

User Manual

CompassPoint V2Xe

Electronic 2-Axis Compass Module



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1 Copyright & Warranty Information

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2 Introduction

Thank you for purchasing PNI Sensor Corporation's CompassPoint V2Xe (pn 11862). This RoHS-compliant, low-power-consumption, 2-axis compass module, provides all-digital compass heading outputs accurate to 1°. The V2Xe provides low power consumption, a small footprint, large signal noise immunity under all conditions, and a large magnetic field dynamic range. And measurement data is very stable over temperature and inherently free from offset drift.

The CompassPoint V2Xe allows designers to bypass the time and expense required to build a 2-axis digital compass from scratch. Features include:

- an onboard microprocessor for true plug-and-play compassing and magnetic field sensing,
- a SPI interface,
- 3 V operation,
- software configurable resolution and field measurement range,
- the ability to calibrate the device to account for local magnetic fields, and
- non-volatile memory that retains calibration data after being powered down.

These advantages make the CompassPoint V2Xe the choice for compassing applications that require a high degree of azimuth accuracy, low power consumption, and/or a small package size.

The V2Xe has proven itself in a variety of applications, including

- seismic monitoring,
- range finding and binocular systems,
- wind direction sensing, and
- robotic navigation.

3 Specifications

3.1 Performance Specifications

Table 3-1: Absolute Maximum Ratings

Parameter	Minimum	Maximum	Units
DC Supply Voltage (V_{DD})	-0.3	4.1	VDC
Input Pin Voltage (V_{IN})	$V_{DD} - 0.3$	$V_{DD} + 0.3$	VDC
Input Pin Current (I_{IN})	-2.0	+2.0	mA
Storage Temperature	-40	+85	C

CAUTION:

Stresses beyond those listed above may cause permanent damage to the device. These are stress ratings only. Assuming operation with the 3D MagIC ASIC per the guidelines in this manual, these maximum ratings will not be violated.

