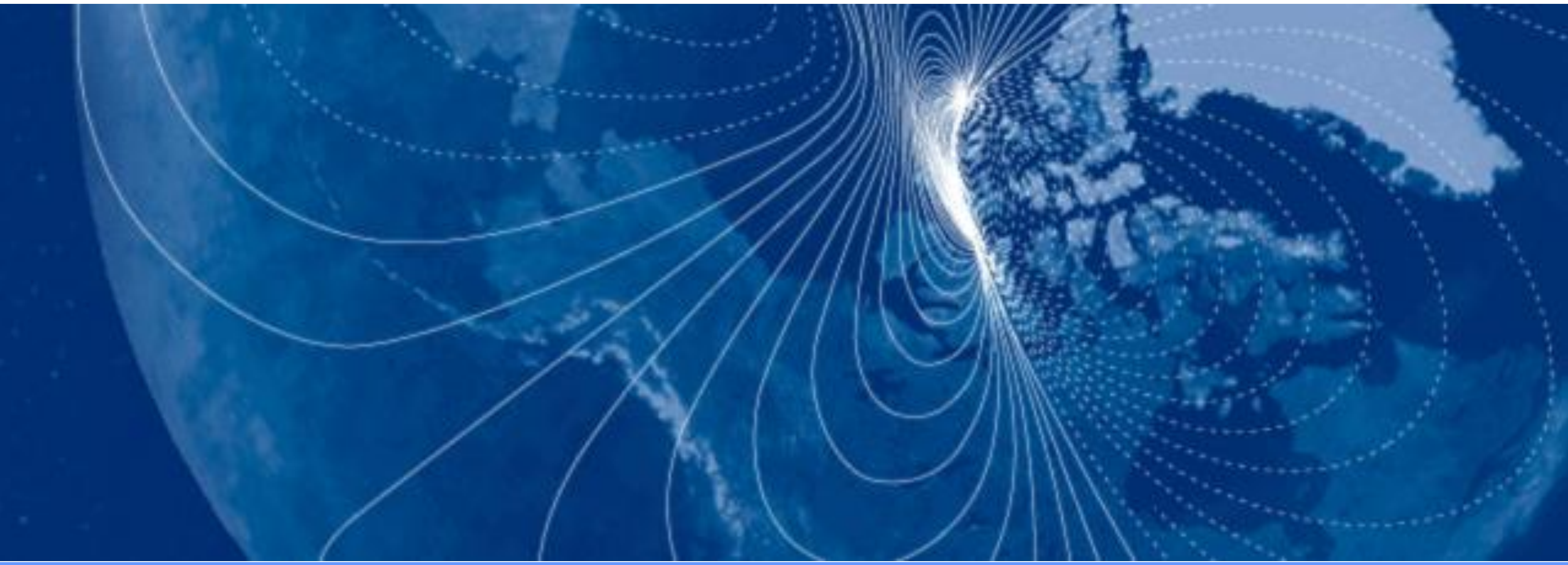

User Manual

SmartSens MicroMag

Magneto-Inductive Sensor Module

PNI SENSOR CORPORATION

SUNSTAR传感与控制 http://www.sensor-ic.com/ TEL:0755-83376549 FAX:0755-83376182 E-MAIL:szss20@163.com

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1 Copyright & Warranty Information

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2 Introduction

Thank you for purchasing PNI Sensor Corporation's MicroMag magneto-inductive sensing module. Whether you purchased the MicroMag2 2-axis sensing module or the MicroMag3 3-axis sensing module, we're sure you'll be happy with your purchase. If you do have issues with your device, please feel free to contact us.

The MicroMag is an integrated magnetic field sensing module combining PNI's patented SmartSens magneto-inductive (MI) sensors with the PNI ASIC. Designed primarily to aid in the evaluation and prototyping of PNI's SmartSens technology, the MicroMag board contains connectors, test points, option solder jumpers and extra support circuits to expedite evaluation. The microprocessor-compatible SPI interface allows easy access to the MicroMag's measurement parameters and resulting field measurement data.

PNI's MicroMag benefits include low power consumption, large signal noise immunity under all conditions, and a large dynamic range. Measurements are very stable over temperature and inherently free from offset drift. Also, the MicroMag features software-configurable resolution, sample rate and field measurement range. These advantages make PNI's MicroMag not only the choice for prototyping high volume SmartSens solutions, but also for lower volume applications that require a complete solution.

For more information on PNI's magneto-inductive technology please refer to PNI's Magneto-Inductive Technology Overview (http://www.pnicorp.com/support/articles). For information on the PNI ASIC and Sen-XY & Sen-Z sensors at the core of the MicroMag module, please refer to their respective manuals (http://www.pnicorp.com/support/manuals).

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3 Specifications

3.1 Module Characteristics

Table 3-1: Absolute Maximum Ratings

Parameter	Symbol	Maximum	Units
DC Supply Voltage	V_{DD}	5.25	VDC
Input Pin Voltage	V_{IN}	V_{DD} + 0.3	VDC
Input Pin Current @ 25C	I_{IN}	10 mA	mA
Storage Temperature	T_{STRG}	+85	C

CAUTION:

Stresses beyond those listed in Table 3-1 may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 3-2: Module Operating Characteristic

Parameter	Value	Units
Field Measurement Range[1]	-1100 to +1100	µT
Gain[2]	31.24	counts/µT
Resolution[2] (1/Gain)	0.03	µT
Linearity, ± 300 µT	0.6	%
DC Supply Voltage (V_{DD})	3.0 nominal 2.2 to 5.0 allowable	VDC
Idle Current[3]	< 0.1	mA rms
Continuous Current[3]	0.5	mA rms
Sensor Frequency[3,4]	175	kHz
Operating Temperature	-20 to +70	C

Notes:

1) Field Measurement Range is defined as the monotonic region of the output characteristic curve.
2) Period select value of 2048. The Gain and Resolution can be increased by a factor of 2 by setting the period select to 4095. However, the ASIC counter can overflow if the field is strong enough to drive the count beyond a signed 16-bit signed integer. Period select set to 2048 is the highest setting where it is impossible to overflow the counter. In practical magnetometer

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applications, a sensor gain calibration is optimally performed when the sensor module is in the host system.

