PNI – V2Xe 2-Axis Compass Module

General Description

The V2Xe is an integrated 2-axis compass and magnetic field sensing module featuring an on-board microprocessor for control and interfacing. The V2Xe combines PNI Corporation's patented Magneto-Inductive (MI) sensors and measurement circuit technology for unparalleled cost effectiveness and performance. The MI sensor changes inductance by 100% over its field measurement range. This variable inductance property is used in a cost and space efficient ASIC (PNI 11096) which incorporates a temperature and noise stabilized oscillator/counter circuit. The microprocessor controls the ASIC and provides easy access to the V2Xe's heading information as well as magnetic field measurement data via a Motorola compatible SPI interface.

Advantages include 3V operation for compatibility with new systems, low power consumption, a small footprint, large signal noise immunity under all conditions, and a large magnetic field dynamic range. Resolution and field measurement range are software configurable for a variety of applications. The measurement is very stable over temperature and inherently free from offset drift.

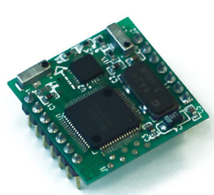
These advantages make PNI Corporation's V2Xe the choice for applications that require a solution that has a high degree of azimuth accuracy, requires little power, and has a small package size.

Features

- Complete 2-axis compass draws < 1mA at 3VDC.
- Several low power modes.
- Part size: 25.4 x 25.4 x 11.55 mm.
- EEPROM allows for retained calibration coefficients after removal of power.
- Compass heading output (0.01° Resolution).
- Compass heading accuracy of 2° RMS (built-in calibration required).
- Magnetic field measurement output.
- Field measurement range ±1100 µT (±11 Gauss)
- Resolution as low as 0.015µT (0.00015 Gauss)
- All digital solution, no additional circuitry is required.
- SPI protocol for interfacing to a host processor.

Applications

- Remote terrestrial antenna direction indicators
- High-performance magnetic field sensing
- High-performance solid state navigation equipment
- Survey equipment
- Robotics systems
- Vehicle detection
- Consumer and hobbyist markets



.............*Ordering Information*

NAME	PART NUMBER	Package
V2Xe	11862	Bulk

Functional Diagram appears at end of data sheet

For more information, please call PNI Corporation direct at (707) 566-2260, email: sales@pnicorp.com, or visit PNI's website at http://www.pnicorp.com

Absolute Maximum Ratings

SYMBOL	PARAMETER	MIN	MAX	UNITS	NOTES
V_{DD}	DC Supply Voltage	-0.3	4.1	VDC	
V_{IN}	Input Pin Voltage	- 0.3 VDD	VDD+0.3	VDC	
I_{IN}	Input Pin Current	- 2.0	2.0	mA DC	25° C
T_{STRG}	Storage Temperature	-40	85	°C	

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Module Characteristics

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
OPERATING CHARACTERISTICS						
Supply Voltage				3.0		VDC
Current	Idle (1)			0.40		mA
	Continuous (2)			0.75		
Processor Frequency	VCC = 3.0 V				8	MHz
Standard Inputs	Low-level Input	VCC = 3.0 V	V_{SS}		V_{SS} +0.6	VDC
	High-level Input		0.8 x V_{CC}		V_{CC}	
Outputs	High-level Output	VCC = 3.0 V	V_{CC} - 0.25		V_{CC}	
	Low-level Output		V_{SS}		V_{SS} +0.25	
Operating Temp. Range			-20		70	°C
Storage Temp. Range			-40		85	

(1) **Idle:** Measurement taken with NO sensor activity.
(2) **Continuous:** Measurement taken during continuous polling of the sensors.

Module Characteristics (continued)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
MAGNETOMETER MODE CHARACTERISTICS					
Field Measurement Range (1)		-1100		1100	µT
Gain (2)			31.24		Count/ µT
Resolution			1/Gain		µT
Linearity	Error from best fit straight line at ± 300 µT		0.6	1	% of 300 µT
Sensor Frequency	Within free Earth's magnetic field.		175		KHz
COMPASS MODE CHARACTERISTICS					
Accuracy (3)			1	2	Degree RMS
Resolution			0.01		Degree

(1) Field Measurement Range is defined as the monotonic region of the output characteristic curve.

(2) Gain is defined as the change in the number of counts from the ASIC, when the period select is set to 2048, per change in the magnetic field in µT. For situations requiring higher gain and less field measurement range, the gain and resolution can be increased by a factor of 2 by setting the ASIC period select to 4096. When setting higher period selects, be aware that the ASIC counter can overflow if the field is strong enough drive the count beyond a signed 16-bit integer. Period select set to 2048 is the highest setting where it is impossible to overflow the counter.

