User Manual

Prime Pro

Digital Magnetic Compass

PNI

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1 Copyright & Warranty Information

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2   Introduction

Introducing Prime Pro, a new digital magnetic compass that's half the size and twice as robust as our standard Prime DMC. It delivers field-accurate heading, pitch and roll data, even where GPS is compromised or unavailable – with 1º of accuracy.

New Prime Pro is extremely robust, uses exceptionally low power, and is pinpoint accurate over time. It's ideal for use in devices working underwater, underground, beneath bridges, or in densely urban situations, alone or as a supplement to GPS.

Thank you for selecting the Prime Pro.
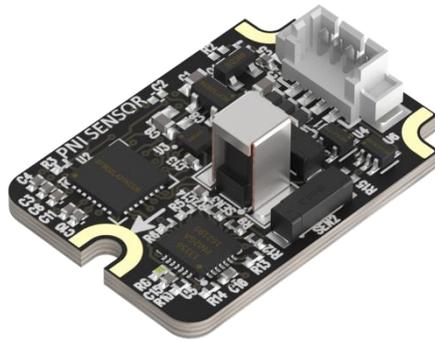
Figure 2-1: Prime Pro

3   Specifications

3.1   Characteristics & Requirements

Table 3-1: Performance Specifications[1,3]

Parameter				Value
Compass Mode	Heading	Static Accuracy[2]		1.0° rms
		Resolution		0.01°
		Repeatability		0.05° rms
	Tilt	Range	Pitch	± 90°
			Roll	± 180°
		Static Accuracy[2]		0.6° rms
		Resolution		0.01°
		Repeatability		0.05° rms
Magnetometer Range				± 150 µT
Accelerometer Range				± 1.0 g

Footnotes:
1. Specifications are typical unless otherwise noted, and subject to change.
2. Assumes that the Prime Pro is motionless; that the local magnetic field is clean relative to user calibration; that the magnetic dip angle is <= 65° that the pitch angle is ≤ 50°; and that a Full-Range calibration has been performed.
3. To meet performance specifications, the module must be operated over a temperature range of –10C to 50C. A magnetometer user calibration should be performed if the temperature changes by more than +-10C.

Table 3-2: Absolute Maximum Ratings

Parameter	Minimum	Maximum	Units
Supply Voltage	-0.3	+6	VDC
Input Voltage (Rx)	-0.5	+7	VDC
Storage Temperature	-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 3-3: Electrical Requirements

Parameter		Conditions	Value
V_{IN}	Supply Voltage		2.9 to 5.5 VDC [1]
I_{IN}	Supply Current	Maximum Output Rate	9.5 mA typical
		Typical Current Draw Profile	See Figure 3-1
		Sleep Mode	0.38 mA typical
I_{OH}	High-level output current (Tx)	V_{IN} = 3.3 V	-7mA max
		V_{IN} = 5 V	-8mA max
I_{OL}	Low-level output current (Tx)	V_{IN} = 3.3 V	7mA max
		V_{IN} = 5 V	8mA max
V_{IH}	High-level input voltage (Rx)	V_{IN} = 3 V to 3.3 V	1.39 V min
		V_{IN} = 3.6 V	1.48 V min
		V_{IN} = 4.5 V to 5 V	2.03 V min
		V_{IN} = 5.5 V	2.11 V min
V_{IL}	Low-level input voltage (Rx)	V_{IN} = 3 V to 3.6 V	0.65 V Max
		V_{IN} = 4.5 V to 5.5 V	0.8 V Max
V_{OH}	High-level output voltage (Tx)	V_{IN} = 2.9 V to 5.5V I_{OH} = -20uA	V_{IN} - 0.1V min
		V_{IN} = 3 V I_{OH} = -3mA	2.7 V min
		V_{IN} = 3 V I_{OH} = -5.5mA	2.49 V min [2]
		V_{IN} = 3.3 V, I_{OH} = -5.5mA	2.8 V min
		V_{IN} = 4.5 V, I_{OH} = -4mA	4.1V min
		V_{IN} = 4.5 V, I_{OH} = -8mA	3.95V min
		V_{IN} = 5 V, I_{OH} = -8mA	4.5 V min
V_{OL}	Low-level output voltage (Tx)	V_{IN} = 2.9 V to 5.5V I_{OH} = 20uA	0.1V max
		V_{IN} = 3 V, I_{OH} = 3mA	0.15 V max
		V_{IN} = 3 V, I_{OH} = 3mA	0.252 V max
		V_{IN} = 4.5 V, I_{OH} = 3mA	0.2 V max
		V_{IN} = 4.5 V, I_{OH} = 3mA	0.35 V max

Footnotes:

(1) *TTL-compliant logic levels guaranteed for V_{IN} = 3.0V to 5.5V with R_X load ≤ 3mA or V_{IN} = 3.3V to 5.5V with loads ≤ 8mA. CMOS-compliance is guaranteed the entire V_{IN} voltage range.*

(2) *High load currents at low V_{IN} voltages may prevent device from producing TTL-compliant voltages.*
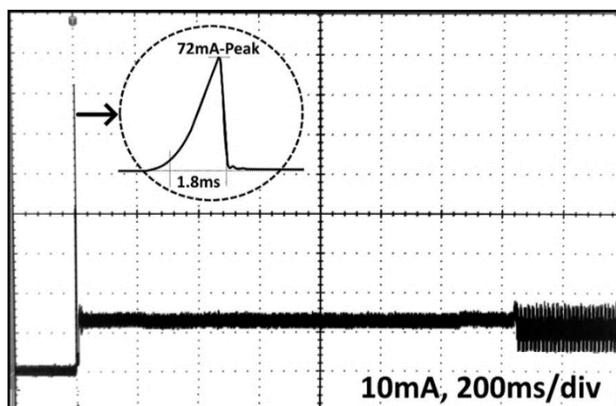
Figure 3-1: Typical Current Drawing During Application of External Power

Table 3-4: I/O Characteristics

Parameter	Value
Communication Interface	TTL/CMOS serial UART
Communication Protocol	PNI Binary
Communication Rate[1]	2400 to 921,600 baud
Maximum Data Output Rate	50 samples/sec

Footnote:
1. The Prime Pro can operate up to 921,600 baud, but native TTL is limited to 115,200 baud.

Table 3-5: Environmental Requirements

Parameter	Value
Operating Temperature	-20C to +70C
Storage Temperature	-40C to +85C

Table 3-6: Mechanical Characteristics

Parameter	Value
Dimensions (l x w x h)	29.3 x 21.3 x 10.1 mm
Weight	2.4 gm
Connector	4-pin Molex, part number 0533980410 Mating Molex connector part number 051020400

Table 3-7: ESD Ratings

		Value	Unit
V(ESD) Electrostatic Discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	2000	V
	Charged device model (CDM), per JEDEC specification JESD22-C101[2]	1000	
	Machine Model (A115-A)	200	

Footnote:

(1) *JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.*

(2) *JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.*

3.2 Mechanical Drawings
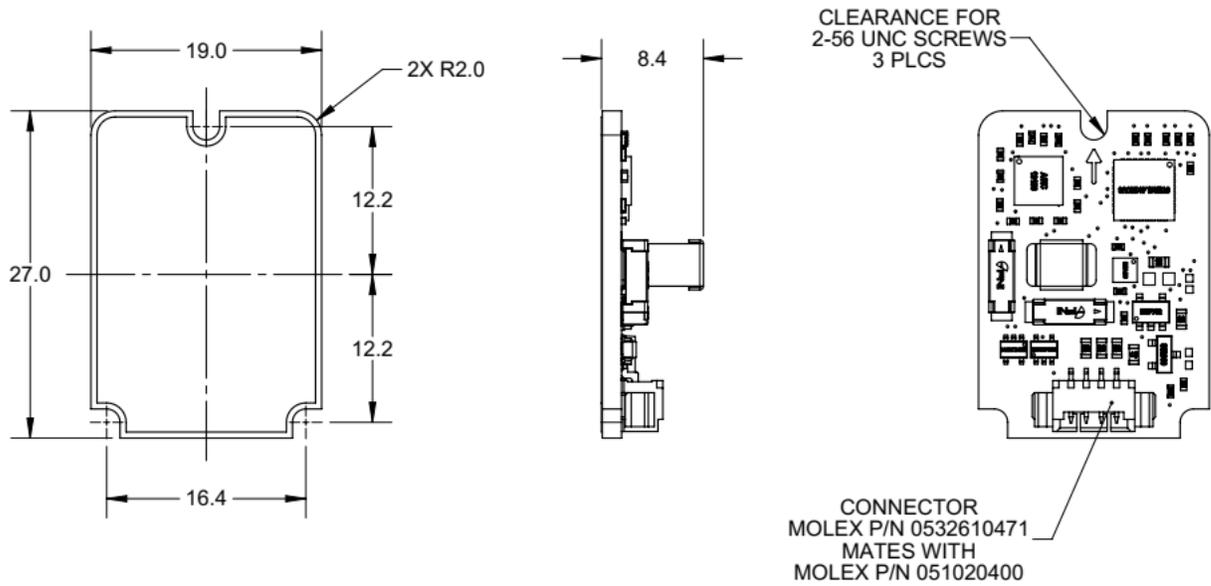
Figure 3-2: Prime Pro Mechanical Drawing
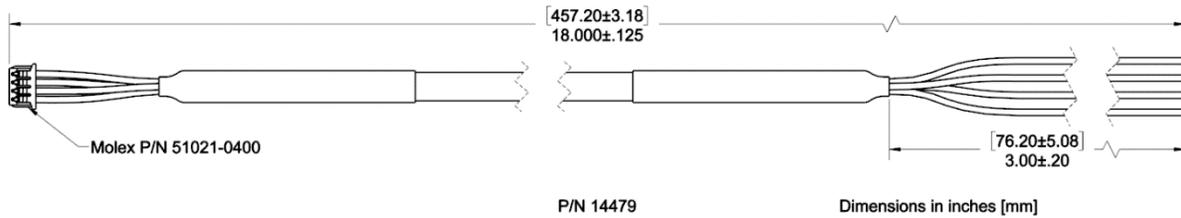
Figure 3-3: Molex-to-Pigtail Cable Drawing, pn 14479

Note: Alternatively, an unjacketed cable is available from Molex Part Numbers 218112040X, where X = 0 thorugh 3
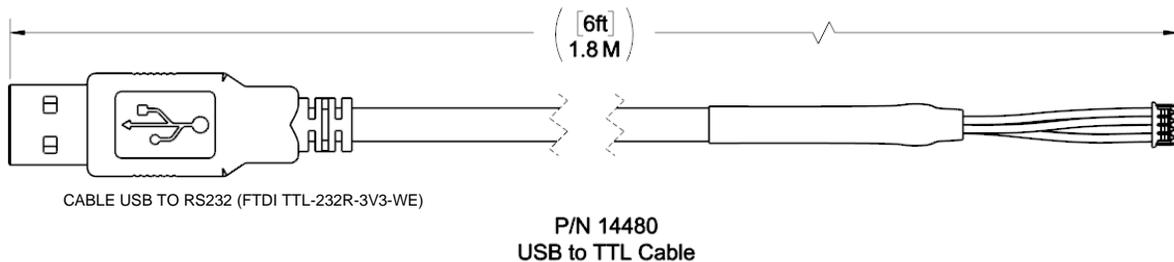
Figure 3-4: Molex-to-USB Cable Drawing, pn 14480

4   Set-Up and Evaluation

This section describes how to configure the Prime Pro in your host system. To install the Prime Pro into your system, follow these steps:

- Make electrical connections to the Prime Pro.
- Evaluate the Prime Pro using the PNI Studio program, or a binary terminal emulation program, such as RealTerm or Tera Term, to ensure the Prime Pro is working properly.
- Choose a mounting location.
- Mechanically mount the Prime Pro in the host system.
- Perform a user calibration.

4.1   Electrical Connections

The Prime Pro incorporates a 4 pin Molex connector, part number 53047-0410, which mates with Molex part 51021-0410 or equivalent. The pin-out for both is given below in Table 4-1.

Table 4-1: Prime Pro Pin Descriptions

Pin #[1]	Prime Pro		
	4 Pin Molex Connector	USB Demo Cable Wire Color	Pigtailed Cable
1	Ground	Black	Black
2	+2.9-5.5V Power	Red	Red
3	TTL UART Tx	Green	Green
4	TTL UART Rx	White	White

Footnote:

1. Pin #1 is the left most position of the connector as indicated on Figure 3-2

After making the electrical connections, it is a good idea to perform some simple tests to ensure the Prime Pro is working as expected. See Section 6 for how to operate the Prime Pro with PNI Studio or Section 7 for how to operate the Prime Pro using PNI's binary protocol.

4.2   Installation Location

The Prime Pro's wide dynamic range and sophisticated algorithms allow it to operate in many environments. For optimal performance however, you should mount the Prime Pro with the following considerations in mind:

4.2.1   Operate within the Prime Pro's dynamic range

The Prime Pro can be user calibrated to correct for static magnetic fields created by the host system. However, each axis of the Prime Pro has a calibrated dynamic range of ±150 µT. If the total field exceeds this value for any axis, the Prime Pro may not perform to specification. When mounting the Prime Pro, consider the effect of any sources of magnetic fields in the host environment that, when added to Earth's field, may take the Prime Pro out of its dynamic range. For example, large masses of ferrous metals such as transformers and vehicle chassis, large electric currents, permanent magnets, and electric motors.

4.2.2   Locate away from changing magnetic fields

Keep the Prime Pro away from sources of local magnetic distortion that will knowingly change with time, such as electrical equipment that will be turned on and off, or ferrous bodies that will move.

4.2.3   Mount in a physically stable location

Choose a location that is isolated from persistent vibration or other dynamic motion. Accurate measurement of gravity vector is required for accurate heading, but vibration and acceleration will induce errors in the gravity measurement by the accelerometer sensor on the Prime Pro. Mounting should minimize mechanical stress on the device.

4.2.4   Choose Non-magnetic Mounting Screws

Use non-magnetic mounting screws. There are 3 mounting holes in Prime Pro. Brass, copper or aluminum screws should be used to secure it in place to eliminate close proximity magnetic distortion from the fasteners.

4.2.5   Keep Proper Distance

Keeping good distance from known magnetic interference, such as batteries, magnets and ferrous objects, can reduce magnetic distortion significantly. Magnetic fields diminish mathematically as $1/(distance^3)$.