3) V_{DD} = 3.0VDC
4) The sensor frequency is related to the strength of the magnetic field. The specified value is for when the MicroMag is solely within Earth's magnetic field.

3.2 Typical Operating Characteristics

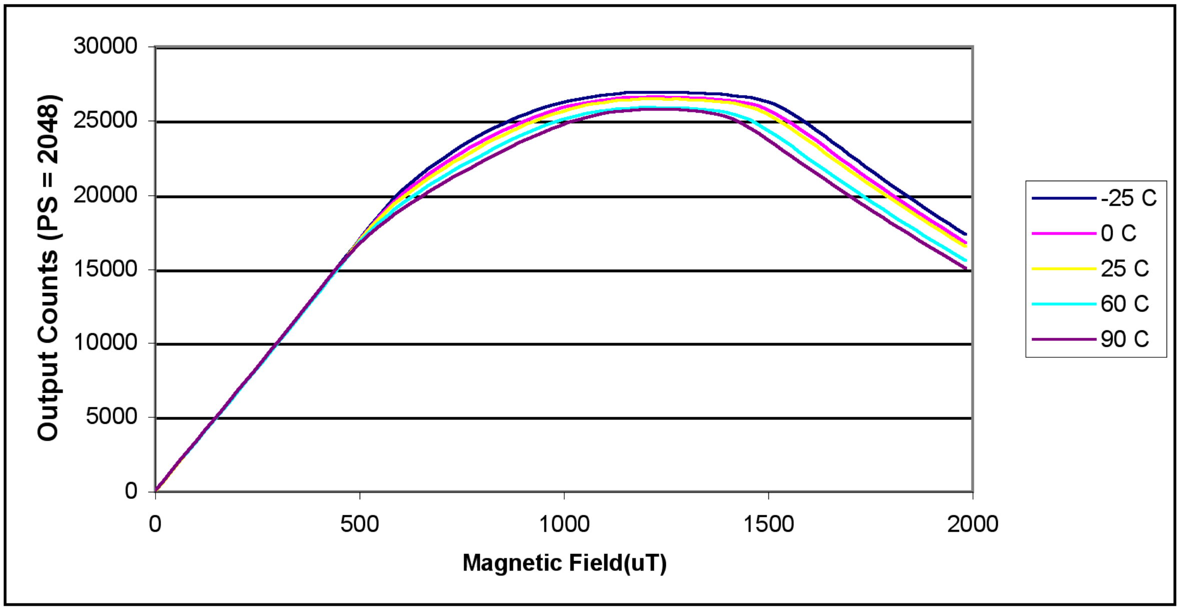

Figure 3-1: Temperature Characteristics

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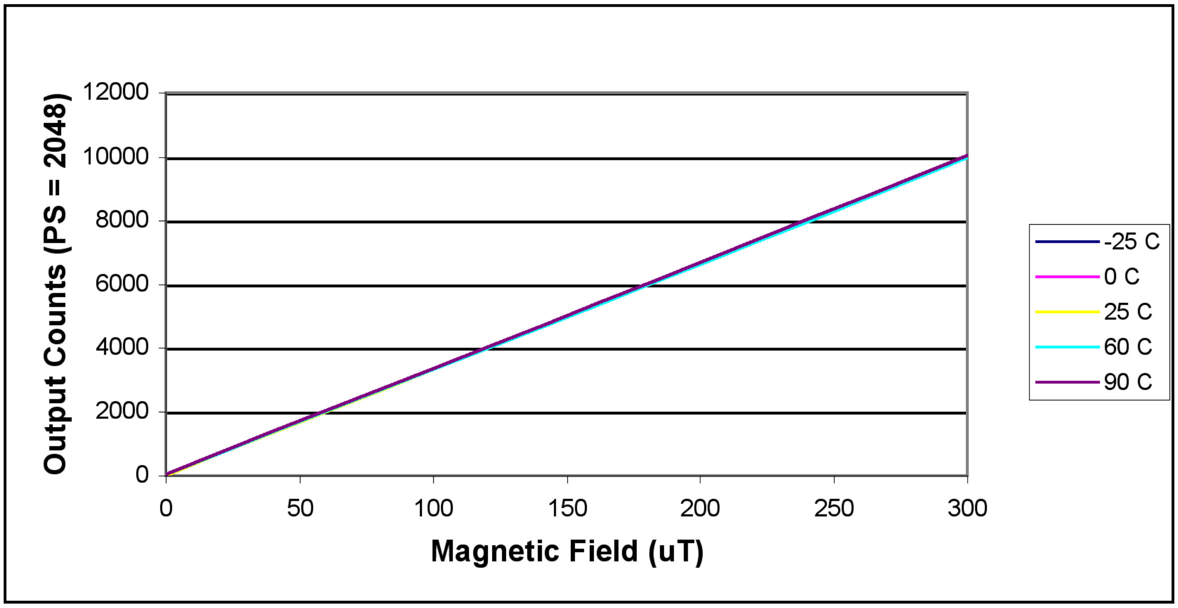