(3) Requires that the built-in calibration be performed. In practical compass applications, a calibration is normally performed when the compass module is in the host system.

Pin Descriptions

PIN	NAME	FUNCTION	NOTES
1	SCLK	Serial Clock input for SPI port	
2	MISO	Serial data output (Master In Slave Out)	
3	MOSI	Serial data input (Master Out Slave In)	
4	SSNOT	Active low Chip select for SPI port	
5	DRDY	Data Ready	
6	SYNC	Sync input	
7	GND	Ground	
8	GIO0	Reserved I/O	
9	GIO1	Reserved I/O	
10	GIO2	Reserved I/O	
11	GIO3	Reserved I/O	
12	VDD	Supply Voltage	3.0 VDC Regulated
13	N/C		N/C
14	GND	Ground	

Host Processor Interface

All accesses to and from the V2Xe are through a hardware handshaking, synchronous serial interface that adheres to the Motorola SPI protocol. The interface consists of six signals; SCLK, MOSI, MISO, SSNOT, SYNC and DRDY.

SPI Port Pin Descriptions

- **MOSI** – Master Out, Slave In for the Module SPI port.
- **SSNOT** – Slave Select for the Module SPI port. SSNOT must remain low until the command response is clocked out.
- **SCLK** – Serial Clock input for SPI port.
- **MISO** – Master In, Slave Out for the Module SPI port.

Hardware Handshaking Pin Descriptions

- **SYNC** – SYNC is usually low. SYNC must be toggled from low-high-low.
- **DRDY** – Data Ready. The module returns DRDY. DRDY is low after SYNC; after a command has been received and the data is ready, DRDY is raised.

SPI Port Usage Tips

A SPI port can be implemented using different clock polarity options. The clock polarity can be normally low (***cpol = 0***) or normally high (***cpol = 1***). Figure 1 graphically shows the timing sequence of the two clock polarity options when used to communicate with the V2Xe. Regardless of the polarity chosen, data is always considered valid while the SCLK is high (***t***t_{DASH} = Time, Data After SCLK High). When SCLK is low, the data is in transition (t_{DBSH} = Time, Data Before SCLK High).

When implementing a SPI port, whether it is a dedicated hardware peripheral port, or a software implemented port using general purpose I/O (also known as *Bit-Banging*) the timing parameters given in Figure 1 must be met to ensure reliable communications. The clock set-up and hold times, t_{DBSH} and t_{DASH} must be greater than 100nS.

