# Application Note

## Two-Pole Magnet Selection for Rotary Motion

## Contents



## 1. Scope

This application note provides some guidelines to select a magnet to be used in combination with Melexis sensors utilizing two-pole diametrically magnetized magnets and two-pole axially magnetized magnets for linear motion. On-axis rotary and single-axis linear motion modes are covered in this application note. For four-pole magnet designs please refer to the application note "Magnet Selection for MLX9037x – Rotary Stray-Field Immune Mode"

## 2. Applications

On-axis Rotary Motion

*Table 1: Magnetic Configurations*

## 3. Related Melexis Products

Melexis products sensing homogenous (vs gradient) magnetic fields such as the MLX90316, MLX90324, MLX90340, MLX90363, MLX90364, MLX90365, MLX90366, MLX90367, MLX90371, MLX90372, MLX90373, MLX90374, MLX90377, MLX90421, MLX90422, MLX90392, MLX90393, MLX90395

## 4. Related Melexis Tools

To program most magnetic sensors the PTC-04 programming tool is required. For additional details please refer to the “Selection Guide for PTC-04 and Daughterboard”

## 5. On-Axis Rotary Motion

The Triaxis magnetic position sensors measure two or three magnetic field components (Bx, By, Bz), depending on the sensor. Figure 1 shows a typical example of an End-of-shaft application for which a diametrically magnetized magnet is rotating above the IC. In the sensor plane, the two components of the flux density (i.e. Bx and By) represent a sine and cosine wave while the magnet rotates (Figure 2). With the integrated digital signal processing these signals are transformed into a rotary position of 0 to 360 degrees through an arctangent operation on the ratio Vy/Vx.

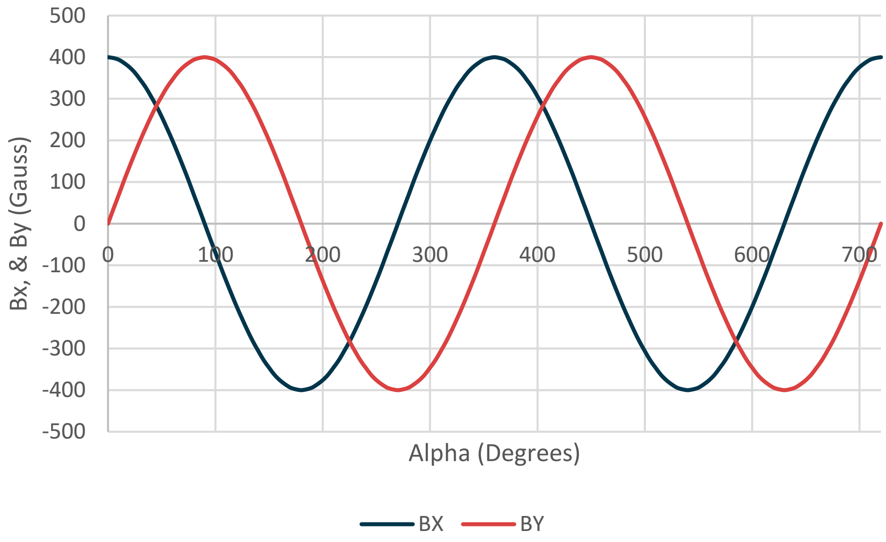



*Figure 1: Bx and By Field Plots*

## 5.1. Mechanical Description

The mechanical alignment between axis of rotation, magnet position and sensor position strongly determines measurement accuracy. Mechanical alignment errors (Figure 3) can result in additional offset, phase shift, amplitude change and non-linearity vs. the ideal Sine and Cosine output curves. Whereas offset, phase and amplitude are easily trimmed and compensated at the IC level (see the Application Note on the Front-End Calibration of MLX90316), linearity errors due to off-axis (between sensor and the rotating magnet) in the XY plane (eccentricity) are ideally compensated though a linearization of the output transfer characteristic. In most cases the best solution is to choose a magnet big enough to limit linearity to a tolerable value for the predefined mechanical tolerances.