4.3   Mechanical Mounting

The Prime Pro must be aligned within the host system with respect to these mounting holes. Ensure any stand-offs or screws used to mount the Prime Pro are non-magnetic. Refer to Section 0 for dimensions, hole locations, and the reference frame orientation.

4.3.1   Pitch and Roll Convention

The Prime Pro utilizes 3-2-1 Euler angles as the primary method for providing orientation data, although quaternions outputs also are available. The Euler angles are the common method used for aircraft orientation, where the outputs are heading, pitch and roll. When using Euler angles in aviation, roll is defined as the angle rotated around an axis through the center of the fuselage, while pitch is rotation around an axis through the center of the wings. These rotations are dependent on each other since the axes of rotation move with the plane.

As shown in Figure 4-1, for the Prime Pro a positive pitch is when the front edge of the board is rotated upward, and a positive roll is when the right edge of the board is rotated downward. The order of rotation is given as heading, pitch, and then roll.
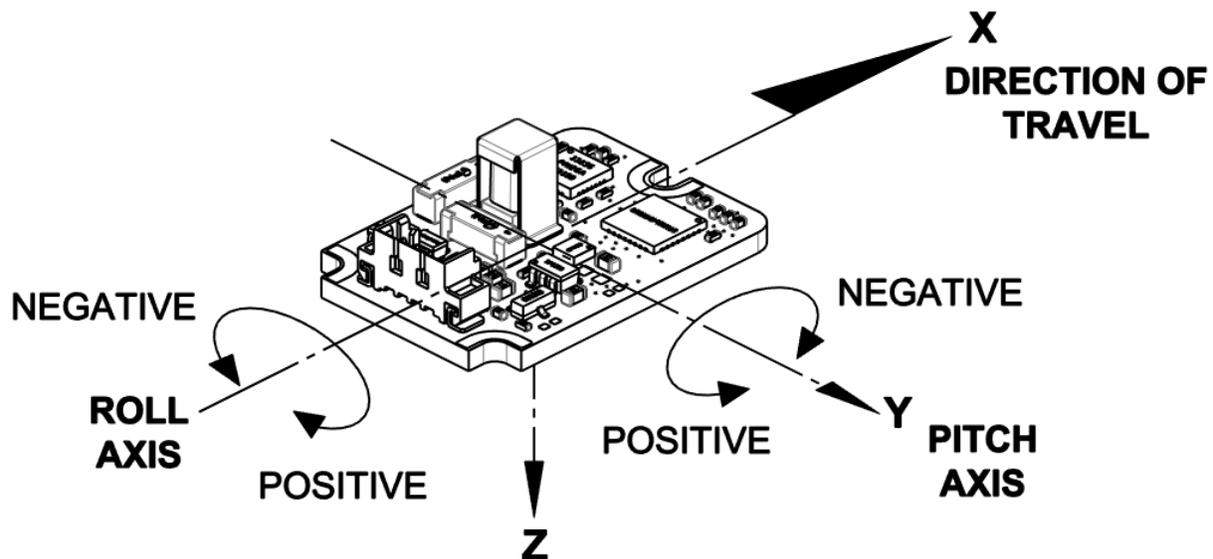
Figure 4-1: Positive & Negative Roll and Pitch Definition

4.3.2　Coordinate System

The Prime Pro utilizes North East Down (NED) coordinate system (frame) to define X, Y and Z axes as shown in Figure 4-1.

4.3.3　Mounting Orientation

The Prime Pro can be mounted in 16 different orientations, as shown in Figure 4-2. All reference points are based on the default orientation shown in Figure 4-1. The orientation should be programmed in the Prime Pro using the Configuration Tab in PNI Studio or using the kSetConfig command and the kMountingRef setting in the PNI Protocol, as described in Section 7.4.2. The default orientation is "STD 0°".
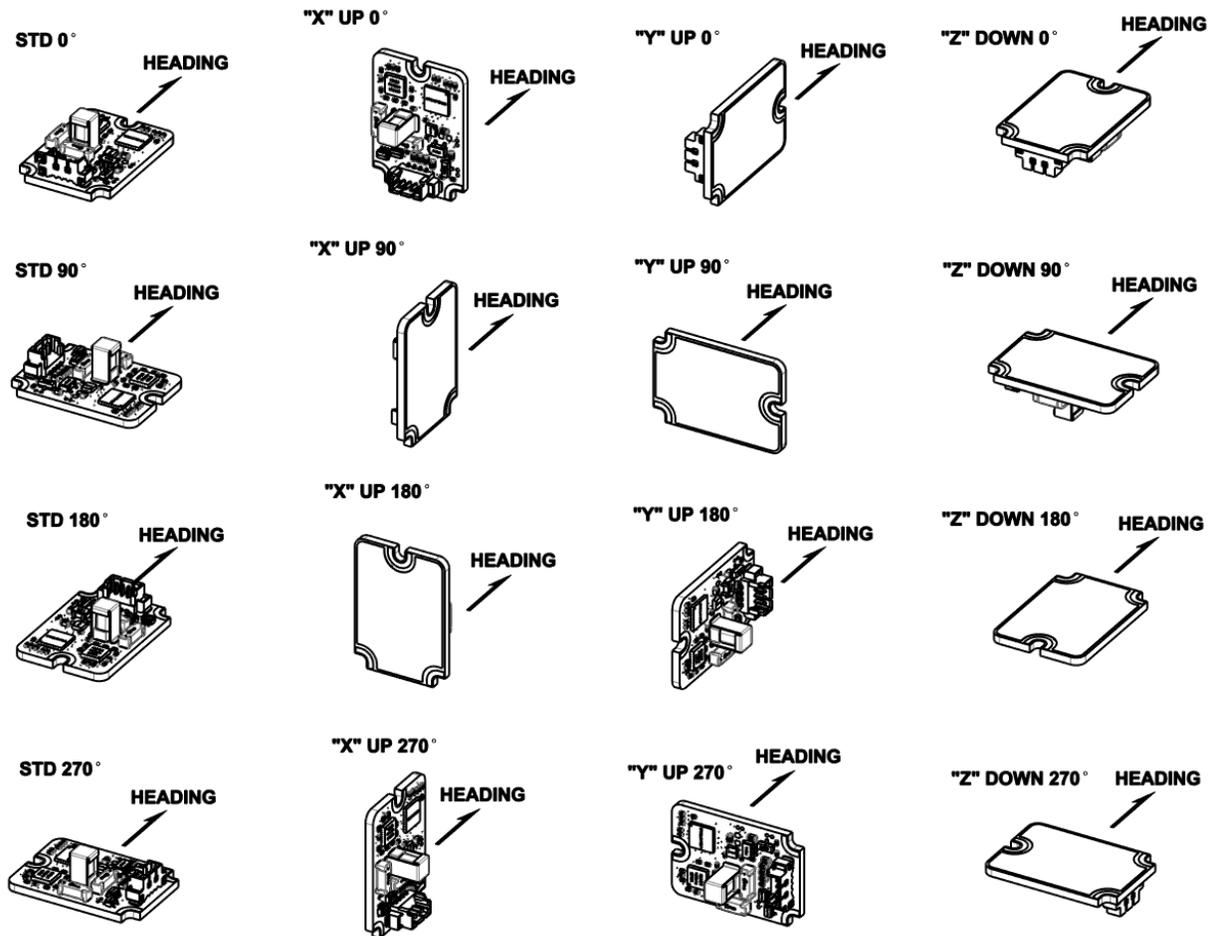
Figure 4-2:　Prime Pro Enclosed Mounting Orientations

5   User Calibration

The magnetic sensor in the Prime Pro is calibrated at PNI's factory in a magnetically controlled environment. However, sources of magnetic distortion positioned near the Prime Pro in the user's system will distort Earth's magnetic field and must be compensated for in the host system with a user calibration. Examples of such sources include ferrous metals and alloys (e.g., iron, nickel, steel, etc.), batteries, audio speakers, current-carrying wires, and electric motors. Compensation is accomplished by mounting the Prime Pro in the host system and performing a user calibration. It is expected that the magnetic distortion sources will remain fixed, relative to the Prime Pro's position within the host system. By performing a calibration, the Prime Pro identifies the local sources of magnetic distortion and negates their effects from the overall reading to provide an accurate heading.

Key Points:

- Magnetic calibration:
  - Requires incorporating the Prime Pro into the user's host system such that the magnetic components of the user's system can be compensated for.
  - Allows for 4 different methods of calibration. Full-Range Calibration provides the highest heading accuracy but requires ≥30° of pitch. 2D and Limited-Tilt Calibration allow for good calibration when the range of allowable motion is limited. Hard-Iron-Only Calibration updates the hard-iron compensation coefficients with a relatively easy procedure.
- If the Prime Pro will experience different states during operation, such as operating with a nearby shutter sometimes closed and sometimes open, or operating over a broad temperature range, then different sets of calibration coefficients can be saved for the various states. Up to 8 magnetic calibration coefficient sets can be saved.

As with the magnetic sensor, the accelerometer in the Prime Pro is calibrated at PNI's factory. If for any reason the accelerometer needs to be checked or calibrated, please refer to the accelerometer calibration section below.

5.1   Magnetic Calibration

Two fundamental types of magnetic distortion exist: hard-iron and soft-iron. These are discussed in the following paragraphs, plus a discussion on how temperature also affects magnetic fields and other considerations. For more information 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).

Hard-Iron Effects

Hard-iron distortions are caused by permanent magnets and magnetized objects in close proximity to the sensors. These distortions add or subtract a fixed component to each axis of the magnetic field reading. Hard-iron distortions usually are unchanging and in a constant location relative to the sensors, for all heading orientations.

Soft-Iron Effects

Magnetically "soft" materials effectively bend the magnetic field near them. These materials have a high magnetic permeability, meaning they easily serve as a path for magnetic field lines. Unlike hard-iron effects, soft-iron effects do not increase or decrease the total field in the area. However, the effect of the soft-iron distortion changes as the host system's orientation changes. Because of this, it is more difficult to compensate for soft-iron materials.

Temperature Effects

While the hard-iron and soft-iron distortion of a system may remain quite stable over time, normally the distortion signature will change over temperature. As a general rule, the hard-iron component will change 1% per 10°C temperature change. Exactly how this affects heading depends on several factors, most notably the hard-iron component of the system and the inclination, or dip angle.

Consider the example of a host system with a 100 µT hard-iron component. This is a fairly large hard-iron component, but not completely uncommon. A 10°C temperature change will alter the magnetic field by ~1 µT in the direction of the hard-iron component. Around San Francisco, with an inclination of ~60°, this results in up to a couple of degrees of heading change over 10°C.

Consequently, no matter how stable a compass is over temperature, it is wise to recalibrate after significant temperature change since the magnetic signature of the host system will change with temperature. The Prime Pro helps accommodate this issue by allowing the user to save up to 8 sets of magnetic calibration coefficient sets, so different calibration coefficients can be generated and loaded at different temperatures.

Other Considerations

Prime Pro can store up to 8 different sets of magnetic calibration coefficients, hence if the system magnetic signature will change in different known unique states, perform a user calibration in these unique states and save each of the calibration coefficients. The unique calibration coefficients can be recalled when the system is operated in that specific state again.

The main objective of a magnetic user calibration is to compensate for hard-iron and soft-iron distortions to the magnetic field caused by components within the user's host system. To that end, the Prime Pro needs to be mounted within the host system and the entire host system needs to be moved as a single unit during a user calibration. The Prime Pro allows the user to perform a calibration only in a 2D plane or with limited tilt but provides the greatest accuracy if the user can rotate through 360° of heading and at least ±30°of tilt.

The following subsections provide instructions for performing a magnetic calibration of a Prime Pro system. Several calibration mode options exist, as summarized in Table 5-1. To meet the accuracy specification, the number of samples should be the "Minimum Recommended" value, or greater. Calibration may be performed using PNI Studio or using the PNI binary protocol, and up to 8 sets of magnetic calibration coefficients may be saved. The recommended calibration patterns described in the following sub-sections provide a good distribution of sample points.

Table 5-1: Magnetic Calibration Mode Summary

Calibration Mode	Static Accuracy in Compass Mode	Pitch Range during Cal	Minimum Recommended # of Samples [1]
Full-Range	0.25° rms	>±30°	12
2D Calibration	<2°	<±5°	12
Limited-Tilt	<2° over 2x tilt range	±5° to ±30°	12
Hard-Iron-Only	Restores prior accuracy	>±30°	4

Footnote:

1. Maximum number of sample points is 32 in Prime Pro.

Before proceeding with a calibration, ensure the Prime Pro is properly installed in the host system. The device should be installed as discussed in Section 4, and the software should be properly configured with respect to the mounting orientation, Endianness, north reference, etc.

Section 6.5 outlines how to perform a calibration using Prime Pro Studio, while Section 7.6.2 provides a step-by-step example of how to perform a calibration using the PNI protocol.

5.1.1   Full-Range Calibration

A Full-Range Calibration is appropriate when the system with the Prime Pro installed can be tilted ±30° or more. This method compensates for hard and soft-iron effects in three dimensions and allows for the highest accuracy readings. The recommended 12-point calibration pattern is a series of 2 circles of evenly spaced points, as illustrated Figure 5-1

as the realistic view and listed in Table 5-2 and Table 5-3. The pitch used in the two circles of the calibration should at least match the maximum and minimum pitch the device is expected to encounter in use.

Table 5-2: 12 Point Full-Range Calibration Pattern (Two Circles)

Sample #[4]	Heading[1]	Pitch[2]	Roll[3]
First Circle			
1	0°	≥ +30°	Any
2	60°	≥ +30°	Any
3	120°	≥ +30°	Any
4	180°	≥ +30°	Any
5	240°	≥ +30°	Any
6	300°	≥ +30°	Any
Second Circle			
7	0°	≤ -30°	Any
8	60°	≤ -30°	Any
9	120°	≤ -30°	Any
10	180°	≤ -30°	Any
11	240°	≤ -30°	Any
12	300°	≤ -30°	Any

Table 5-3: 12 Point Full-Range Calibration Pattern (One Circle)

Sample #[4]	Heading[1]	Pitch[2]	Roll[3]
1	0°	≥ +30°	Any
2	0°	≤ -30°	Any
3	60°	≥ +30°	Any
4	60°	≤ -30°	Any
5	120°	≥ +30°	Any
6	120°	≤ -30°	Any
7	180°	≥ +30°	Any
8	180°	≤ -30°	Any
9	240°	≥ +30°	Any
10	240°	≤ -30°	Any
11	300°	≥ +30°	Any
12	300°	≤ -30°	Any

Footnote:

1. Heading and Tilt listings are not absolute heading directions, but rather relative heading referenced to the first sample.

