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 3 V 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.

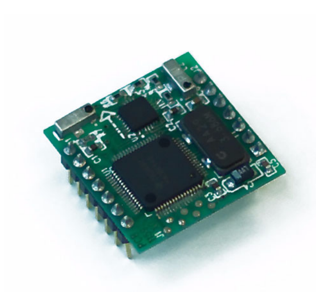
These advantages make PNI Corporation's V2Xe the choice for applications that require a solution that has a high degree of azimuth accuracy, requires little power, and has a small package size.

Features

- Low power: draws 2 mA at 3 VDC (continuous output)
- Small size: 25.4 x 25.4 x 11.55 mm
- High resolution compass heading: 0.01 °
- High accuracy compass heading: 2 °
- Non-volatile memory: retains calibration when power is removed
- Multiple measurement modes: compass heading or magnetic field
- Large field measurement range: ±1100 µT (±11 Gauss)
- High resolution field measurement: 0.015 µT (0.00015 Gauss)
- Fully digital interface: SPI protocol at 3V

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
- Security/tamper detection



Ordering Information

Name	Part Number	Package
V2Xe	11862	Each

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Specifications

CAUTION

Stresses beyond those listed under Table 1 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.

Table 1. Absolute Maximum Ratings

Symbol	Parameter	Minimum	Maximum
V_{DD}	DC supply voltage	–0.3 VDC	4.1 VDC
V_{IN}	Input pin voltage	V_{DD} – 0.3VDC	V_{DD} + 0.3VDC
I_{IN}	Input pin current	–2.0 mA	2.0 mA
T_{STRG}	Storage temperature	–40 °C	85 °C

Table 2. Module Characteristics

Parameter	Minimum	Maximum	Typical
Operating Characteristics			
Supply voltage			3.0 VDC
Idle current[a]			0.20 mA
Continuous current[b]			2.0 mA
SCLK frequency (V_{CC} = 3V)		3.6864 MHz	
Low-level input (V_{CC} = 3V)	V_{SS}	V_{SS} + 0.6 VDC	
High-level input (V_{CC} = 3V)	0.8 x V_{CC}	V_{CC}	
Low-level output (V_{CC} = 3V)	V_{SS}	V_{SS} + 0.25 VDC	
High-level output (V_{CC} = 3V)	V_{CC} – 0.25 VDC	V_{CC}	
Operating Temperature	–20 °C	70 °C	
Storage Temperature	–40 °C	85 °C	
Weight			3 grams

Table 2. Module Characteristics

Parameter	Minimum	Maximum	Typical
Magnetometer Mode Characteristics			
Field measurement range[c]	–1100 µT	1100 µT	
Gain[d]			31.24 count/µT
Resolution			1/gain
Linearity (error from best fit straight line at ±300 µT)		1%	0.6%
Sensor frequency (within free Earth's magnetic field)			175 kHz
Compass Mode Characteristics			
Accuracy[e]		2 ° RMS	1 ° RMS
Resolution			0.01 °

a. Measurement taken with no sensor activity.
b. Measurement taken during continuous polling of sensors.
c. Field measurement range is defined as the monotonic region of the output characteristic curve
d. 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 to 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.
e. Requires that built-in calibration be performed. In practical compass applications, a calibration is normally performed when the compass module is in the host system.

Protocol Specification for V2Xe SPI Communication Interface

The following section describes the data structure used and the commands needed to communicate with the V2Xe over its SPI interface.

Datagram Structure

Datagram for basic message.

Sync Flag 0xAA	Frame Type 0xXX	Terminator 0x00
byte 1	byte 2	byte 3

Datagram for message with data.

Sync Flag 0xAA	Frame Type 0xXX	Optional Data Field 0xXX, 0xXX ...	Terminator 0x00
byte 1	byte 2	byte 3 to byte n-1	byte n

For a command like `StartCal` (frame type 0x0A), the frame to send to the V2Xe would be 3 bytes as specified below.