Table 3-2: Module Characteristics¹

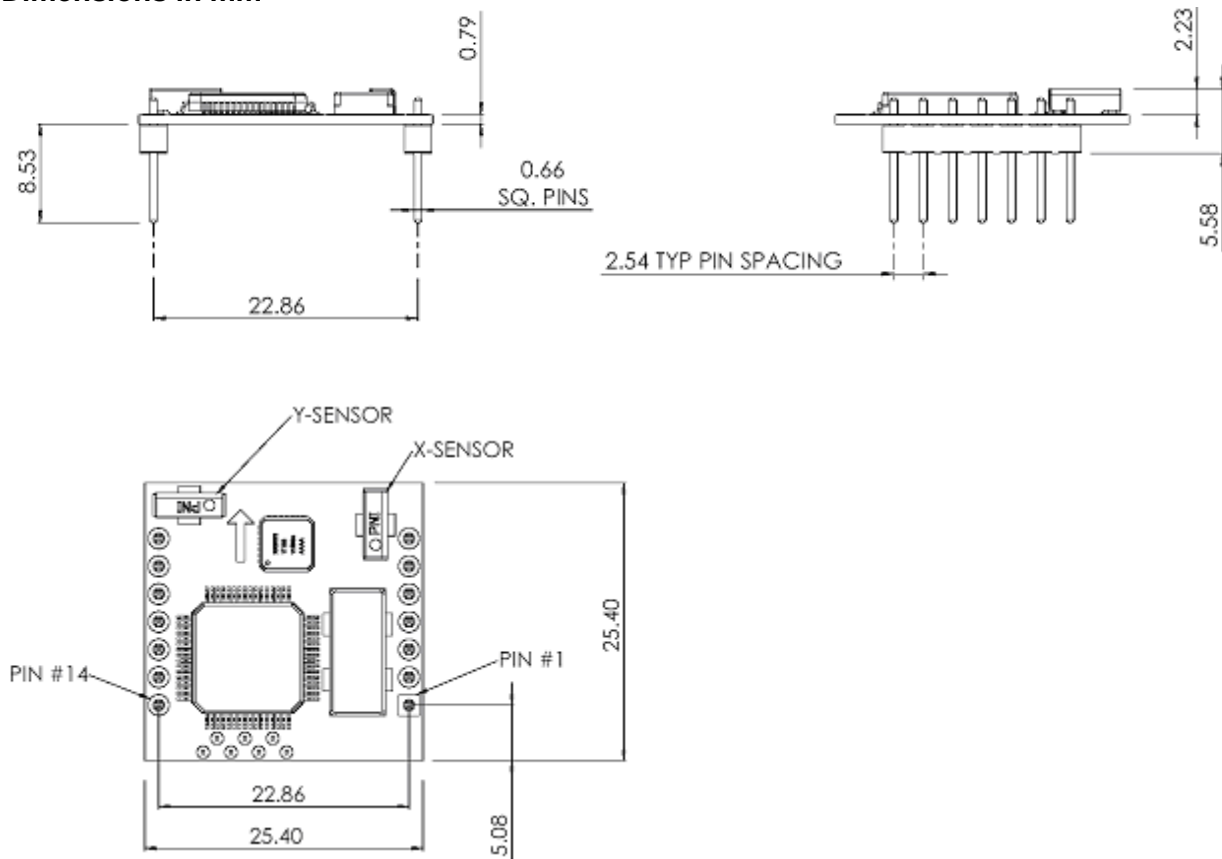
Parameter	Minimum	Maximum	Typical	
Supply Voltage (V_{DD})			3.0 VDC	
Idle Current ²			0.2 mA	
Continuous Current ³			2.0 mA	
SCLK frequency		3.6864 MHz		
Low-level input	GND	GND + 0.6 VDC		
High-level input	$0.8 \times V_{DD}$	V_{DD}		
Low-level output	GND	GND + 0.25 VDC		
High-level output	$V_{DD} - 0.25$ VDC	V_{DD}		
Operating Temperature	-20 °C	70 °C		
Storage Temperature	-40 °C	85 °C		
Weight			3 gm	
Magnetometer Mode Characteristics	Field Measurement Range ⁴	-1100 μ T	+1100 μ T	
	Gain ⁵			32 counts/ μ T
	Resolution ⁶			1/gain
	Linearity		1%	0.6%
	Sensor Frequency			175 kHz
Compass Mode Characteristics	Accuracy ⁷		2° rms	1° rms
	Resolution			0.01°

Footnotes:

1. Characteristics are subject to change. Values assume supply voltage of 3 VDC.
2. Measurement taken with no sensor activity
3. Measurement taken during continuous polling of sensors
4. Field measurement range is defined as the monotonic region of the output characteristic curve
5. 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 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.
6. Resolution is $1/\text{gain}$ to the noise limit.
7. Requires that a field calibration be performed. In practical compass applications, a calibration is normally performed when the compass module is in the host system.

3.2 Package Information

Dimensions in mm



The default orientation is for the silk-screened arrow to point in the “forward” direction.

Figure 3-1: Mechanical Drawing

4 Set-Up

4.1 Electrical Connections

The V2Xe incorporates two 7-pin SIP connectors. The pin-out is given below in Table 4-1, where pin #1 and pin #14 are defined in the mechanical drawing (Figure 3-1).