2. Pitch 30° or more is recommended; acceptable range is between ±10° to ±60°.

3. Roll is not required.

4. Both the One Circle and Two Circle patterns are the same since the sequence order of sample points is not required. The 12 points can be sampled in any order.
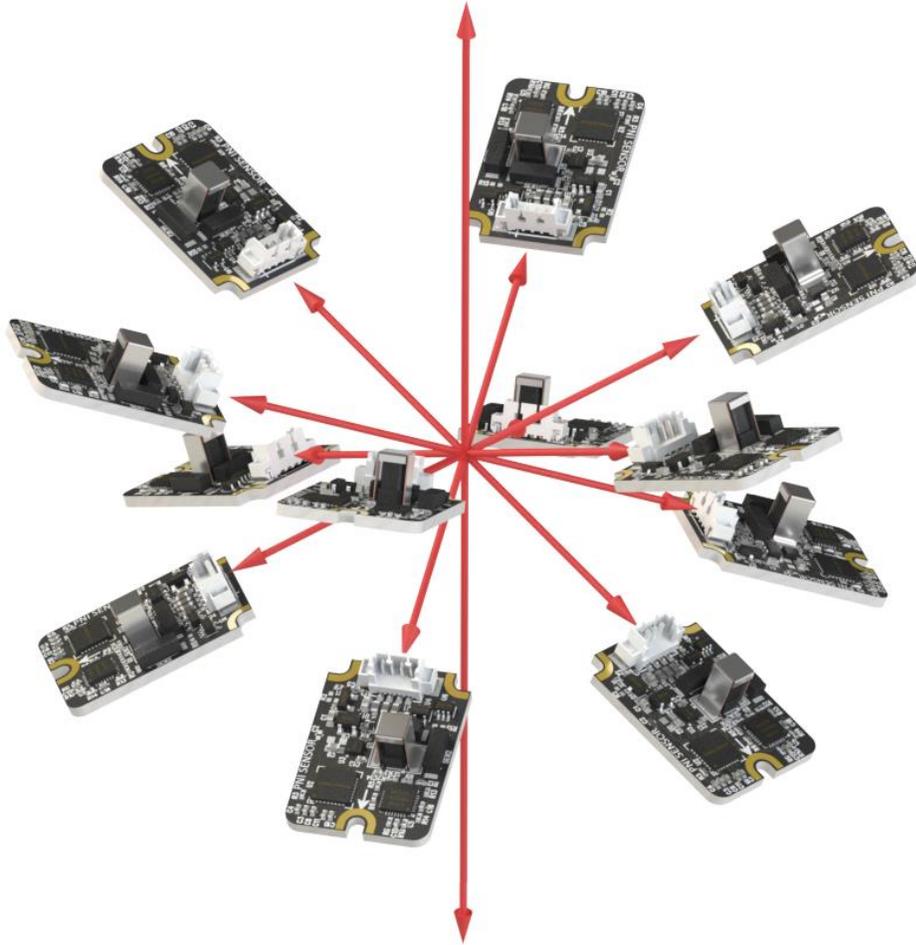
Figure 5-1: 12 Point Full-Range Calibration (Realistic View)

Notes

- *The location of the device changing in realist view is for illustration purpose. If possible, it is best to rotate around the center of the device as a pivot point.*

5.1.2   2D Calibration

A 2D Calibration is intended for applications with very low tilt operation, (<5°) and where calibrating the Prime Pro with greater tilt is not practical.

This procedure calibrates for hard and soft-iron effects in only two dimensions, and in general is effective for operation and calibration in the tilt range of -5° to +5°. The recommended 12-point calibration pattern is a circle of evenly spaced points, as given in Table 5-4.

Table 5-4: 12 Point 2D Calibration Pattern

Sample #	Heading[1]	Pitch[2,3]	Roll[3]
1	0°	0°	0°
2	30°	max. negative	0°
3	60°	0°	0°
4	90°	max. positive	0°
5	120°	0°	0°
6	150°	max. negative	0°
7	180°	0°	0°
8	210°	max. positive	0°
9	240°	0°	0°
10	270°	max. negative	0°
11	300°	0°	0°
12	330°	max. positive	0°

Footnote:

1. Heading and Tilt listings are not absolute heading directions, but rather relative heading referenced to the first sample.

2. For best results, the pitch experienced during calibration should match that of the expected pitch experienced when the module is in service.

3. If the device frame has a fixed tilt, the 2D calibration still works when the fixed tilt is constant through the 2D rotation. The tilt range of a fixed-tilt device frame can be in the range of -30° to +30°.

5.1.3   Limited-Tilt Calibration

A Limited-Tilt Calibration is recommended when 30° of pitch isn't feasible, but >5° of pitch is possible. It provides both hard-iron and soft-iron distortion correction. The recommended 12-point calibration pattern given below is a series of 3 circles of evenly spaced points, with as much tilt variation as expected during use.

Table 5-5: 12 Point Limited-Tilt Calibration Pattern

Sample #	Yaw[1]	Pitch[1]	Roll
First Circle			
1	0°	0°	Any
2	90°	0°	Any
3	180°	0°	Any
4	270°	0°	Any
Second Circle			
5	45°	> +5°	Any
6	135°	> +5°	Any
7	225°	> +5°	Any
8	315°	> +5°	Any
Third Circle			
9	45°	< -5°	Any
10	135°	< -5°	Any
11	225°	< -5°	Any
12	315°	< -5°	Any

Footnote:

1. Heading and Tilt listings are not absolute heading directions, but rather relative heading referenced to the first sample.

Alternatively, a similar and acceptable pattern would be to follow the recommended 12 point Full-Range Calibration pattern but substituting the >±30° of pitch with whatever pitch can be achieved. See Section 5.1.1 for more information.

Table 5-6: 12 Point Limited-Tilt Calibration Alternative Pattern

Sample #	Heading[1]	Pitch[1]	Roll
First Circle			
1	0°	> +5°	Any
2	60°	> +5°	Any
3	120°	> +5°	Any
4	180°	> +5°	Any
5	240°	> +5°	Any
6	300°	> +5°	Any
Second Circle			
7	0°	< -5°	Any
8	60°	< -5°	Any
9	120°	< -5°	Any
10	180°	< -5°	Any
11	240°	< -5°	Any
12	300°	< -5°	Any

Footnote:

5.1.4   Hard-Iron-Only Calibration

It is not uncommon for the hard-iron magnetic distortions around the Prime Pro to change. Some reasons for this include significant temperature change or temperature shock to a system, as well as gradual aging of components. A Hard-Iron-Only Calibration allows for quick recalibration of the Prime Pro for hard-iron effects, and generally is effective for operation. Calibration in the pitch range of ≥30° is preferred. Less than 30° will result in reduced accuracy. The recommended 6-point calibration pattern given below is a circle of alternately tilted, evenly spaced points, with as much tilt as expected during use.

Table 5-7: 6 Point Hard-Iron-Only Calibration Pattern

Sample #	Heading[1]	Pitch[2]	Roll[2]
1	0°	max. negative	Any
2	90°	max. positive	Any
3	180°	max. negative	Any
4	270°	max. positive	Any

Footnote:

1. Heading and Tilt listings are not absolute heading directions, but rather relative heading referenced to the first sample.

2. For best results, the tilt experienced during calibration should match that experienced in service. For example, if the Prime Pro will be subject to ±30° of pitch when in service, then "max negative" should be -30° and "max positive" should be +30°.

5.2 Accelerometer Calibration

The Prime Pro uses a MEMS accelerometer to measure attitude. This data is output as pitch and roll data. The accelerometer data is critical for establishing an accurate heading reading when the Prime Pro is tilted.

The Prime Pro algorithms assume the accelerometer only measures the gravitational field. If the Prime Pro is accelerating during a measurement, this will result in the Prime Pro calculating an inaccurate gravitational vector, which in turn will result in an inaccurate heading reading. For this reason, the Prime Pro should be stationary when taking a measurement.

PNI calibrates the accelerometer in its factory prior to shipment. Accelerometer calibration should only be done if there is a noticeable change in tilt performance. Possible causes being the inherent accelerometer slow drift over time or a sudden change from a shock event.

If an accelerometer calibration is warranted, use the below field calibration pattern.

The requirements for a good accelerometer calibration differ from the requirements for a good magnetic sensor calibration. For example, a level heading sweep, no matter how many points are acquired, is effectively only 1 accelerometer calibration point. PNI recommends 18-32 calibration points for Accelerometer Only Calibration.

Figure 5-2 shows the two basic starting positions for Accelerometer Only Calibration. Calibration can occur within the user's system or with the module alone. It is not necessary to place the Prime Pro on a flat surface as shown, but it must be held very still during calibration, and holding it against a stable surface is a way to help ensure this.

- Starting with the Prime Pro as shown on the left in Figure 5-2, rotate the module such that it sits on each of its 6 faces. Take a calibration point on each face.

- Starting with the Prime Pro as shown on the right, take a calibration point with it being vertical (0°). Tilt the module back 45° and take another calibration point (+45°), then tilt the module forward 45° and take another calibration point (–45°). Repeat this 3-point process by holding the module on each of its 4 corners.
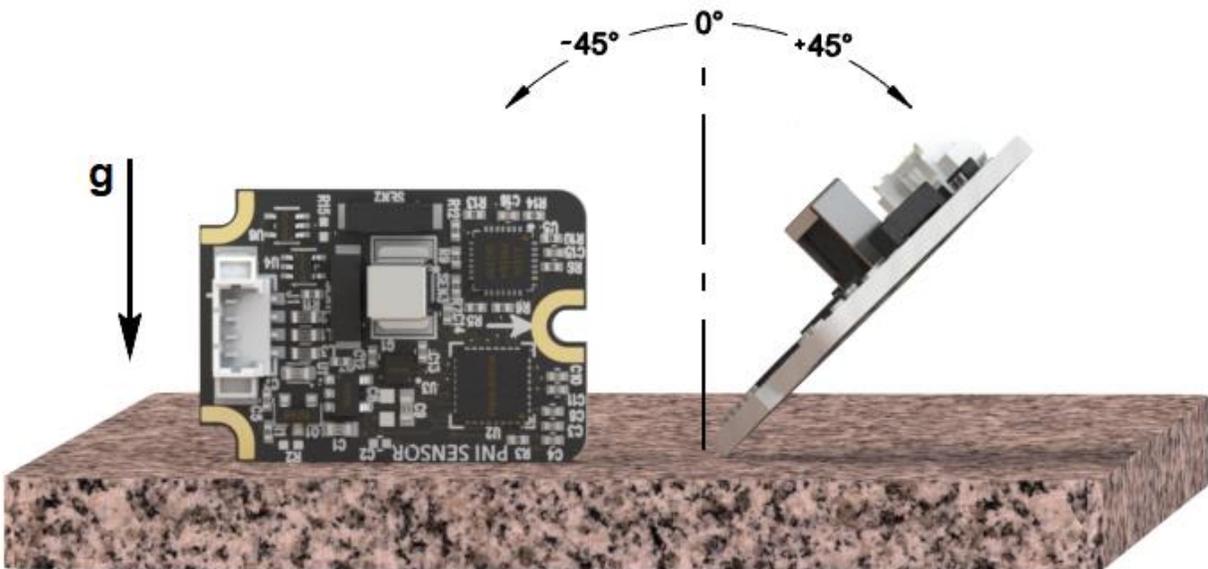
Figure 5-2: Accelerometer Calibration Starting Positions

Table 5-8: Accelerometer Calibration Pattern

Sample #	Heading[1]	Pitch[1]	Roll[1]
Sides			
1	0°	0°	90°
2	0°	90°	90°
3	180°	0°	-90°
4	0°	-90°	90°
5	0°	0°	0°
6	0°	0°	180°
First Corner			
7	0°	±5°	10° to 20°
8	90°	±5°	-10° to -20°
9	180°	±5°	10° to 20°
Second Corner			
10	270°	±5°	-10° to -20°
11	30°	> +45°	10° to 20°
12	120°	> +45°	-10° to -20°
Third Corner			
13	210°	> +45°	10° to 20°
14	300°	> +45°	-10° to -20°
15	60°	< -45°	10° to 20°
Fourth Corner			
16	150°	< -45°	-10° to -20°
17	240°	< -45°	10° to 20°
18	330°	< -45°	-10° to -20°

Footnote:

1. Heading and Tilt listings are not absolute heading directions, but rather relative heading referenced to the first sample.

6 Operation with PNI Studio

The PNI Studio program (pni-electron app) puts an easy-to-use, graphical-user interface (GUI) onto the binary command language used by the Prime Pro. PNI Studio is intended for evaluating, demonstrating, and calibrating multiple PNI products, including TRAX, TRAX2, TPTCM and Prime Pro. Among other features, the program can log and save the outputs from the Prime Pro to a file for off-line evaluation. Anything that can be done using PNI Studio also can be done using PNI's binary protocol, as discussed in Section 7. Please note that the PNI Studio has an option to switch between Compass and AHRS mode. Prime Pro only works in Compass mode.

6.1 Installation

PNI Studio is provided as an executable program which can be downloaded from PNI's website. It will work with Windows 7, and Windows 10 operating systems. Check the PNI web page at www.pnicorp.com/support/ for the latest version.

Unzip the pni-electron Setup 1.0.4.zip and copy the "pni-electron Setup 1.0.4.exe" file onto your computer. Double-click on the icon and step through the Setup Wizard. The program will be installed into the following directory unless you direct it otherwise: Program Files\PNI Sensor Corporation\PNI Studio\. A "PNI Studio" shortcut icon will be placed on your computer's desktop.

Now plug the Prime Pro into the USB or Serial port of your computer. Since the *Prime Pro interface is TTL, in order to use the PNI Studio a USB to TTL cable as shown in Figure 3-4 is required to interface with the PNI Studio*

If you are using Windows 7 or later version the computer automatically searches for and installs the driver. If there is a problem with this, download the driver from FTDI's website at http://www.ftdichip.com/Drivers/VCP.htm.

You have now completed the installation of PNI Studio.

