Angle Sensors

xMR-Based Angular Sensors

Magnetic Design Tool

TLE5009(D)
TLE5011
TLE5012B(D)
TLE5309D
TLE5014

Application Note

Ver. 1.0, 2014-12-03

Sense & Control

Edition 2014-12-03

Published by
Infineon Technologies AG
81726 Munich, Germany

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Revision History	
Page or Item	**Subjects (major changes since previous revision)**
Ver. 1.0, 2014-12-03	

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1 Introduction

The Magnetic Design Tool for Angle Sensors (**Figure 1**) is a tool designed to support designs with xMR-based angular sensors and diametrically magnetized disk magnets.

On the one hand the magnet's magnetic field measured at the angle sensor position is calculated to determine the required air-gap (distance from magnet surface to sensor). On the other hand, assembly tolerances like tilt and eccentricity of magnet and sensor with respect to the axis of rotation lead to an error in the measured angle, the assembly error. The assembly error can be calculated in the tool and be added to the specified angle error from the data sheet.

Figure 1 Magnetic Design Tool Angle Sensors interface

2 Data inputs

To simulate the magnetic field and the assembly error the following inputs are required:

- Magnetic Properties (description in Chapter 2.1)
- Sensor Specifications (description in Chapter 2.2)
- Assembly Tolerances (description in Chapter 2.3)

2.1 Magnetic Properties

Diametrically magnetized disk magnets are the most common magnets used in designs with angular sensors. The magnet's remanence and geometry are the key parameters to be defined ().

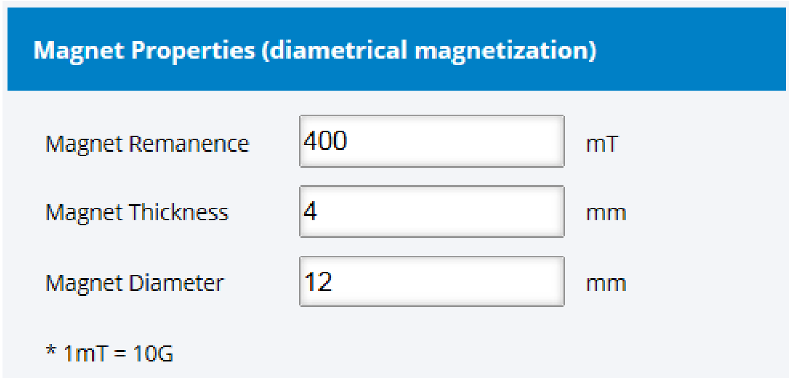

Figure 2 **Magnetic Properties (e.g. 400mT magnet with 4mm thickness and 12mm diameter)**

Remanence

Remanence -or residual magnetization- is the measure of the magnetization in a ferromagnetic material after an external magnetic field has been applied. Remanence is measured in Tesla [T] or Gauss [G]; 1mT equals 10G. Typical values of remanence are between 200mT and 400mT for sintered hard ferrite magnets and between 900mT and 1,400mT for sintered neodymium magnets (NdFeB). Plastic bonded magnets have weaker remanences than sintered magnets.

Remanence is to be defined in mT (millitesla) in the tool and it is used for both the Magnet Field at Sensor and for the Angle Error due to Assembly Tolerances calculations.

Magnet Thickness

Magnet Thickness is the thickness of the magnet (distance between the bottom and top surfaces of the magnet).

Magnet Thickness is to be defined in mm (millimeters) in the tool and it is used for both the Magnet Field at Sensor and for the Angle Error due to Assembly Tolerance calculations.

Magnet Diameter

Magnet Diameter is the diameter of the magnet (radius times two).

Magnet Diameter is to be defined in mm (millimeters) in the tool and it is only used for the Magnet Field at Sensor calculation. For the Angle Error due to Assembly Tolerance calculation the diameter is a variable (x-axis).

2.2 Sensor Specification

Infineon angular sensors have a specified magnetic field to guarantee the angle performance[1)]. The specified magnetic field (minimum and maximum values) is available in the data sheet (see **Figure 4**) and refer to the ambient temperature. Any magnet that fulfills the temperature profile from the data sheet (e.g. neodymium-based magnets) is proven to work through the temperature range even if only calculated at ambient temperature.

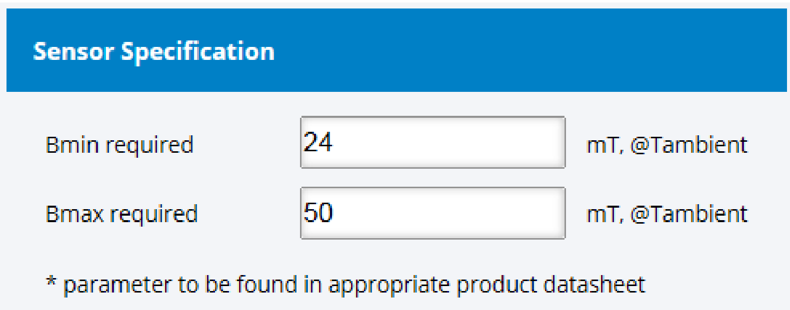

Figure 3 Sensor Specification (e.g. TLE5009 magnetic field specification)

Bmin required

Bmin required is to be defined in mT (millitesla) in the tool and it is only used for the Magnet Field at Sensor calculation.