Table 4-1: Pin Descriptions

Pin #	Pin Name	Description
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	SSN	Slave Select for the V2Xe's SPI port. SSN must remain low until the command response is clocked out.
5	GIO4	Reserved I/O. Do not connect.
6	SYNC	The SYNC line is not needed except in cases where the V2Xe gets out of synchronization with the host. Synchronization issues primarily occur during power-up when I/O and hardware are initialized. This may cause glitches in the clock line, which can be interpreted by the V2Xe as clock cycles. A rising edge on the V2Xe SYNC line resets the V2Xe's SPI and communication buffers. The SYNC line is asynchronous with respect to the SPI, so proper care in its implementation is mandatory. Contact PNI if you are experiencing synchronization issues.
7	GND	Ground
8	GIO0	Reserved I/O. Do not connect.
9	GIO1	Reserved I/O. Do not connect.
10	GIO2	Reserved I/O. Do not connect.
11	GIO3	Reserved I/O. Do not connect.
12	V _{DD}	3V regulated supply voltage
13	---	Not connected
14	GND	Ground

After making the electrical connections, it is a good idea to perform some simple tests to ensure the V2Xe is working as expected. See Section 5 for how to operate the V2Xe using the V2Xe binary protocol.

4.2 Mechanical Installation

4.2.1 Mounting Orientation

The V2Xe should be mounted horizontally and as level as possible. The arrow on the top of the board should point in the direction of travel or line of sight.

4.2.2 Locate away from changing magnetic fields

It is not possible to calibrate for changing magnetic anomalies. Thus, for greatest accuracy, keep the V2Xe away from sources of local magnetic distortion that will change with time; such as electrical equipment that will be turned on and off, or ferrous bodies that will move. Make sure the V2Xe is not mounted close to cargo or payload areas that may be loaded with large sources of local magnetic fields.

4.2.3 Location-verification testing

Location-verification testing should be performed at an early stage of development to understand and accommodate the magnetic distortion contributors in a host system. Place the compass in a fixed position, then move or energize suspect components while observing the output to determine when they are an influence.

4.3 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” (SSN) 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, where CHPA = 0.

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.

