Using MagAlpha Rotary Magnetic Sensors in Side Shaft Mode

Abstract

The previous article discussed types of magnets and their uses with MPS's MagAlpha sensors in "end of shaft" mode; this article will examine "side shaft "mode topology. MPS MagAlpha sensors utilize an array of Hall elements in the center of the IC that sense the horizontal vector of the field from the rotating magnet. This field typically comes from a simple two-pole diametrically polarized magnet situated above or to the side of the sensor (see Figure 1).

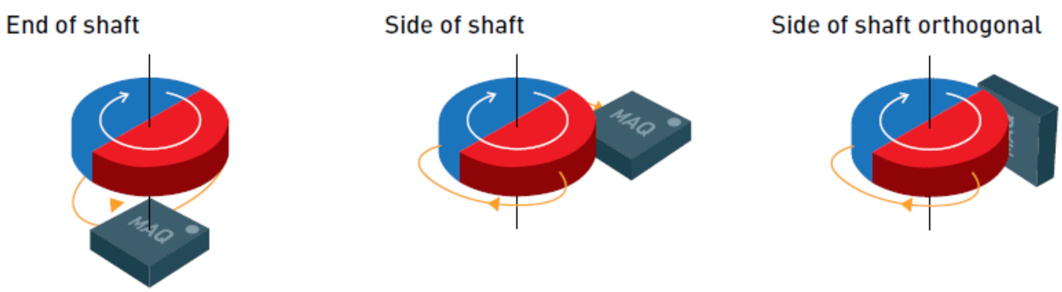

Figure 1: End and Side of Shaft Modes of the MagAlpha Sensor

There are two types of side shaft topology: "standard" side shaft, where the sensor package surface is perpendicular to the magnet's rotation axis, and "orthogonal" side shaft, where the sensor package surface is parallel to the magnet's rotation axis. Both require more consideration in the design process than end of shaft mode, and the MPS magnetic simulation tool provides an effective way to evaluate performance before committing to the real mechanical design.

Introduction

When MagAlpha sensors are used with a magnet to the side of the rotating shaft, the Hall array sees both a radial magnetic field component Br and a tangential component Bt (or in the case of orthogonal side shaft, a vertical component Bz). The most common side shaft topology uses a radially-polarized ring magnet (see Figure 2).

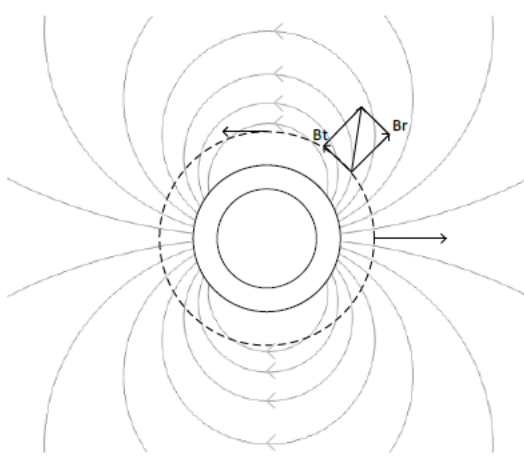

Figure 2: Radial and Tangential Magnetic Fields around a Diametrically Polarized Two-Pole Ring

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2022 MPS. All Rights Reserved.

In this configuration, the magnitude of the radial field Br is usually larger than the tangential component Bt. When the sensor sees two fields with unequal magnitudes, the angle output becomes non-linear as the magnet is rotated. The magnitude of both fields must be normalized so that the sensor observes a rotating field vector with a constant magnitude. MagAlpha sensors feature bias current trimming (BCT) adjustment registers to allow the two field magnitudes to be equalized to obtain a linear angle response. For more details, see the application note "Using MagAlpha in Off-Axis Mounting".

After the trimming action described above, the sensor sees a resultant magnetic field that is lower due to the gain reduction in either the X or Y axis. In standard side shaft topology, the sensors Hall array is also further away from the magnet surface due to the width of the IC package. These two effects combined mean that the magnet ring design must have enough remanent field (usually denoted by Br) to satisfy the minimum field requirements of the sensor. Because of their low remanent fields in the 200 mT to 300mT Br range, ferrite and plasto-ferrite magnets are unlikely to work well in side shaft operation, especially after the reduction caused by the BCT trimming.

To achieve adequate field strength, the ring usually needs to be made from a material with a higher initial remanent field such Neodymium Iron Boron (NdFeB) in either sintered (about 0.9T to 1.4T Br) or bonded polymer format (about 0.6T to 0.7T Br). Bonded polymer is more cost effective with larger-diameter rings, but bonded polymer rings have approximately half the field strength when compared to an equally sized sintered ring. The ring's dimensions must be adjusted to ensure the sensors minimum field requirement is met at the chosen distance, and after the BCT field adjustments.

When low field strength is an issue, the MagAlpha series has two sensors optimized for side shaft mode: the MA710 and MA310. These products have higher internal gain to accommodate operation with minimum fields down to 15mT (as opposed to the usual 30mT to 40mT for most of the MagAlpha family).