Bmax required

Bmax required is to be defined in mT (millitesla) in the tool and it is only used for the Magnet Field at Sensor calculation.

Table 3 Operating range

Parameter	Symbol	Values			Unit	Note / Test Condition
		Min.	Typ.	Max.		
Supply voltage[1)]	V_{DD}	4.5	5.0	5.5	V	TLE5009-E2000, TLE5009-E2010
		3.0	3.3	3.6	V	TLE5009-E1000, TLE5009-E1010
Output current[2)]	I_Q	0		0.5	mA	COS_N; COS_P; SIN_N; SIN_P
		0		0.1	mA	V_{GMR}
Load capacitance[2)3)]	C_L	0		4.7	nF	COS_N; COS_P; SIN_N; SIN_P; V_{GMR}
Magnetic field[2)4)]	B_{XY_25}	24		50	mT	at room temperature, in X/Y direction
Angle range	α	0		360	°	
Rotation speed[2)5)]	n			30000	rpm	

1) Supply voltage V_{DD} buffered with 100 nF ceramic capacitor in close proximity to the sensor.
2) Not subject to production test - verified by design/characterization.
3) Directly connected to the pin.
4) Values refer to an homogenous magnetic field (B_{XY}) without vertical magnetic induction (B_Z = 0mT).
5) Typical angle propagation delay is 1.62° at 30000 rpm.

Figure 4 Magnetic field specifications from data sheet (e.g. TLE5009 operating range).

1)For extended magnetic field an additional angle error has to be considered; for more details refer to **Angle_Error_Extension_GMR_AN_Rev1.2**

2.3 Assembly Tolerances

Independent of the used sensor principle (Hall effect or magneto resistive/xMR effect) assembly tolerances cause an additional angle error, the assembly error. The smaller the sensitive are the smaller this additional angle error. The Magnetic Desing Tool for Angle Sensors calculates the assembly error for xMR-based sensors.

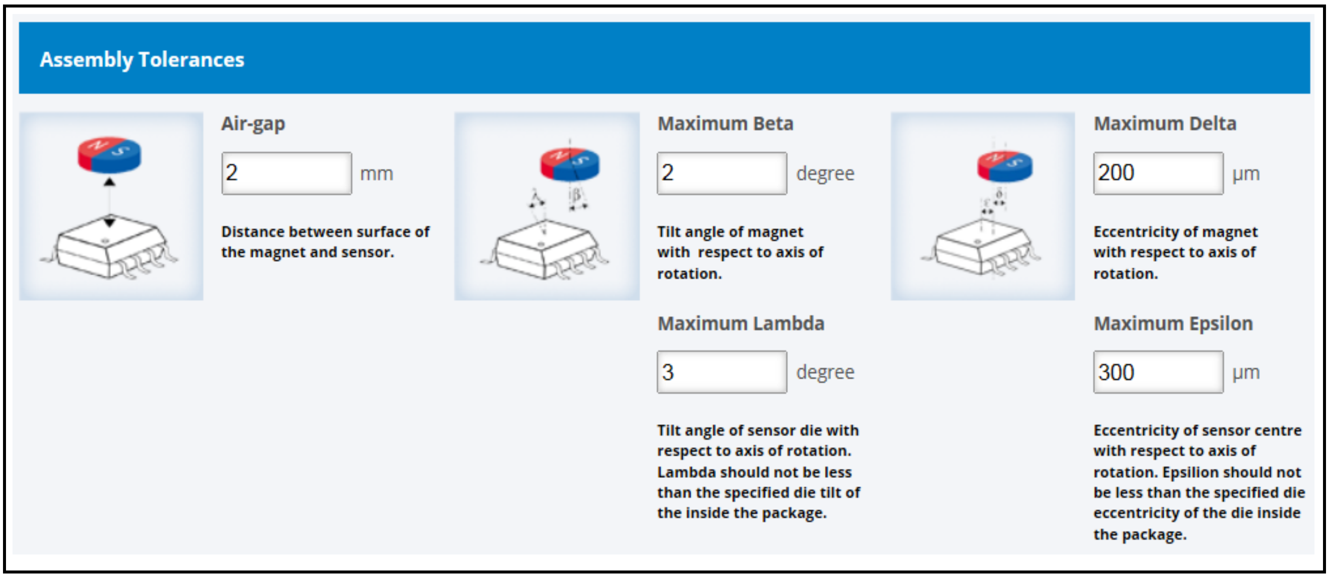

Figure 5 Assembly Tolerances

Air-gap

Air-gap is the distance between surface of the magnet (and not the centre) and the angular sensor as defined in **Figure 6**.

