Application Note

Selecting the Right Magnet for the MagAlpha in End-of-Shaft Mounting

January 2017

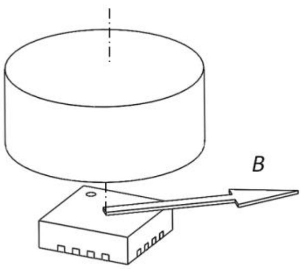
Introduction

The MagAlpha is an angle sensor that detects the direction of the magnetic vector locally. This means that the only quantity detected by the MagAlpha is the angle of the magnetic vector field in the chip center projected in the chip plane. This allows the MagAlpha to be coupled with a magnet in a variety of ways, in contrast to most of the other sensor technologies where the sensor-magnet configuration is imposed precisely.

The choice of the magnet and the position of the sensor will affect key performances, namely resolution and linearity. The resolution is affected by the field strength: the larger the field the better, since increasing the field strength increases the signal-to-noise ratio directly. By design, the MagAlpha does not saturate at a high field. Therefore, there is no upper limit to the field strength. The lower limit for achieving the target performance is indicated in the datasheet. Let’s assume it is 30mT in this note..

Sensor linearity depends on the shape and size of the magnet. A large magnet increases misalignment tolerances.

This application note focuses on the end-of-shaft configuration, such as where the MagAlpha center is placed on the rotation axis (see below).



Magnet Selection

Material

To reach the magnetic field strength required by the MagAlpha, suitable magnets are usually rare earth magnets (sintered NdFeB or SmCo). Their materials have remanent fields ranging from 0.9 to 1.4T. NdFeB is the cheapest and most common. For instance, the N35 grade has a remanent field of 1.2T at room temperature. At 150°C, the remanent field of the N35 is reduced to 1.0T. On the other hand, SmCo has a much smaller remanence reduction as a functioning temperature (only 3% - 4% at 150°C).

Table 1: Remanent Fields

	Remanent Field (T)	Temperature Coefficient (%/°C)
NdFeB	1 to 1.4	-0.08 to -0.12
SmCo	0.9 to 1.1	-0.03 to -0.05

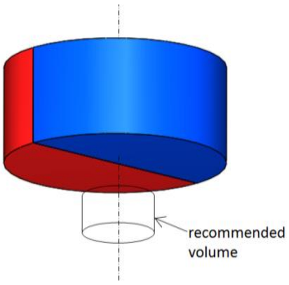
Note that bonded rare earth can also be used. Depending on the composition, their remanent field is a fraction of a T, which is suitable for most applications.

Shape

Any shape creating a rotating field vector can be used, but this application concerns the most natural shape: a simple cylinder, diametrically magnetized, with or without a hole. In principle, any cylinder would be sufficient. The differences are found in the authorized air gap and the mechanical tolerances.

Therefore, for different cylinder dimensions, this application note provides the recommended spatial volume for where the MagAlpha can be located. With this information, users can select a magnet suitable to his or her requirements (which typically are the available space, minimum sensor-magnet distance, and mechanical tolerances).

The MagAlpha is recommended to be positioned somewhere inside a cylindrical volume (see below).



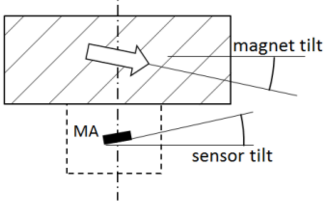
This volume, given in Appendix A and Appendix B, is determined so that the magnetic field is more than 30mT, and the non-linearity introduced by the misalignment is less than 1 degree.

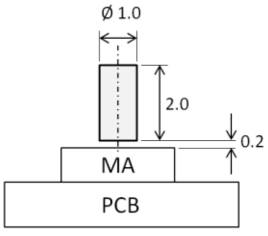
Notes

First, the linearity, or more precisely, the integral non-linearity (INL), is defined as the largest systematic deviation between the sensor output and the linear best fit of the outputs over one rotation.

Second, the 1 degree INL limit taken here is optimum. For many applications where the INL is not critical, this limit can be relaxed, and the radius of the acceptable cylinder (r_h) is about 50% larger than in Appendix A and Appendix B.