6.2 PNI Studio Header and Connecting to PNI Studio

If the Prime Pro is not already plugged into the computer, then do so.

Double-click on the pni-electron icon to launch PNI Studio. For some versions of the electron app to connect it first needs an api key to connect to a server. However, a server and internet connection are not required. If it is desired to use the program locally perform the following steps.

Enter an 'API Key' in the designated box. If connecting locally this can be any number/letter combination. For a server hosted session or one connecting with a PNI engineer, use a designated API Key provided by PNI Sensor.
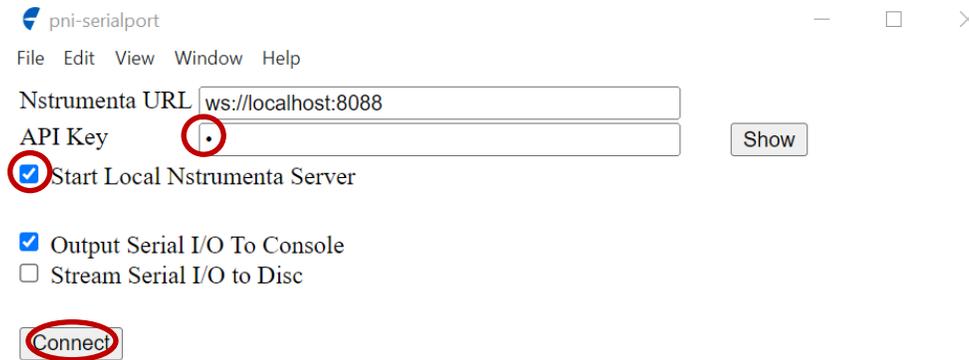
Enter the same 'API Key' in the second "pni-studio" window and hit connect.
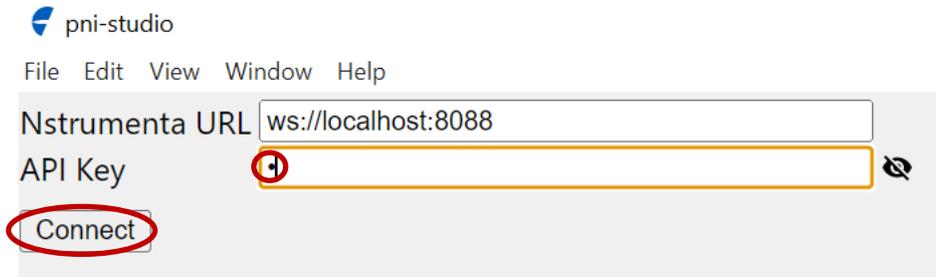
This will start up the PNI-Studio program. Be sure to open the 'pni-serialport' connection first, before connecting 'pni-studio.'

Below is a picture of the PNI Studio header. The header includes "Module Information" and "Connection Settings", and under the header are the various PNI Studio tabs, which are discussed in the subsequent sections. The header is the same regardless of which tab is selected.
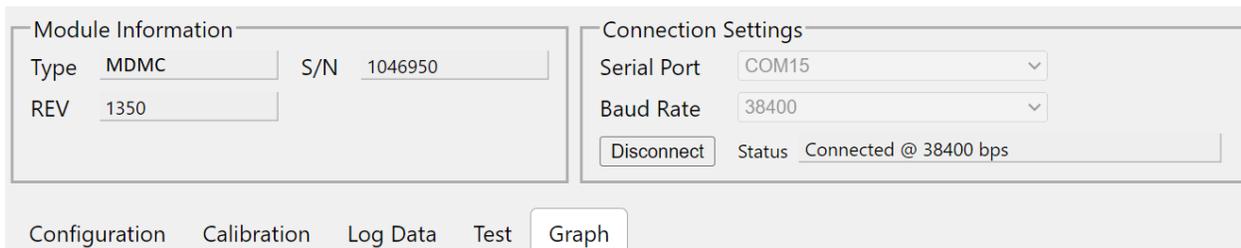
To connect, set the "Serial" field to the appropriate COM port. To determine this, in Windows right click on "My Computer", select "Manage", then select "Device Manager". Expand

"Ports" and note the port for "USB Serial Port". This should be the assigned COM port for the Prime Pro.

Set the baud rate. The default is 38400, and this should be the setting the first time the Prime Pro is used. Once a connection has been established, the desired baud rate can be changed on the Configuration Tab, as discussed in Section 6.4.1.

Click the <Connect> button. When the connection is established, the light to the left of "Status" will turn green, "Status" will change to "Connected @ [the baud rate]", the <Connect> button will now say <Disconnect>, the <Power Down> button will be live, and the "Device Information" section of the header will populate.

6.3   PNI Studio Footer and Saving/Applying Settings

Below is a picture of the PNI Studio footer. The footer includes 4 buttons which are discussed below. The footer is the same regardless of which tab is selected. Note that if a field is changed on any of the PNI Studio tabs, then either <Apply> or <Save> must be selected for the change to take effect.
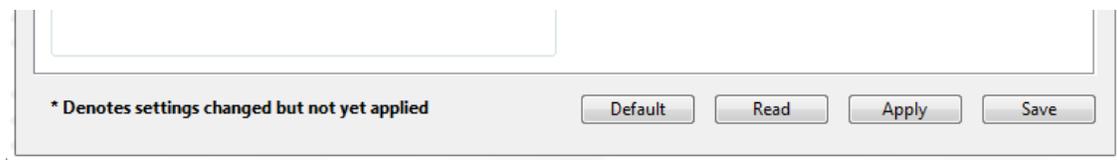
Save

Clicking the <Save> button will save any changes made in PNI Studio to the Prime Pro's onboard non-volatile and volatile memory.

Apply

Selecting the <Apply> button will apply any changes to the Prime Pro's volatile memory, but not to the non-volatile memory. If the Prime Pro is powered off/on, the settings will revert to whatever was last saved in the non-volatile memory.

Read

Clicking the <Read> button will read the current settings in the Prime Pro's volatile memory and display them. This will change any item in bold, which indicates a setting was changed in PNI Studio but not applied to the Prime Pro's volatile memory, back to regular type and the setting change will not be applied to the Prime Pro's memory.

Default

Selecting the <Default> button will display the default settings, which are stored in PNI Studio. Selecting this button will not automatically apply these values, and either <Apply> or <Save> must be selected for the read values to be applied.

6.4 Configuration Tab

The Configuration Tab is shown below, and its contents discussed in the following subsections. For any changes to take effect, the <Save> button must be selected. Clicking on the <Default> button will load the factory default values, although these must be saved to take effect. Clicking the <Read> button will show the current settings of the device.

6.4.1 General Settings

Baud Rate

The baud rate can be altered by selecting the desired baud rate from the pull-down menu, clicking on "Save", and then powering the device off and back on. The new baud rate will not take effect until the device has been powered off/on. The default baud rate is 38400.

Mounting

PNI Studio supports 16 mounting orientations, as previously illustrated in Figure 4-2. The default is "Standard".

Output Units

The Prime Pro can output heading, pitch, and roll in either degrees or mils. The default is "Degrees". (There are 6400 mils in a circle, such that 1 degree = 17.7778 mils and 1 mil = 0.05625 degree.)

North Reference

When "Magnetic" is selected, the heading output will be relative to magnetic north. When "True" is selected, heading will be relative to true north, and the declination value should be entered in the next field. The default is "Magnetic".

Declination

The declination represents the heading difference between magnetic north and true north and needs to be entered if "True" is selected as the "North Reference". Declination varies primarily with location, although it also gradually changes over time (years) for a given location. To find the declination for where the Prime Pro will be used, go to https://ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination.

Filter Taps

When operating the Prime Pro in Compass Mode, the Prime Pro will use a finite impulse response (FIR) filter to effectively provide a stable heading reading.

The number of taps (or samples) represents the amount of filtering to be performed. Either 0, 4, 8, 16, or 32 taps may be selected, with zero taps representing no filtering. Note that selecting a larger number of taps can significantly slow the time for the initial sample reading and, if "Flush Filters" is selected, the rate at which data is output. The default setting is 32.

The FIR filtering operates on a first-in, first-out (FIFO) basis. For example, with FIR Taps set to 32, once the initial 32 samples are taken the next sample (#33) is included in the filtering and the initial sample (#1) is dropped from the filtering.

Endianness

Endianness represents the byte order for inputs and outputs. Big endian refers to transmission of the most significant bits first when sending data. Big endian is the default and is recommended for use with all PNI software. All further I/O sentences in this document are written as big endian.

Flush Filter

The Flush Filter setting is only relevant when in Compass Mode, as it affects how the FIR filters are implemented. Flushing the FIR filter clears all the filter values so it is necessary to fully repopulate the filter before a good reading can be given. For example, if 32 FIR-tap is set, then 32 new samples must be taken to provide a good reading. It is particularly prudent to flush the filter if the Sampling Delay is set to a non-zero value as this will purge old data. Note that flushing the filters increases the delay until data is output, with the length of the delay being directly correlated to the number of FIR taps. The default is not to Flush Filters.

6.4.2   Acquisition Settings

Acquisition Mode

When operating in Continuous Acquisition Mode, the Prime Pro continuously outputs data to the host system. The rate is set by the Sample Delay. When operating in Polled Mode, PNI Studio simulates a host system and polls the Prime Pro for a single measurement; but PNI Studio makes this request at a fixed rate which is set by the Polling Delay. In both cases data is continuously output, but in Continuous Acquisition Mode the Prime Pro controls the data rate while in Polled Mode the PNI Studio program controls the data rate. Polled Mode is the default.

Sample Delay

The Sample Delay is relevant when Continuous Mode is selected. It is the time delay, in seconds, between completion of Prime Pro sending one set of data and the start of sending the next sample set. If the delay is set to 0, then Prime Pro will begin sending new data as soon as the previous data set has been sent. Note that the inverse of the Sample Delay is greater than the sample rate, since the Sample Delay does not include the actual measurement acquisition time. The default is 0.

Polling Delay

The Polling Delay is relevant when Polled Mode is selected. It represents the time delay, in seconds, between the completion of PNI Studio receiving one set of sampled data and requesting the next sample set. If the delay is set to 0, then PNI Studio requests new data as soon as the previous request is fulfilled. Note that the inverse of the Polling Delay is greater than the sample rate, since the Polling Delay does not include the actual measurement acquisition time. The default is 0.

6.5 Calibration and the Calibration Tab

As discussed in Section 5, a user calibration should be performed to optimize Prime Pro performance. The Calibration Tab is shown below and following this are discussions of how to set the calibration settings, how to perform a calibration, and how to interpret the results.

6.5.1   Calibration Settings

Calibration Type

The "Type" pull down menu establishes the type of calibration to be performed. The options are Full, 2D, Hard-Iron-Only, Limited-Tilt, and Accelerometer. These are briefly discussed below and in more detail in Section 5.

Full Range – recommended calibration method when ≥30° of tilt is possible.

2D – recommended when the available tilt range is limited to ≤5°.

Hard Iron Only – serves as a hard-iron recalibration to a prior calibration. If the hard-iron distortion around the device changes, this procedure can bring the device back into specification more quickly than other methods.

Limited Tilt Range – recommended calibration method when >5° of tilt calibration is available, but tilt is restricted to <30°. (i.e. full range calibration is not possible.)

Accelerometer – The user should select this when accelerometer calibration will be performed. Accelerometer calibration is recommended every 6 to 12 months to compensate for bias drift in the accelerometer. The Prime Pro can also be returned to PNI for accelerometer calibration.

Number of Points

This establishes how many samples will be taken during the calibration. The minimum and recommended number of samples depends on the calibration method and is summarized in The following subsections provide instructions for performing a magnetic calibration of a Prime Pro system. Several calibration mode options exist, as summarized in Table 5-1. To meet the accuracy specification, the number of samples should be the "Minimum Recommended" value, or greater. Calibration may be

performed using PNI Studio or using the PNI binary protocol, and up to 8 sets of magnetic calibration coefficients may be saved. The recommended calibration patterns described in the following sub-sections provide a good distribution of sample points.

Table 5-1. The maximum number of samples is 32. The evaluation program PNI Studio limits number of sample points to 18.

Mag Coefficient Set & Accel Coefficient Set

At any one time, the Prime Pro will use one set of magnetic calibration coefficients and one set of accelerometer calibration coefficients. The magnetic coefficients compensate for measured magnetic distortions in the host system as determined during a magnetic calibration. The accelerometer coefficients compensate for bias and offset of the accelerometers, as determined during an accelerometer calibration.

However, the Prime Pro can store eight (8) sets of magnetic calibration coefficients and eight (8) sets of accelerometer calibration coefficients. This feature is useful if the compass will be placed in multiple locations that have different local magnetic field properties. The default is index number 0 and initially this is populated at PNI with factory-generated coefficients for the device itself. The other sets initially are unpopulated.

To store a coefficient set, first select the index number (0 to 7), then perform a calibration. The coefficient values will be stored in the defined index number, assuming the <Save> is selected after the calibration. To recall and use a different set of coefficients, change the "Mag Coefficient Set" and/or "Accel Coefficient Set" number, then click the <Save> button.

Automatic Sampling

If selected, the Prime Pro will take a sample point once predefined minimum change and stability requirements have been satisfied. If the minimum change and stability criteria are not met in 5 seconds as a timeout period, Prime Pro will take a sample at the end of the timeout. If the user wants to have more control over when the point will be taken, then Auto Sampling should be deselected.

H/P/R Output During Cal

When selected, the heading, pitch, and roll of the device will be output below the sample number during a calibration. Using this feature, the user can monitor the device's orientation to easily follow the appropriate recommended calibration pattern. Since a calibration is being performed, these values are relative and should not be considered accurate.

6.5.2 Performing a Calibration

Before proceeding, ensure you are familiar with the recommended calibration pattern corresponding to the "Type" selected. These are discussed in Section 5.

To perform a calibration, follow the following steps:

- Click the <Start> button to begin the calibration process.
- If "Automatic Sampling" is not checked the first sample will be taken automatically assuming the Prime Pro is relatively stationary. After this, it is necessary to click the <Take Sample> button to take a calibration sample point. This should be repeated until the total number of samples is taken, changing the orientation of the device between samples as discussed in Section 0.
- If "Automatic Sampling" is checked the Prime Pro needs to be held steady for a short time and then a sample automatically will be taken. Once the window indicates the next number, the device's orientation should be changed and held steady for the next sample. Once the pre-set number of samples has been taken (as set on the Configuration tab) the calibration is complete.