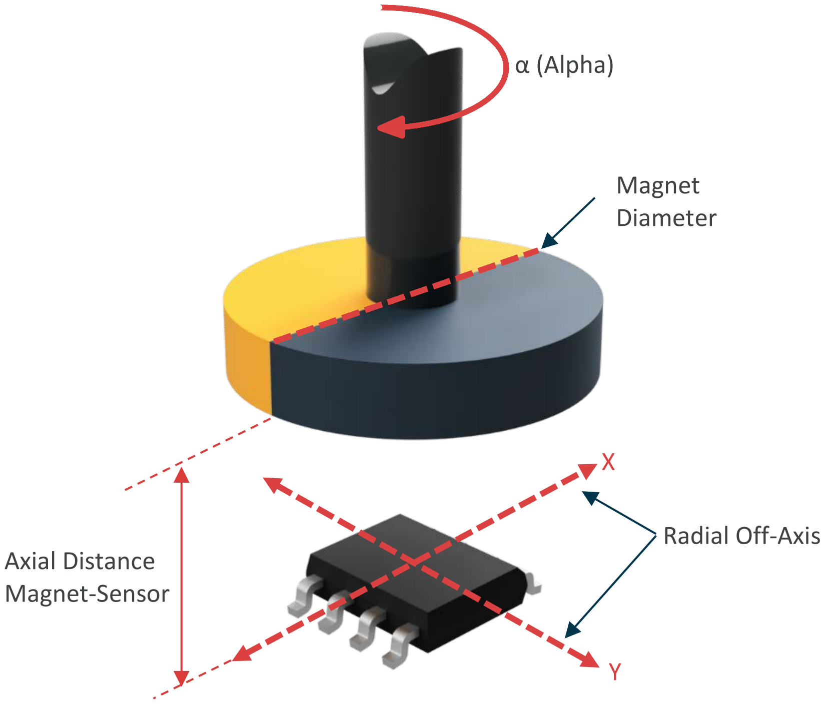



*Figure 2: Mechanical Setup for Angular Sensing*

The axial working distance between Magnet and Sensor is defined by the saturation effects (electrical or magnetic) for the lower limit and by the required signal-to-offset or signal-to-noise ratio for the higher limit.

## 5.2. Radial Off-Axis & Magnet Diameter

Off-axis position due to production tolerances, mechanical play, vibration will lead to non-linearity of the angle output signal. The Figure 4 shows the non-linearity for a given setup with a disk shape magnet D15H4 (Diameter = D = 15 mm - Height = H = 4 mm). The airgap between magnet surface and sensitive area of MLX90316 is 5mm.

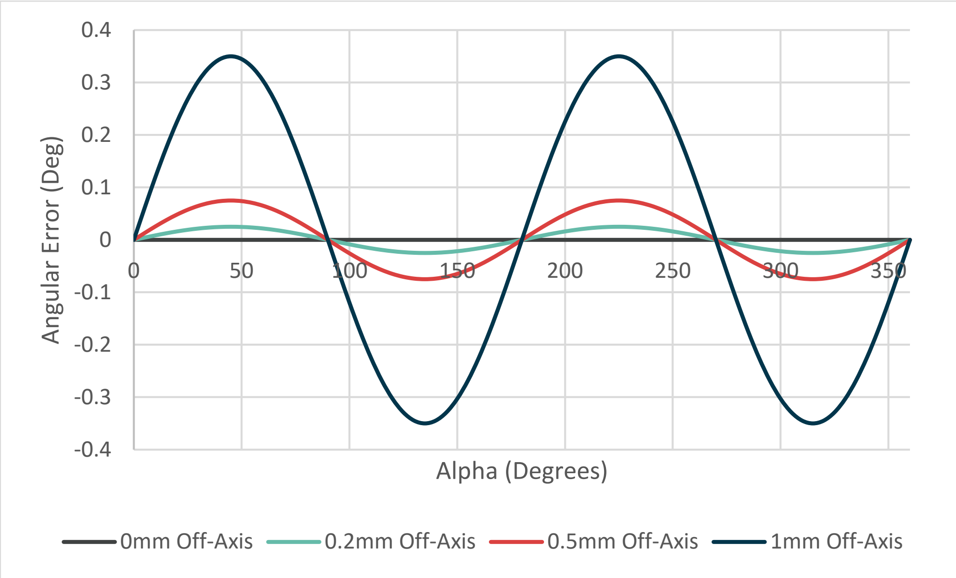



*Figure 3: Magnet D15H4 - Linearity Error due to Off-Axis Misalignment*

Angular errors due to a given off-axis misalignment will become smaller with an increasing diameter of the magnet. The Figure 5 below helps to estimate the required magnet diameter for given manufacturing tolerances plus lifetime wear-out if a predefined non-linearity (angle error) shall not be exceeded.

