Choosing the Right Magnet for MagAlpha Sensors

Overview

The MPS MagAlpha family offers rotary Hall effect magnetic sensors that sense the position of a magnet as it rotates above or at the side of the sensor. Exact magnet sizes, shapes, and materials should be selected depending on application requirements and target costs. This article discusses tradeoffs, and how to choose the best magnet for an application.

Introduction

MPS MagAlpha sensors utilize an array of Hall elements in the center of the IC that sense the field from the rotating magnet. This field typically comes from a simple dipole, diametrically polarized magnet situated above or to the side of the sensor (see Figure 1).

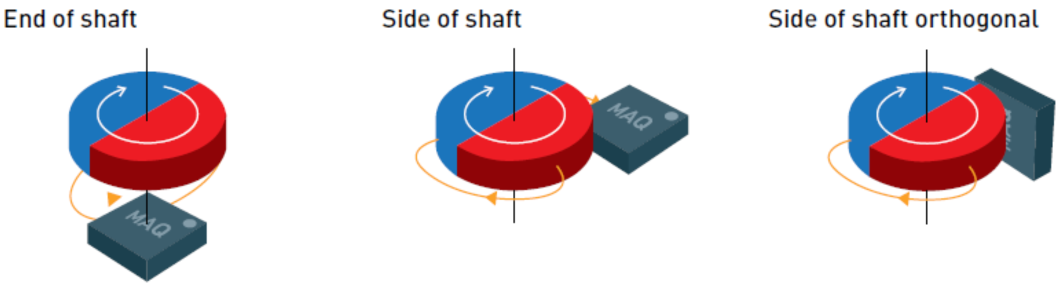


Figure 1: End and Side of Shaft Modes with the MagAlpha Sensor

The Hall array senses the field vector that is parallel to the IC surface. MagAlpha sensors require that the magnetic field strength of this horizontal component be between 30mT and 150mT (millitesla). The type of magnetic material, magnet size, and distance to the sensor must be considered to ensure that the magnetic field falls in the correct range.

Magnet Materials and Cost

Magnets are produced in a variety of forms that are combinations of magnetic elements and compounds. These compounds can become magnets in two ways: they can be sintered (fused at high temperatures) into solid magnets, or they can be made from a molded construction where the magnetic material is suspended in granular form using a plastic polymer carrier compound. Sintered magnets have a higher magnetic field strength because the magnetic materials are more densely packed together than in the bonded polymer magnets.

The cost of a magnet is based on the magnet's volume, the type of materials used in the construction, and the manufacturing process. Sintered magnets are generally more expensive than bonded magnets of the same size and volume due to their greater field strength, and the density of magnetic material.

Ferrite magnets are the least expensive due to the wide availability of iron compound based materials. "Rare earth" type magnets made from neodymium iron boron or samarium cobalt alloys are more expensive due to the scarcity of the raw materials.

Lower density, bonded polymer magnets made from ferrite or rare earth compounds offer the ability to control the cost when a larger magnet size is needed. They also provide more flexibility when customizing a magnet's shape. However, bonded polymer magnets have a weaker field strength due to the lower density of magnetic material present.

Sintered rare earth magnets are cost effective in small disc sizes (up to about 10mm in diameter), and can be used for end of shaft and side of shaft topologies. Some applications require a larger ring (e.g. 20mm or 40mm in diameter) if they are mounted on a larger rotating shaft. To reduce cost, these larger rings are often made using bonded polymer rare earth magnets to reduce the total volume of magnetic material used.