Figure 3-2: Linearity vs. Temperature

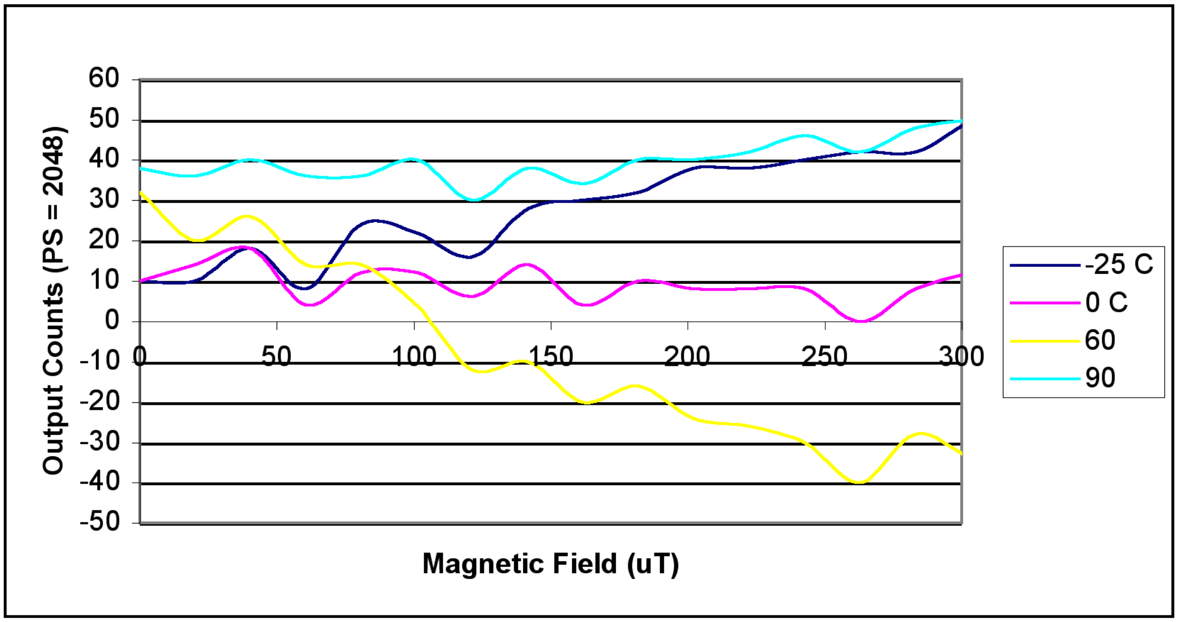

Figure 3-3: Linearity vs. Temperature, Normalized to Room Temperature

3.3 Mechanical Drawings

ALL DIMENSIONS IN MM

3.3.1 MicroMag2

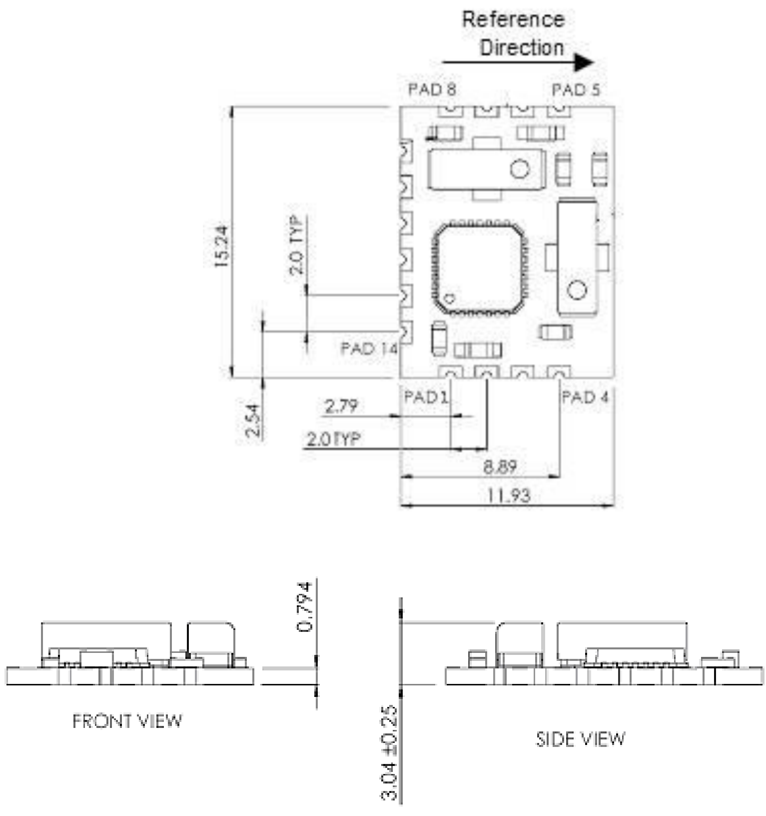

Figure 3-4: MicroMag2 Mechanical Drawing

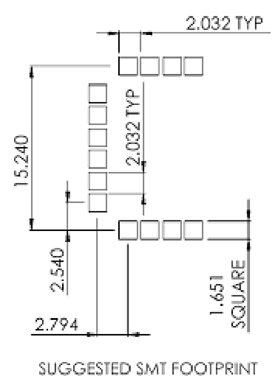

Figure 3-5: MicroMag2 Suggested SMT Footprint

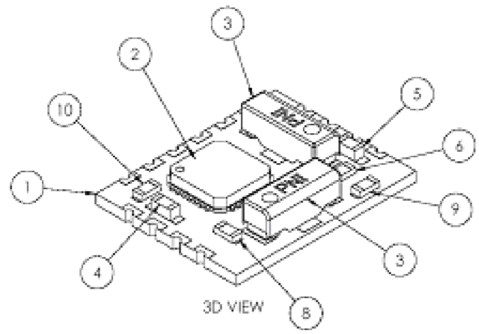

Figure 3-6: MicroMag2 3-D View with Component Call-Out

Table 3-3: MicroMag2 Component Call-Out

Item Number	Quantity	Description
1	1	MicroMag2 PCB
2	1	PNI ASIC, MLF package