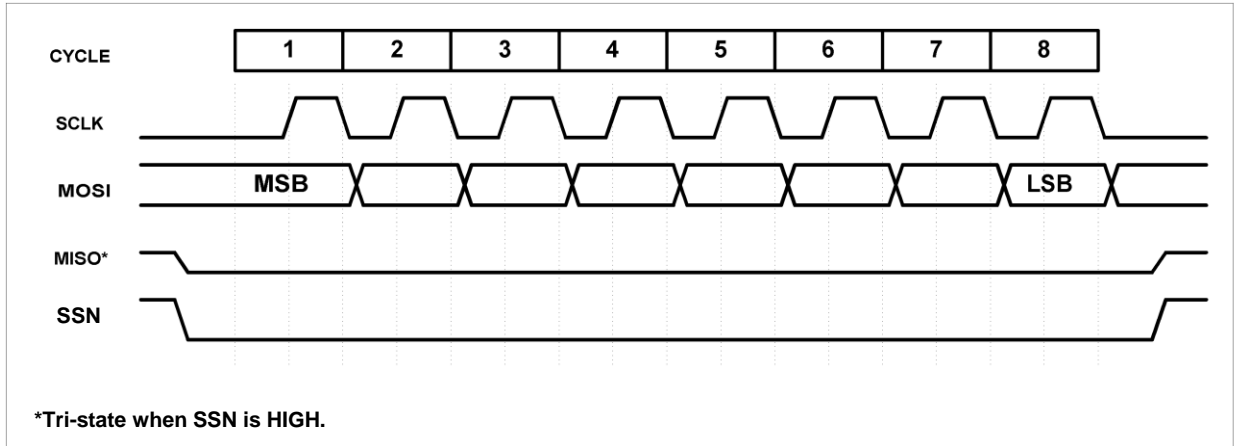


Figure 4-1: Transfer from Host to V2Xe

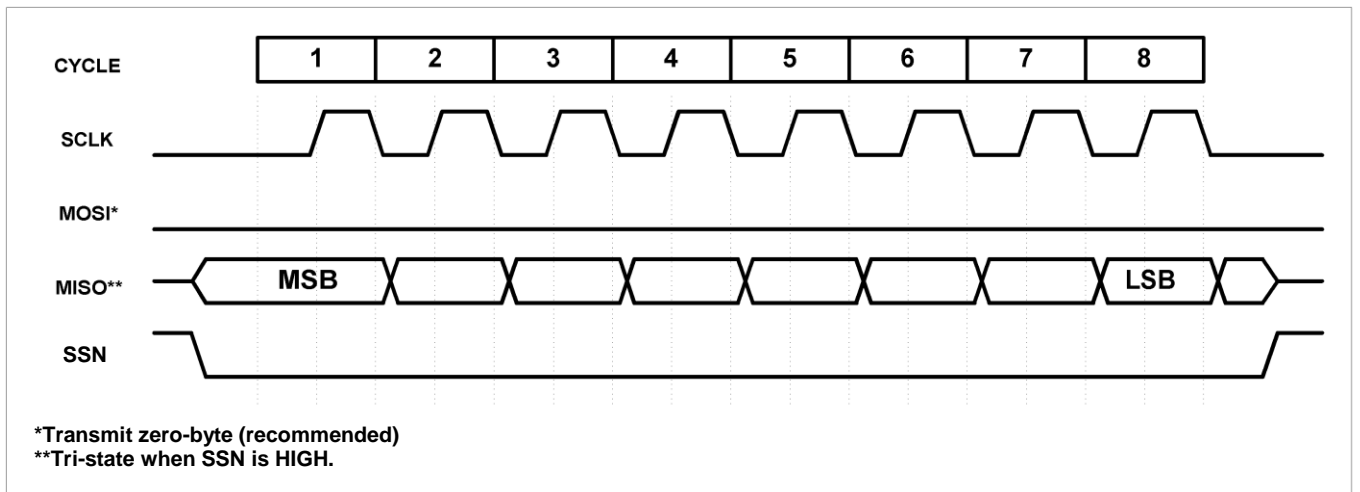


Figure 4-2: Transfer from V2Xe to Host

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.

5 Operation with V2Xe Protocol

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

5.1 Datagram Structure

The datagram structure for a basic message is given below:

Sync Flag 0xAA	Frame Type 0xFF	Terminator 0x00
Byte 1	Byte 2	Byte 3

Example: the command for kStartCal would be as specified below.

Sync Flag 0xAA	Frame Type 0x0A	Terminator 0x00
Byte 1	Byte 2 (kStartCal)	Byte 3

The datagram for a message with data is given below. This is a variable length message depending on the number of parameters.

Sync Flag 0xAA	Frame Type 0xFF	Optional Data Field 0xFF, 0xFF,...	Terminator 0x00
Byte 1	Byte 2	Byte 3	Byte 4

Example: the command for kSetDataComponents with parameters kHeading and kMagnitude is specified below.

Sync Flag 0xAA	Frame Type 0x03	Param Count 0x02	Param 1 0x05	Param 2 0x06	Terminator 0x00
Byte 1	Byte 2 (kSetData Components)	Byte 3	Byte 4 (kHeading)	Byte 5 (kMagnitude)	Byte 6

5.2 Parameter Formats

Note: Floating-point based parameters conform to ANSI/IEEE Std 754-1985. Please refer to the Standard for more information. PNI also recommends the user refer to the compiler's instructions to understand how the compiler implements floating-point format.

32 Bit Floating Point (Float32)

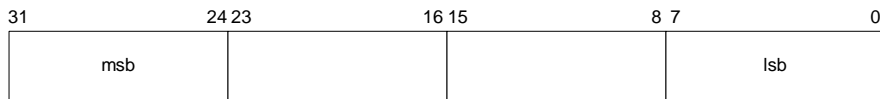
Shown below is the 32 bit float format in big Endian. In little Endian format, the 4 bytes are in reverse order (LSB first).



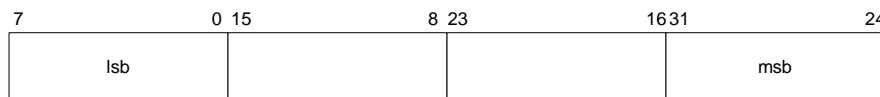
The value (v) is determined as, if and only if $0 < \text{Exponent} < 255$: $v = (-1)^S * 2^{(\text{Exponent}-127)} * 1.\text{Mantissa}$. Zero is represented by 4 bytes of zeros.

