I^2C host bus SDA data line	5
SDAM	I^2C sensor bus SDA data line (do not connect)	9
SCLM	I^2C sensor bus SCL clock line (Do not connect)	10
GPIO[4]	Reserved	6
INT GPIO[6]	Host Event Interrupt	4
Reserved	Reserved (not connected)	1,12,13

Footnote:

NaviGuider I2C's I^2C interfaces comply with NXP's UM10204 specification and user manual, rev 04. Standard, Fast, Fast Plus, and High-Speed modes of the I^2C protocol are supported by NaviGuider I2C's I^2C host interface.

I²C TIMING

NaviGuider I2C's I²C timing requirements are set forth below, in

Figure 3-1, Table 3-2, and Table 3-3. For the timing requirements shown in

Figure 3-1, transitions are 30% and 70% of V_{DD}.

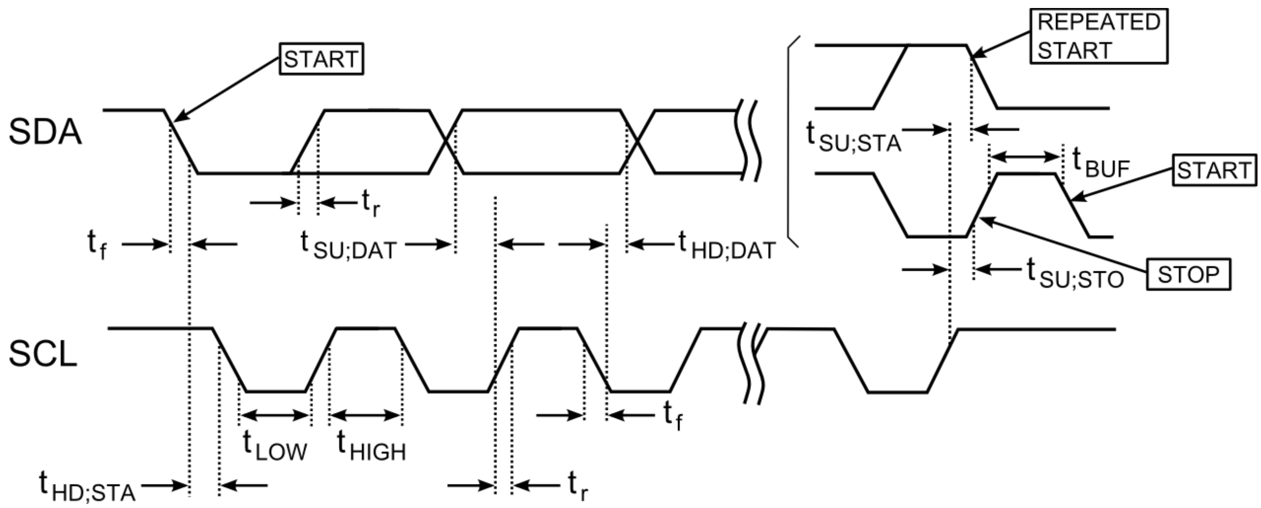


Figure 3-1: I²C Timing Diagram

Table 3-2: I²C Timing Characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
System Clock Frequency (SYSOSC)	F_{SYS}		9	10	11	MHz
Timing Clock Frequency (TIMOSC)	F_{TIM}		124	128	132	kHz
I2C Slave Port Operating Frequency	F_{SCLS}	(1) (2)	100		2000	kHz
I2C Master Port Operating Frequency	F_{SCLM}	(1) (3)	100		1000	kHz

Notes: Unless otherwise specified: V_{DD}= 3.0V to 3.3V, T_A=-40 to +85°C

I²C Protocol Implementation is compliant with UM10204 I2C-bus Specification and User Manual, Rev. 04, February 13th, 2012

I²C Slave port supports Standard, Fast, Fast+ and High-Speed Mode. High Speed Mode is supported with a reduced range of V_{DD} and bus capacitance.