3	2	SEN-XY
4	1	C1, chip capacitor
5	1	C2, chip capacitor
6	1	R1, chip resistor
7	1	R2, chip resistor
8	1	R3, chip resistor
9	1	R4, chip resistor
10	1	R5, chip resistor

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3.3.2 MicroMag2-on-Carrier Board

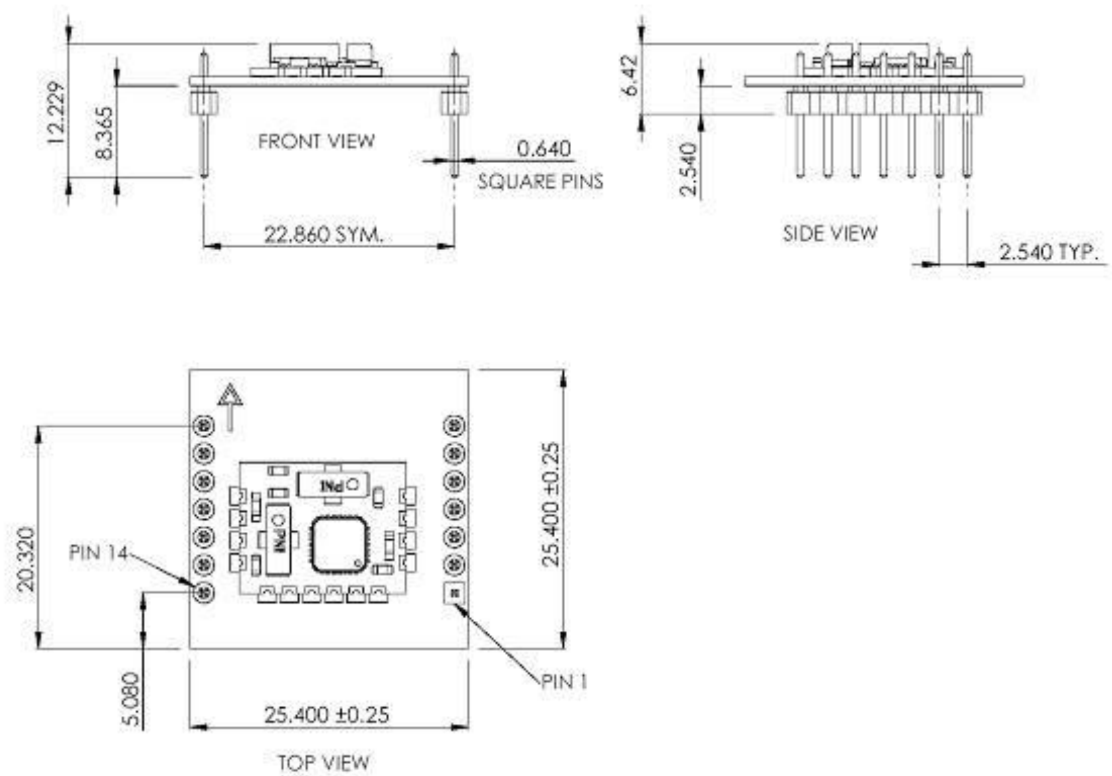

Figure 3-7: MicroMag2-on-Carrier Mechanical Drawing

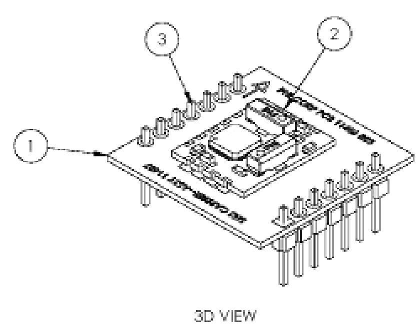

Figure 3-8: MicroMag2-on-Carrier 3-D View

Table 3-4: MicroMag2-on-Carrier Component Call-Out

Item Number	Quantity	Description
1	1	MicroMag2 carrier PCB
2	1	MicroMag2 module
3	2	7-pin header

