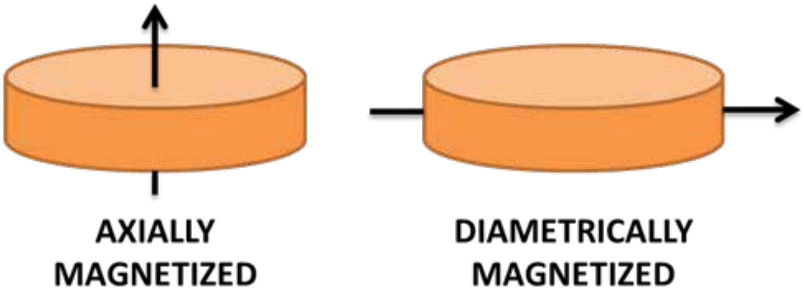
Magnet Optimized for Angular Position Sensor Application

The angle position sensor, also referred to as a rotary sensor, measures position relative to another about a common axis of rotation. In our case, this is the positional relationship between a stationary integrated circuit (IC) and a rotating magnet. This relative angular position information is converted into an electrical signal by the sensing IC which converts this relative position into an absolute angle measurement by performing the necessary calculations. These sensor devices can operate over extended temperature ranges and are accurate and reliable enough to be used in industrial, military, and scientific applications. They offer mechanical robustness through non-contact operation between the rotating object attached to the magnet and the IC.

The use of cylindrical magnets in rotary position magnetic sensors is ideal to generate the field components required for proper operation. There are two types of field orientations used for this purpose and they are specific to the type of IC used in the application. The magnet can be magnetized either diametrically, or axially.

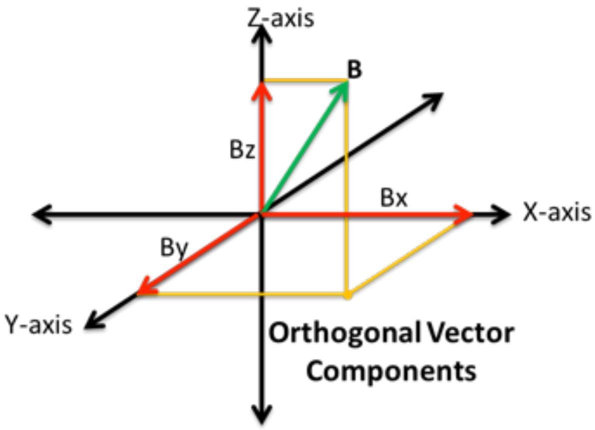


For the purpose of this study, we will look at the diametrically magnetized magnet which is most commonly used in these applications. In order pick the best size of the magnet there are several factors that need to be taken into consideration:

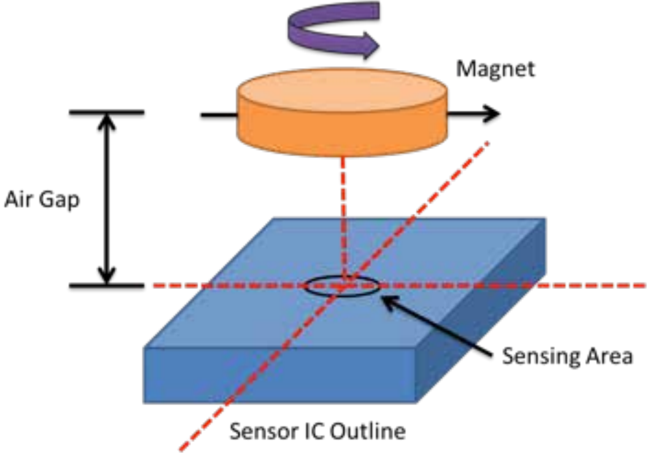
1. What is the magnetic flux density (B) required by the IC? Magnetic flux density is the amount of magnetic flux in an area taken perpendicular to the magnetic flux's direction. The SI unit for flux is the Weber (Wb), flux density is defined as Wb/m2. This is specified by the IC manufacturer in the sensor datasheet and is typically expressed in Gauss (G) or milli-Tesla (mT).
2. What is the desired operating air-gap between the surface of the IC and the magnet? This is an important design consideration as variations in gap distance can greatly affect accuracy and overall performance.

3. Do we have any mechanical constraints on the size of the magnet that we need to be aware of? No point selecting a magnet that meets criteria 1 and 2, but doesn't fit in the application.
There is a common misconception in magnetic sensors that bigger is always better when it comes to magnet size. This is not the case. The aim of this study is to demonstrate the effect of magnet diameter and thickness of operating air gap and how a bigger magnet isn't always an optimal solution.