I²C Master port supports Standard, Fast and Fast+ Mode

In pass-through mode, I2C Slave and Master ports are connected to form a single I2C bus. Standard and Fast mode is supported.

Table 3-3: I²C Timing Parameters

Symbol	Parameter	Standard		Fast		Fast Plus		Units
		Min	Max	Min	Max	Min	Max	
f_{SCL}	SCL Clock	0	100	0	200	0	1000	kHz
t_r	SDA & SCL Rise Time	-	1000	20	300		120	ns
t_f	SDA & SCL Fall Time	-	300	20*(V_{DD}/ 5.5V)	300	20*(V_{DD}/ 5.5V)	120	ns
t_{LOW}	LOW period of SCL Clock	4.7	-	1.3	-	0.5	-	µs
t_{HIGH}	HIGH period of SCL Clock	4.0	-	0.6	-	0.26	-	µs
$t_{HD;STA}$	Hold time (repeated) START	4.0	-	0.6	-	0.26	-	µs
$t_{HD;DAT}$	Data hold time	0	-	0	-	0	-	µs
$t_{SU:DAT}$	Data set-up time	250	-	100	-	50	-	ns
$t_{SU;STA}$	Set-Up time for repeated Start	4.7	-	0.6	-	0.26	-	µs
$t_{SU;STO}$	Stop set-up time	4.0	-	0.6	-	0.26	-	µs
t_{BUF}	Bus free time between STOP & START	4.7	-	1.3	-	0.5	-	µs

I²C HOST INTERFACE (HOST BUS)

The host controls the NaviGuider I2C on the host bus via NaviGuider I2C's I²C host interface. The host interface consists of 2 wires: the serial clock, SCLS, and the serial data line, SDAS. Both lines are bi-directional. NaviGuider I2C is connected to the host bus via the SDAS and SCLS pins, which incorporate open drain drivers within the device. Note the NaviGuider I2C module incorporates 4.7 kΩ pull-up resistors on the host bus clock and data lines, so if the host system also incorporates pull-up resistors on these lines the resistors will act in parallel.

The NaviGuider I2C's 7-bit I²C slave address is 0x28 (0b0101000). The shifted address is 0x50.

Data transfer is always initiated by the host. Data is transferred between the host and NaviGuider I2C serially through the data line, SDAS, in an 8-bit transfer format. The transfer is synchronized by the serial clock line, SCLS. Supported transfer formats are single-byte read, multiple-byte read, single-byte write, and multiple-byte write. The data line can be driven either by the host or NaviGuider I2C. Normally the serial clock line will be driven by the host, although exceptions can exist when clock-stretching is implemented in Pass-Through State.

I^{2}C TRANSFER FORMATS

Figure 3-2 illustrates writing data to registers in single-byte or multiple-byte mode.

START	SLAVE ADDRESS							RW	ACK	REGISTER ADDRESS (N)								ACK	DATA TO REGISTER (N)									ACK	DATA TO REGISTER (N+1)								ACK	STOP
S	A6	A5	A4	A3	A2	A1	A0	0	0	R7	R6	R5	R4	R3	R2	R1	R0	0	D7	D6	D5	D4	D3	D2	D1	D0		0	D7	D6	D5	D4	D3	D2	D1	D0	0	P

From Host to NaviGuider I2C

From NaviGuider I2C to Host

------------ Data Transferred (n bytes + acknowledge) ------------

Figure 3-2: I^{2}C Slave Write Example

The I^{2}C host interface supports both a read sequence using repeated START conditions, shown in Figure 3-3, and a sequence in which the register address is sent in a separate sequence than the data, shown in Figure 3-4 and Figure 3-5.