3.3.3 MicroMag3

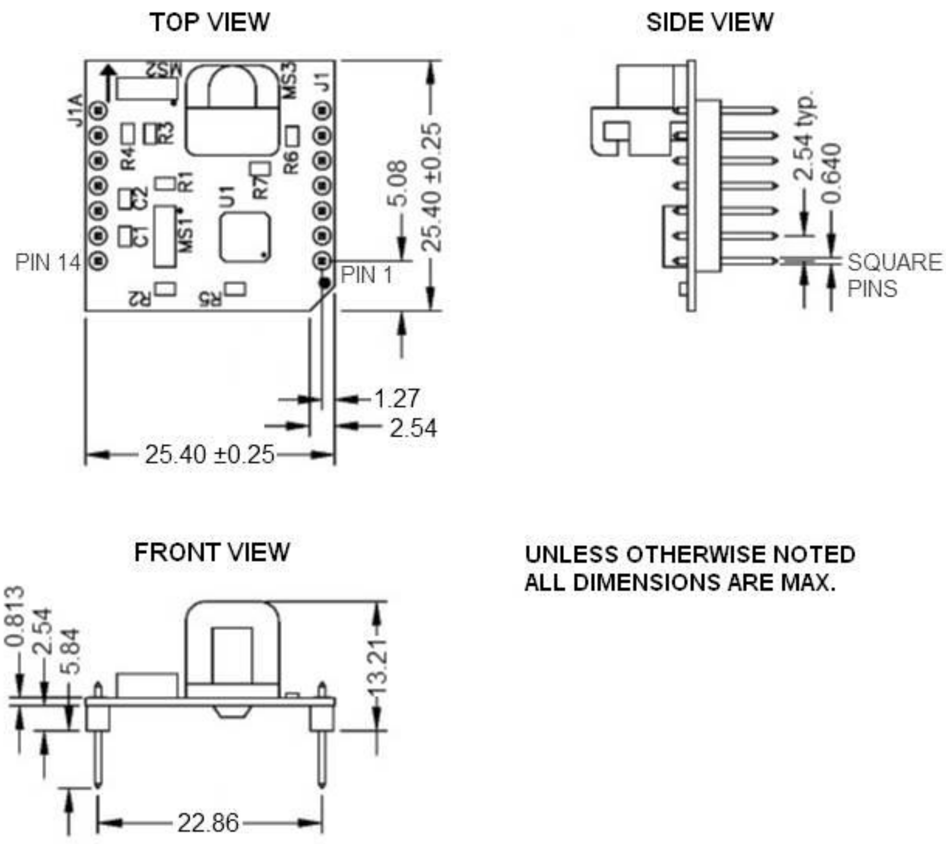

Figure 3-9: MicroMag3 Mechanical Drawing

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4 Set-Up & Interface Lines

4.1 PCB Orientation and Output Polarities

Both the MicroMag2-on-Carrier and MicroMag3 have an arrow printed on the PCB indicating the "reference direction" for the module, while the MicroMag2's reference direction is shown in Figure 3-4. The sensors on the MicroMag modules are arranged in a south-west-down (SWD) coordinate system. The reference direction is parallel to the x-axis sensor, such that when the MicroMag is pointing directly magnetic south (in the absence of any other magnetic field) the x-axis reading of the module will be maximized and the y-axis will be zero. Likewise, when the MicroMag module is pointing directly west the y-axis reading of the module will be maximized and the x-axis reading will be zero. For the MicroMag3, the z-axis reading will depend on the dip angle or inclination at the given location (which is related to latitude). At the geomagnetic equator, where Earth's magnetic field is horizontal, the z-axis reading will be zero when flat and at its maximum when the module is pointed down such that the top of the module faces magnetic north.

Note that if the MicroMag is used with the PNI CommBoard, the coordinate system is changed in software to be north-east-down (NED).

4.2 Pin/Pad Connections

The pin and pad numbers for the MicroMag modules are identified on their respective mechanical drawings, as given in Section 3.3. The connections to be made the various pins and pads are given below in Table 4-1. The MicroMag2-on-Carrier and MicroMag3 have similar pin-outs, while the pad connections for the MicroMag2 are different and include some additional lines. Descriptions of the functions of the various connections is provided in Section 4.3.

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Table 4-1: Pin/Pad Indentifier Table

Identifier	MicroMag2-on-Carrier & MicroMag3 Pin #	MicroMag2 Pad #	Description
SCLK	1	13	Serial clock input for SPI port, 1 MHz maximum (Rext = 100 kHz)
MISO	2	14	Master In, Slave Out for the SPI port
MOSI	3	1	Master Out, Slave In for the SPI port
SSNOT	4	2	Active low device select for SPI port
DRDY	5	10	Data ready
RESET	6	9	Reset input
GND	7, 14	3, 5, 7	Ground
VDD	12	4, 6	DC supply voltage
COMP	NA	8	Comparator output
DHST	NA	11	High-speed oscillator output.
VSTBY	NA	12	Input protection clamp diode common, connected to VDD

For reference, a block diagram for the MicroMag2-on-Carrier is given below. This shows the connections for the MicroMag2 as well. The concept also applies to the MicroMag3, although an additional sensor circuit (APZDRV, APZIN..) would be shown.