Magnetic Field Strength vs. Material Type

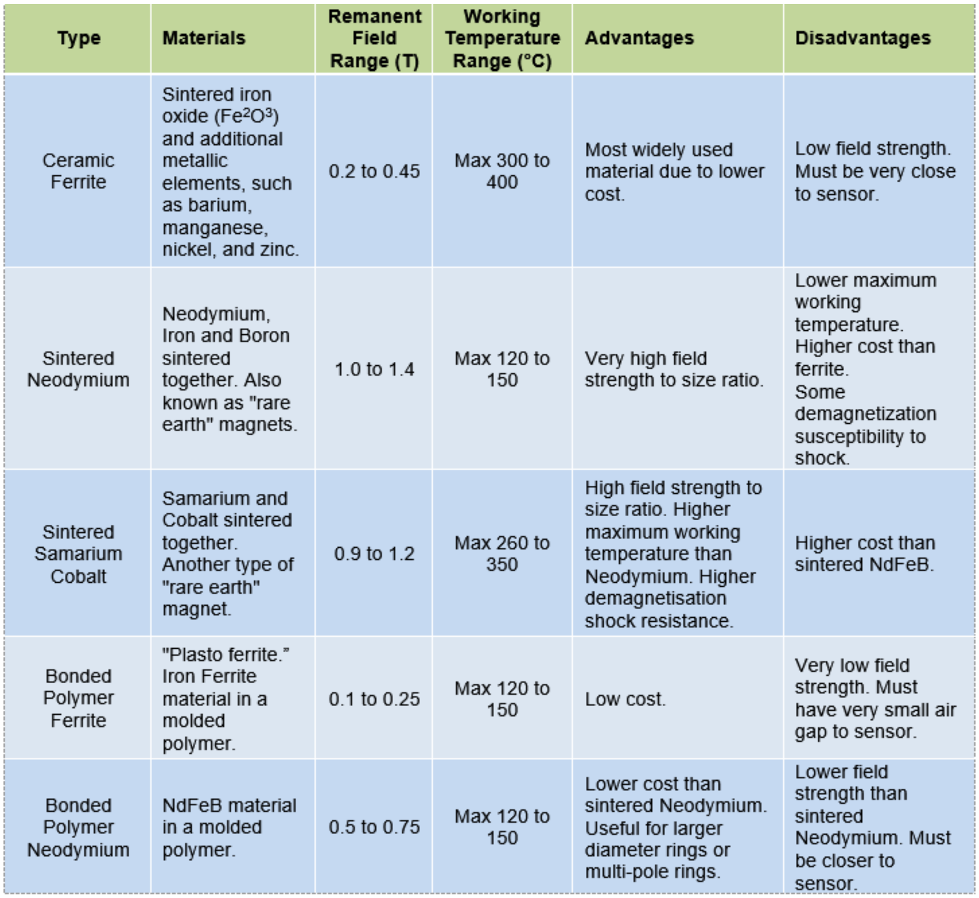
The measure of the magnetic field strength (or flux density) for a particular magnet type is given by its remanent field, usually denoted as "Br." This is the field that remains after the magnetization process.

Magnetic field strength is denoted in Tesla or in Gauss. 1 Tesla (1T) is equivalent to 10,000 Gauss. Tesla is measured in SI units of kilograms per ampere seconds squared, or $T = kg/As^2$.

The most common form of magnetic material is iron oxide based ferrite. This is fused with other compounds, such as barium or strontium carbonate, to make hard ferrite magnets (sintered). These magnets have the lowest cost, and low field strengths between 200mT and 400mT. Bonded polymer ferrite construction, or "plasto-ferrite," further reduces the field strength. A bonded polymer ferrite magnet with the same size and volume as a sintered type has a field strength between 100mT and 200mT.

"Rare earth" neodymium or samarium cobalt magnets are popular since they achieve high field strength in smaller volume magnets. Sintered magnets offer remanent fields between 900mT and 1400mT depending on grade. The grade is denoted by an "N" number, where the higher number indicates a higher remanent field (Br). For example, N35 has a Br of about 1.2T, while N48 has a Br of about 1.4T. These Br values are generally halved if the magnet is constructed via bonded polymer. Table 1 summarizes the most common magnet types and their associated characteristics.