Sync Flag 0xAA	Frame Type 0x0A	Terminator 0x00
byte 1	byte 2	byte 3

For a command like `SetDataComponents` (frame type 0x03), the frame to send to the V2Xe would be a variable length message depending on the amount of parameters. For example the command `SetDataComponents` with parameters Heading (component type 0x05) and Magnitude (component type 0x06) would look like:

Sync Flag 0xAA	Frame Type 0x03	Param Count 0x02	Param 1 0x05	Param 2 0x06	Terminator 0x00
byte 1	byte 2	byte 3	byte 4	byte 5	byte 6

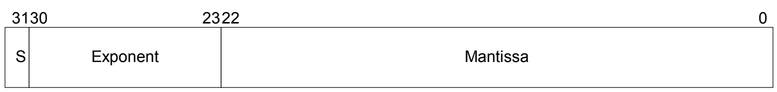
The nature of the SPI interface is such that the host receives the bytes synchronously while sending bytes. Therefore the V2Xe will send a byte containing 0x00 for every byte received. The V2Xe itself will ignore any bytes received while it is sending a response. When the host keeps clocking the SPI interface after the V2Xe has completed sending a response, the V2Xe will keep sending 0x00 for each byte clocked out. In effect the connection is made to act like a half duplex connection. The host sends a request and the V2Xe responds (if applicable).

The V2Xe has a built-in transmit response timeout. If the host sends a query command to the V2Xe, the host needs to clock in the response within 0.5 seconds. The V2Xe will flush the response after the 0.5-second timeout to accommodate new commands.

Parameter Formats

Floating Point (Float32)

The floating-point based parameters are in the IEEE standard format for 32 bit floats (ANSI/ IEEE Std 754-1985). Shown below is the float format in big endian, in little endian all 4 bytes are in reverse order (LSB first).



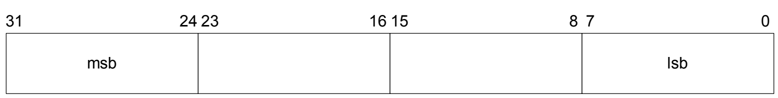
The value of the number is:

$$(-1)^s \times 2^{(Exponent - 127)} \times 1.Mantissa$$

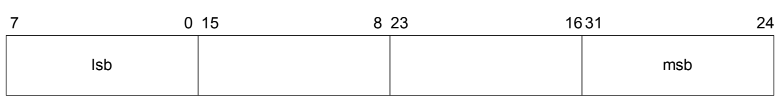
Zero is represented by 4 bytes of zeros.

Signed 32-bit Integer (SInt32)

SInt32 based parameters are signed 32 bit numbers (2's compliment). Bit 31 represents the sign of the value (0 = positive, 1 = negative)



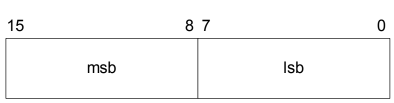
Big Endian



Little Endian

Signed 16-bit Integer (SInt16)

SInt16 based parameters are signed 16 bit numbers (2's compliment). Bit 15 represents the sign of the value (0 = positive, 1= negative)



Big Endian

7 0	15 8
lsb	msb

Little Endian

Signed 8-bit Integer (SInt8) SInt8 based parameters are signed 8-bit numbers. Bit 7 represents the sign of the value (0 = positive, 1= negative)

7 0
byte

Unsigned 32-bit Integer (UInt32) UInt32 based parameters are unsigned 32 bit numbers.

31 24	23 16	15 8	7 0
msb			lsb

Big Endian

7 0	15 8	23 16	31 24
lsb			msb

Little Endian

Unsigned 16-bit Integer (UInt16) UInt16 based parameters are unsigned 16 bit numbers.

15 8	7 0
msb	lsb

Big Endian

7 0	15 8
lsb	msb

Little Endian

Unsigned 8-bit Integer (UInt8) UInt8 based parameters are unsigned 8-bit numbers.

7 0
byte

Boolean Boolean is a 1-byte parameter that *must* have the value 0 (false) or 1 (true).

7   0
byte

FourCharCode

FourCharCode is a four-byte parameter.

7 0	7 0	7 0	7 0
ASCII Char 1	ASCII Char 2	ASCII Char 3	ASCII Char 4

Commands & Communication Frames

Module Type and Firmware Revision

GetModInfo (frame type 0x01)

Queries the V2Xe for module information. The response is a `ModInfoResp` frame. This command has no parameters.

ModInfoResp (frame type 0x02)

Is the response to command `GetModInfo`. The frame's data field contains a FourCharCode module type identifier followed by a FourCharCode firmware version number. See the example below.