Regardless of whether "Automatic Sampling" is selected, two criteria must be met for a calibration sample to be taken. First, the Prime Pro must be held steady enough to meet PNI-defined stability criteria. Second, the Prime Pro's orientation must have changed enough to meet PNI-defined orientation change criteria.

If "H/P/R Output During Cal" is selected, then the "Heading", "Pitch", and "Roll" fields will be populated in real-time once the <Start> button is selected. Note that the readings in these fields are relative because calibration is in process.

6.5.3 Calibration Results

Once the calibration is complete the "Calibration Results" section will indicate the quality of the calibration. This may take a few seconds to populate. The primary score of concern is the MagCalScore. The other parameters provide information that may assist in improving the MagCalScore should it be unacceptably high. If a calibration is acceptable, then click the <Save> button to save the calibration coefficients to the coefficient set defined on the Configuration Tab.

Note: If a calibration is aborted, all the scores will read "179.80", and the calibration coefficients will not be changed. (Clicking the <Save> button will not change the calibration coefficients.)

Mag Cal

Approximately represents RMS heading accuracy. Recommended scores are less than 1 for Full-Range Calibration and less than 2 for other methods. Note that it is possible to obtain acceptable Distribution Error and Tilt Error scores and still have a rather high Mag Cal value. The most likely reason for this is that the Prime Pro is close to a source of magnetic distortion that is not fixed with respect to the device.

Distribution Error

Indicates whether the distribution of sample points is good, with an emphasis on the heading distribution. The score should be 0. Significant clumping or a lack of sample points in a particular section can result in a poor score.

Tilt Error

Indicates whether the Prime Pro experienced sufficient tilt during the calibration, taking the calibration method into account. The score should be 0.

Tilt Range

This reports the half of the full pitch range of all sample points. For example, if the Prime Pro is pitched +25° to -15°, the Tilt Range value would be 20°, as derived from [+25° - {-15°}]/2. For Full-Range Calibration and Hard-Iron-Only Calibration, this should be ≥30°. For 2D Calibration, this ideally would be ~2°. For Limited-Tilt Calibration the value should be as large as possible given the user's constraints.

Mag Factory Reset & Accel Factory Reset

Clicking the Mag Factory Reset and/or Accel Factory Reset will reset the calibration coefficients currently indexed to those established at PNI. For example, if "Mag Coefficient Set 1" is selected as the current set, "Mag Factory Reset" will reset it to factory coefficients. Note that the mag factory coefficients will not take into account the magnetic influences inherent in the host system, which could result in very large heading errors. The accel factory coefficients will not correct for any possible accelerometer drift. If either of these Reset buttons are selected, it is necessary to click <Save> or <Apply> to have the factory coefficients take effect.

6.6   Test Tab

The Test Tab is used to demonstrate and evaluate the performance of the Prime Pro. The Heading, Pitch, and Roll are output during testing. Prime Pro works in "Compass" mode. "AHRS" mode is ignored.
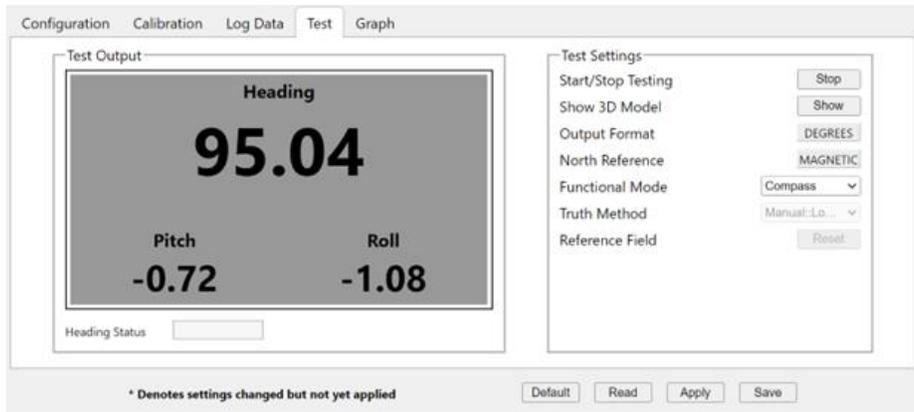
Start/Stop Testing

Clicking the <Start> button results in the Heading, Pitch, and Roll values being updated on the Test Tab screen, as well as the Heading Status.

If the Acquisition Mode is set to "Continuous", then the data will be continuously updated. The button will change to read <Stop>, such that clicking it again will stop the screen from updating.

If the Acquisition Mode is set to "Single", then only one measurement will be displayed on the screen. The button will briefly gray out while the data is being output to the screen, then return to reading <Start>.

Show 3D Model

Selecting the <Show> button launches the 3D Model window, as shown below.
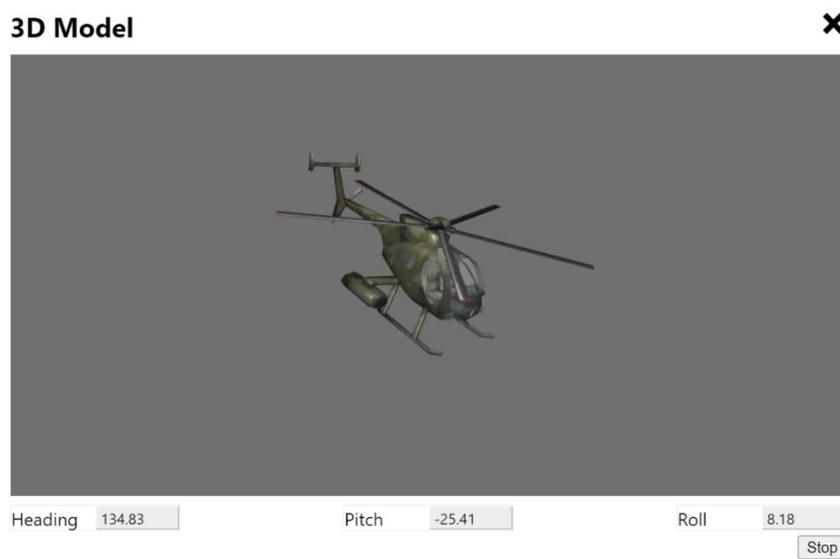
Clicking the <Start> button begins continuous updating of the orientation of the rendered model, and of the heading, pitch, and roll output fields. The <Start> button on the Test Tab screen and on the 3D Model screen are linked such that selecting either of them will stop or start both screens.

Output Format & North Reference

The "Output Format" and "North Reference" fields mimic the settings on the Configuration Tab. To change these, return to the Configuration Tab, make the change, then <Apply> or <Save> the change.

Functional Mode

The Prime Pro is designed to operate in Compass Mode. AHRS Mode is ignored.

6.7   Log Data Tab

PNI Studio can capture measurement data and then export it to a text file.

Configuration	Calibration	Log Data	Test	Graph	Parameters		

Counts (ms)	Heading	Pitch	Roll	MagX	MagY	MagZ	
237	171.1463	0.0883	0.1878	-22.0288	-3.2939	39.1059	
339	171.1507	0.088	0.1857	-22.027	-3.2933	39.1076	
460	171.1419	0.0874	0.191	-22.0266	-3.2931	39.1084	
580	171.1305	0.0832	0.1978	-22.0291	-3.2938	39.1065	
700	171.1281	0.0781	0.1978	-22.0316	-3.2957	39.1061	
802	171.1256	0.0773	0.1973	-22.0313	-3.297	39.1068	
921	171.1182	0.0806	0.2023	-22.0303	-3.2961	39.1055	
1023	171.1166	0.0835	0.2063	-22.0311	-3.2937	39.1038	
1143	171.1203	0.0842	0.2049	-22.0319	-3.2933	39.1034	
1246	171.1168	0.0836	0.2027	-22.0316	-3.2962	39.1043	
1367	171.1071	0.0892	0.2031	-22.0299	-3.2988	39.1054	
1487	171.103	0.0967	0.2061	-22.029	-3.2975	39.1052	
1607	171.1182	0.0965	0.2005	-22.0306	-3.2956	39.1057	

Checkboxes (left panel): ☑ Heading, ☑ Pitch, ☑ Roll, ☑ MagX, ☑ MagY, ☑ MagZ, ☐ AccelX, ☐ AccelY, ☐ AccelZ, ☐ GyroX, ☐ GyroY, ☐ GyroZ, ☐ Heading Status, ☐ Temperature, ☐ Distortion, ☐ Mag Accuracy, ☐ MagRawX

☑ Autoscroll   Samples [1000 ▾]   Start   Clear   Export

* Denotes settings changed but not yet applied   Default   Read   Apply   Save

To acquire data and export it, follow the procedure below:

- Select the parameters you wish to log in the window on the left. Click on each to select multiple items. In the screen shot above, "Heading", "Pitch", "Roll", and "Temperature" were selected.
- Click the <Start> button to start logging. The <Start> button changes to a <Stop> button after data logging begins.
- Click the <Stop> button to stop logging data.
- Click the <Export> button to save the data to a file.
- Click the <Clear> button to clear the data from the window.

Note that the "Distortion" log indicates if the magnetic field is >|±150 µT| for any of the magnetic sensors.

6.8   Graph Tab

The Graph Tab provides a plot of the measured field strength on the x-axis and y-axis magnetic sensors.
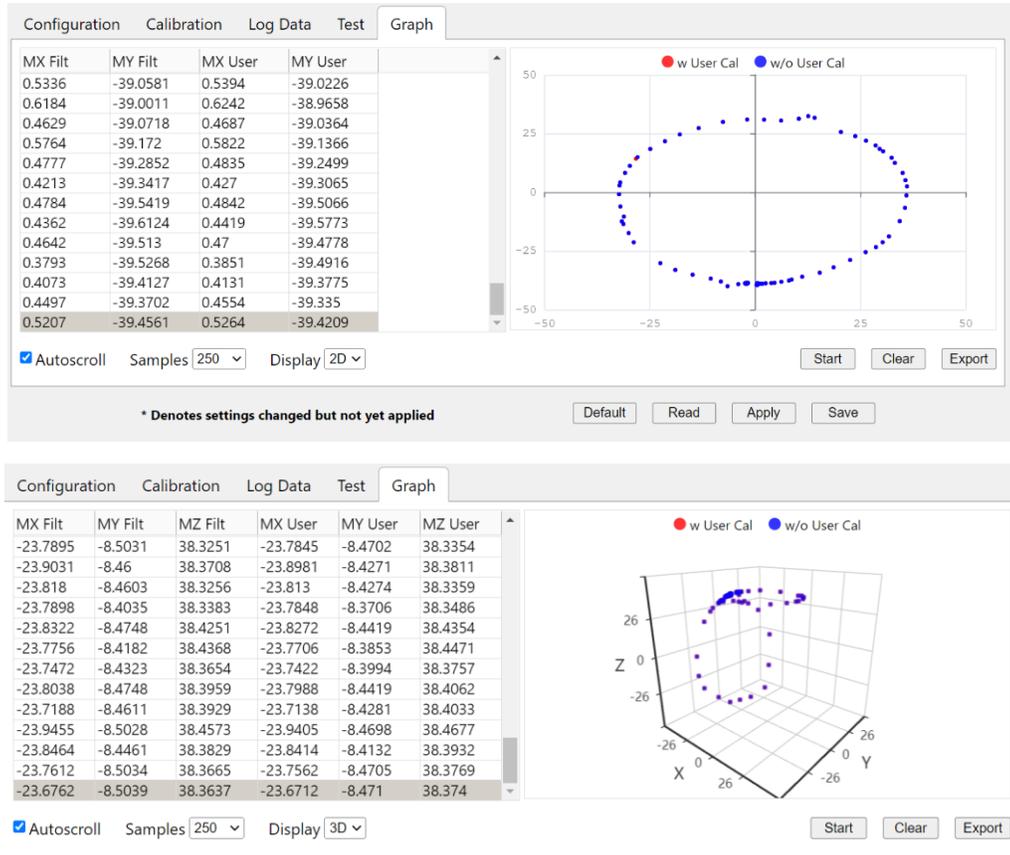
The "MX or MY Filt" data and "w/o User Cal" plot (blue) provide magnetic field strength measurements after the FIR filter taps are applied, but prior to applying the user calibration coefficients. The "MX or My User" data and "w User Cal" plot (red) provide data after applying the user calibration coefficients. The graph can be used to visually see hard and soft-iron effects within the environment measured by the Prime Pro, as well as corrected output after a user calibration has been performed. All 3 axes of data can also be displayed in 3-D via the "Display" selection.

The data can be saved to a .txt log file by clicking <Export>. To clear the data, select <Clear>. To clear both the data and the plot, select <Apply>.

7   Operation with PNI Binary Protocol

The Prime Pro utilizes a binary communication protocol, where the communication parameters should be configured as follows:

Table 7-1: Port Configuration

Parameter	Value
Number of Data Bits	8
Start Bits	1
Stop Bits	1
Parity	none

7.1   Datagram Structure

The data structure is shown below:
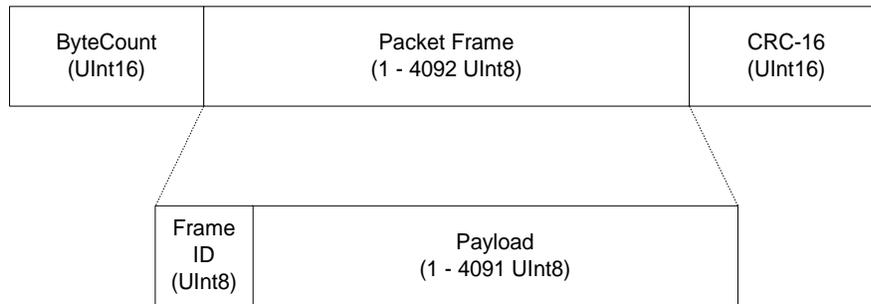
Figure 7-1: Datagram Structure

The ByteCount is the total number of bytes in the packet including the CRC-16 (checksum). The CRC-16 is calculated starting from the ByteCount to the last byte of the Packet Frame. The ByteCount and CRC-16 are always transmitted in big-Endian. Two examples follow.