Table 1: Magnet Material Types and Characteristics



Type	Materials	Remanent Field Range (T)	Working Temperature Range (°C)	Advantages	Disadvantages
Ceramic Ferrite	Sintered iron oxide (Fe^2O^3) and additional metallic elements, such as barium, manganese, nickel, and zinc.	0.2 to 0.45	Max 300 to 400	Most widely used material due to lower cost.	Low field strength. Must be very close to sensor.
Sintered Neodymium	Neodymium, Iron and Boron sintered together. Also known as "rare earth" magnets.	1.0 to 1.4	Max 120 to 150	Very high field strength to size ratio.	Lower maximum working temperature. Higher cost than ferrite. Some demagnetization susceptibility to shock.
Sintered Samarium Cobalt	Samarium and Cobalt sintered together. Another type of "rare earth" magnet.	0.9 to 1.2	Max 260 to 350	High field strength to size ratio. Higher maximum working temperature than Neodymium. Higher demagnetisation shock resistance.	Higher cost than sintered NdFeB.
Bonded Polymer Ferrite	"Plasto ferrite." Iron Ferrite material in a molded polymer.	0.1 to 0.25	Max 120 to 150	Low cost.	Very low field strength. Must have very small air gap to sensor.
Bonded Polymer Neodymium	NdFeB material in a molded polymer.	0.5 to 0.75	Max 120 to 150	Lower cost than sintered Neodymium. Useful for larger diameter rings or multi-pole rings.	Lower field strength than sintered Neodymium. Must be closer to sensor.

Field Strength and Distance in “End of Shaft” Mode

Magnetic field strength decays with distance, according to an approximate inverse cube law. A magnet’s initial remanent field value (Br) determines how close the sensor should be to the magnet’s surface in order to sense a magnetic field strong enough for operation.

In end-of-shaft mode, the MagAlpha sensor only detects the tangential magnetic field (Bt) that exists directly between the poles on the underside of the magnet.

For example, consider a diametrically magnetized disc magnet with a remanent field of Br = 1.0T, a 5mm diameter, and a 3mm height. Figure 2 shows how the tangential Bt field decays, from just under 200mT at the surface of the magnet to below 5mT at a 10mm distance. Figure 3 shows the magnet when viewed from the side.

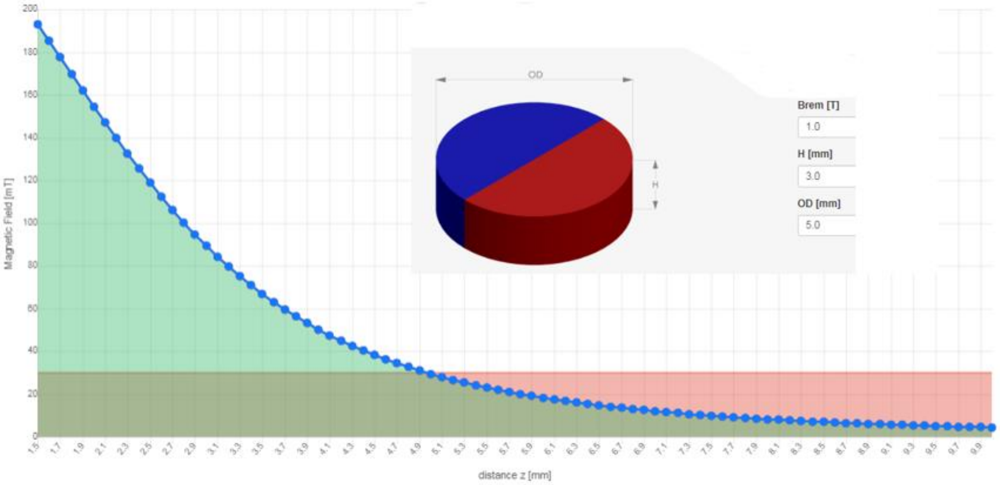


Figure 2: Magnetic Field vs. Distance – 5mmx3mm Neodymium Magnet with 1T Remanent Field

The MagAlpha sensor typically requires a minimum field of 30mT. The field hits the 30mT lower limit at z = 5mm. The value of z is the distance from half the magnet’s height to the surface of the internal Hall array elements inside the sensor IC. The maximum air gap between the magnet and the sensor is therefore 3mm (calculated as z = 5mm, subtract half the height, H = 1.5mm, then subtract 0.5mm, which is the distance between the MagAlpha package and the surface of the Hall array) (see Figure 3).