Module Type	FourCharCode	For example 'V2Xe'
Firmware Version	FourCharCode	For example 'V201'

Data Output Components

SetDataComponents (frame type 0x03)

This command sets the data components to be sent back by the V2Xe after reception of a `GetData` command. When the V2Xe receives a `GetData` (frame type 0x04) command, it will respond with a `DataResp` (frame type 0x05) frame containing the data components requested with `SetDataComponents`. The data field of SetDataComponents should contain the number of components wanted followed by component identifiers. Possible components, their IDs and formats are specified in the table below.

	Component Count (n)	UInt8	Specifies the number of components
Component 1	Component Identifier (CID)	UInt8	Component Identifier
Component 2	Component Identifier (CID)	UInt8	Component Identifier
Component n	Component Identifier (CID)	UInt8	Component Identifier

For example, if the host wants to get a `DataResp` frame containing the components Heading (CID 0x05) and Magnitude (CID 0x06), the data fields for `SetDataComponents` would look like:

	0x02	UInt8	Component count
Component 1	0x05	UInt8	Heading identifier
Component 2	0x06	UInt8	Magnitude Identifier

Table 3. Components Identifiers

Component	CID	Format	Units	Range
XRaw	0x01	SInt32	counts	–32768 to 32767
YRaw	0x02	SInt32	counts	–32768 to 32767
XCal	0x03	Float32		scaled to 1.0
YCal	0x04	Float32		scaled to 1.0
Heading	0x05	Float32	degrees	0.0 ° to 359.9 °
Magnitude	0x06	Float32		scaled to 1.0
Temperature	0x07	Float32	° Celsius	
Distortion	0x08	Boolean	true or false	
CalStatus	0x09	Boolean	true or false	

XRaw & YRaw contain the raw sensor count as read from the ASIC registers.

XCal & YCal contain the calibrated X & Y components of the sample vector. Their values are the result after hard and soft iron corrections are applied. Their values are used to compute the actual heading.

Heading is the actual heading calculated from `XCal` & `YCal`. If mathematical error occurs or after calibration CalStatus is true, Heading will be equal to –1.0 to indicate an error.

Magnitude is calculated using the formula Magnitude = SQRT ($XCal^2 + YCal^2$). Its value is compared to the calibration magnitude to determine distortion.

Temperature is sampled from the internal temperature sensor of the V2Xe. Its value is in ° Celsius and has an accuracy of +/- 8%.

Distortion indicates if the magnitude of the vector used to calculate the heading when it is below 50% or above 150% of the calibration magnitude.

CalStatus indicates true if the V2Xe needs to be calibrated. This could be due to calibration errors or the fact that the unit has never been calibrated.

GetData (frame type 0x04)

Queries the V2Xe for data. In response the V2Xe will send `DataResp` with in its data fields the components as configured with `SetDataComponents`. This command has no parameters.

DataResp (frame type 0x05)

Is the response to the command `GetData` (frame type 0x04). In its data field it will contain the components as configured with `SetDataComponents`. The order of the components follows the order of component identifiers in the frame `SetDataComponents`.

	Component Count (n)	UInt8	The number of components in this frame
Component 1	Component Identifier (CID)	UInt8	Component Identifier
	Component value		The value format is specific to the preceeding Component identifier
Component 2	Component Identifier (CID)	UInt8	Component Identifier
	Component value		The value format is specific to the preceeding Component identifier
Component n	Component Identifier (CID)	UInt8	Component Identifier
	Component value		The value format is specific to the preceeding Component identifier

Example:

If frame `SetDataComponents` contained heading and magnitude identifiers, the first byte of the data field would contain the amount of components in a UInt8 followed by:

- the heading identifier (0x05),
- Float32 with its value,
- the magnitude identifier (0x06), and
- Float32 with its value.

	0x02	UInt8	The number of components in this frame
Component 1	0x05	UInt8	Heading Identifier
	Heading Value	Float32	Heading value
Component 2	0x06	UInt8	Magnitude Identifier
	Magnitude value	Float32	Magnitude value

Configure Module

SetConfig (frame type 0x06)

Sets internal configuration parameters in the V2Xe. The V2Xe uses configuration parameters during calibration and normal operation. These parameters must be set appropriately prior to calibration or data component acquisition. The data field of the `SetConfig` frame contains a parameter identifier followed by more parameter-specific data.