For the volume given in Appendix A and Appendix B, it is further assumed that the remanent field is 1.0T (a typical value for a rare earth magnet), the sensor can be tilted by a 2.5 degree maximum, and the magnet (or the magnetization vector inside the magnet) can be tilted a maximum 2.5 degrees.

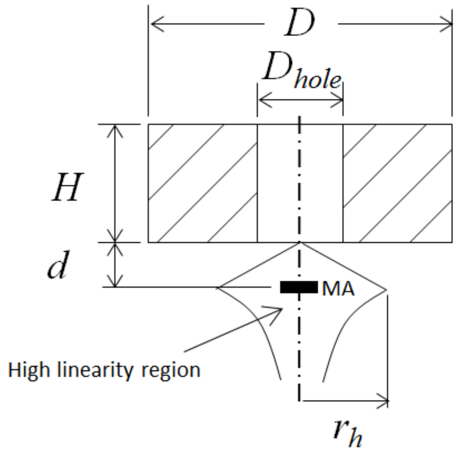




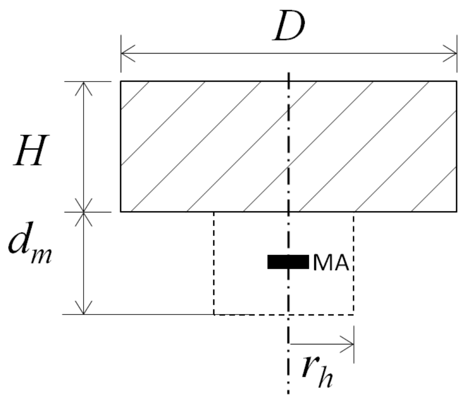
Note that when releasing the INL tolerances, it is possible to use magnets smaller than 3mm. For example, an overall INL of ±2.5 deg can be obtained with a 2x1mm magnet.

Optimum Air Gap for High Lateral Tolerance

The non-linearity resulting from the sensor lateral displacement depends on the air-gap. At a certain distance from a magnet with a hole, the MagAlpha can be displaced laterally by a large amount with little effect on the non-linearity. For applications requiring a large tolerance for misalignment, place the sensor at this particular air gap (see Appendix C and the figure below).



Appendix A: Sensor Position for a Cylinder without a Hole



Use Table 1a and Table 1b to determine the height and radius of the cylinder.

Table 1a: Specifications to Determine the Height of the Cylinder

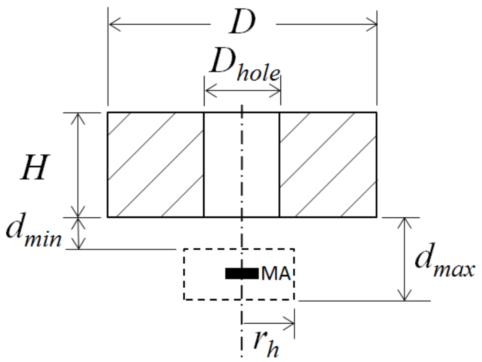
d_m (mm)		D (mm)							
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**
H (mm)	**2.0**	2.1	2.6	3.1	3.5	3.8	4.1	4.3	4.6
	2.5	2.2	2.8	3.3	3.7	4.1	4.5	4.8	5.1
	3.0	2.3	2.9	3.5	4.0	4.4	4.8	5.2	5.5
	3.5	2.4	3.0	3.6	4.1	4.6	5.0	5.5	5.9
	4.0	2.4	3.1	3.7	4.3	4.8	5.3	5.7	6.1
	4.5	2.5	3.2	3.8	4.4	4.9	5.4	5.9	6.4
	5.0	2.5	3.2	3.9	4.5	5.1	5.6	6.1	6.6

Table 1b: Specifications to Determine the Radius of the Cylinder

r_h (mm)		D (mm)							
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**
H (mm)	**2.0**	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.6
	2.5	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6
	3.0	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
	3.5	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
	4.0	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
	4.5	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
	5.0	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6

Appendix B: Sensor Position for a Cylinder with a Hole

Hole size: 25% of the cylinder outer diameter.



Use Table 2a and Table 2b to determine the height and radius of the cylinder.