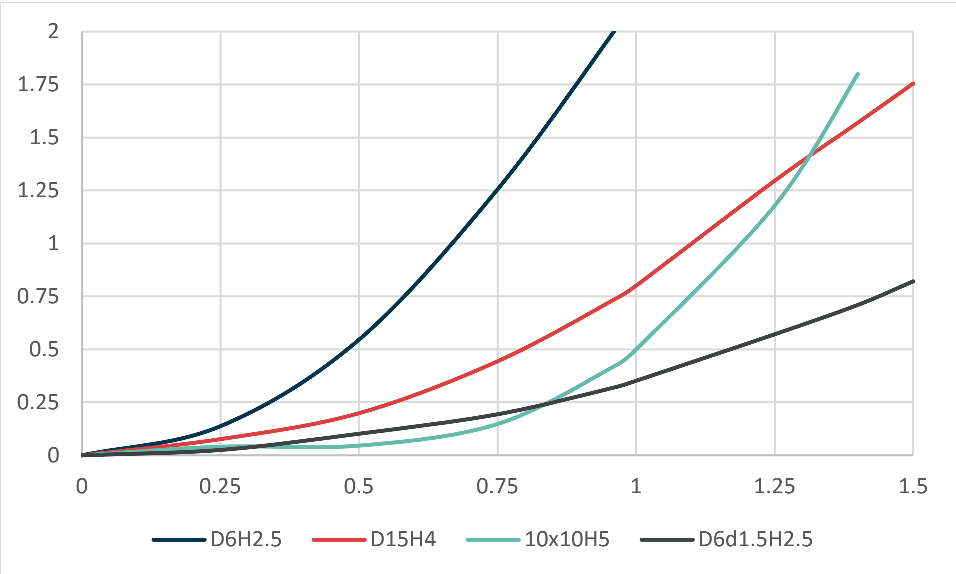



*Figure 4: Angle Error vs Eccentricity/Off-Axis for Different Magnets*

For example: If maximum expected eccentricity due to production/manufacturing positioning tolerances (incl. lifetime wear-out) is 0.5 mm and maximum admitted non-linearity is 0.2 Deg. (0.05% of 360 Deg. full scale). Then a magnet of 10 mm diameter is a good choice.

However, choosing a magnet as big as possible will not lead to the best result:

- Large magnets can be less homogeneous (hot spots on the magnet surface will also create angular errors)
- Strong fields require a bigger distance between sensor and magnet to avoid saturation effects (flux density has to be kept below 70 mT)
- Big magnets are more expensive

Typically, the magnet diameter has to be 10 times bigger than the maximum eccentricity for less than 1 degree of non-linearity error and 20 times bigger for less than 0.3 degree of non-linearity error

## 5.3. Axial Distance Between Sensor and Magnet – Airgap

The Magnet should also be selected vs. the airgap range (axial distance) in the given application. Horizontal flux density needs to be within 20 and 70 mT (i.e. 45 mT ± 25 mT) at the IC level.

Using a small distance between sensor and magnet will increase the danger of either electrical or magnetic saturation. Furthermore imperfections of the magnet material may create magnetic hot spots on the magnet surface which cause local field deflection and eventually result in additional angular errors;

For this reason we advise our customers not to use for example bonded ferrite material with large diameters.

The magnetic saturation level of the Melexis Triaxis sensors is described in each products datasheet and is typically 70mT. No damage or any hysteresis impact will occur if fields higher than 70mT are applied.

Using a big distance (small amplitude) will decrease the signal to noise ratio.

