PNI Application Note:

Geomagnetic Sensor Layout Guidelines

1 Introduction

This document provides layout guidelines for PNI's geomagnetic sensors. PCB layout, part placement and system considerations are discussed so a designer can make informed decisions for optimum layout and system design. PNI's magnetic sensing technology utilizes a unique direct-to-digital frequency mode conversion technique that makes system layout and integration relatively straight-forward. As with any measurement system, good analog design practices should help maximize system performance.

2 Power Supply Considerations

A good mixed signal layout will run all power and ground connections in a "star" configuration or use plane layers in the design. For PNI's 3D MagIC and MagI2C ASICs, parallel bypass capacitors of 0.1 µF and 1 µF are recommended for each supply input. To significantly lower the current on the AVDD supply input, a 10 µF or higher capacitor may be substituted for the 1 µF capacitor.

For certain applications it may be appropriate to run PNI's ASICs directly from a battery, but for precision applications a regulated power supply is recommended. PNI has successfully used the TPS764xx series of low-noise regulators in many applications. Be aware that some regulators with good overall specifications exhibit poor transient response when transitioning from very low currents to operating currents, even when these are well within the regulator's operating current range. This is an important consideration with PNI ASICs since their low idle currents can be below the threshold of some regulator's optimal operating range.

The use of switching regulators typically is not recommended for sensitive measurement systems, and this also applies to PNI's magnetic sensor technology. One reason is the regulator's switching frequencies can couple with the sensor oscillation frequency via power supply ripple or magnetic flux coupling. Another reason is the flyback and filtering inductors used in these regulator designs have cores made of soft-iron material (see next section). PNI has seen satisfactory results using inductive switching regulator designs if the inductors are located away from the sensors and the output of the switching regulator is highly filtered. For example, in one pointer application, which measures relative heading, the switching inductor was a 6 mm diameter magnetically-shielded type (low flux leakage) and located about 25 mm from the sensors. The output of the switching regulator was followed by a linear regulator. The output voltage of the switching regulator was selected to be higher than the desired linear regulator voltage to accommodate for the dropout voltage. Satisfactory results also have been achieved using non-inductive switching regulator topologies with switching frequencies above 1 MHz.

3 Sensor Routing

Normally in a benign environment, the distance from the geomagnetic sensor to the ASIC is not critical since the sense signals (XINN, XINP etc.) have relatively low impedance, making them robust to external interference. However, it is possible for other signals to couple into the sense input signals if the other signals contain high transient currents. A common example is power supply routes. In these cases follow industry guidelines for minimizing signal crosstalk. These guidelines include, but are not limited to, the following:

- Keep drive and sense input pairs as close together as possible to reduce effective conductor loop diameter. There are 6 drive/sense input pairs in a 3-axis PNI circuit: (X_{DRVP}/X_{INP}),(X_{DRVN}/X_{INN}), (Y_{DRVP}/Y_{INP}),$(Y_{DRVN}/_{YINN})$, (Z_{DRVP}/Z_{INP}),(Z_{DRVN}/Z_{INN}).
- Minimize the parallelism of the power supply signal or other potentially high transient signals with the sense input signals. Route the high transient signals away from the sensor signal and, when they must cross, route them as perpendicular to the sense input signals as possible. The power supply routes to the PNI ASIC are less critical because the PNI ASIC does not create transients during critical times of a sensor measurement. This assumes the ASIC's power supply route is terminated at the ASIC and is not daisy-chained to other loads.
- Power and ground plane layers can help mitigate coupling. Placing signals of concern on different sides of the plane layers from the sense input signals can be beneficial.

4 Sensor Placement

Sensor orientation is critical to achieve the desired reference alignment (e.g. NED alignment), and this is discussed in the RM3100 and RM3000-f User Manuals. Sensor location, on the other hand, is important when laying out a PCB to help reduce unwanted magnetic distorting effects from the surrounding environment. Distortion factors fall into three main categories: hard-iron material interference, soft-iron material interference, and interference signals.