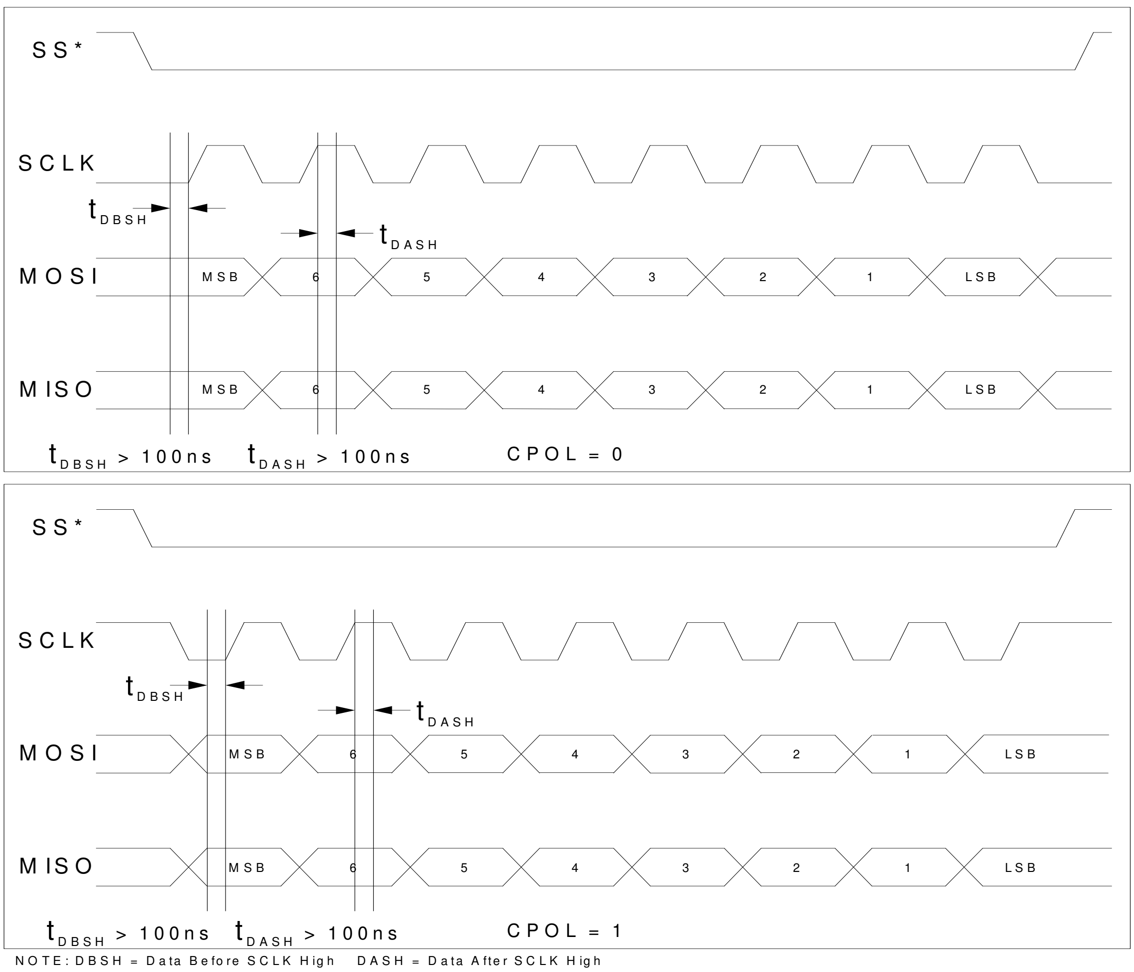


Figure 1
SPI Port timing parameters (*cpol = 1* & *cpol = 0*)

Communication Sequence Using: *cpol* = 0
(Reference Figure 2)

1. SSNOT = 1 // Default when module not in use
2. SCLK = 0 // CLK default is 0
3. SSNOT = 0 // Indicate communication with Module started
4. Toggle SYNC // Toggle SYNC line
    a. SYNC = 0 // De-assert SYNC line
    b. SYNC = 1 // Assert SYNC line
    c. SYNC = 0 // De-assert SYNC line
5. Clock out data // msb = first, lsb = last
    a. MOSI = n // Data changes during SCLK low
    b. SCLK = 1 // Indicate data valid
    c. Hold tValid // Hold SCLK hi for minimum tValid
    d. SCLK = 0 // Lower SCLK to change data
    e. Repeat for n bits // n = (8, 16, 32) bits depending on cmd
6. Wait DRDY = 1 // When command processed & DRDY set to 1
7. Clock in response // msb = first, lsb = last
    a. SCLK = 1 // Data should be valid during SCLK hi
    b. Hold tValid // Hold SCLK hi for minimum tValid
    c. Read MISO // Evaluate response bit
    d. SCLK = 0 // Lower SCLK to allow data to change
    e. Repeat for n bits // n = (8, 16, 32) bits based on response
8. SSNOT = 1 // Return to default state, release module

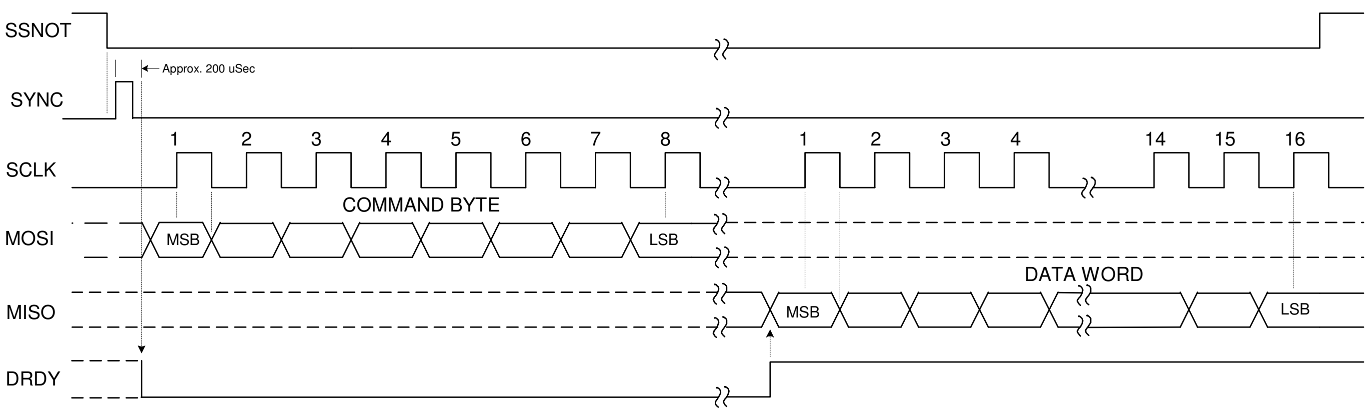


Figure 2
SPI Port Full Timing Sequence (*cpol = 0*)