START	SLAVE ADDRESS							RW	ACK	REGISTER ADDRESS (N)								ACK	START	SLAVE ADDRESS							RW	ACK	DATA FROM REGISTER (N)								NACK	STOP
S	A6	A5	A4	A3	A2	A1	A0	0	0	R7	R6	R5	R4	R3	R2	R1	R0	0	SR	A6	A5	A4	A3	A2	A1	A0	1	0	D7	D6	D5	D4	D3	D2	D1	D0	1	P

Data Transferred
(n bytes + acknowledge)

Figure 3-3: I^{2}C Slave Read Example, with Repeated START

START	SLAVE ADDRESS							RW	ACK	REGISTER ADDRESS (N)								ACK	STOP
S	A6	A5	A4	A3	A2	A1	A0	0	0	R7	R6	R5	R4	R3	R2	R1	R0	0	P

Figure 3-4: I^{2}C Slave Write Register Address Only

START	SLAVE ADDRESS							RW	ACK	DATA FROM REG. (N)								ACK	DATA FROM REG. (N+1)								NACK	STOP
S	A6	A5	A4	A3	A2	A1	A0	1	0	D7	D6	D5	D4	D3	D2	D1	D0	0	D7	D6	D5	D4	D3	D2	D1	D0	1	P

From Host to NaviGuider I2C

From NaviGuider I2C to Host

------------- Data Transferred (n bytes + acknowledge) -------------

Figure 3-5: I^{2}C Slave read register from current address

I²C PULL-UP RESISTANCE

The pull up resistance values for both host and sensor bus will depend on the I²C data rate and the number of devices on the bus. Table 3-4 provides the maximum acceptable bus capacitance, as a function of bus rate, which can be accommodated with a 4.7kΩ or 2.4kΩ pull-up resistor. The NaviGuider-I2C includes internal 4.7KΩ pull-up resistors on-board. To achieve 2.4kΩ, external 4.9KΩ (4.7KΩ) pull-up resistors are required on the SDAS and SDAM pins. As a general guideline, each device connected to the bus represents approximately 10pF of capacitance on the bus, so a bus with 4 devices would require a "Max C_b" value of >40pF.

Table 3-4: I²C Pull-Up Resistance Table

I2C Mode		Rate (kbit/s)	Rise Time (ns)	Max Cb (pF)	
				4.7kΩ pull-up	2.4kΩ pull-up (external)
Standard		100	1000	251.1	491.8
Fast		400	300	75.3	147.5
Fast Plus		1000	120	30.1	59.0
High Speed-1.7MHz	Clock	1700	80	20.1	39.3
	Data	1700	160	40.2	78.7
High Speed-3.4MHz	Clock	3400	40	10.0	19.7
	Data	3400	80	20.1	39.3

As the table implies, for most Standard and Fast Mode implementations a 4.7kΩ pull-up should work well, while a 2.4kΩ pull-up normally should be used for Fast Plus.

4 OPERATION

NaviGuider I2C has two distinct modes of execution: Boot Mode and Main Execution Mode.

The ROM is essentially split into two parts – the small boot loader and the large set of libraries and drivers which can be used by a RAM-based program or "patch." It is this latter part of the ROM which provides most of the functionality required for sensor fusion, host interface interactions, data batching, and so on. However, without a RAM patch, none of these more advanced behaviors can occur. This is where boot loading comes in.

BOOT MODE

When NaviGuider I2C first comes out of reset (due to power on reset, watchdog reset, or host-initiated reset), it executes a small portion of its ROM: the boot loader.

The boot loader loads and makes use of factory trim values, initializes the host interrupt GPIO line, then automatically scans the master I2C bus for an attached EEPROM.

MAIN EXECUTION MODE

Once in this mode, the full Android host interface and sensor suite is available. NaviGuider I2C indicates it is ready by inserting an Initialized meta event in the FIFO, setting the Bytes Remaining registers to the size of this event plus timestamp, then asserting the host interrupt. The host should wait for this before attempting to query or configure sensors or other features.