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)



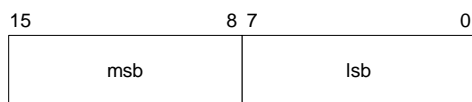
Big Endian



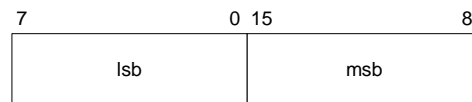
Little Endian

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)



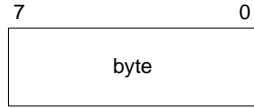
Big Endian



Little Endian

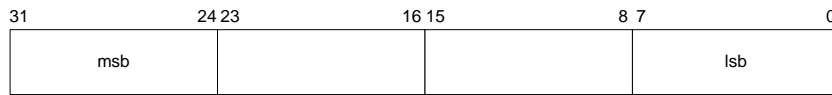
Signed 8 Bit Integer (SInt8)

UInt8-based parameters are unsigned 8-bit numbers. Bit 7 represents the sign of the value (0=positive, 1=negative)

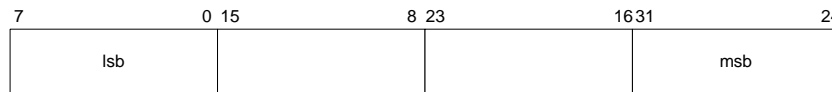


Unsigned 32 Bit Integer (UInt32)

UInt32-based parameters are unsigned 32 bit numbers.



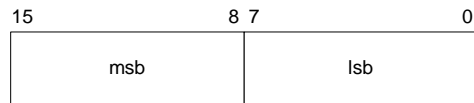
Big Endian



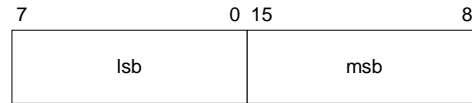
Little Endian

Unsigned 16 Bit Integer (UInt16)

UInt16-based parameters are unsigned 16 bit numbers.



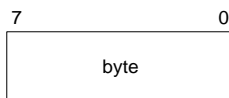
Big Endian



Little Endian

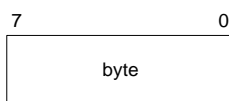
Unsigned 8 Bit Integer (UInt8)

UInt8-based parameters are unsigned 8-bit numbers.



Boolean

Boolean is a 1-byte parameter that MUST have the value 0 (FALSE) or 1 (TRUE).



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	

5.3 Commands & Communication Frames

Table 5-1: V2Xe Command Set

Frame ID	Command	Description
<u>Set Up</u>		
0x01	kGetModInfo	Queries the device's type and firmware revision.
0x02	kGetModInfoResp	Response to kGetModInfo
0x06	kSetConfig	Sets internal configurations in V2Xe
0x07	kGetConfig	Queries V2Xe for the current internal configuration
0x08	kGetConfigResp	Response to kGetConfig
0x09	kSave	Saves the current internal configuration and any new user calibration coefficients to non-volatile memory.
<u>Calibration</u>		
0x0A	kStartCal	Commands the V2Xe to start user calibration
0x0B	kStopCal	Commands the V2Xe to stop user calibration
0x0C	kGetCalData	Queries for the calibration coefficients
0x0D	kGetCalDataResp	Provides the calibration coefficients
0x0E	kSetCalData	Allows the user to write the calibration coefficients.
<u>Operation</u>		
0x03	kSetDataComponents	Sets the data components to be output.
0x04	kGetData	Queries the V2Xe for data
0x05	kGetDataResp	Response to kGetData

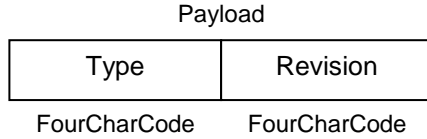
5.4 Module Set-Up

kGetModInfo (frame ID 0x01)

This frame queries the device's type and firmware revision number. The frame has no payload.