Example: The complete packet for the kGetModInfo command, which has no payload is:

00 05	01	EF D4
ByteCount	Frame ID	Checksum

Example: Below is a complete sample packet to start a 2D Calibration (kStartCal):

00 09	0A	00 00	00 14	5C F9
ByteCount	Frame ID	CalOption (MSBs)	CalOption (2D Calibration)	Checksum
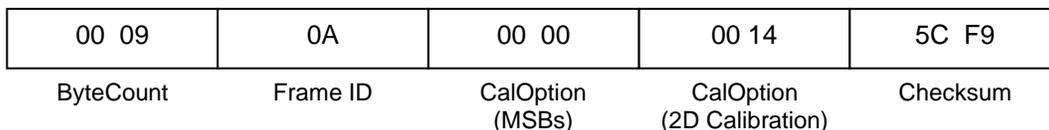
7.2   Parameter Formats

7.2.1   Endianness

Prime Pro can treat 32-bit and 16-bit parameters as having big- or little-Endian formatting. For 32-bit parameters, the big-Endian byte order is ABCD EFGH, while the little-Endian byte order is DCBA HGFE. For 16-bit parameters the big-Endian byte order is ABCD, while the little-Endian byte order is DCBA. The Endianness is selectable by the user per Section 7.4.2. The default is big-Endian, and this is generally assumed in the manual.

7.2.2   Floating Point

Floating-point parameters conform to ANSI/IEEE Std 754-1985. A hex-to-floating-point converter can be found at http://babbage.cs.qc.cuny.edu/IEEE-754.old/32bit.html. Note that for this converter, little-Endian values must be manually converted to big-Endian.

Please refer to the Standard for more information. PNI also recommends referencing the user's compiler instructions to understand how the compiler implements floating-point.

64-Bit Floating Point (Float64)

Below is the 64-bit float format in big-Endian. In little-Endian the bytes are in reverse order in 4-byte groups (e.g. DCBA HGFE).

63 62	52 51	0
S	Exponent	Mantissa

The value (v) is determined as:

$v = (-1)S * 2(Exponent-1023) * 1.Mantissa$, if and only if $0 < Exponent < 2047$

32-Bit Floating Point (Float32)

Shown below is the 32-bit float format in big-Endian. In little-Endian, the 4 bytes are in reverse order (e.g. DCBA).

31 30	23 22	0
S	Exponent	Mantissa

The value (v) is determined as:

$v = (-1)S * 2(Exponent-127) * 1.Mantissa$, if and only if $0 < Exponent < 255$

7.2.3 Signed Integer

For signed integers, the most significant bit (msb) represents the sign of the value, where 0=positive and 1=negative. Signed integers are represents in 2's compliment.

Signed 32-Bit Integer (SInt32)

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

31	24	23	16	15	8	7	0
msb						lsb	

Big Endian

7	0	15	8	23	16	31	24
lsb						msb	
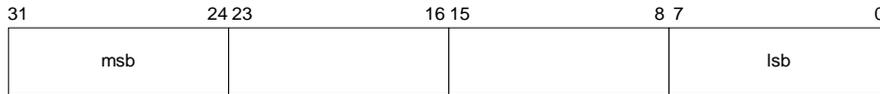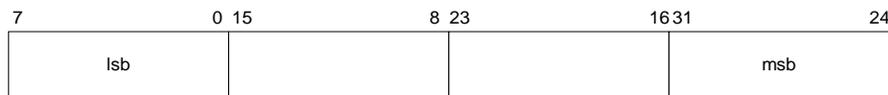
Little Endian

Signed 16-Bit Integer (SInt16)

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

15	8	7	0
msb		lsb	

Big Endian

7	0	15	8
lsb		msb	
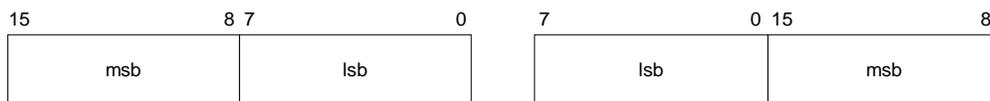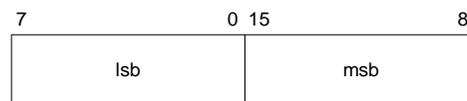
Little Endian

Signed 8-Bit Integer (SInt8)

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

7	0
byte	
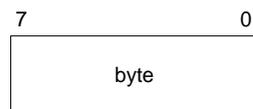
7.2.4   Unsigned Integer

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	
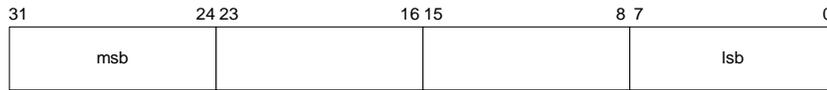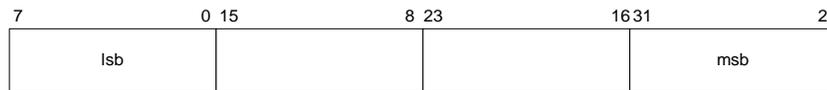
Little Endian

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	
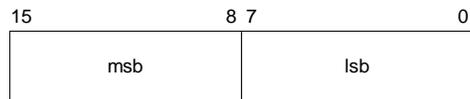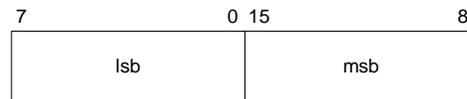
Little Endian

Unsigned 8-Bit Integer (UInt8)

UInt8-based parameters are unsigned 8-bit numbers.

7	0
byte	
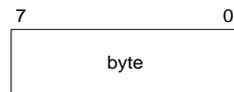
7.2.5   Boolean

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

7	0
byte	
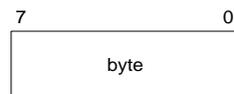
7.3 Commands Overview

Table 7-2 provides a summary of the basic commands available with the Prime Pro.

Table 7-2: Prime Pro Command Set

Frame ID Dec	Hex	Command	Description
1	0x01	kGetModInfo	Queries the device's type and firmware revision.
2	0x02	kGetModInfoResp	Response to kGetModInfo
3	0x03	kSetDataComponents	Sets the data components to be output.
4	0x04	kGetData	Queries the Prime Pro for data
5	0x05	kGetDataResp	Response to kGetData
6	0x06	kSetConfig	Sets internal configurations in Prime Pro
7	0x07	kGetConfig	Queries Prime Pro for the current internal configuration
8	0x08	kGetConfigResp	Response to kGetConfig
9	0x09	kSave	Saves the current internal configuration and any new user calibration coefficients to non-volatile memory.
10	0x0A	kStartCal	Commands the Prime Pro to start user calibration
11	0x0B	kStopCal	Commands the Prime Pro to stop user calibration
12	0x0C	kSetFIRFilters	Sets the FIR filter settings for the magnetometer & accelerometer sensors.
13	0x0D	kGetFIRFilters	Queries for the FIR filter settings for the magnetometer & accelerometer sensors.
14	0x0E	kGetFIRFiltersResp	Contains the FIR filter settings for the magnetometer & accelerometer sensors.
15	0x0F	kPowerDown	Powers down the module
16	0x10	kSaveDone	Response to kSave
17	0x11	kUserCalSampleCount	Sent from the Prime Pro after taking a calibration sample point
18	0x12	kUserCalScore	Contains the calibration score
19	0x13	kSetConfigDone	Response to kSetConfig
20	0x14	kSetFIRFiltersDone	Response to kSetFIRFilters
21	0x15	kStartContinuousMode	Commands the Prime Pro to output data at a fixed interval
22	0x16	kStopContinuousMode	Stops data output when in Continuous Mode

23	0x17	kPowerUpDone	Confirms the Prime Pro has received a signal to power up
24	0x18	kSetAcqParams	Sets the sensor acquisition parameters
25	0x19	kGetAcqParams	Queries for the sensor acquisition parameters
26	0x1A	kSetAcqParamsDone	Response to kSetAcqParams
27	0x1B	kGetAcqParamsResp	Response to kGetAcqParams
28	0x1C	kPowerDownDone	Response to kPowerDown
29	0x1D	kFactoryMagCoeff	Resets magnetometer calibration coefficients to original factory-established values
30	0x1E	kFactoryMagCoeffDone	Response to kFactoryMagCoeff
31	0x1F	kTakeUserCalSample	Commands the Prime Pro to take a sample during user calibration
36	0x24	kFactoryIAccelCoeff	Resets accelerometer calibration coefficients to original factory-established values
37	0x25	kFactoryAccelCoeffDone	Respond to kFactoryAccelCoeff
43	0x2B	kCopyCoeffSet	Copy one set of calibration coefficient to another set
44	0x2C	kCopyCoeffSetDone	Respond to kCopyCoeffSet
52	0x34	kSerialNumber	Request Serial Number of Prime Pro unit
53	0x35	kSerialNumberResp	Respond to kSerialNumber

7.4   Set-Up Commands

7.4.1   Module Information

kGetModInfo (frame ID 1$_d$, 0X01)

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

kGetModInfoResp (frame ID 2$_d$, 0X02)

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

Payload

Type	Revision
UInt32	UInt32
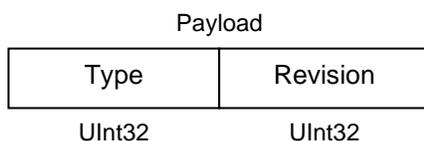
Note that the Type and Revision can be decoded from the binary format to character format using the ASCII standard. For example, the hex string "00 0D 02 54 50 54 31 31 32 30 38 C7 87" can be decoded to read "TPT1 1208". A Hex-to-ASCII converter can be found at: http://www.dolcevie.com/js/converter.html

kSerialNumber (frame ID 52d, 0X34)

This frame queries the device's serial number. The frame has no payload.

kSerialNumberResp (frame ID 53d, 0X35)

The response to kSerialNumber is given below. The payload contains the device serial number.

Payload

Serial Number

UInt32
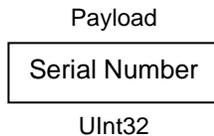
For example, the hex string "00 09 35 00 0F BE 43 0E CF" can be decoded with payload "00 0F BE 43" to read "1031747" as the serial number.

7.4.2   Module Configuration

kSetConfig (frame ID 6d, 0X06)

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

Payload

Config ID	Value
UInt8	ID Specific
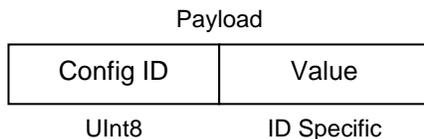
Example: To configure the declination, the payload would look like:

Payload

1	10.0
Declination ID	Declination Angle (Float32)
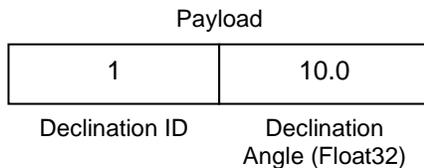
Table 7-3: Configuration Identifiers

Settings	Config. ID$_d$	Format	Values / Range	Default
kDeclination	1	Float32	-180˚ to +180˚	0
kTrueNorth	2	Boolean	True or False	False
kBigEndian	6	Boolean	True or False	True
kMountingRef	10	UInt8	1 = STD 0° 2 = X UP 0° 3 = Y UP 0° 4 = STD 90° 5 = STD 180° 6 = STD 270° 7 = Z DOWN 0° 8 = X UP 90° 9 = X UP 180° 10 = X UP 270° 11 = Y UP 90° 12 = Y UP 180° 13 = Y UP 270° 14 = Z DOWN 90° 15 = Z DOWN 180° 16 = Z DOWN 270°	1
kUserCalNumPoints	12	UInt32	4 – 18	12
kUserCalAutoSampling	13	Boolean	True or False	True
kBaudRate	14	UInt8	4 – 2400 5 – 3600 6 – 4800 7 – 7200 8 – 9600 9 – 14400 10 – 19200 11 – 28800 12 – 38400 13 – 57600 14 - 115200	12
kMilOut	15	Boolean	True or False	False
kHPRDuringCal	16	Boolean	True or False	True
kMagCoeffSet	18	UInt32	0 - 7	0
kAccelCoeffSet	19	UInt32	0 - 7	0

Configuration parameters and settings for kSetConfig:

kDeclination (Config. ID 1d)

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 2_d)

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

kBigEndian (Config. ID 6_d)

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

kMountingRef (Config. ID 10_d)

This sets the reference orientation for the Prime Pro. Please refer to Figure 4-2 for additional information.

kUserCalNumPoints (Config. ID 12_d)

The user must select the number of points to take during a calibration. Table 7-4 provides the "Minimum Recommended" number of sample points, as well as the full "Allowable Range". The "Minimum Recommended" number of samples normally is sufficient to meet the Prime Pro's heading accuracy specification, while less than this may make it difficult to meet specification. See Section 5 for additional information.

Table 7-4: Sample Points

Calibration Mode	Number of Samples	
	Allowable Range	Minimum Recommended
Full-Range	10 to 32	12
Limited-Tilt	10 to 32	12
2D Calibration	10 to 32	12
Hard-Iron-Only	4 to 32	6
Accelerometer-Only	12 to 18	18
Mag-and-Accel	12 to 18	18

kUserCalAutoSampling (Config. ID 13_d)

This flag is used during user calibration. If set to TRUE, the Prime Pro automatically takes calibration sample points once the minimum change and stability requirements are met. If set to FALSE, the device waits for kTakeUserCalSample to take a sample with the condition that a magnetic field vector component delta is greater than 5 µT from the last sample point. If the user wants to have maximum control over when the calibration sample points are taken, this flag should be set to FALSE.

kBaudRate (Config. ID 14_d)

Baud rate index value. A power-down, power-up cycle is required when changing the baud rate.

kMilOut (Config. ID 15$_d$)

Sets the output units as mils (TRUE) or degrees (FALSE). The default is FALSE.

kHPRDuringCal (Config. ID 16$_d$)

This flag sets whether or not heading, pitch, and roll data are output simultaneously while the Prime Pro is being calibrated. The default is TRUE, such that heading, pitch, and roll are output during calibration. FALSE disables simultaneous output.

kMagCoeffSet (Config. ID 18$_d$)

This command provides the flexibility to store up to eight (8) sets of magnetometer calibration coefficients in the Prime Pro. The default is set number 0. To store a set of coefficients, first establish the set number (number 0 to 7) using kMagCoeffSet, then perform the magnetometer calibration. The coefficient values will be stored in the defined set number. This feature is useful if the compass will be placed in multiple locations that have different local magnetic field properties.

kAccelCoeffSet (Config. ID 19$_d$)

This command provides the flexibility to store up to eight (8) sets of accelerometer calibration coefficients in the Prime Pro. The default is set number 0. To store a set of coefficients, first establish the set number (number 0 to 7) using kAccelCoeffSet, then perform the accelerometer calibration. The coefficient values will be stored in the defined set number.

kSetConfigDone (frame ID 19$_d$, 0X13)

This frame is the response to kSetConfig frame. The frame has no payload.

kGetConfig (frame ID 7$_d$, 0X07)

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

Payload

Config ID

UInt8
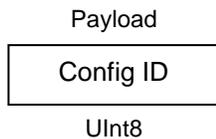
kGetConfigResp (frame ID 8$_d$, 0X08)

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

Payload

Config ID	Value

UInt8   ID Specific
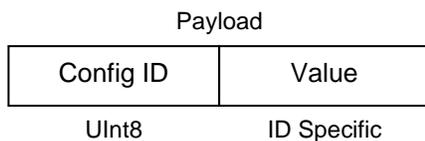
Example: If a request to get the set declination angle, the payload would look like:

Payload

1	10.0
Declination ID	Declination Angle (Float32)
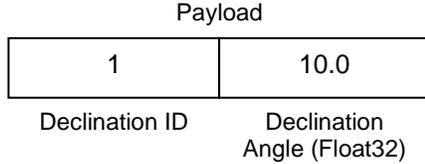
7.4.3   Saving Settings

kSave (frame ID 9$_d$, 0X09)

This frame commands the Prime Pro 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.

kSaveDone (frame ID 16 $_d$, 0X10)

This frame is the response to kSave frame. The payload contains a UInt16 error code: 0 indicates no error; 1 indicates an error when attempting to save data to memory.