In the nominal case, however, the host is now free to query which sensors are present by reading the Sensor Status bits, learn the details of each sensor by querying the Sensor Information parameters, load any Warm Start values using the Algorithm Warm Start parameters, and/or configure sensors to start generating output using the Sensor Configuration parameters. If you need further information, please email support@pnisensor.zendesk.com for an Application Note on Warm Start Algorithm Parameters.

The host may also wish to configure which meta events will appear in the FIFO, such as FIFO Overflow, Watermark, or many others. It can specify whether certain meta events can cause an immediate host interrupt or are batched until later.

Finally, the host may wish to configure the optional Watermark value using the FIFO Control parameter. This allows the host to be informed that the FIFO is full enough that the host may wish to read its contents before data is lost. This is especially useful when the Application Processor is asleep.

NAVIGUIDER I2C BOARD SUPPORTED VIRTUAL SENSORS

Sensor ID	Description	Type
0x01	Accelerometer	Continuous
0x02	Magnetometer	Continuous
0x03	Orientation (deprecated in Android SDK but not HAL; azimuth / pitch / roll)	Continuous
0x04	Gyroscope	Continuous
0x06	Barometer	Continuous
0x09	Gravity	Continuous
0x0A	Linear Acceleration	Continuous
0x0B	Rotation Vector (9DOF)	Continuous
0x0E	Magnetometer Un-calibrated	Continuous
0x0F	Game Rotation Vector (6DOF accelerometer + gyroscope)	Continuous
0x10	Gyroscope Un-calibrated	Continuous
0x14	Geomagnetic Rotation Vector (6DOF accelerometer + magnetometer)	Continuous
0x16	Tilt Detector	special

VIRTUAL SENSOR INFORMATION

Listed below are the interface specifications and 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. All virtual sensors are by default aligned to the ENU coordinate frame per Android sensor definition.

KEY

SENSOR_TYPE ID#:	This is the SENSOR_TYPE ID value written to ParamIO page 3 to select a particular virtual sensor.
Sample_Rate:	This is how a non-zero sample rate value written to the ParamIO page 3 parameter 0 is interpreted by the virtual sensor (of SENSOR_TYPE specified above). 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 bytes of data (not including the SENSOR_TYPE ID) in each report packet sent to the host interface FIFO.
Payload Values:	The size and type of each data piece is listed along with a short description.
Description:	Describes the operation of this virtual sensor.

Accelerometer

SENSOR_TYPE ID#:	0x01
Sample Rate:	Set by user, 0-400Hz
Reporting Type:	Continuous
Payload size:	7
Payload Values:	SInt16 X
	SInt16 Y
	SInt16 Z
	UInt8 Accuracy
Description:	Device specific output data from Accelerometer sensor
	Values X, Y, and Z are scaled to maximize range and resolution. To convert this value to engineering units in meters per second squared perform the following operation.
	Value(m/s2) = x * 0.0005
	Where: **x** is the sensor data X, Y or Z

Magnetometer

SENSOR_TYPE ID#:	0x02
Sample Rate:	Set by user, 0-125Hz
Reporting Type:	Continuous
Payload size:	7
Payload Values:	SInt16 X
	SInt16 Y
	SInt16 Z
	UInt8 Accuracy
Description:	Device specific output data from Magnetometer sensor
	Values X, Y, and Z are scaled to maximize range and resolution. To convert this value to engineering units in microTesla(uT) perform the following operation.
	Value(uT) = x * 0.01962
	Where: **x** is the sensor data X, Y or Z

Gyroscope

SENSOR_TYPE ID#:	0x04
Sample Rate:	Set by user, 0-400Hz
Reporting Type:	Continuous
Payload size:	7
Payload Values:	SInt16 X
	SInt16 Y
	SInt16 Z
	UInt8 Accuracy
Description:	Device specific output data from Gyroscope sensor

Values X, Y, and Z are scaled to maximize range and resolution. To convert this value to engineering units in radians per second perform the following operation.