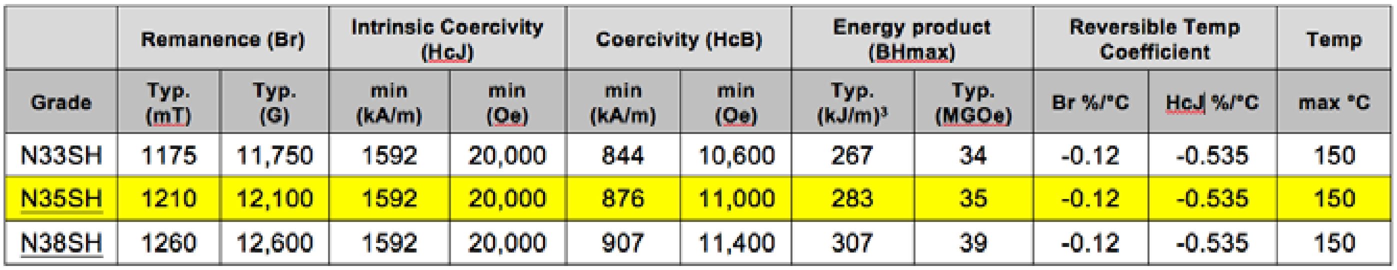
For this example, a series of finite element models were evaluated using Opera 3D software. It was assumed that the sensor IC requires for proper operation, a magnetic field component that is orthogonal to the IC face. A magnetic flux density is mathematically expressed as a vector B comprised of the sum of 3 orthogonal components (Bx, By, Bz). Orthogonal means that the directions of the (x,y,z) components are at 90° to each other.



We will assume that the field level required be within a range of 35mT – 70mT at a circle with a diameter of 2.0 mm at the centerline of the magnet. Using these values as a guide, the next step was to choose an appropriate magnetic material for the application.

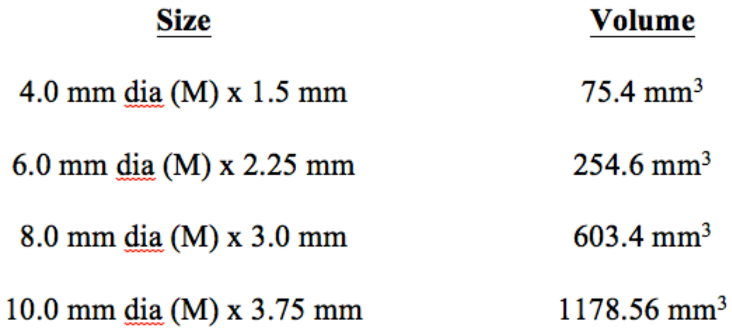


Because of the magnetic field level required, and the relatively smaller size, it was decided to choose a rare earth material which could meet these requirements. The material selected was Neodymium Iron Boron (NdFeB) N35SH. A magnetics company with technical support, such as Magnet Applications, will be able to provide the designer with this type of materials guidance.



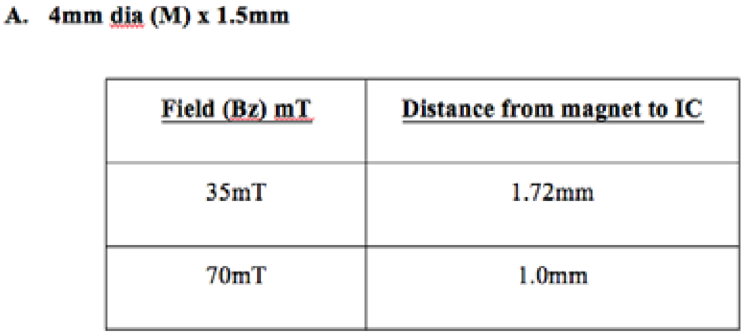
	Remanence (Br)		Intrinsic Coercivity (HcJ)		Coercivity (HcB)		Energy product (BHmax)		Reversible Temp Coefficient		Temp
Grade	Typ. (mT)	Typ. (G)	min (kA/m)	min (Oe)	min (kA/m)	min (Oe)	Typ. (kJ/m)³	Typ. (MGOe)	Br %/°C	HcJ %/°C	max °C
N33SH	1175	11,750	1592	20,000	844	10,600	267	34	-0.12	-0.535	150
N35SH	1210	12,100	1592	20,000	876	11,000	283	35	-0.12	-0.535	150
N38SH	1260	12,600	1592	20,000	907	11,400	307	39	-0.12	-0.535	150

Based on previous experience, four magnet sizes were considered for comparison and modeled with the Opera 3D software at 20°C. Furthermore, the ratio of the magnet diameter to its thickness remained constant to minimize the design variables. The sizes evaluated were:



Size	Volume
4.0 mm dia (M) x 1.5 mm	75.4 mm^3
6.0 mm dia (M) x 2.25 mm	254.6 mm^3
8.0 mm dia (M) x 3.0 mm	603.4 mm^3
10.0 mm dia (M) x 3.75 mm	1178.56 mm^3

Simulations results for on-axis operating air gaps to achieve 35mT-70 mT at 1.1mm circle :



A. 4mm dia (M) x 1.5mm

Field (Bz) mT	Distance from magnet to IC
35mT	1.72mm
70mT	1.0mm

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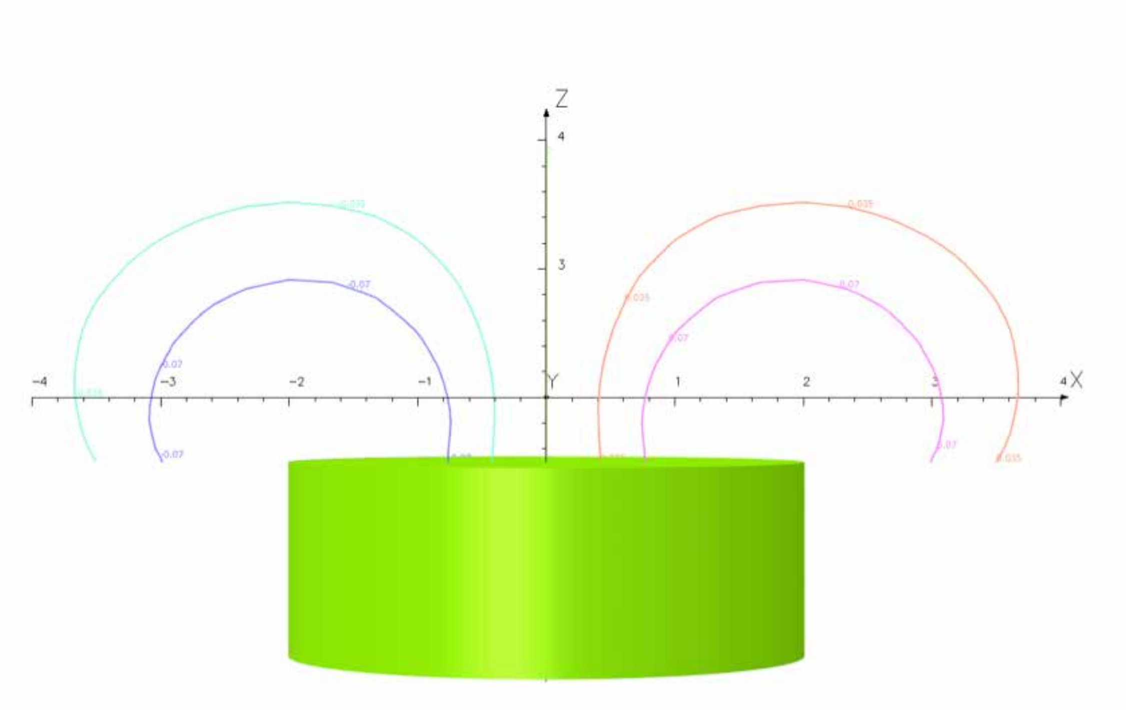
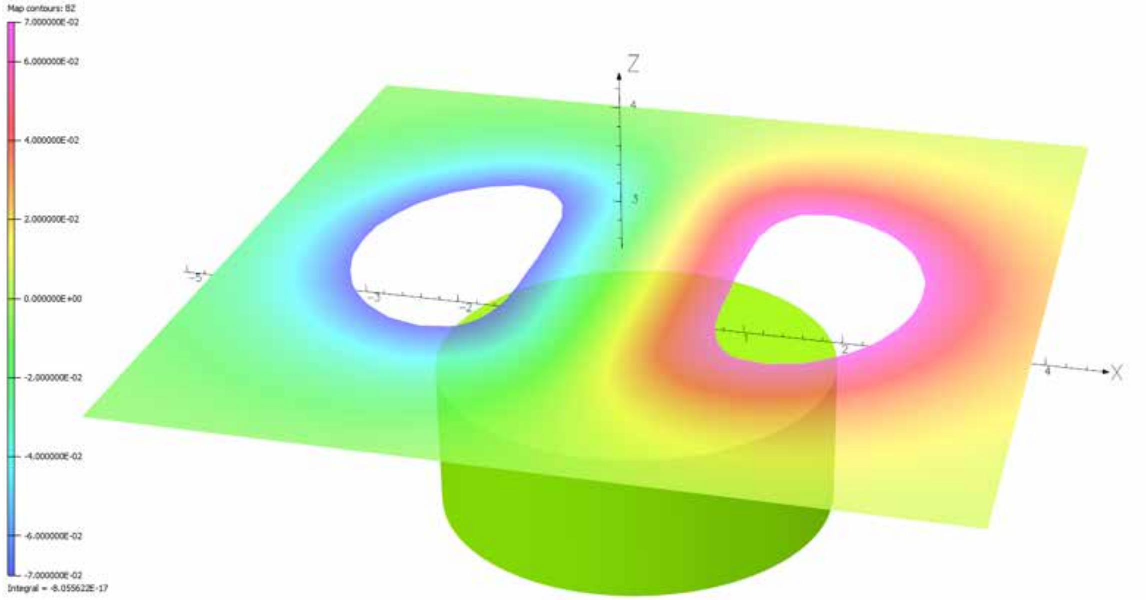