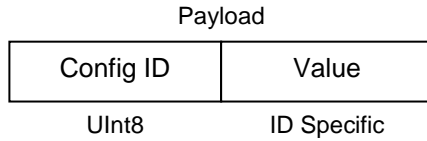
kGetModInfoResp (frame ID 0x02)

The response to kGetModInfo is given below. The payload contains the device type identifier followed by the firmware revision number.



kSetConfig (frame ID 0x06)

This frame sets internal configurations in the V2Xe. The first byte of the payload is the configuration ID followed by a format-specific value. These configurations can only be set one at a time. To save these in non-volatile memory, the kSave command must be issued.



Example: To configure the declination, the payload would look like:

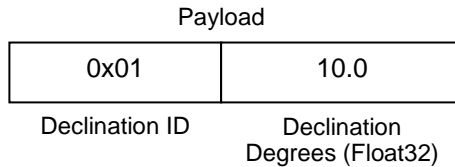


Table 5-2: Configuration Identifiers

Parameter	Config. ID	Format	Values / Range	Default
kDeclination	0x01	Float32	-180° to +180°	0
kTrueNorth	0x02	Boolean	True or False	False
kCalSampleFreq	0x03	UInt8	1 to 8 (Hz)	8
kSampleFreq	0x04	UInt8	0 to 8 (Hz)	0
kPeriod	0x05	UInt8	1 to 8	5
kBigEndian	0x06	Boolean	True or False	True
kDampingSize	0x07	UInt8	1 to 8	1

Configuration parameters and settings for kSetConfig:

kDeclination (Config. ID 0x01)

This sets the declination angle to determine True North heading. Positive declination is easterly declination and negative is westerly declination. This is not applied unless kTrueNorth is set to TRUE.

kTrueNorth (Config. ID 0x02)

Flag to set compass heading output to true north heading by adding the declination angle to the magnetic north heading.

kCalSampleFreq (Config. ID 0x03)

This sets the sampling frequency during calibration.

kSampleFreq (Config. ID 0x04)

This sets the sampling frequency when damping is enabled. If this is greater than 0 Hz, then the last calculated heading is returned when a heading query command is received from the host. If kSampleFreq is set to 0 Hz, then X and Y counts are sampled and the heading calculated after a query is received.

kPeriod (Config. ID 0x05)

This sets the period or number of sensor circuit oscillation cycles (cycle counts) to be counted while simultaneously using the internal fixed reference clock to measure the time to obtain this count, as defined in Table 5-3.

Table 5-3: ASIC Period Values

Period Select Value	Cycle Counts (1/Period)
1	32
2	64
3	128
4	256
5	512 (default)
6	1024
7	2048
8	4096

kBigEndian (Config. ID 0x06)

Sets the Endianness of packets. TRUE is Big Endian. FALSE is Little Endian.

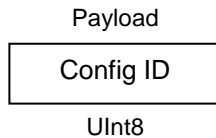
kDampingSize (Config. ID 0x07)

kDampingSize indicates the number of heading samples to be averaged, and then returned as the heading reading. When 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. 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.

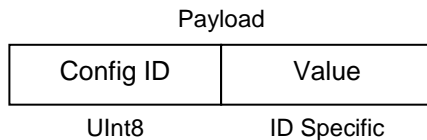
kGetConfig (frame ID 0x07)

This frame queries the TCM for the current internal configuration value. The payload contains the configuration ID requested.

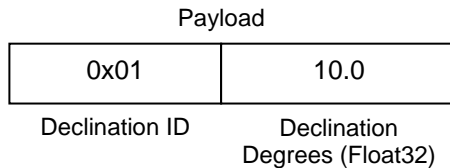


kGetConfigResp (frame ID 0x08)

The response to kGetConfig is given below. The payload contains the configuration ID and value.