Value(rps) = x * 0.0010647

Where: **x** is the sensor data X, Y or Z

Orientation

SENSOR_TYPE ID#:	0x03
Sample Rate:	0-400Hz
Reporting Type:	Continuous
Payload size:	7
Payload Values:	SInt16 Yaw
	SInt16 Pitch
	SInt16 Roll
	UInt8 Accuracy
Description:	Output data from Orientation sensor

Values X, Y, and Z are scaled to maximize range and resolution. To convert this value to engineering units in degrees perform the following operation. Range is from 0 to 360 degrees.

Value(deg) = x * 0.010986

Where: **x** is the sensor data X, Y or Z

Rotation Vectors

SENSOR_TYPE ID#:	0x09	Rotation Vector (9-DOF)
	0x0F	Game Rotation (6-DOF Accel/Gyro)
	0x14	Geo-magnetic Rotation (6-DOF Mag/Accel)
Sample Rate:	0-400Hz	(Geo-magnetic Rotation maximum rate is 125Hz)
Reporting Type:	Continuous	
Payload size:	10	
Payload Values:	SInt16 Q_X	
	SInt16 Q_Y	
	SInt16 Q_Z	
	SInt16 Q_W	
	Sint16 Accuracy	

Description:

Quaternion Output data from Rotation Virtual Sensors

Unit Vector Q Values are scaled to maximize range and resolution.

$$\hat{Q} = \frac{x}{2^{14}}$$

Where: **x** is the Sint16 Quaternion data Q_X, Q_Y, Q_Z, or Q_W

For more information, see Appendix A – Converting Quaternions

Barometer

SENSOR_TYPE ID#: 0x06

Sample Rate: 0-50Hz

Reporting Type: Continuous

Payload size: 3

Payload Values: SInt24 Pressure

Description: Output data from Temperature sensor

To convert this value to engineering units in Pascals perform the following operation.

Value(Pa) = x * 128

Where: **x** is the sensor data X, Y or Z

Event Wake

SENSOR_TYPE ID#: 0x41 through 0x7E

Reporting Type: On Change

Payload size: Same size as Virtual SensorID (SENSOR_TYPE ID# - 64)

Description: A wake Event has occurred for Virtual SensorID (SENSOR_TYPE ID# - 64)

Meta Event Wake

SENSOR_TYPE ID#: 0xF8

Reporting Type: On Change

Payload size: 3

Description: A Meta Event has occurred

Meta Event

SENSOR_TYPE ID#: 0xFE

Reporting Type: On Change

Payload size: 3

Payload Values			
Value 1 – Meta Event type ID		**Value 2**	**Value 3**
0x02	Sample Rate Changed	Sensor ID	0
0x03	Power Mode Changed	Sensor ID	0
0x04	Error	Error Register	Debug State
0x05	Magnetic Transient	1 = transient detected 0 = no transient detected	0
0x06	Cal Status Changed	Cal Status Value	Trans Component
0x07	Stillness Changed	1 = now still 0 = no longer still	0
0x09	Calibration Stable	1 = stable 0 = not stable	0
0x0B	Sensor Error	Sensor ID	Sensor status bits
0x0C	FIFO Overflow	Loss count LSB	Loss count MSB
0x0D	Dynamic Rage Changed	Sensor ID	0
0x0E	FIFO Watermark	Bytes remaining	0
0x0F	Self-Test (BIST) Results	Sensor ID	Test results 0 = pass
0x10	Initialized	RAM version LSB	RAM version MSB
0x11	Transfer Cause	0	0

SELF TEST (BIST)

The self-test feature invokes the Built-In Self-Test (BIST) of any and all sensors attached to SENtral which such capabilities. The RM3100 sensor’s BIST test includes testing for full operation of the driver IC including external magneto-inductive sensor connection tests for opens and shorts.