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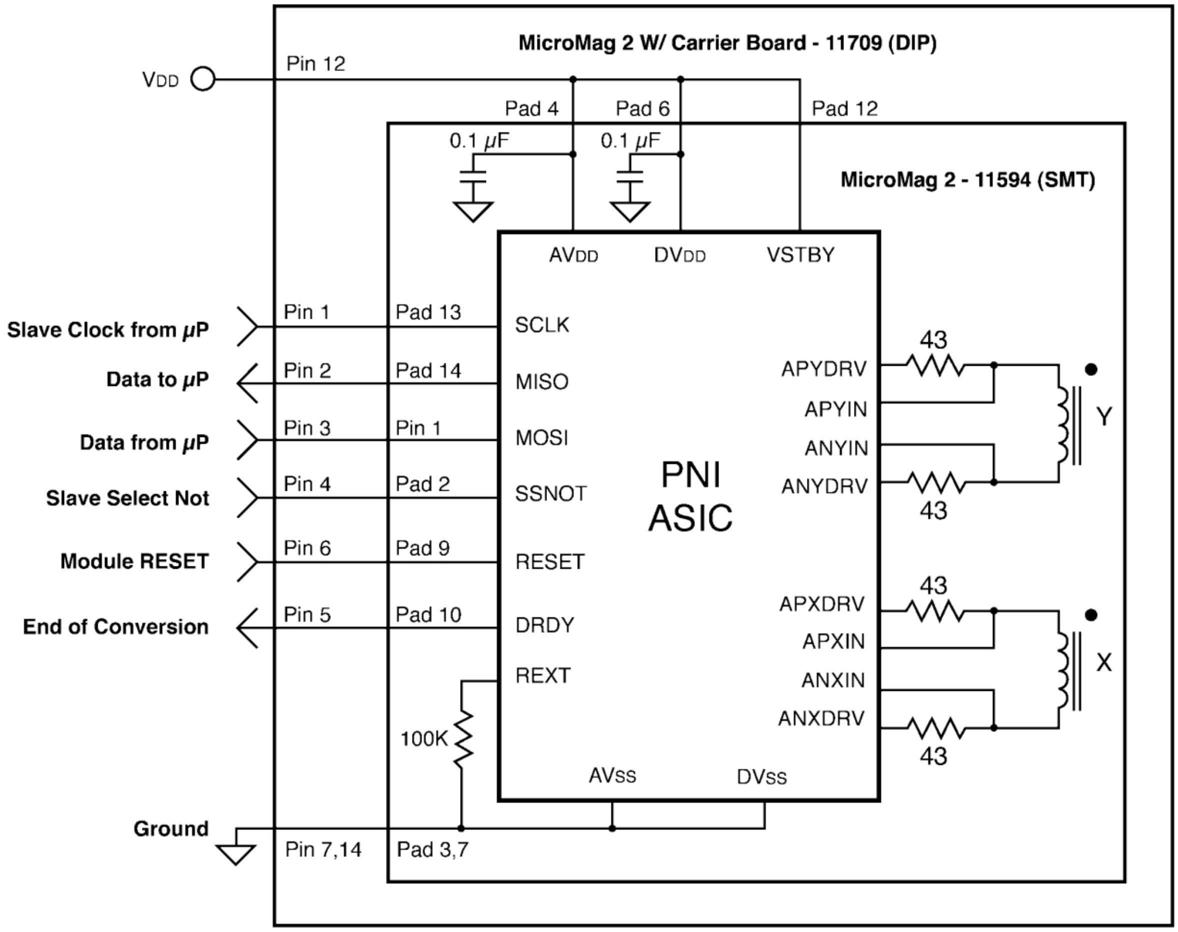

Figure 4-1: MicroMag2-on-Carrier Reference Block Diagram

4.3 Line Descriptions

4.3.1 SCLK (SPI Serial Clock)

The serial clock input is used to synchronize both the data in and out through the MISO and MOSI lines. The serial clock signal is provided by the customer-supplied master device and should be 1 MHz or less. One byte of data is exchanged over eight clock cycles. Data is captured by the master device on the rising edge of SCLK. Data is shifted out and presented to the MicroMag2 on the MOSI pin on the falling edge of SCLK.

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4.3.2 MISO (SPI Master In, Slave Out)

An SPI output that sends data from the MicroMag module to the master device. Data is transferred most significant bit first. The MISO line is placed in a high impedance state if the MicroMag is not selected by the master device (SSNOT = 1).

4.3.3 MOSI (SPI Master Out, Slave In)

An SPI input that provides data from the master device to the MicroMag module. Data is transferred most significant bit first. Valid data must be presented at least 100 ns before the rising edge of SCLK, and remain valid for 100 ns after the rising edge. New data may be presented to the MOSI pin after the falling edge of SCLK.

4.3.4 SSNOT (SPI Slave Select)

This signal sets the MicroMag module as the selected slave device on the SPI bus. The SSNOT line must be LOW prior to data transfer in either direction, and must stay LOW during the entire transfer. The SPI bus can be freed up (SSNOT line set HIGH) for communication with another slave device while the MicroMag module is taking a measurement or idle, but only after all communication between the MicroMag and master device is finished. If the host system has no other slave devices, the SSNOT line can be permanently grounded.

4.3.5 DRDY (Data Ready)

It is recommended the DRDY line be used to ensure data is clocked out of the MicroMag only when it is available. DRDY is set low after a RESET. After a command has been received and the data is ready, DRDY will be changed to high.

If it is determined the DRDY line cannot be used due to lack of I/O lines to the host processor, then the times listed in Table 4-2 can be used to set open-loop wait times. The values listed are the maximum delays from the end of the SCLK command until the rise of the DRDY at each period select setting. The maximum delay occurs when the sensor being sampled is in a zero field

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Table 4-2: Maximum Delay for DRDY

Period Select	Maximum Delay
32	500 μS
64	1.0 mS
128	2.0 mS
256	4.0 mS
512	7.5 mS
1024	15 mS
2048	35.5 mS
4096	60 mS

4.3.6 RESET (Reset)

RESET must be toggled from LOW-HIGH-LOW before sending a measurement command. RESET is usually LOW.

4.3.7 VDD (DC Voltage Input)

It is recommended the user supply 3.0 VDC on this line, in part because the bias resistor values on the MicroMag module were optimized for 3.0 VDC operation.

However, the MicroMag can be run at other voltages within the specification. While not necessary, if the MicroMag will be run at some other voltage it may be desirable to change the bias resistors for better performance. Refer to the PNI ASIC User Manual for bias resistor values for other operating voltages. The resistors to be changed are labeled R1, R2, R3, R4, R6, & R7.