Table 2a: Specifications to Determine the Height of the Cylinder

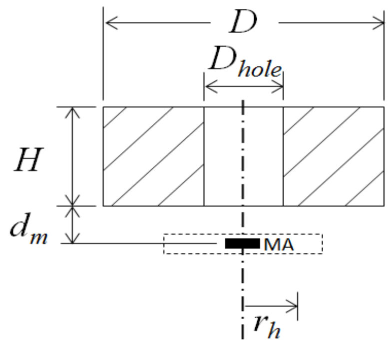
		D (mm)							
d_{min} - d_{max} (mm)		**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		D_{hole} (mm)							
		0.75	**1**	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**
H (mm)	**2.0**	0.5-2.0	0.6-2.5	0.8-2.9	1.0-3.2	1.2-3.5	1.5-3.7	1.7-3.9	2.0-4.0
	2.5	0.5-2.1	0.6-2.7	0.8-3.1	1.0-3.5	1.2-3.8	1.4-4.1	1.6-4.4	1.8-4.6
	3.0	0.5-2.2	0.6-.2.8	0.8-3.3	0.9-3.7	1.1-4.1	1.3-4.5	1.5-4.8	1.7-5.1
	3.5	0.5-2.2	0.6-2.9	0.8-3.4	0.9-3.9	1.1-4.4	1.3-4.8	1.4-5.1	1.6-5.4
	4.0	0.5-2.3	0.6-3.0	0.8-3.5	0.9-4.1	1.1-4.5	1.2-5.0	1.4-5.4	1.6-5.7
	4.5	0.5-2.2.34	0.6-3.0	0.8-3.6	0.9-4.2	1.1-4.7	1.2-5.2	1.4-5.6	1.6-6.0
	5.0	0.5-2.4	0.6-3.1	0.8-3.7	0.9-4.3	1.1-4.8	1.2-5.3	1.4-5.8	1.6-6.2

Table 2b: Specifications to Determine the Radius of the Cylinder

		D (mm)							
r_h (mm)		**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		D_{hole} (mm)							
		0.75	**1**	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**
H (mm)	**2.0**	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8
	2.5	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7
	3.0	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
	3.5	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
	4.0	0.2	0.2	0.3	0.4	0.4	0.5	0..6	0.6
	4.5	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.6
	5.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6

Appendix C: Position with Large Misalignment Tolerance for a Cylinder with a Hole

Hole size: 25% of the cylinder outer diameter.



Use Table 3a and Table 3b to determine the height and radius of the cylinder.

Table 3a: Specifications to Determine the Height of the Cylinder

d_m(mm)		*D* (mm)							
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		D_{hole} (mm)							
		0.75	**1**	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**
H (mm)	**2.0**	0.8	1.2	1.5	1.8	2.1	2.5	2.9	3.2
	2.5	0.8	1.2	1.4	1.7	2.1	2.4	2.7	3.1
	3.0	0.8	1.1	1.4	1.7	2.0	2.3	2.6	3.0
	3.5	0.8	1.1	1.4	1.7	2.0	2.3	2.6	2.9
	4.0	0.9	1.1	1.4	1.7	2.0	2.2	2.5	2.8
	4.5	0.9	1.1	1.4	1.7	1.9	2.2	2.5	2.8
	5.0	0.9	1.1	1.4	1.7	1.9	2.2	2.5	2.8

Table 3b: Specifications to Determine the Radius of the Cylinder

r_h (mm)		*D* (mm)							
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**
		D_{hole} (mm)							
		0.75	**1**	**1.25**	**1.5**	**1.75**	**2**	**2.25**	**2.5**
H (mm)	**2.0**	0.5	0.6	0.8	1.1	1.3	1.4	1.6	1.8
	2.5	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8
	3.0	0.5	0.5	0.8	1.0	1.2	1.4	1.6	1.8
	3.5	0.3	0.5	0.8	1.0	1.1	1.4	1.6	1.8
	4.0	0.3	0.5	0.8	1.0	1.1	1.3	1.6	1.8
	4.5	0.3	0.5	0.8	1.0	1.1	1.3	1.6	1.8
	5.0	0.3	0.5	0.7	0.7	1.1	1.3	1.6	1.7