Configuration Parameter ID	UInt8	
value		The value format will be specific to the preceeding Parameter Identifier

Example:

To configure the declination, the data field of the `SetConfig` frame would contain a parameter ID of `Declination` (ID 0x01) and a Float32 for the declination value.

0x01	UInt8	Declination Identifier
Declination value	Float32	Declination value

Table 4. Configuration Parameter Identifiers

Settings	Parameter ID	Format	Units/Range	Default Values
Declination	0x01	Float32	degrees (–180 ° to 180 °)	0 °
TrueNorth	0x02	Boolean	true or false	false
CalSampleFreq	0x03	UInt8	1 to 8 (Hz)	8
SampleFreq	0x04	UInt8	0 to 8 (Hz)	0
Period	0x05	UInt8	1 to 8	5
BigEndian	0x06	Boolean	true or false	true
DampingSize	0x07	UInt8	1 to 8	1

Declination sets the declination angle to determine True North heading. Positive declination is easterly declination and negative is westerly declination. This is not applied until TrueNorth is set to true.

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 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. 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`

TrueNorth sets the heading reference to True North or Magnetic North. If the value is set to true then declination is applied to get True North heading.

CalSampleFreq is the sampling frequency during calibration.

SampleFreq is the sampling frequency when damping is enabled. If this is greater than 0 Hz the last calculated heading is returned when a heading query command is receive from the host. If SampleFreq is set to 0 Hz raw, X and Y counts are sampled and a query is received to calculate the heading.

Period is the ASIC period. Valid values are shown in Table 5:

Table 5. Valid ASIC Period Values

Value	Period
1	/32
2	/64
3	/128
4	/256
5	/512
6	/1024
7	/2048
8	/4096

BigEndian (Boolean) indicates the endianism of multi-byte parameters (Float32, UInt32, SInt32). If set true, all parameters communicated to and from the V2Xe are assumed to be big endian, if false they are assumed to be little endian.

DampingSize indicates the number of heading samples that is averaged and returned as the heading. When Digital Damping is enabled and a value (n = 1 to 8) 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.

GetConfig (frame type 0x07)

Queries the V2Xe for configuration information. This data field of this frame contains a parameter identifier. The V2Xe responds with the frame `ConfigResp` (frame type 0x08).

Configuration Parameter ID	UInt8	Configuration Identifier

ConfigResp (frame type 0x08)

Is the response to the frame `GetConfig`. The data field contains a parameter identifier followed by a parameter-specific type variable containing the value of the parameter.

Configuration Parameter ID	UInt8	Configuration Parameter Identifier
value		The value format is specific to the preceeding Configuration Parameter Identifier

Example:

A response to a `GetConfig:Declination` command, would contain the following structure in its data field.

0x01	UInt8	Declination Identifier
Declination value	Float32	Declination value

Save Command

SaveConfig (frame type 0x09)

Saves V2Xe configuration parameters in non-volatile memory. This command has no parameters. Also saves SetDataComponents settings and calibration information

Calibration Commands

V2Xe Compass Calibration

Calibration is the process used with PNI sensor technology to separate the earth's magnetic field from magnetic field distortions created by the environment into which the sensors are mounted. By implementing a simple calibration routine with the sensors in a fixed position within the host system, the maximum and minimum strength fields can be determined and then used to correct the sensor output for the distortions present. A calibration should be performed under the following conditions:

- when the V2Xe is first installed into a host system.
- when the V2Xe is moved.
- when the V2Xe indicates that it is in need of a calibration.

Follow the steps below to perform a calibration.

1 Place the unit to be calibrated into the host system.

2 Set the V2Xe to its intended operating position in as level of a position as possible.

3 Sent the `StartCal` (frame type 0x0A) command.

4 Rotate the unit through two 360 degree circles while maintaining a level position. The rotations should be no faster than 30 seconds each to achieve the highest possible accuracy.

5 Sent the `StopCal` (frame type 0x0B) command.

6 Send the `SaveConfig` (frame type 0x09) command to save the calibration information to the V2Xe.

StartCal
(frame type 0x0A)

Starts the V2Xe calibration. The calibration sampling frequency is set in `SetConfig:CalSampleFreq` frame. To query raw X & Y counts during calibration, make sure to send `SetDataComponents` with XRaw & YRaw as requested data components prior to calibration and then send `GetData` at a proper interval to get calibration output. This command has no parameters.