Command Order

The process to obtain data from the module is as follows:

1. Sample Command
2. Query commands (sample data remains until next sample command)
    a. Retrieve Xdata
    b. Retrieve Ydata
    c. Retrieve Hdg

Data Format

- UInt8 = 8 bits
- UInt16 = 16 bits
- SInt16 = 16 bits (2's Complement)
- UInt32 = 32 bits
- SInt32 = 32 bits (2's Complement)
- SInt32Scaled = 32 bits (2's Complement) * 1000
- V2XBCD = 16 bits
- V2XBinary = 16 bits
- V2XRaw = 32 bits

SInt32Scaled is represented as follows:

- **SInt32Scaled** is for passing fractional values between the V2Xe and client.
- scalingFactor = 1000.0

Example Data:

Decimal	SInt32Scaled
1.5	000005DC
0.5	000001F4
0.001	00000001
0.0	00000000
-0.001	FFFFFFFF
-0.5	FFFFFE0C
-1.5	FFFFFA24

Steps to convert float to long:

1. Multiply float variable by scalingFactor.
2. Assign float variable to long variable.

Example:

```
#define kFloatScaler 1000
SInt32 ConvertFloatToSInt32Scaled(float value)
{
        return (SInt32)(value * kFloatScaler);
}
```

Steps to convert long to float:

1. Assign long to float variable.
2. Divide float variable by scalingFactor.

Example:

```
#define kFloatScaler 1000
float ConvertSInt32ScaledToFloat (SInt32 value)
{
        return (float)(value / kFloatScaler);
}
```

V2XBCD is represented as follows:

- **B**inary **C**oded **D**ecimal
- First 6 bits are 0
- Bits: 000000HH MMMMLLLL
  HH (0-3)
  MM (0-9)
  LL (0-9)

Example: Input: 0x0064 = decimal 100
Output: 0x0100 (1 = d2, 0 = d1, 0 = d0)

HEX	BCD
0x00FF	0x0255
0x0100	0x0256
0x0167	0x0359

V2XBinary is represented as follows:

- Msb = sign
- First 7 bits are 0
- Bits: 0000000n nnnnnnnn
- Data Range = 0-359

Examples:

HEX	Value
0x1000	4096
0x9000	-4096
0x0167	359
0x8167	-359
0x0001	1
0x8001	-1

V2XRaw binary format is represented as follows:

- Msb = sign
- Bits: snnnnnnn nnnnnnnn
- **XnnnYnnn** where: **Xnnn** = V2X Binary Format
  Ynnn = V2X Binary Format

Examples:

HEX	X Value	Y Value
0x10008001	4096	-1
0x900000FF	-4096	255
0x01670167	359	359
0x81670167	-359	359
0x00010000	1	0
0x80010002	-1	2

Polled Sample Format

Sensor Bitmap:

```
k_Sample_Xaxis          = 0x01     // X axis sensor
k_Sample_Yaxis          = 0x02     // Y axis sensor
k_Sample_Compass        = 0x80     // All compass related sensors
```

Result:

```
k_NoErrors              = 0x0000   // No error
k_SensorErrors          = 0x01nn   // Then nn is the Sensor Bitmap
k_SensorDistortion      = 0x02nn   // Then distortion due to out of range (1)
k_SensorUncalibrated    = 0x04nn   // Then unit is uncalibrated
```

Note 1: Indicates that the magnetic field has gone outside of the range of 25% to 200% of the corrected maximum value recorded during calibration.

Note 2: The results can equal any combination of the above values which would indicate multiple errors.