Bz Profile Contours 4mm Magnet
Figure 1



(Bz) Planar Distribution @ 1.0mm Gap – 70mT
Figure 2

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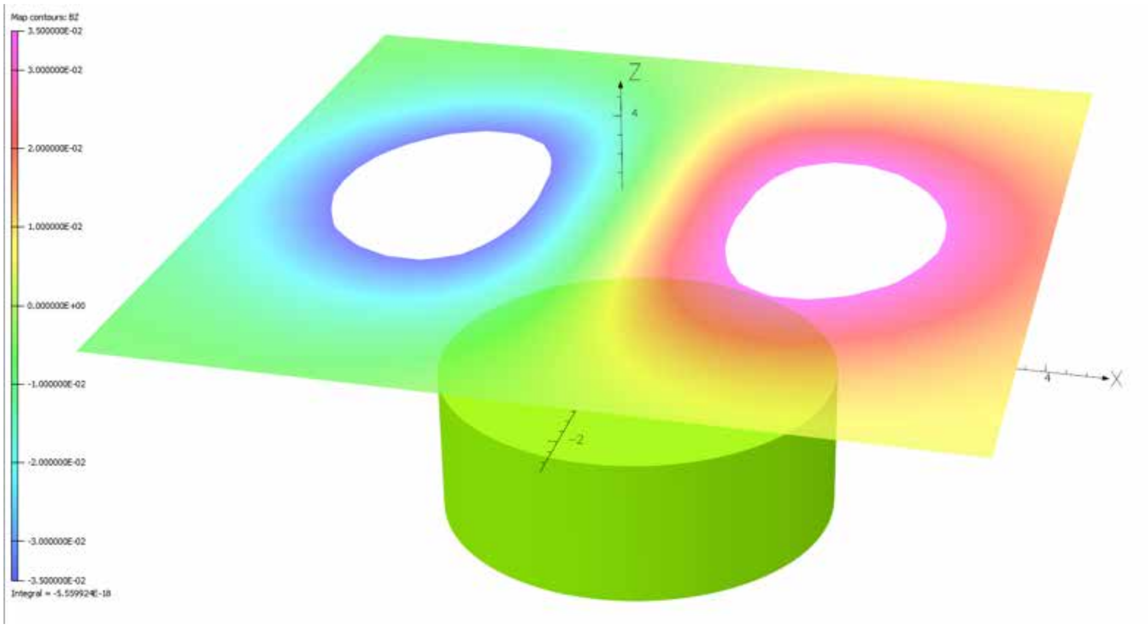
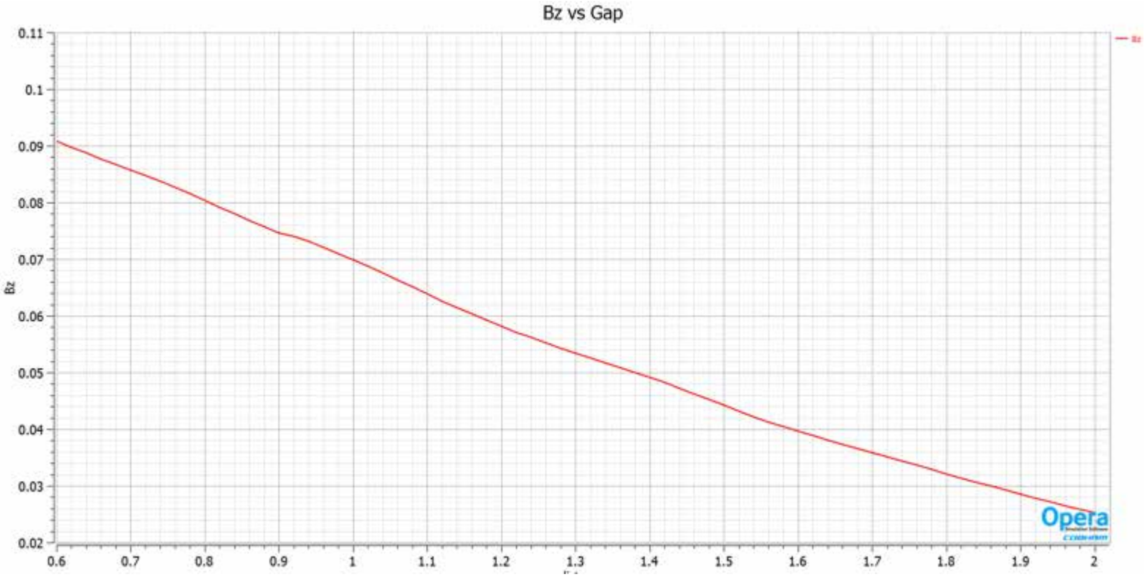