To initiate BIST perform the following sequence:

Write 0x01(Request Algorithm Standby) to SENtral register 0x55(Host Interface Control)
Read Host Status Register to confirm Algorithm Standby (bit 1 == 1)
Write 0x40(Cancel Algorithm Standby and Request Self-Test) to register 0x55(Host Interface Control)
SENtral will send Meta Event payload values are as follows
Byte #1: 0x15 (event number for self-test results)
Byte #2: Sensor ID number
Byte #3: Self-Test Result value
0 = Sensor Self-Test Passed
1 = Sensor Error Self-Test Axis-X Failed
2 = Sensor Error Self-Test Axis-Y Failed
4 = Sensor Error Self-Test Axis-Z Failed

5 MECHANICAL DRAWINGS

ID	FUNC
PIN-1	N/C
PIN-2	VDDIO
PIN-3	SCLS
PIN-4	GPIO6P
PIN-5	SDAS
PIN-6	GPIO4
PIN-7	AVDD
PIN-8	GND
PIN-9	SDAM
PIN-10	SCLM
PIN-11	GND
PIN-12	N/C
PIN-13	N/C

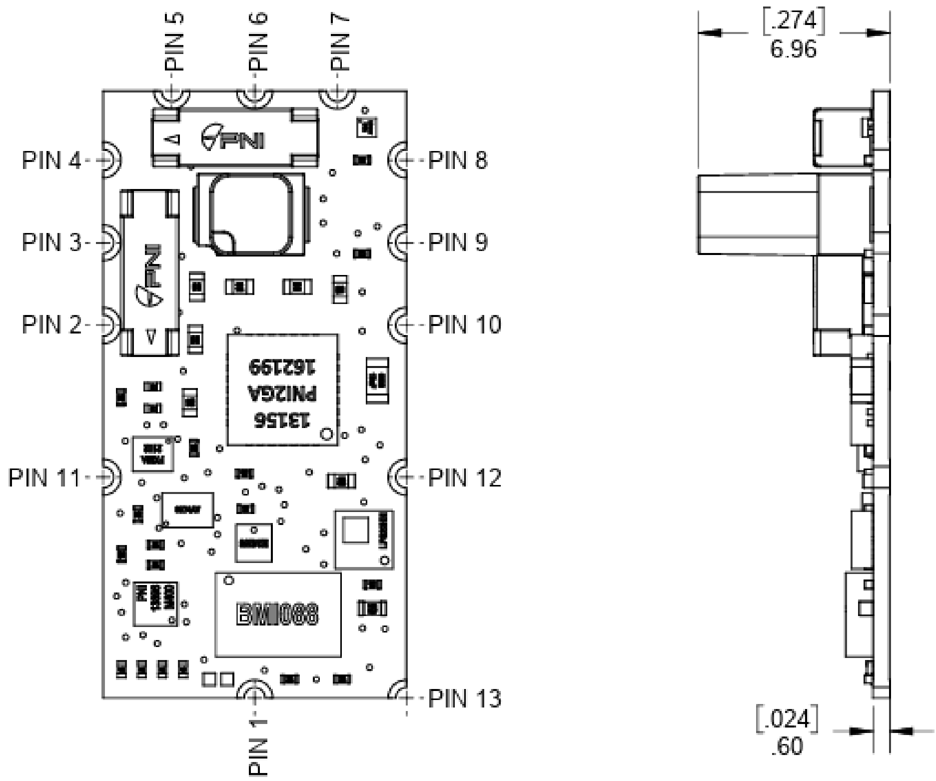


Figure 5-1: NaviGuider I2C

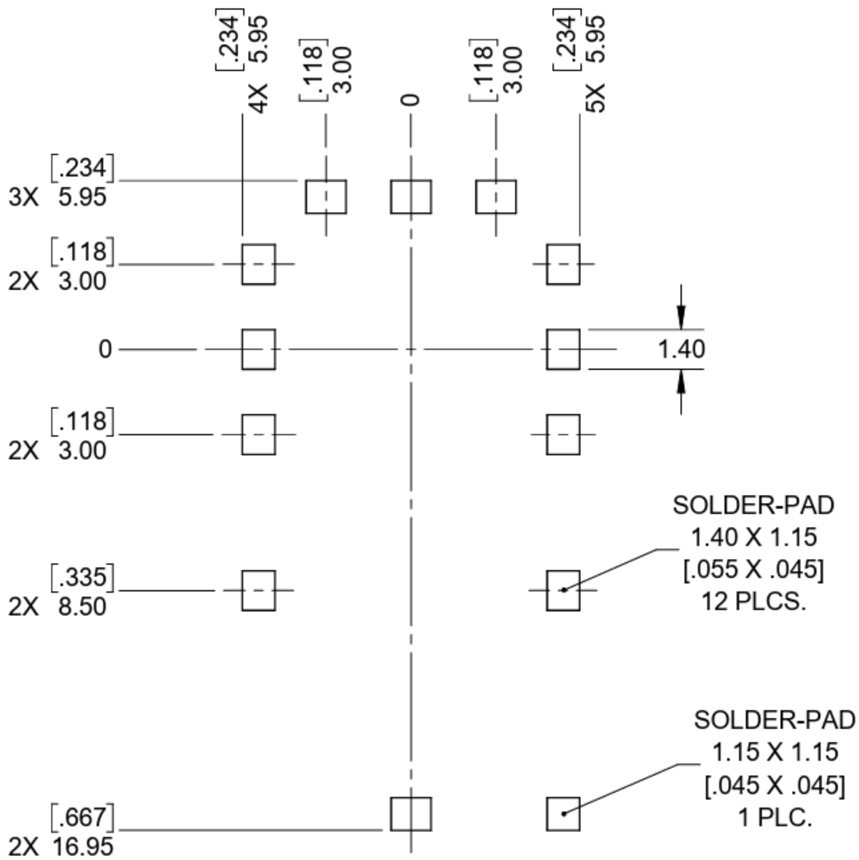


Figure 5-2: NaviGuider I2C Solder Pad Layout

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If any Product furnished hereunder fails to conform to the above warranty, Customer's sole and exclusive remedy and PNI's sole and exclusive liability will be, at PNI's option, to repair, replace, or credit Customer's account with an amount equal to the price paid for any such Product which fails during the applicable warranty period provided that (i) Customer promptly notifies PNI in writing that such Product is defective and furnishes an explanation of the deficiency; (ii) such Product is returned to PNI's service facility at Customer's risk and expense; and (iii) PNI is satisfied that claimed deficiencies exist and were not caused by