V2Xe Commands

COMMAND	COMMAND FORMAT	RESPONSE FORMAT	SYNTAX	DESCRIPTION
0x00	void	Word	-	Get Module ID
0x01	void	Long	-	Get Module Version
0x05	UInt8	UInt8	See Period Select Table	Set ASIC Period Select
0x06	void	UInt8	-	Get ASIC Period Select
0x0A	void	UInt8	-	Save Changes
0x0B	UInt8	UInt8	Enable = 1 Disable = 0	Set Xflip
0x0C	void	UInt8	Enable = 1 Disable = 0	Get Xflip
0x0D	UInt8	UInt8	Enable = 1 Disable = 0	Set Yflip
0x0E	void	UInt8	Enable = 1 Disable = 0	Get Yflip
0x0F	void	UInt8	-	Clear Calibration
0x10	UInt8	UInt8	Enable = 1 Disable = 0	Set mpcal
0x11	void	UInt8	Enable = 1 Disable = 0	Get mpcal
0x12	UInt8	UInt8	Enable = 1 Disable = 0	Set upcal
0x13	void	UInt8	Enable = 1 Disable = 0	Get upcal
0x14	SInt32Scaled	UInt8	Degrees (+/-)	Set Heading Declination
0x15	SInt32Scaled	UInt8	Mils (+/-)	Set Heading Declination
0x16	UInt8	UInt8	True = 1 Magnetic = 0	Set North Mode
0x17	UInt8	UInt8	Enable =1 Disable =0	Set Digital Damping Enabled
0x18	UInt8	UInt8	Value	Set Digital Damping Size
0x1A	void	SInt32Scaled	Degrees	Get Heading Declination
0x1B	void	SInt32Scaled	Mils	Get Heading Declination
0x1C	void	UInt8	True = 1 Magnetic = 0	Get North Mode
0x20	UInt8	UInt16	sensorBitmap	Polled Sample
0x22	void	ASICWord	*polledData (raw)	Get X axis sensor counts
0x23	void	ASICWord	*polledData (raw)	Get Y axis sensor counts
0x2D	void	SInt32Scaled	*polledData (degrees)	Get calibrated Heading
0x2E	void	SInt32Scaled	*polledData (mils)	Get calibrated Heading
0x40	void	UInt8	-	Get V2X sensors
0x41	void	V2XBinary	Bin	Get V2X hdg
0x42	void	V2XBCD	BCD	Get V2X hdg
0x43	void	V2XRaw	X word, Y word	Get V2X raw

***polledData** is the data that is derived from the last Polled Sample. This allows the user to access the data taken during the Polled Sample. An example of this would be to access the X and Y sensor values used to calculate the heading.

Period Select Settings (1)

Period Select	Syntax	Response Time (2)	Units
/32	0	37.6	mS
/64	1	38.4	
/128	2	39.6	
/256	3	42.8	
/512	4	49.2	
/1024	5	62.0	
/2048	6	87.2	
/4096	7	137.2	

(1) The lowest setting (/32) will give the fastest response time but the lowest resolution. The highest setting (/4096) will give the slowest response time but the highest resolution.
(2) Response time is defined as the time between falling edge of last MOSI clock until rising edge of DRDY. The response time should not change regardless of the host microcontroller. These times are per sensor.

Calibration

There are 2 different kinds of calibrations:

1. Polled calibration, allows the client to record data used for calibration.
    a. Polled calibration begin // cmd 10 = 01
    b. Rotate module (2 full rotations) // Rotate 720 degrees
        i. Polled Sample Command
            1. Read Xdata // Raw or µTesla
            2. Read Ydata // Raw or µTesla
            3. Continue polling // until 2 full rotations are completed
    c. Polled calibration end // cmd 10 = 00

2. Non-polled calibration, the calibration is done internally by the module.
    a. Non-polled calibration begin // cmd 12 = 01
    b. Rotate module (2 full rotations) // Rotate 720 degrees
    c. Non-polled calibration end // cmd 12= 00

Note 1. The above instructions require that the module be level during the calibration procedure.

Note 2. The compass must be installed in the host system in its final configuration. Do not calibrate the module and then place it into the host system else heading errors will occur.

Heading: Degrees vs. Mils

The V2Xe is capable of outputting heading information in either degrees or mils.

- Degrees = 0.00 to 359.99
- Mils = 0 to 6399

- Degrees = (mils * 360) / 6400
- Mils = (deg * 6400) / 360

Note: When the unit is set to either degrees or mils, it is important to remember that any values set for declination need to input in the same format. Failing to do so will result in inaccurate heading data.