The magnetic simulation tool for the MagAlpha family used in the above examples can be found here.

The simulator tool supports all of the possible magnet types and sensor to magnet topologies supported by the MagAlpha range. It provides an effective way to prototype and evaluate the performance of the sensor with different magnet types and in different positions to eliminate a trial and error approach. The effects of mechanical and magnetic tolerances on the system can also be input via the tools advanced settings option to gauge the effect on angle resolution performance.

Figure 3 shows an example of a side shaft design using a bonded Neodymium ring. The ring has an inner diameter of 20mm, outer diameter 30mm, and height 2mm. In this example, the ring has a simple two-pole diametric polarization and a remanent field of 700mT. Using an MA710 sensor in standard side shaft topology, the sensor package is ideally placed to the side of the ring magnet such that the Hall array is exactly halfway up the height of the magnet. The MA710 QFN sensor package is nominally 0.9mm in height and the internal Hall array is located 0.5mm below the package surface. The vertical z parameter is therefore 0mm.

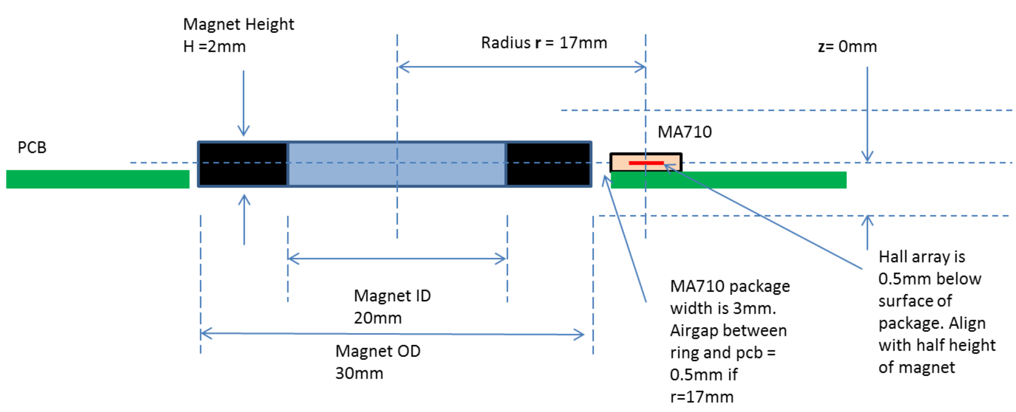

Figure 3: MA710 Angle Sensor in Standard Side Shaft Topology

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2022 MPS. All Rights Reserved.

Using the simulator to scan the radius from r = 16.5mm to 20mm, it is noted that a suitable position for the sensor would be at r = 17mm (see Figure 4). In this position, the sensor has a 0.5mm airgap between the edge of the IC package and the surface of the ring magnet. The tangential magnetic field Bt is approximately 18mT. The radial field Br is much larger at approximately 82mT, which causes a non linear sensor angle response unless some correction via the BCT registers is applied to reduce the amplitude of the radial field. The simulator calculates the required register value for BCT trimming to be 200. Applying this value to the sensor creates a solution with a resolution of approximately 11.3 bits (3-sigma).

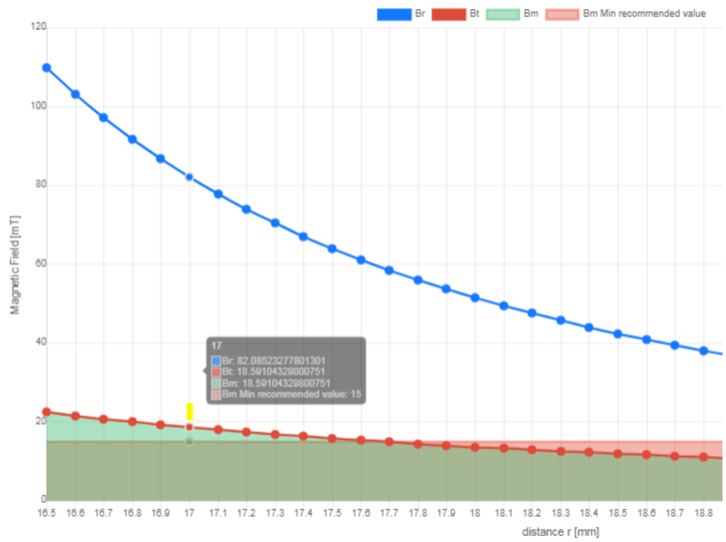

Figure 4: Simulator Plots of the Magnetic Fields vs. Radius Observed By the Sensor in Standard Side Shaft Topology

Figure 5 shows the simulator summary report.