Example: The payload for a request to get the declination angle would look like:



kSave (frame ID 0x09)

This frame commands the V2Xe to save internal configurations and user calibration to non-volatile memory. Internal configurations and user calibration are restored on power up. The frame has no payload. This is the ONLY command that causes the device to save information to non-volatile memory.

5.5 Calibration

Sources of magnetic distortion permanently positioned near the V2Xe in the user’s system will distort Earth’s magnetic field and should be compensated for with a user calibration. Examples of such sources include ferrous metals and alloys (ex. iron, nickel, steel, etc.), batteries, audio speakers, current-carrying wires, and electric motors. It is expected the sources of magnetic distortion remain fixed relative to the V2Xe’s position within the host system.

By performing a calibration, the V2Xe identifies local sources of distortion and negates their effects from the overall reading to provide an accurate heading. For more on magnetic distortion and calibration, see PNI’s white paper “Local Magnetic Distortion Effects on 3-Axis Compassing” at PNI’s website (<http://www.pnicorp.com/technology/papers>).

Follow the steps below to perform a calibration:

- Mount the V2Xe in the host system in its operating position and as level as possible.
- Set the period select value (kPeriod) to 4 or higher using kSetConfig.
- Send the kStartCal command.
- Rotate the unit through two 360° circles while maintaining a level position. The rotations should be no faster than 30 seconds each.
- Send the kStopCal command.
- Send the kSaveConfig command to save the calibration data to the V2Xe.

When the V2Xe modules is not calibrated, or the calibration did not allow for valid samples, the reported heading will be -1.00 degree.

kStartCal (frame ID 0x0A)

This frame commands the module to start a user field calibration. The calibration sampling frequency is set with the kCalSampleFreq identifier in the kSetConfig command. To query raw X & Y counts during calibration, make sure to send kSetDataComponents with XRaw & YRaw as requested data components prior to calibration and then send kGetData at a proper interval to get calibration output. This command has no parameters.

kStopCal (frame ID 0x0B)

This command stops the V2Xe calibration process, and the calibration coefficients are calculated. However, the calibration data is not saved until the V2Xe receives the kSaveConfig command. This command has no parameters.

kGetCalData (frame ID 0x0C)

This command queries the V2Xe for its calibration data. The V2Xe will respond with the frame kCalDataResp. The command has no parameters.

kCalDataResp (frame ID 0x0D)

kCalDataResp is the response to kGetCalData. It contains the calibration data. The structure looks like:

Payload						
Byte Count	X Offset	X Offset	X Gain	Y Gain	Phi	Cal Magnitude
UInt8	SInt32	SInt32	SInt32	SInt32	Float32	Float32

kSetCalData (frame ID 0x0E)

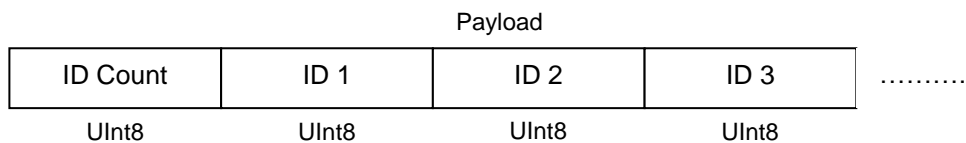
This frame writes calibration data into the V2Xe using the same frame structure as kCalDataResp. This is an optional command and is not used for most applications. However, it allows the user to store multiple sets of calibration coefficients on the host system, and write them into the V2Xe when appropriate. For example, if the host system has a motor that sometimes is off and sometimes on, then one set of calibration coefficients can be generated and stored in the host system for when the motor is on, and a second set for when the motor is off. The first set of calibration coefficients would be written to the V2Xe whenever taking a reading with the motor on, and the second set whenever the motor is off.