StopCal
(frame type 0x0B)

Completes the V2Xe calibration when the calibration data is ready for use to calculate heading. However, calibration data is not saved until the V2Xe receives the `SaveConfig` command. This command has no parameters.

GetCalData
(frame type 0x0C)

Queries the V2Xe for its calibration data. The V2Xe will respond with the frame `CalDataResp`. This command has no parameters.

CalDataResp
(frame type 0x0D)

Is the response to `GetCalData`. The structure looks like:

Byte Count	UInt8	Calibration data structure length (24 bytes for the V2Xe)
X Offset	SInt32	X Offset value
Y Offset	SInt32	Y Offset value
X Gain	SInt32	X Gain value
Y Gain	SInt32	Y Gain value
Phi	Float32	Phi value
Calibration Magnitude	Float32	Calibration magnitude value

SetCalData
(frame type 0x0E)

Stores previously saved calibration data into the V2Xe. This will overwrite the current calibration data in the V2Xe. The data fields of this frame MUST contain the same structure as mentioned under `CalDataResp`. The normal calibration process is to send `StartCal/StopCal` command-pair instead of using `SetCalData`. Under normal circumstances, `SetCalData` is not to be used.

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 five signals; SCLK, MOSI, MISO, SSNOT (required), and SYNC (optional).

Table 6. Pin Descriptions

Pin	Name	Function
1	SCLK	Serial clock input for SPI port
2	MISO	Master In, Slave Out for the Module SPI port
3	MOSI	Master Out, Slave In for the Module SPI port
4	SSNOT	Slave Select for the Module SPI port. SSNOT must remain low until the command response is clocked out.
5	GIO4	Reserved I/O
6	SYNC	The SYNC line is not needed except in cases where the V2Xe gets out of synchronization with the host; a rising edge on the VX2e SYNC line will reset the V2Xe's SPI and communication buffers. Synchronization problems mostly occur during power up when I/O ports and hardware are being initialized. This may cause glitches in the clock line and might be interpreted by the V2Xe as clock cycles. The SYNC line is totally asynchronous with respect to the SPI so proper care in its implementation is highly recommended.
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	3V regulated supply voltage
13	-------	Not connected
14	GND	Ground

SPI Hardware Protocol

The V2Xe is a slave SPI device. The host must supply the required eight clock pulses to transfer a byte to and from the V2Xe. In addition a "Slave Select" (SS) line must be held low prior to any transmission.

The V2Xe assumes the clock polarity to be zero (CPOL=0) which means the clock idles low. The clocking phase is shown in the diagram below.

The V2Xe samples the "Master-Out-Slave-In" (MOSI) line during the rising edge of the clock and on the falling edge of the clock, the "Master-In-Slave-Out" (MISO) will have the next valid bit value.

The V2Xe communicates in half duplex mode. When the V2Xe is in receive mode (waiting for valid bytes), it will transmit a zero-byte (0x00) while receiving bytes. During transmission (response frames), the V2Xe will ignore the MOSI line but it is recommended that the host transmit zero-bytes while receiving.