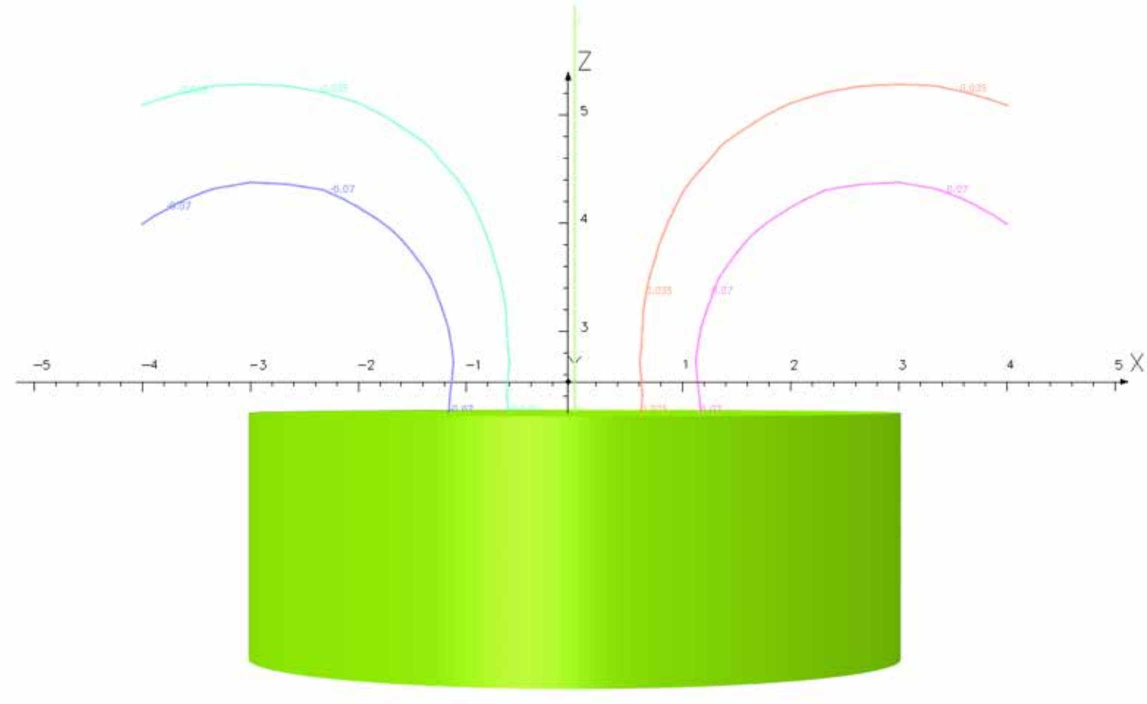
(Bz) Planar Distribution @ 1.72mm Gap – 35mT
Figure 3