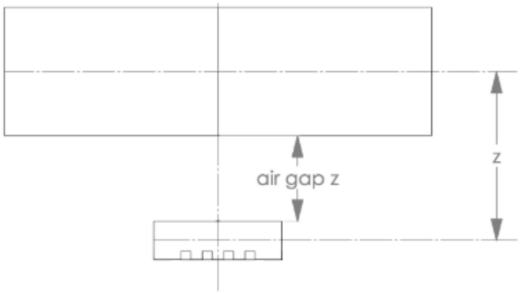


Figure 3: Magnet and Sensor Side View Showing “z” Dimension

A recommended target field strength would be between 40mT and 60mT. In the above example, this equates to the following values: z = 4.3mm to 3.7mm, with a physical air gap of 2.3mm to 1.7mm.

If the same analysis is applied to a sintered ferrite magnet that has a lower remanent field of Br = 300mT, the “z” value is reduced to 2.8mm for the minimum 30mT field position, and therefore the sensor air gap must be reduced to no more than 0.8mm (calculated as 2.8mm, minus 1.5mm for half the magnet height, minus the 0.5mm for the internal IC package distance to the Hall array). Figure 4 shows this relationship.

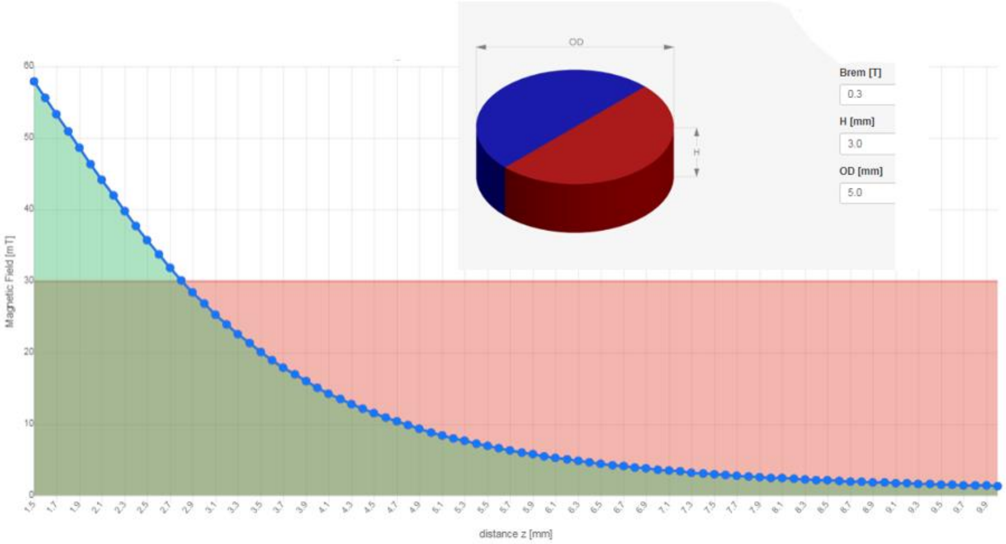


Figure 4: Magnetic Field vs. Distance – 5mmx3mm Ferrite Magnet with 0.3T Remanent Field

Allowing for a margin with a target field of 40mT would be ideal, but it would require an even smaller air gap of only 0.3mm (2.3mm - 1.5mm - 0.5mm). Using a magnet with a weaker remanent field costs less, but restricts the maximum range of air gap available in the design.

For more details on how to select the right magnet size and position for end-of-shaft mounting, please refer to the application note “The Right Magnet for the MagAlpha at the End of the Shaft”.

The magnetic simulation tool for the MagAlpha family used in the above examples can be found here. This simulator tool supports all possible magnet types and sensor-to-magnet topologies offered by the MagAlpha family. It provides an effective way to evaluate the performance of the sensor with different magnet types and in different positions, eliminating the need for trial and error. The tool can also be used to gauge the effect on sensor performance based on various mechanical and magnetic tolerance levels.

Click here for more information on the MagAlpha sensor range. The next article in the series will give an example of how to use the simulator tool to configure the MagAlpha in a side-shaft magnet topology.