Payload

Error Code
UInt16
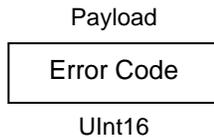
7.5 Measurement Commands

7.5.1   Data Acquisition Parameters

kSetAcqParams (frame ID 24 $_d$)

This frame sets the sensor acquisition parameters in the Prime Pro. The payload should contain the following:

Payload

AcquisitionMode	FlushFilter	PNIReserved	SampleDelay
UInt8	UInt8	Float32	Float32
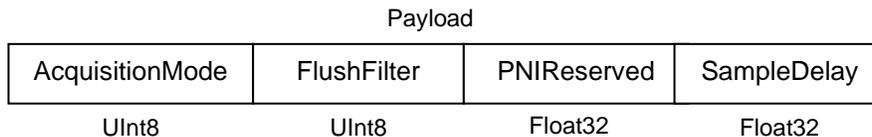
AcquisitionMode:

This flag sets whether output will be presented in Continuous or Polled Acquisition Mode. Poll Mode is TRUE and should be selected when the host system will poll the Prime Pro for each data set. Continuous Mode is FALSE and should be selected

if the user will have the Prime Pro output data to the host system at a relatively fixed rate. Poll Mode is the default.

FlushFilter:

This is only relevant in Compass Mode. Setting this flag to TRUE results in the FIR filter being flushed (cleared) after every measurement. The default is FALSE.

Flushing the filter clears all tap values, thus purging old data. This can be useful if a significant change in heading has occurred since the last reading, as the old heading data would be in the filter. Once the taps are cleared, it is necessary to fully repopulate the filter before data is output. For example, if 32 FIR taps is set, 32 new samples must be taken before a reading will be output. The length of the delay before outputting data is directly correlated to the number of FIR taps.

PNIReserved:

These 4 bytes serve no function. PNI recommends populating the bytes with 0.

SampleDelay:

The SampleDelay is relevant when the Continuous Acquisition Mode is selected. It is the time delay, in seconds, between completion of Prime Pro sending one set of data and the start of sending the next data set. The default is 0 seconds, which means Prime Pro will send new data as soon as the previous data set has been sent. Note that the inverse of the SampleDelay is somewhat greater than the actual sample rate, since the SampleDelay does not include actual acquisition time.

kSetAcqParamsDone (frame ID 26 $_d$)

This frame is the response to kSetAcqParams frame. The frame has no payload.

kGetAcqParams (frame ID 25 $_d$)

This frame queries the unit for acquisition parameters. The frame has no payload.

kGetAcqParamsResp (frame ID 27 $_d$)

This frame is the response to kGetAcqParams frame. The payload should contain the same payload as the kSetAcqParams frame.

7.5.2   Data Components

kSetDataComponents (frame ID 3 $_d$)

This frame defines what data is output when kGetData is sent. Table 7-5 summarizes the various data components and more detail follows this table. Note that this is not a query for the device's model type and software revision (see kGetModInfo). The first byte of the payload indicates the number of data components followed by the data

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

Payload

ID Count	ID 1	ID 2	ID 3	……….
UInt8	UInt8	UInt8	UInt8	
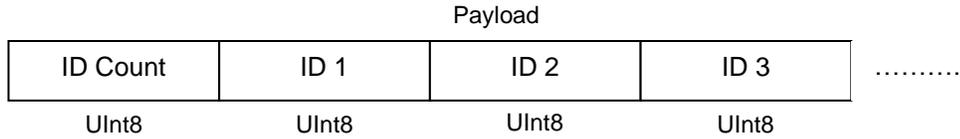
Example: To query for heading and heading status, the payload should contain:

Payload

02	05	4F
ID Count	Heading ID	Heading Status ID
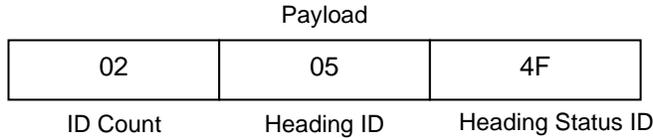
Table 7-5: Component Identifiers

Component	Component ID		Format	Units
	Decimal	Hex		
kHeading	5	0x05	Float32	degrees
kPitch	24	0x18	Float32	degrees
kRoll	25	0x19	Float32	degrees
kTemperature	7	0x07	Float32	˚ Celsius
kDistortion	8	0x08	Boolean	True or False (Default)
kCalStatus	9	0x09	Boolean	True or False (Default)
kAccelX	21	0x15	Float32	G
kAccelY	22	0x16	Float32	G
kAccelZ	23	0x17	Float32	G
kMagX	27	0x1B	Float32	μT
kMagY	28	0x1C	Float32	μT
kMagZ	29	0x1D	Float32	μT
kMagAccuracy	88	0x58	Float32	degrees

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

kHeading, kPitch, kRoll (Component IDs 5_d, 24_d, 25_d)

Provides compass heading, pitch and roll outputs. The heading range is 0.0˚ to +359.9˚, the pitch range is -90.0˚ to +90.0˚, and the roll range is to -180.0˚ to +180.0˚.

kTemperature (Component ID 7_d)

This value is provided by the device's internal temperature sensor. Its value is in degrees Celsius and has an accuracy of ±3° C.

kDistortion (Component ID 8$_d$)

This flag indicates at least one magnetometer axis reading is beyond ±150 µT.

kCalStatus (Component ID 9$_d$)

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

kAccelX, kAccelY & kAccelZ (Component IDs 21$_d$, 22$_d$, 23$_d$)

These values represent the accelerometer sensor data for the x, y, and z axis, respectively. The values are normalized to g (Earth's gravitational force).

kMagX, kMagY & kMagZ (Component IDs 27$_d$, 28$_d$, 29$_d$)

These values represent the magnetic sensor data for the x, y, and z axis, respectively. The values are given in µT.

kMagAccuracy (Component ID 88$_d$)

This value represents the approximate current magnetic accuracy of the system. When no user cal has been performed, the accuracy of this measurement is significantly reduced. This value combines the estimated accuracy of the most recent magnetic user calibration (cal score), change in the magnetic field since the last user cal, and any observed short-term transients observed in the background. This measurement is more accurate if the system is held somewhat still (as opposed to waving the unit around quickly). Allowing the unit to see different orientations and pitch/rolls in an area will give a better background measurement of relative accuracy. Values are in degrees of heading. Because this measurement is based on post-fit residual measurements, it is not always a perfect indicator of true accuracy. This score should be a good indicator of relative accuracy, i.e., if one location has a high score, and a second location has a lower score, the second location is more likely to have a clean field.

7.5.3   Making a Measurement

kGetData (frame ID 4$_d$)

If the Prime Pro is configured to operate in Polled Acquisition Mode (see kSetAcqParams), then this frame requests a single measurement data set. The frame has no payload.

kStartContinuousMode (frame ID 21 $_d$)

If the Prime Pro is configured to operate in Continuous Acquisition Mode (see kSetAcqParams), then this frame initiates the outputting of data at a relatively fixed

data rate, where the data rate is established by the SampleDelay parameter. The frame has no payload.

kStopContinuousMode (frame ID 22 d)

This frame commands the Prime Pro to stop data output when in Continuous Acquisition Mode. The frame has no payload.

kGetDataResp (frame ID 5d)

The response to kGetData and kStartContinuousMode 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.

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 heading status are set to be output per the kSetDataComponents command, the payload would look like:

Payload

2	5	359.9	79	1
ID Count	Heading ID	Heading (Float32)	Heading Status ID	Heading Status (UInt8)

7.5.4   Continuous Data Output After Power Cycle

Prime Pro is configurable to continuously send out data at next power on. The following procedure shows the steps on how to enable this feature, and how to disable it.

To Enable the Continuous Data Output

kSetAcqParams (frame ID 24 d)

Configure Prime Pro data acquisition as Continuous Mode (see AcquisitionMode) and set SampleDelay in expected interval in seconds, for example, interval 0.5s will result in 2Hz output rate.

kSetDataComponents (frame ID 3d)

This frame defines what data is output by selecting the various data components by their IDs (See Component ID).

kStartContinuousMode (frame ID 21 d)

This frame initiates the outputting of data at the expected fixed data rate, where the data rate is established by the SampleDelay parameter. The frame has no payload.

kSave (frame ID 9 d)

This frame commands the Prime Pro to save internal configurations and user calibration to non-volatile memory. The frame has no payload. This is the ONLY command that causes the device to save information to non-volatile memory.

Power Cycle Prime Pro

Power off and then power on, Prime Pro will start to output the same data as the set of data before the power off.

To Disable the Continuous Data Output

Send the following two commands, Prime Pro will stop outputting data after next power cycle.

kStopContinuousMode (frame ID 22 d)

This frame commands the Prime Pro to stop data output when in Continuous Acquisition Mode. The frame has no payload.

kSave (frame ID 9 d)

Power Cycle Prime Pro

Power off and then power on, Prime Pro will not automatically output data.

7.6   Calibration Commands

7.6.1   User Calibration Commands

First, note that in order to perform a user calibration, it is necessary to place the Prime Pro in Compass Mode, as discussed in Section 7.7. Note that Prime Pro allows for a maximum of 18 calibration points.

kStartCal (frame ID 10$_d$)

This frame commands the Prime Pro to start user calibration with the current sensor acquisition parameters, internal configurations, and FIR filter settings.

Payload

CalOption

UInt32
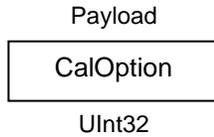
CalOption Payload Value:
"10_d" or "$0A_h$": Full-Range Calibration (default)
"20_d" or "14_h": 2D Calibration
"30_d" or "$1E_h$": Hard-Iron-Only Calibration
"40_d" or "28_h": Limited-Tilt Calibration
"100_d" or "64_h": Accel-Only Calibration
"110_d" or "$6E_h$": Mag-and-Accel Calibration

Note: The payload needs to be 32 bit (4 byte). If no payload is entered or if less than 4 bytes are entered, the unit will default to the previous calibration method.

The CalOption values are given below, along with basic descriptions of the options.

Full-Range Calibration

Recommended calibration method when >30° of pitch is possible. Can be used for between 20° and 30° of pitch, but accuracy will not be as good

2D Calibration

Recommended when the available tilt range is limited to ≤5°. Can be used for 5° to 10° of tilt, but accuracy will not be as good.

Hard-Iron-Only Calibration

Recalibrates the hard-iron offset for a prior calibration. If the local field hard-iron distortion has changed, this calibration can bring the Prime Pro back into specification.

Limited-Tilt Calibration

Recommended calibration method when >5° of tilt calibration is available, but tilt is restricted to <30°. (i.e. full range calibration is not possible.)

Accel-Only Calibration

Select this when an accelerometer calibration will be performed.

Accelerometer and Magnetic Calibration ($110_d = 6E_h$)

Selected when magnetic and accelerometer calibration will be done simultaneously.

Below is a complete sample packet to start a 2D Calibration (kStartCal):

00 09	0A	00 00	00 14	5C F9
ByteCount	Frame ID	CalOption (MSBs)	CalOption (2D Calibration)	Checksum

Heading, pitch, and roll information is output via the kGetDataResp frame during the calibration process. This feature provides guidance during the calibration regarding calibration sample point coverage. During calibration, in the kGetDataResp frame, the

number of data components is set to be 3 and then followed by the data component ID-value pairs. The sequence of the component IDs are kHeading, kPitch and kRoll.

kTakeUserCalSample (frame ID 31 _d)

This frame commands the Prime Pro to take a sample during user calibration. The frame has no payload.

kUserCalSampleCount (frame ID 17 _d)

This frame is sent from the Prime Pro after taking a calibration sample point. The payload contains the sample count with the range of 0 to 32. Payload 0 is sent from Prime Pro after kStartCal is received by Prime Pro, it indicates user calibration start, and Prime Pro is ready to take samples. Payload 1 to 32 indicates each point sampled successfully.

Payload

SampleCount#

UInt32
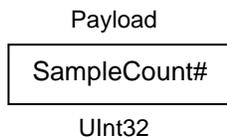
kStopCal (frame ID 11_d)

This command aborts the calibration process. The prior calibration results are retained.

7.6.2   Performing a User calibration

The steps below provide an example of the steps to perform a user calibration.

- Using the kSetFIRFilters command, set the number of tap filters to 0.
- Using the kSetConfig command, set kUserCalAutoSampling. "False" is generally recommended, but "True" may be more convenient.
- Using the kSetConfig command, set kMagCoeffSet (magnetometer calibration) and/or kAccelCoeffSet (accelerometer calibration). These fields allow the user to save multiple sets of calibration coefficients. "0" is the default.
- Using the kSetConfig command again, set kUserCalNumPoints to the appropriate number of calibration points.
- Initiate a calibration using the kStartCal command. Note that this command requires identifying the type of calibration procedure (i.e. Full-Range, 2D, etc.).
- Follow the appropriate calibration procedure, as discussed in Section 5. If kUserCalAutoSampling was set to "False", then send a kTakeUserCalSample command when ready to take a calibration point. If kUserCalAutoSampling was set to "True", then look for kUserCalSampleCount to confirm when a calibration point has been taken. During the calibration process, heading, pitch, and roll

information will be output from the Prime Pro, and this can be monitored using kDataResp.