4.1 Hard-Iron Material Interference

Hard-iron (HI) materials typically are ferromagnetic materials such as steel, iron, nickel and cobalt. Permanent magnets also are HI materials. Indeed, HI materials act as permanent magnets, introducing an offset to Earth's magnetic field. Ferromagnetic materials may not immediately show signs of being magnetized; however, they can be magnetized by any DC magnetic field including Earth's field. This can result in a gradual change in the measured signal, appearing as an offset drift. A ferromagnetic material is particularly susceptible to magnetization by Earth's field when the unit is at rest for extended periods. For system design, PNI recommends keeping HI materials as far from the sensors as possible and generally minimizing the use of ferromagnetic materials. See Table 1 for a list of typical magnetic materials found in electronic hardware designs.

Table 1: Typical Magnetic Materials Found in Electronic Hardware Designs

Component	Comments
Hardware, such as screws, RF shields, dome switches, battery terminals, battery clips & bezels.	Many are made from, or plated with, ferromagnetic materials such as iron and/or nickel. Consider sourcing brass screws and tin-plated phosphor-bronze hardware.
Soft core inductors: ferrite, iron powder	Consider other topologies or keep inductors as far from sensors as practical.
Gold-plated components	Gold-plated components are generally under-plated with nickel. This is common for connectors and PCB traces. Consider using tin-plated materials near sensors.
Capacitors	The end-cap materials are commonly Ferromagnetic. Tantalum capacitors have the largest end-caps. Most ceramics used in ceramics capacitors have SI properties. Place capacitors away from sensors.
Motors	Motors used in handheld devices such as vibrator motors (for "rumble" or silent ring) contain permanent magnets and metal cases.
Batteries	Typical alkaline, Ni-Cd and NiMH batteries have strong HI & SI properties due primarily to their nickel-plated steel housings. As with all HI materials they can become slowly magnetized by Earth's field. Replacing or even rotating cylindrical batteries in their holders can change the local magnetic offset. Consider lithium-ion batteries which are commonly available without metal casings.

4.2 Soft-Iron Material Interference

Soft-iron (SI) materials distort or concentrate the local magnet field. This increases the apparent magnetic field density when an SI material is in inline with the sensor and decreases the apparent field density when the SI material is perpendicular with the sensor. All HI materials have SI material properties but SI materials do not necessarily have HI material properties. For example, ferrite is an SI material but not an HI material. SI materials will be attracted to a magnet but will not retain a magnetic field when the magnet is removed. See Table 1 for a list of typical magnetic materials found in electronic hardware designs.

4.3 Interference Signals

An interference signal is any generated signal that interferes with the geomagnetic sensor's ability to measure the intended signal. Sources include both emitted and conductive signals. Table 2 provides a list of typical interference signals.

Table 2: Typical Interference Signals

Coupling Mode	Signal Source	Possible Solution
Emitted	Current loops from external sources, such as power cables or battery wires. (Current loops generate magnetic fields)	1. Twisted wire pairs emit less field 2. Reroute wires/cables away from sensors
	Current loops from internal power routes.	1. Route power and return ground traces for suspecting components/devices as close together as possible and in a "star" configuration. 2. Timing: Disable or refrain from activity with culprit device. For example, some MEMS gyroscopes have high transient currents when accessed. In this case try to make measurements at separate times
	Magnetic coupling from switching regulator.	1. Keep soft-core inductors as far from sensors as possible 2. Use better regulator design (See Power Supply Considerations section).

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Coupling Mode	Signal Source	Possible Solution
Conducted	Power supply coupling caused by transients from other on-board devices.	1. Use “Star” power routing or power/ground plane layers 2. Check for sufficient use of decoupling capacitors 3. Timing: Disable or refrain from activity with culprit device. For example, some MEMS gyroscopes have high transient currents when accessed. In this case try to make measurements at separate times 4. Consider separate voltage regulators
	Power supply ripple/transients.	1. Improve pre- and/or post- regulator filtering 2. Check for sufficient use of decoupling capacitors 3. Use better regulator design (See Power Supply Considerations section).