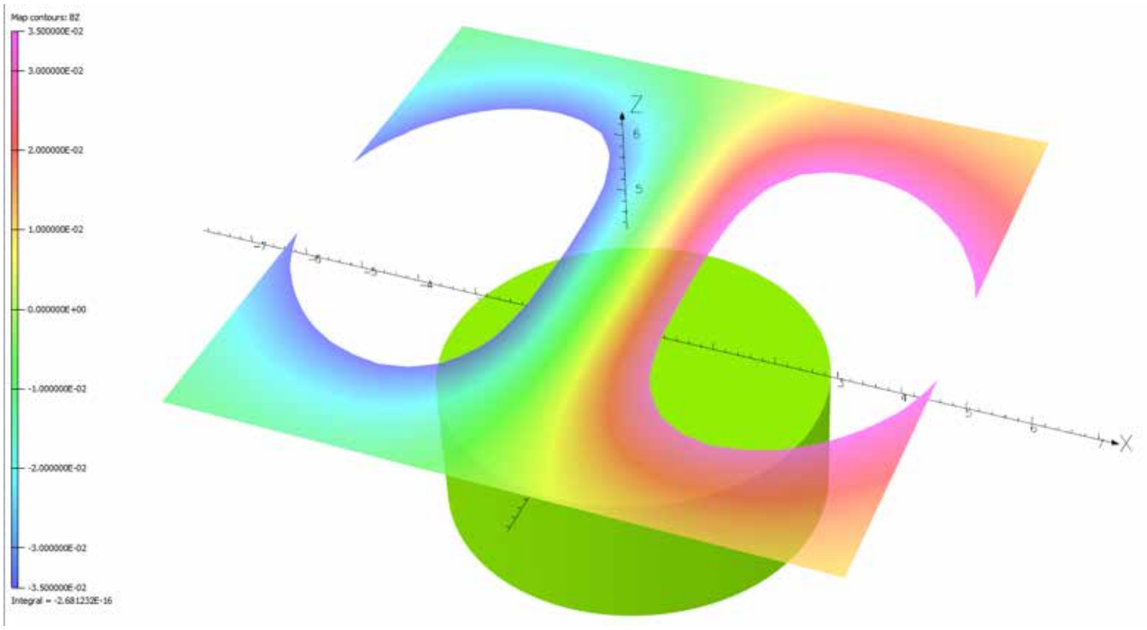
Bz vs Gap @ 1mm from Center
Figure 4

B. 6mm dia (M) x 2.25mm

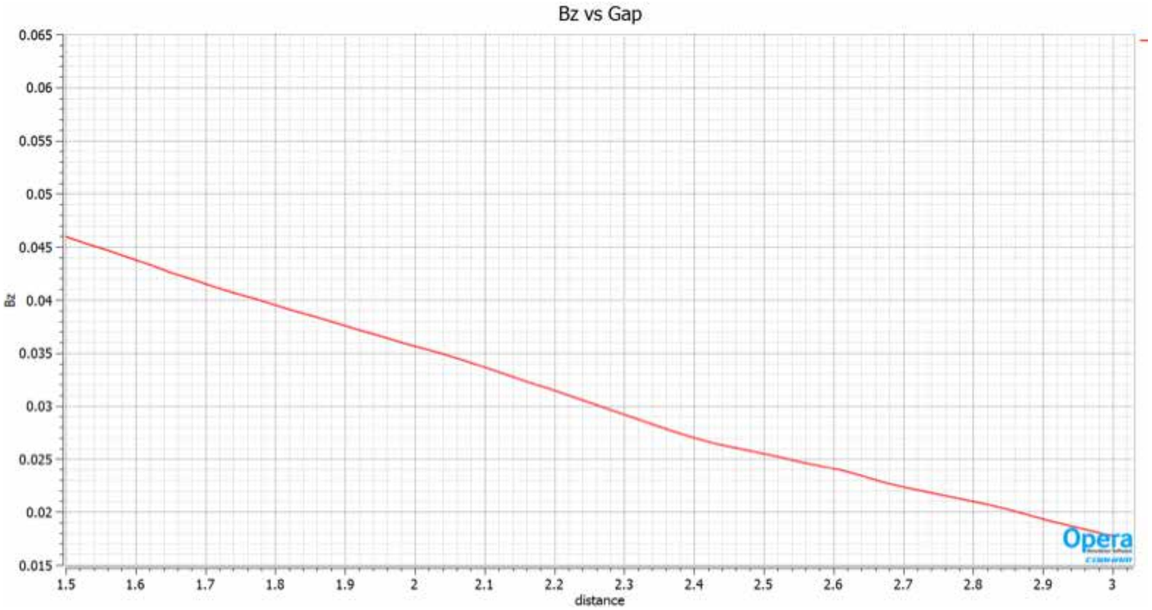
Field (Bz) mT	Distance from magnet to IC
35mT	2.036mm
70mT	Not Achieved