4.3.8 COMP (Comparator)

COMP is only available on the MicroMag2 and it provides the output signal from the comparator component built into the PNI ASIC. This is used for diagnostics.

4.3.9 DHST (Clock Output)

DHST is only available on the MicroMag2 and it outputs the ASIC's high speed clock, but at half the speed. This is used for diagnostics.

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4.3.10 VSTBY

VSTBY is only available on the MicroMag2. (It is wired to VDD on the MicroMag2-on-Carrier and the MicroMag3.) VSTBY provides power to the SPI ports on the PNI ASIC. It should be tied to VDD to prevent current sinking which could be caused when another device is using the SPI bus.

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5 Operation

A single 8-bit command from the host system configures and initiates a sensor measurement. Only one sensor can be measured at a time. Each magneto-inductive sensor operates in an individual oscillator circuit composed of an external bias resistor along with digital gates and a comparator internal to the PNI ASIC. (See Figure 4-1.)

To make a sensor measurement, a command byte is sent to the MicroMag through the SPI port specifying the sensor (axis) to be measured and the "Period Select". The Period Select defines the number of oscillation cycles (periods) to be measured in both the forward and reverse bias directions. A sensor measurement consists of measuring the time required to complete the host-specified number of oscillation cycles (set by the Period Select) in both the forward and reverse bias directions. The measurement is made with the PNI ASIC's internal high speed clock, which runs at nominally 2 MHz. The MicroMag returns the difference between the two measurement times represented as a number in a 16-bit 2's complement format (range: -32768 to 32767), and this number is directly proportional to the strength of the local magnetic field in the direction of the specified axis. Note that the greater the Period Select value, the higher the resolution of the measurement and the longer the sample time.

For a more detailed discussion on the underlying operation of the MicroMag module please refer to the PNI ASIC User Manual (http://www.pnicorp.com/support/manuals) and/or PNI's Magneto-Inductive Technology Overview (http://www.pnicorp.com/support/articles).

Data flow to and from the MicroMag is through a hardware-handshaking, synchronous serial interface adhering to the SPI bus protocol. Section 4.3 reviews the various interface lines.

5.1 SPI Port Timing

Figure 5-1 graphically shows the timing sequence for the MicroMag. The clock polarity used with the MicroMag must be normally LOW (cpol = 0).

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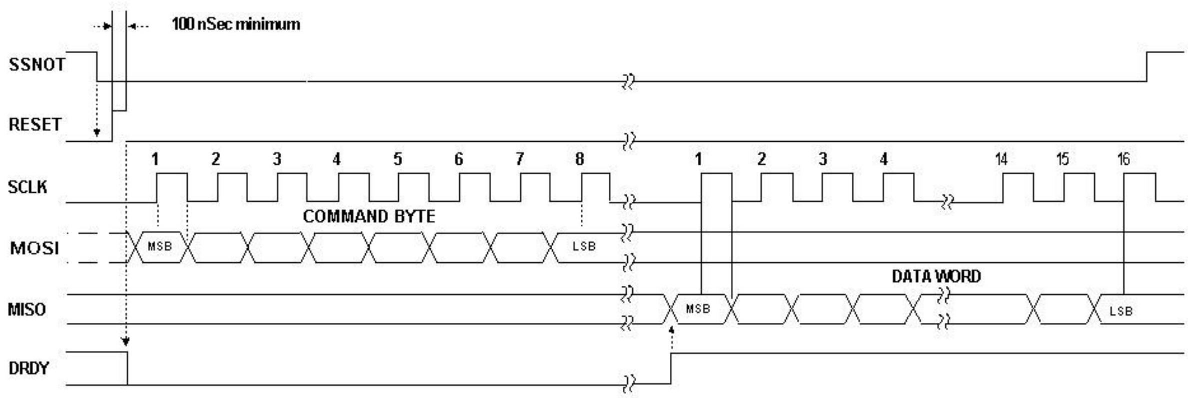

Figure 5-1: SPI Port Full Timing Sequence

When implementing an SPI port, whether it is a dedicated hardware peripheral port or a software implemented port using general purpose I/O (also known as *bit-banging*) the timing parameters given in Figure 5-2 must be met to ensure reliable communications. Data is always considered valid while SCLK is HIGH (tDASH = Time, Data After SCLK High). When SCLK is LOW, data is in transition (tDBSH = Time, Data Before SCLK High).The clock set-up and hold times, $\boldsymbol{t}_{DBSH}$ and $\boldsymbol{t}_{DASH}$ must be greater than 100 ns.