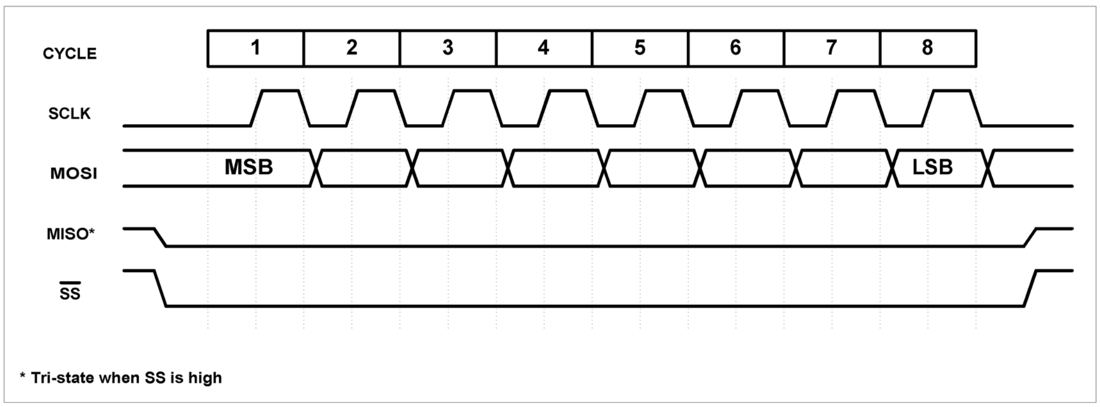


Figure 1. Transfer from Host to V2Xe

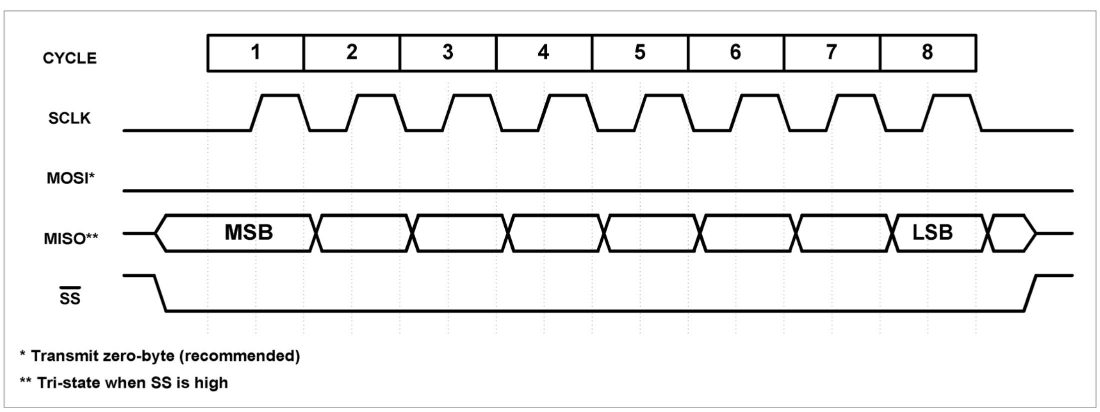


Figure 2. Transfer from V2Xe to Host

Package Information

Refer to Table 6 on page 2-17 for pin descriptions.

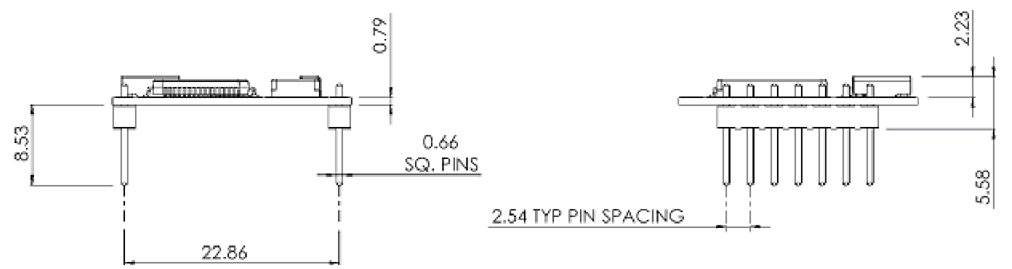


Figure 3. Side Views

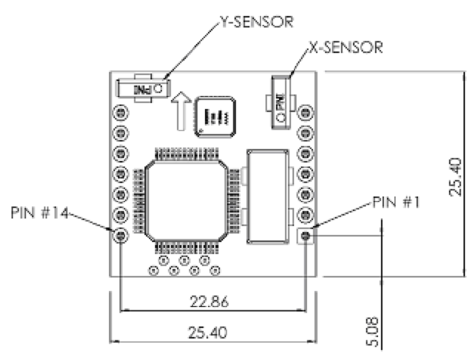


Figure 4. Top View

Pin	Name
1	SCLK
2	MISO
3	MOSI
4	SSNOT
5	GIO4
6	SYNC
7	GND
8	GIO0
9	GIO1
10	GIO2
11	GIO3
12	VDD
13	-------
14	GND

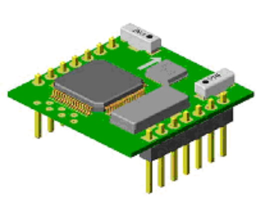


Figure 5. Isometric View