(Bz) Profile Contours 6mm Magnet
Figure 5



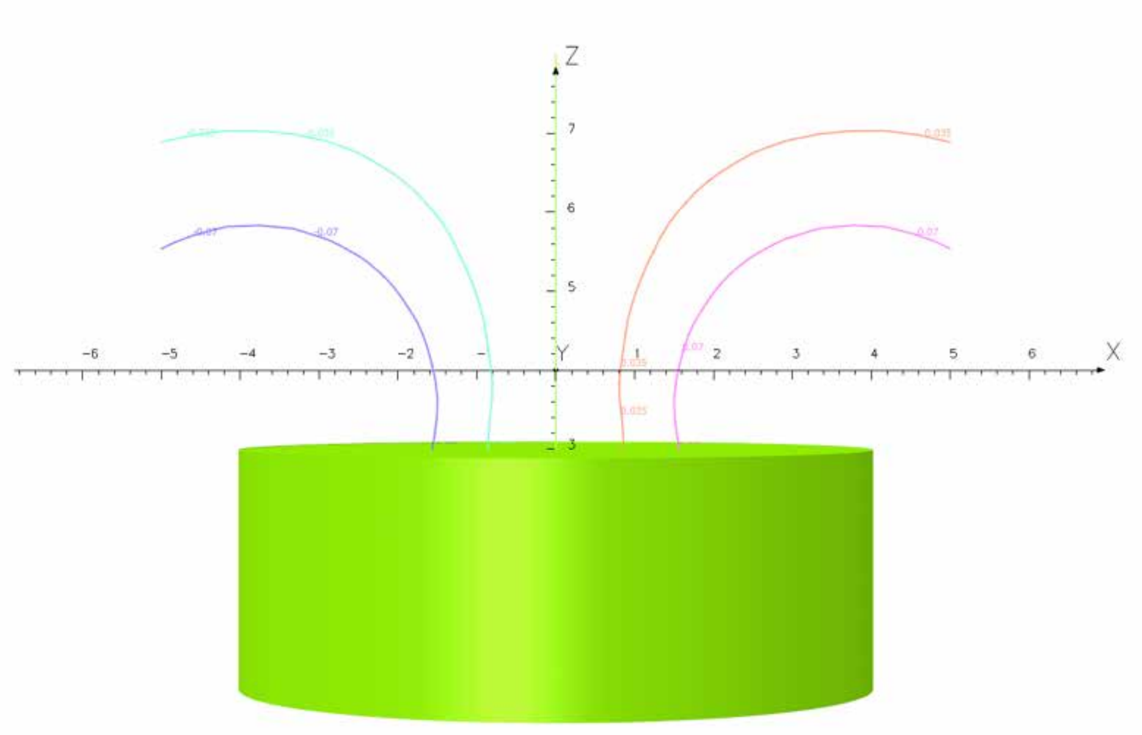
(Bz) Planar Distribution @ 2.036 Gap – 35Mt
Figure 6