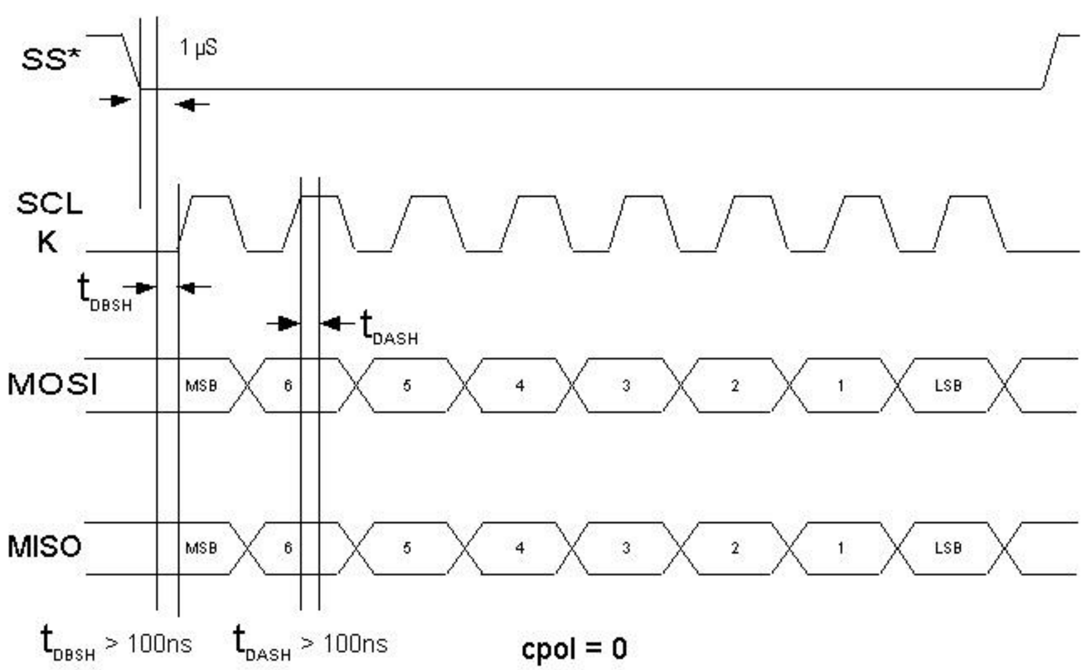

Figure 5-2: SPI Port Timing Parameters

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5.2 Command Byte

The operation of the MicroMag is controlled by the data received into the SPI port on the command byte. The command byte syntax is as follows:

Table 5-1: Command Byte

Position	7	6	5	4	3	2	1	0
BIT Name	DHST	PS2	PS1	PS0	ODIR	MOT	AS1	AS0
RESET	0	0	0	0	0	0	0	0

5.2.1 Axis Select (AS1, AS0)

The Axis Select bits establish which sensor is to be measured, as given below

Table 5-2: Axis Select

Axis Measured	AS1	AS0
X axis	0	0
X axis	0	1
Y axis	1	0
Z axis (MicroMag3)	1	1

5.2.2 Period Select (PS0, PS1, PS2)

The Period Select bits establish how many oscillations are to occur for the measurement. The greater the Period Select, the greater the resolution and the longer the measurement time. Note that with a Period Select of “4096”, the counter buffer may overflow.

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Table 5-3: Period Select

Period Select	PS2	PS1	PS0
32	0	0	0
64	0	0	1
128	0	1	0
256	0	1	1
512	1	0	0
1024	1	0	1
2048	1	1	0
4096	1	1	1

5.2.3 Magnetic Oscillator Test (MOT)

When set HIGH, MOT causes the magnetic oscillator circuit (selected by AS0 and AS1 in the directions selected by ODIR) to run continuously until the MicroMag is RESET.

5.2.4 Oscillator Direction (ODIR)

ODIR determines the magnetic oscillator direction if MOT is set to 1. It has no effect on direction when the MOT bit is set to zero. This is used for debug purposes only, and will not be set in normal operation.

5.2.5 High Speed Oscillator Test (DHST)

When high, the internal high speed clock is set to drive the DHST pad at ½ the clock speed. When low, the DHST pad is set to DVDD. This is used for debug purposes only, and will not be set in normal operation.

5.3 Idle Mode

The MicroMag incorporates an idle mode to reduce power consumption, in which it automatically goes to sleep when it is not exchanging data or taking a measurement. However, it does not necessarily initialize in the idle mode at power-up. To ensure the MicroMag will be in idle mode after being turned on, it is necessary to cycle the system through one measurement operation.

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5.4 Making a Measurement

To make a sensor measurement, a command byte is sent to the MicroMag through the SPI port specifying the sensor (axis) to be measured and the “Period Select”. The Period Select defines the number of oscillation cycles (periods) to be measured in both the forward and reverse bias directions. A sensor measurement consists of measuring the time required to complete the host-specified number of oscillation cycles (set by the Period Select) in both the forward and reverse bias directions. The measurement is made with the PNI ASIC’s internal high speed clock, which runs at nominally 2 MHz. The MicroMag returns the difference between the two measurement times represented as a number in a 16-bit 2’s complement format (range: -32768 to 32767), and this number is directly proportional to the strength of the local magnetic field in the direction of the specified axis. Note that the greater the Period Select value, the higher the resolution of the measurement and the longer the sample time.

The sequence and timing are discussed in Section 5.1 and the command byte syntax is discussed in Section 5.2.

The steps to make a sensor measurement are as follows:

1. SSNOT pin is set LOW. (This enables communication with the master device.)
2. RESET pin is set HIGH, then LOW. This will reset the PNI ASIC. It is necessary to reset the MicroMag before each measurement.
3. A command word is clocked into the MicroMag on the MOSI pin. Once 8 bits have clocked in, the MicroMag will execute the command (take a measurement).
4. A measurement consists of forward biasing the sensor and making a period count; then reverse biasing the sensor and counting again; and then taking the difference between the two directions.
5. At the end of the measurement, the DRDY line is set HIGH, indicating data is ready. The data is clocked out on the MISO pin with the next 16 clock cycles.

If another measurement is to be made, start at Step 2. The next command can be sent after resetting. In this case, SSNOT should be kept LOW. If the MicroMag will not immediately be used again and there are other devices on the SPI bus, set SSNOT to HIGH to free up the SPI bus.

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