accident, misuse, neglect, alteration, repair, improper installation, or improper testing. If a Product is defective, transportation charges for the return of the Product to Customer within the United States and Canada will be paid by PNI. For all other locations, the warranty excludes all costs of shipping, customs clearance, and other related charges. PNI will have a reasonable time to make repairs or to replace the Product or to credit Customer's account. PNI warrants any such repaired or replacement Product to be free from defects in material and workmanship on the same terms as the Product originally purchased.

Except for the breach of warranty remedies set forth herein, or for personal injury, PNI shall have no liability for any indirect or speculative damages (including, but not limited to, consequential, incidental, punitive and special damages) relating to the use of or inability to use this Product, whether arising out of contract, negligence, tort, or under any warranty theory, or for infringement of any other party's intellectual property rights, irrespective of whether PNI had advance notice of the possibility of any such damages, including, but not limited to, loss of use, revenue or profit. In no event shall PNI's total liability for all claims regarding a Product exceed the price paid for the Product. PNI neither assumes nor authorizes any person to assume for it any other liabilities.

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Revision Control Block

Revision	Description of Change	Effective Date	Approval
-	Draft-A	07/13/2022	JMiller
-	Draft-B	02/27/2023	HNguyen
V1.1	Updated Mechanical drawing and Solder pad layout diagrams	03/13/2024	ELiang