Magnet Simulation

Inputs

Parameters used to perform the magnet simulation

Symbol	Value	Description
Sensor Location	Side-Shaft	
Magnet Type	Cylinder with Hole	
Brem	0.7T	Magnet Remanence
H	2.0mm	Magnet Height
OD	30.0mm	Magnet Outer Diameter
ID	20.0mm	Magnet Inner Diameter
r	17.0mm	Radius Between Magnet Center and Sensor Sensitive Point
z	0.0mm	Z offset Between Magnet Center and Sensor Sensitive Point
Sensor Part Number	MA710	

Results

Symbol	Value	Description
Bm	18.6mT	
Br max	82.1mT	
Bt max	18.6mT	
Bz max	-0.0mT	Not measured by the sensor in this setup
k	4.4153	
BCT	200	
ETX	1	
ETY	0	
E	32.24°	Non-Linearity caused by the magnet (can be compensated by the BCT)
Resolution	11.26bit, ±0.0734°	

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2022 MPS. All Rights Reserved.

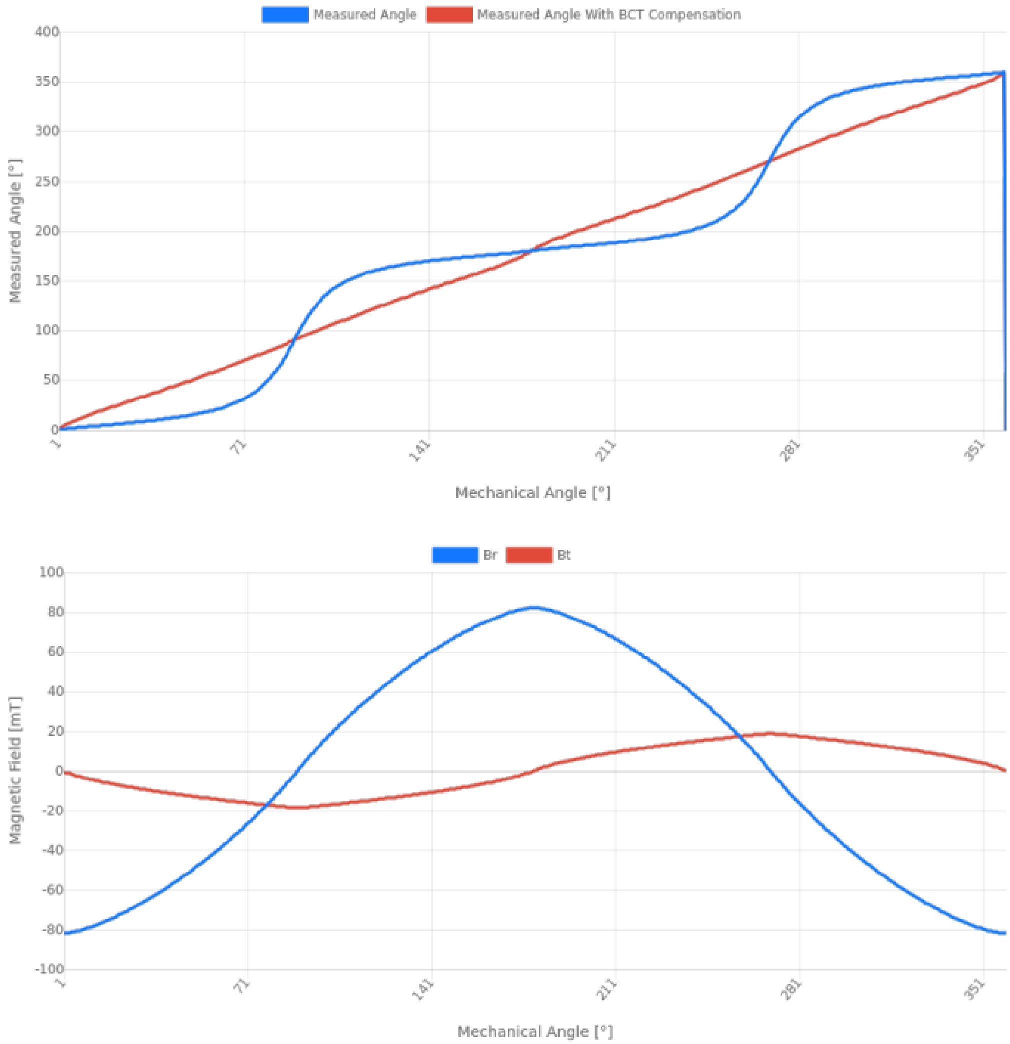

Fig 5: Magnetic Simulation Tool Report

It should be noted that mechanical and magnetization tolerances have a much larger effect on sensor linearity in side shaft modes. As a consequence, these tolerances must be considered to ensure the final design meets expectations. After the initial settings are found using the simulator for a first pass, it is recommended to perform a series of further simulator iterations by adding in the various tolerances via the advance parameters section. A discussion of tolerances and their effects can be read in the application note AN142 ("Linearity in Side-Shaft Configuration").

More information on the full MagAlpha sensor range is available here.

MPS Proprietary Information. Patent Protected. Unauthorized Photocopy and Duplication Prohibited.
© 2022 MPS. All Rights Reserved.