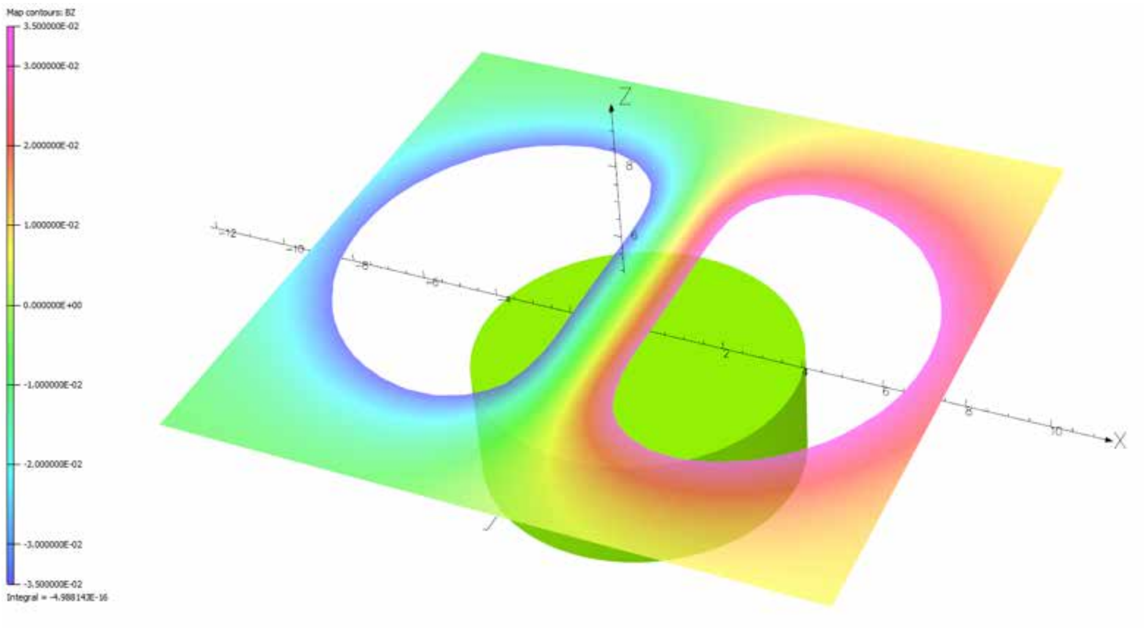
Bz vs Gap @ 1mm from Center
Figure 7

C. 8mm dia (M) x 3mm

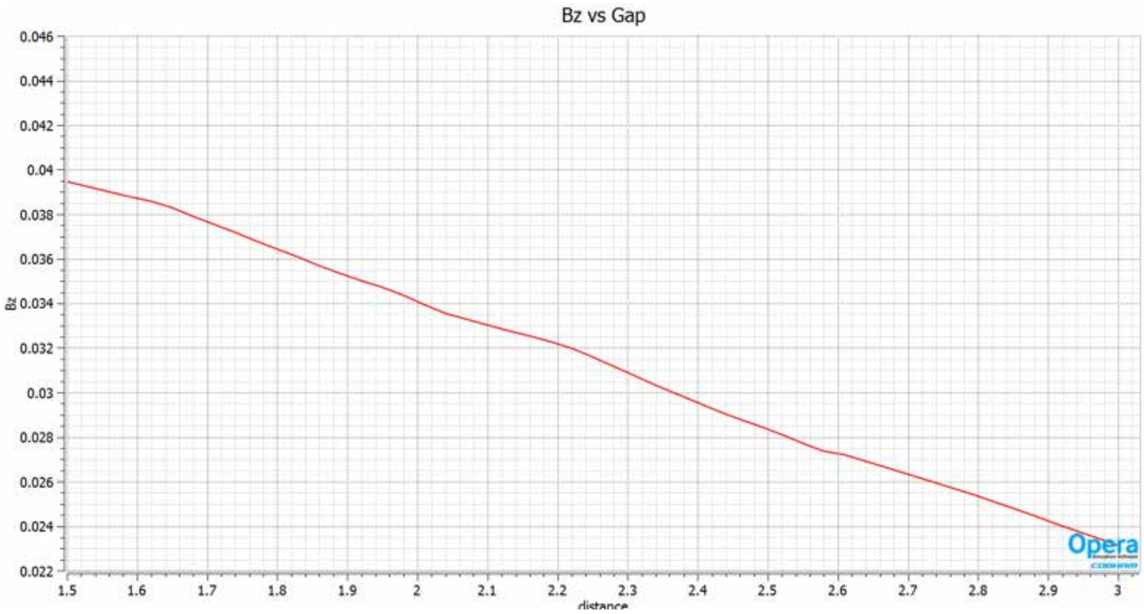
Field (Bz) mT	Distance from magnet to IC
35mT	1.92mm
70mT	Not Achieved



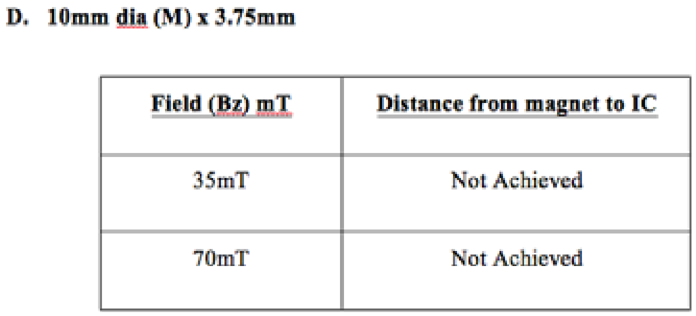
Bz Profile Contours 8mm
Figure 8



(Bz) Planar Distribution @ 1.92mm Gap – 35mT
Figure 9



Bz vs Gap @ 1mm from Center
Figure 10



D. 10mm dia (M) x 3.75mm

Field (Bz) mT	Distance from magnet to IC
35mT	Not Achieved
70mT	Not Achieved

The minimum filed level of 35 mT was not achieved at the 1.0mm radius from the center of the magnet.

CONCLUSION

Using magnetic modeling software allowed for several versions to be tested without the need of making prototypes. Results from this type of simulation have been found to correlate with actual performance to within a few percent. In this case, the difference in operating air gap between a 6mm and an 8mm diameter magnet was very small, about 0.08mm. However, the volume reduction from 603.4 mm3 down to 254.6mm3 is quite significant and would offer a cost saving in the application. One significant factor not addressed in this study is the effect of magnet diameter with respect to rotation centerline misalignment and measurement error. It is known that if there is the potential for this to occur that the accuracy of measurement will be negatively impacted the degree of which is directly dependent on the configuration of the sensing elements within the given sensor IC. This will vary between technologies and approaches used by the different manufacturers of these devices and will require design and experimentation in the particular application to optimize the performance.

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