5.6 Making Measurements

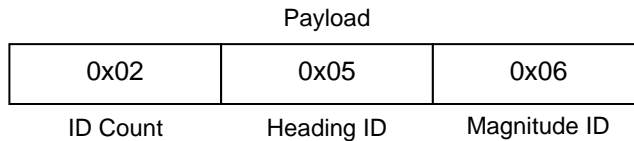
To make a measurement, it is first necessary to establish what data is to be output by sending the kSetDataComponents frame. The kGetData command is sent to initiate a measurement, and the response will be the kGetDataResp frame which will contain the measured data, as established by kSetDataComponents.

kSetDataComponents (frame ID 0x03)

This frame defines what data is output when kGetData is sent. Table 5-4 summarizes the various data components and more detail follows this table. The first byte of the payload indicates the number of data components followed by the data component IDs.



Example: To query for heading and magnitude, the payload should contain:



Note that the sequence of the data components defined by kSetDataComponents will match the output sequence of kGetDataResp.

Table 5-4: Component Identifiers

Component	Component ID	Format	Units
kXRaw	0x01	SInt32	counts
kYRaw	0x02	SInt32	counts
kXCal	0x03	Float32	scaled to 1.0
kYCal	0x04	Float32	scaled to 1.0
kHeading	0x05	Float32	degrees
kMagnitude	0x06	Float32	scaled to 1.0
kTemperature	0x07	Float32	°C
kDistortion	0x08	Boolean	True or False
kCalStatus	0x09	Boolean	True or False

Component types are listed below. All are read-only values.

kXRaw & kYRaw (Component IDs 1_d & 2_d)

These values are the raw sensor counts as read from the ASIC registers.

kXCal & kYCal (Component IDs 3_d & 4_d)

These are the X and Y components of the magnetic vector after the calibration coefficients have been applied to the raw values. Their values are used to calculate the heading.

kHeading (Component ID 5_d)

Provides compass heading calculated from kXCal and kYCal, where the heading range is 0.0° to +359.9. kHeading will equal -1.00 if kCalStatus is True.

kMagnitude (Component ID 0x06)

The value is calculated using the formula $Magnitude = \sqrt{XCal^2 + YCal^2}$. Its value is compared to the calibration magnitude to determine distortion.

kTemperature (Component ID 0x07)

The V2Xe's internal temperature sensor provides the temperature value, in °C.

kDistortion (Component ID 0x08)

This flag indicates if the magnitude of the vector used to calculate the heading is below 50% or above 150% of the calibration magnitude.

kCalStatus (Component ID 0x09)

This flag indicates the user calibration status. True means it is not user calibrated and this is the default value.

kGetData (frame ID 0x04)

This frame queries the V2Xe for data. The frame has no payload. The response is kGetDataResp.

After a request for data is sent, a time delay is required for processing and sampling. The time delay required is relative to the period select value being used and is also influenced by the strength of field being measured. With a period select value of 8 (/4096), a delay of approximately 50 msec is required. The delay proportionately decreases with decreasing period select value.

The kGetData sequence should be:

- Send kGetData.
- Delay.
- Push 1 byte out of V2Xe module.
- Test the response byte for 0xAA (Sync Flag). If True, push data out. If False, loop on delay.

kGetDataResp (frame ID 0x05)

The response to kGetData is kGetDataResp. The specific data fields that will be output (ID 1, Value ID 1, etc.) should have been previously established by the kSetDataComponents command frame. The sequence of the output data components will match that set by kSetDataComponents.

Payload						
ID Count	ID 1	Value ID 1	ID 2	Value ID 2	ID 3	Value ID 3
UInt8	UInt8	ID Specific	UInt8	ID Specific	UInt8	ID Specific

Example: If heading and magnitude are set to be output per the kSetDataComponents command, the payload would look like:

Payload				
0x02	0x05	359.9	0x06	0.50
ID Count	Heading ID	Heading Value (Float32)	Magnitude ID	Magnitude Value (Float32)