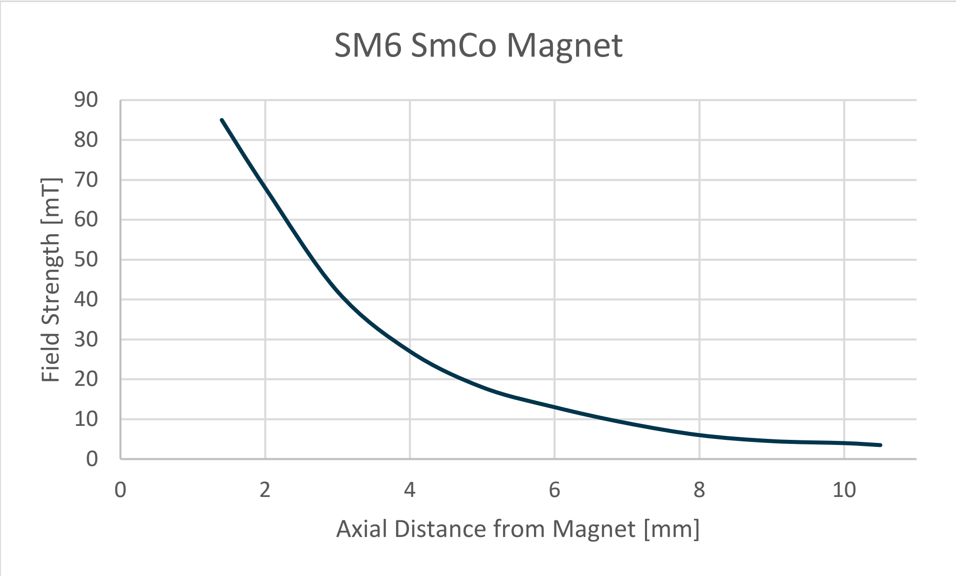
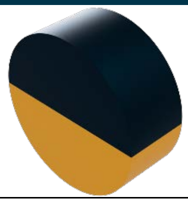
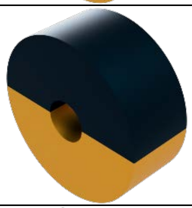
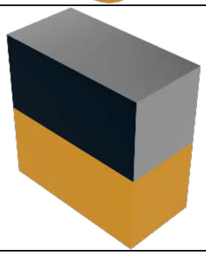



*Figure 5: Horizontal Flux Density vs Axial Distance from Magnet (airgap)*

Figure 5 shows a typical relation between the field strength and the distance. It is obtained from a measurement on a 6 mm diameter SmCo magnet and 2.5 mm height (D6H2.5). The optimum flux density (20mT to 70mT) is reached with 2 mm to 5 mm airgap between magnet surface and the sensor's sensitive spot.

## 6. Magnets and Material Properties

Some typical magnets used in this application note

| Magnet | Size (D; W x L) | Height [mm] | Magnetization | Material [-40°C - 150°C] |
|---|---|---|---|---|
|  | 6 | 2.5 | Diametric | Sintered SmCo<br>Br=900 – 1100mT |
|  | Outer Dia: 6<br>Inner Dia: 1.5 | 2.5 | Diametric | Sintered SmCo<br>Br=900 – 1100mT |
|  | 10 x 10 | 5 | Diametric | Anisotropic Ferrite<br>Br=300 – 500mT |
|  | 15 | 4 | Diametric | Bonded NdFeB<br>Br=350 – 450mT |

### 6.1. Material Properties

| Material | Abbreviation | Strength Br [mT] | Drift [%/°C] | Aging |
|---|---|---|---|---|
| Neodymium Iron Boron | **NdFeB** | 1300 | -0.1 | Specified by magnet supplier |
| Samarium Cobalt | **SmCo** | 1000 | -0.03 | |
| Aluminum Nickle Cobalt | **AlNiCo** | 900 | -0.02 | |
| Hard Ferrite | **Ferrite** | 300 | -0.2 | |
| Plastic bonded NdFeB | **Bonded NdFeB** | 450 | -0.1 | |

| Material | Advantages |
|---|---|
| NdFeB | Best magnetic characteristic |
| SmCo | Excellent thermal drift over wide temperature range |
| AlNiCo | Excellent thermal drift over wide temperature range |
| Ferrite | Lowest cost |
| Bonded NdFeB | Easily produced magnet shapes<br>Good magnetic characteristics<br>Lower cost |

### 6.2. Magnet Suppliers

For magnet suppliers please refer to the Melexis website here

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