- When the final calibration point is taken, the device will present the calibration score using kUserCalScore.
- If the calibration is acceptable (see Section 7.6.2), save the calibration coefficients using kSave.

7.6.3   Calibration Score

kUserCalScore (frame ID 18 d)

The calibration score is automatically sent upon taking the final calibration point. The payload is defined below, and the various payload components are discussed after this.

Payload

MagCalScore	Bytes 5-8	AccelCalScore	DistributionError	TiltError	TiltRange
Float32	Float32	Float32	Float32	Float32	Float32

MagCalScore:
Represents the over-riding indicator of the quality of the magnetometer calibration. Acceptable scores will be ≤1 for full range calibration, ≤2 for other methods. Note that it is possible to get acceptable scores for DistributionError and TiltError and still have a rather high MagCalScore value. The most likely reason for this is the Prime Pro is close to a source of local magnetic distortion that is not fixed with respect to the device.

Bytes 5-8:
Reserved for PNI use.

AccelCalScore:
Represents the over-riding indicator of the quality of the accelerometer calibration. An acceptable score is ≤1.

DistributionError:
Indicates if the distribution of sample points is good, with an emphasis on the heading distribution. The score should be 0. Significant clumping or a lack of sample points in a particular section can result in a poor score.

TiltError:
Indicates if the Prime Pro experienced sufficient tilt during the calibration, taking into account the calibration method. The score should be 0**.**

TiltRange:

This reports half the full pitch range of sample points. For example, if the device is pitched +25º to -15º, the TiltRange value would be 20º (as derived from [+25º - {-15º}]/2). For Full-Range Calibration and Hard-Iron-Only Calibration, this should be ≥30°. For 2D Calibration, ideally this should be ≈2°. For Limited-Tilt Calibration the value should be as large a possible given the user's constraints.

7.6.4   Factory Calibration

kFactoryMagCoeff (frame ID 29 $_d$)

This frame clears the magnetometer calibration coefficients and loads the original factory-generated coefficients. The frame has no payload. This frame must be followed by the kSave frame to save the change in non-volatile memory.

kFactoryMagCoeffDone (frame ID 30 $_d$)

This frame is the response to kFactoryMagCoeff frame. The frame has no payload.

kFactoryAccelCoeff (frame ID 36 $_d$)

This frame clears the accelerometer calibration coefficients and loads the original factory-generated coefficients. The frame has no payload. This frame must be followed by the kSave frame to save the change in non-volatile memory.

kFactoryAccelCoeffDone (frame ID 37 $_d$)

This frame is the response to kFactoryAccelCoeff frame. The frame has no payload.

kCopyCoeffSet (frame ID 43 $_d$)

This frame copies one set of calibration coefficients to another. Prime Pro supports 8 sets of magnetic calibration coefficients, and 8 sets of accel calibration coefficients. The set index is from 0 to 7. This frame must be followed by the kSave frame to save the change in non-volatile memory.

Payload

Type	Set Indexes
UInt8	UInt8
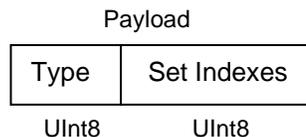
Type:

Value 0 to copy magnetic calibration coefficient set (default), 1 to copy accel coefficient set

Set Indexes:

bit 7 - 4: source coefficient set index from 0 to 7, default 0

bit 0 - 3: destination coefficient set index from 0 to 7, default 0

Example: Copy magnetic calibration coefficient set 1 to set 5 command, the payload would look like:

Payload

0	0x15
Type	Source ID, Destination ID
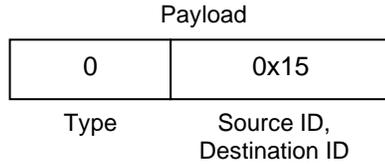
kCopyCoeffSetDone (frame ID 44 d)

This frame is the response to kCopyCoeffSet frame. The frame has no payload.

7.7 Performance Commands

The Prime Pro normally operates as a Compass, wherein it uses the inputs from the accelerometer and magnetometer to establish heading, pitch, and roll to provide higher heading accuracy of 0.25° rms, for a static measurement in a known clean local magnetic field. It can subsequently be placed into Sleep Mode which will significantly reduce power consumption when not taking measurements.

7.7.1 FIR Filters

The Prime Pro incorporates a finite impulse response (FIR) filter to provide a more stable heading reading. The number of taps (or samples) represents the amount of filtering to be performed. The number of taps directly affects the time for the initial sample reading, as all the taps must be populated before data is output.

The Prime Pro can be configured to clear, or flush, the filters after each measurement, as discussed in Section 7.5.1. Flushing the filter clears all tap values, thus purging old data. This can be useful if a significant change in heading has occurred since the last reading, as the old heading data would be in the filter. Once the taps are cleared, it is necessary to fully repopulate the filter before data is output. For example, if 32 FIR-tap is set, 32 new samples must be taken before a reading will be output. The length of the delay before outputting data is directly correlated to the number of FIR taps.

kSetFIRFilters (frame ID 12$_d$)

The payload for kSetFIRFilters is given below.

Payload

Byte 1	Byte 2	Count N	Value 1	Value 2	Value 3	Value N
UInt8	UInt8	UInt8	ID Specific	ID Specific	ID Specific	ID Specific

Byte 1 should be set to 3 and Byte 2 should be set to 1. The third payload byte indicates the number of FIR taps to use, which can be 0 (no filtering), 4, 8, 16, or 32. This is followed by the tap values (0 to 32 total Values can be in the payload), with each Value being a Float64, and suggested values given in Table 7-6.

Table 7-6: Recommended FIR Filter Tap Values

Count	4-Tap Filter	8-Tap Filter	16-Tap Filter	32-Tap Filter
1	04.6708657655334e-2	01.9875512449729e-2	07.9724971069144e-3	01.4823725958818e-3
2	04.5329134234467e-1	06.4500864832660e-2	01.2710056429342e-2	02.0737124095482e-3
3	04.5329134234467e-1	01.6637325898141e-1	02.5971390034516e-2	03.2757326624196e-3
4	04.6708657655334e-2	02.4925036373620e-1	04.6451949792704e-2	05.3097803863757e-3
5		02.4925036373620e-1	07.1024151197772e-2	08.3414139286254e-3
6		01.6637325898141e-1	09.5354386848804e-2	01.2456836057785e-2
7		06.4500864832660e-2	01.1484431942626e-1	01.7646051430536e-2
8		01.9875512449729e-2	01.2567124916369e-1	02.3794805168613e-2
9			01.2567124916369e-1	03.0686505921968e-2
10			01.1484431942626e-1	03.8014333463472e-2
11			09.5354386848804e-2	04.5402682509802e-2
12			07.1024151197772e-2	05.2436112653103e-2
13			04.6451949792704e-2	05.8693165018301e-2
14			02.5971390034516e-2	06.3781858267530e-2
15			01.2710056429342e-2	06.7373451424187e-2
16			07.9724971069144e-3	06.9231186101853e-2
17				06.9231186101853e-2
18				06.7373451424187e-2
19				06.3781858267530e-2
20				05.8693165018301e-2
21				05.2436112653103e-2
22				04.5402682509802e-2

23				03.8014333463472e-2
24				03.0686505921968e-2
25				02.3794805168613e-2
26				01.7646051430536e-2
27				01.2456836057785e-2
28				08.3414139286254e-3
29				05.3097803863757e-3
30				03.2757326624196e-3
31				02.0737124095482e-3
32				01.4823725958818e-3

kSetFIRFiltersDone (frame ID 20 d)

This frame is the response to kSetFIRFilters. The frame has no payload.

kGetFIRFilters (frame ID 13d)

This frame queries the FIR filter settings for the sensors. Byte 1 should be set to 3 and Byte 2 should be set to 1.

Payload

Byte 1	Byte 2
UInt8	UInt8
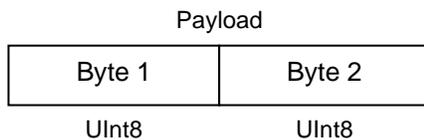
kGetFIRFiltersResp (frame ID 14d)

This is the response to kGetFIRFilters and it has the same payload definition as kSetFIRFilters.

7.7.2   Power Down/Up

Prime Pro may be powered down to save energy when heading data is not required.

kPowerDown (frame ID 15d)

This frame is used to power-down the module. The frame has no payload. The command will power down all peripherals including the sensors, microprocessor, and RS-232 driver. However, the driver chip has a feature to keep the Rx line enabled. The Prime Pro will power up when it receives any signal on the native UART Rx line.

kPowerDownDone (frame ID 28d)

This frame confirms the Prime Pro received a command to power down. The frame has no payload.

kPowerUpDone (frame ID 23$_d$)

> This frame confirms the Prime Pro received a command to power up. (The Prime Pro will power up when it receives any signal on the native UART Rx line.) The frame has no payload.

7.8   Using Multiple Coefficient Sets

The ability to store and access multiple calibration coefficients sets the Prime Pro apart from our Prime or legacy TCM. This section will detail the command list and provide two examples for utilizing this functionality.

Table 7-7: Multiple Coefficient Command List

Magnetometer Calibration					
kSetConfig (frame ID)	**kMagCoeffSet (config ID)**	**Value (UInt32)**	**Examples**	**Command Bytes**	**Prime Pro Response**
0x06	0x12	0-7	Set kMagCoeffSet to be copy 0	0x00 0x0A 0x06 0x12 0x00 0x00 0x00 0x00 0x3E 0x76	0x00 0x05 0x13 0xDD 0xA7
			Set kMagCoeffSet to be copy 1	0x00 0x0A 0x06 0x12 0x00 0x00 0x00 0x01 0x2E 0x57	0x00 0x05 0x13 0xDD 0xA7
			Set kMagCoeffSet to be copy 4	0x00 0x0A 0x06 0x12 0x00 0x00 0x00 0x04 0x7E 0xF2	0x00 0x05 0x13 0xDD 0xA7
kGetConfig (frame ID)	**kMagCoeffSet (config ID)**	**Value (UInt32)**	**Examples**	**Command Bytes**	**Prime Pro Response**
0x07	0x12		get kMagCoeffSet value which is currently used in Prime Pro	0x00 0x06 0x07 0x12 0x19 0x44	0x00 0x0A 0x08 0x12 0x00 0x00 0x00 0x?? CRC1 CRC2
Accelerometer Calibration					
kSetConfig (frame ID)	**kAccelCoeffCopySet (config ID)**	**Value (UInt32)**	**Examples**	**Command Bytes**	**Prime Pro Response**
0x06	0x13	0 - 2	Set kAccelCoeffCopySet to be copy 0	0x00 0x0A 0x06 0x13 0x00 0x00 0x00 0x00 0x94 0x27	0x00 0x05 0x13 0xDD 0xA7
			Set kAccelCoeffCopySet to be copy 1	0x00 0x0A 0x06 0x13 0x00 0x00 0x00 0x01 0x84 0x06	0x00 0x05 0x13 0xDD 0xA7
			Set kAccelCoeffCopySet to be copy 2	0x00 0x0A 0x06 0x13 0x00 0x00 0x00 0x02 0xB4 0x65	0x00 0x05 0x13 0xDD 0xA7
kGetConfig (frame ID)	**kAccelCoeffCopySet (config ID)**	**Value (UInt32)**	**Examples**	**Command Bytes**	**Prime Pro Response**
0x07	0x13		get kAccelCoeffCopySet value which is currently used in Prime Pro	0x00 0x06 0x07 0x13 0x09 0x65	0x00 0x0A 0x08 0x13 0x00 0x00 0x00 0x?? CRC1 CRC2

Examples

Example 1: Save Magnetic Calibration result to Coeff Copy Set 4.

- Set the kMagCoeffSet to copy set 4 by sending the following command.

  0x00 0x0A 0x06 0x12 0x00 0x00 0x00 0x04 0x7E 0xF2

- Get the kMagCoeffSet to verify by sending the following command. (Optional)

  0x00 0x06 0x07 0x12 0x19 0x44

- Send kSave command to save the kMagCoeffSet to flash so that it will be still available after power cycle. The kSave command is as following.

  0x00 0x05 0x09 0x6E 0xDC

- Start a user calibration, when completes, save calibration coeffs to TCM. The coeffs have been saved into coeff set copy 4.

Example 2: Use Magnetic Coeff Copy Set 1 in TCM. (The assumption is user has saved calibration coeffs to set 1 before)

- Set the kMagCoeffSet to copy 1 by sending the following command.

  0x00 0x0A 0x06 0x12 0x00 0x00 0x00 0x01 0x2E 0x57

- Get the kMagCoeffSet to verify by sending the following command. (Optional)

  0x00 0x06 0x07 0x12 0x19 0x44

- Send kSave command to save the kMagCoeffSet to flash so that it will be still available after power cycle. The kSave command is as following.

  0x00 0x05 0x09 0x6E 0xDC

7.9   Communication Protocol Example

Below is a procedure to generate heading, pitch, and roll outputs in Polled Mode.

1. Write kGetModInfo (frame ID = 0x01)

   ```
   00 05 01 ef d4
   ```

2. Read response from Trax kGetModInfoResp (frame ID = 0x2). In ASCII it will contain "TRAXP733" version number.

   ```
   00 0d 02 54 52 41 58 50 37 33 33 5b 76
   ```

3. Write kSetDataComponents (frame ID 0x03). There are 3 components: kHeading, kPitch, kRoll (component IDs = 0x5, 0x18, 0x19).

   ```
   00 0a 03 03 05 18 19 11 3e
   ```

4. Write kGetData (frame ID=0x04)

   ```
   00 05 04 bf 71
   ```

5. Read kGetDataResp (frame ID=0x05). There are 3 components: kHeading, kPitch, kRoll

   ```
   00 15 05 03 05 43 b3 df 5e 18 be 88 ed bd 19 3d b5 15 53 f2 14
   ```

6. Repeat steps 4 and 5 whenever data is desired.