Declination

Declination, also called magnetic variation, is the difference between true and magnetic north, relative to a point on the earth. It is measured in degrees (or mils) east or west of true north. Correcting for declination is accomplished by storing the correct declination angle, and then changing the heading reference from magnetic north to true north (e.g. sn = t). Declination angles vary throughout the world, and change very slowly over time. For the greatest possible accuracy, go to the National Geophysical Data Center web page below to get the declination angle based on your latitude and longitude:
http://www.ngdc.noaa.gov/cgi-bin/seg/gmag/fldsnth1.pl

X-Flip and Y-Flip

During normal operation, the heading is calculated with respect to the front of the module, which coincides with the direction of the arrow printed on the board. This also assumes that the unit is mounted with the "pins down" in the host system. In situations where a different mounting orientation is needed, the user can enable either the X-Flip or Y-Flip, or both. The follow table shows the different orientations available and their associated settings.

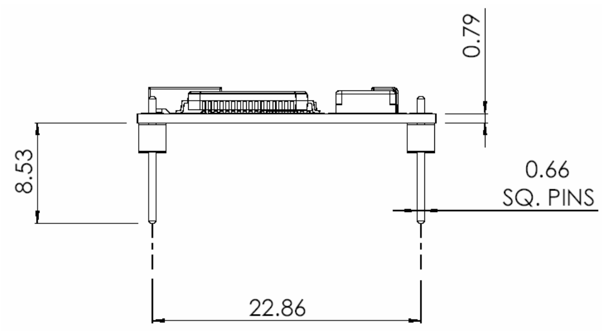
	X-Flip	Y-Flip	Arrow	Pins
Default	0	0	Front	Down
Inverted	0	1	Front	Up
Inverted & Rotated	1	0	Back	Up
Rotated	1	1	Back	Down

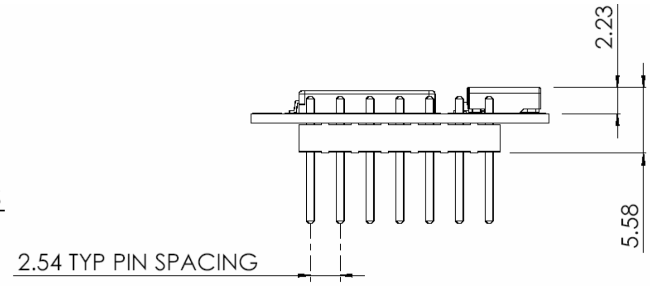
Note: The unit will need to be calibrated in the orientation used.

Digital Damping

When Digital Damping is enabled and a value (n = 1 to 20) for the damping range is selected the V2Xe will perform a simple average of the "n" number elements. The digital damping is only applied to the heading data. This is not a running average but instead an average of the most recent "n" number with the oldest being dropped in each successive heading calculation.

Package Information





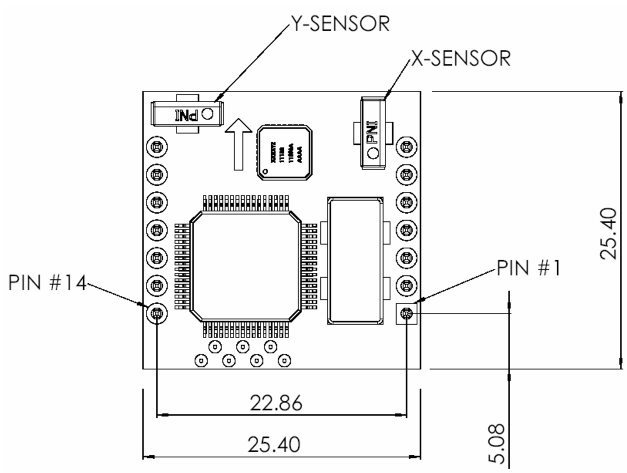
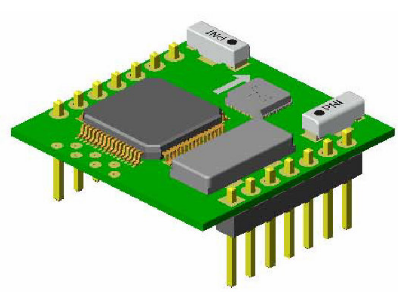


TABLE 1

PIN	FUNCTION
1	SCLK
2	MISO
3	MOSI
4	SSNOT
5	DRDY
6	SYNC
7	GND
8	N/C
9	N/C
10	N/C
11	N/C
12	VDD
13	N/C
14	GND



ISOMETRIC VIEW

NOTES: (UNLESS OTHERWISE SPECIFIED)
1. UNITS: ALL UNITS IN METRIC, MILLIMETERS.
2. TOLERANCES: $\pm$ 0.1
3. TABLE 1 PROVIDES ALL PINOUT DEFINITIONS.