Air-gap is to be defined in mm (millimeter) in the tool and it is only used for the Angle Error due to Assembly Tolerances calculation. In case of air-gap tolerances the minimum and maximum values have to be introduced manually and simulate twice.

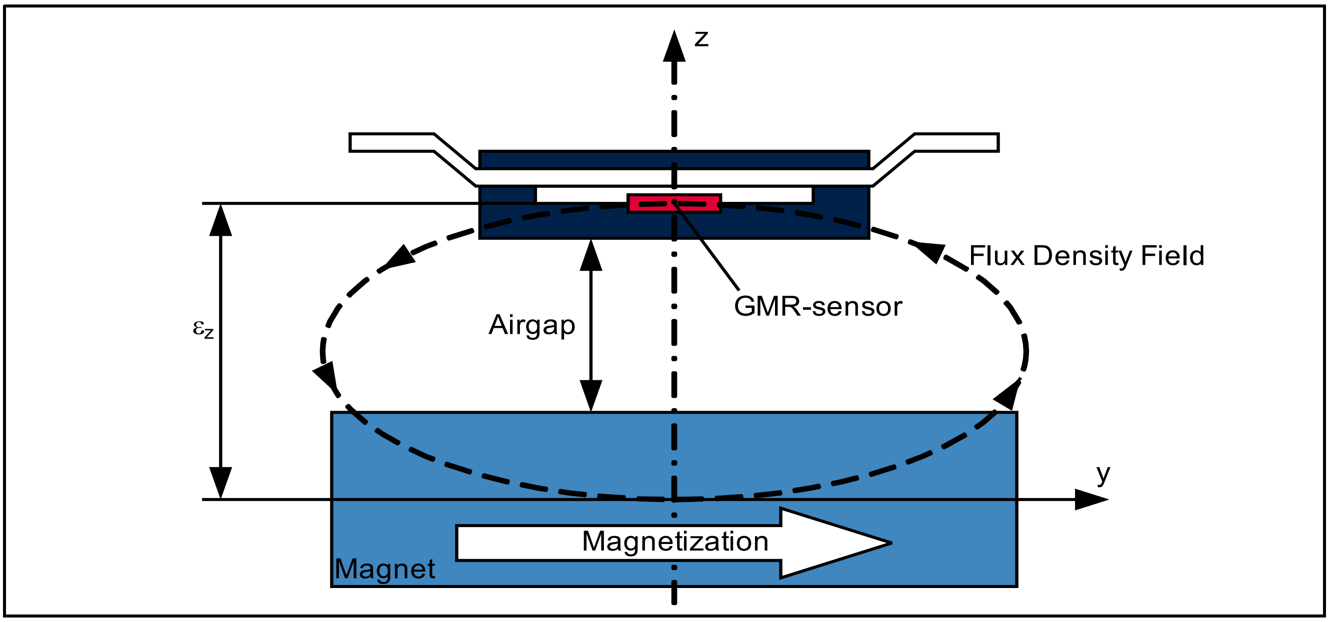

Figure 6 Air gap definition

Maximum Beta

Maximum Beta is the tilt of the magnet with respect to axis of rotation.

Maximum Beta is to be defined in ° (angle degrees) in the tool and it is only used for the Angle Error due to Assembly Tolerances calculation.

Maximum Lambda

Maximum Lambda is the tilt of the angular sensor with respect to axis of rotation.

Maximum Lambda is to be defined in ° (angle degrees) in the tool and it is only used for the Angle Error due to Assembly Tolerances calculation.

Maximum Delta

Maximum Delta is the eccentricity of magnet with respect to axis of rotation.

Maximum Delta is to be defined in µm (micrometers) in the tool and it is only used for the Angle Error due to Assembly Tolerances calculation.

Maximum Epsilon

Maximum Epsilon is the eccentricity of the angular sensor with respect to axis of rotation.

Maximum Epsilon is to be defined in µm (micrometers) in the tool and it is only used for the Angle Error due to Assembly Tolerances calculation.

3 Start simulation

Once the magnet has been defined and all the required data fields completed it is possible to proceed with the calculations by clicking “START SIMULATION”.

This calculation considers no influence of other magnetic fields or magnetic materials such as iron or magnetic steels. Therefore, shafts of non magnetic materials such as aluminum are assumed.

The points of the curve can be read by placing the mouse on top of the graph. Additionaly a report with the input data, the graphs and a table with the points is provided when clicking “SAVE SIMULATION”.

Figure 7 START and SAVE SIMULATION menu

3.1 Magnet Field at Sensor

The *Abs(B) @sensor [mT]* (blue line) shows the magnetic field at sensor (in mT) depending on the air-gap between the surface of the magnet (and not centre) and the angular sensor. The air-gap is shown in the x-axis and it is provided in mm (millimeter). The magnetic field is maximum at 0mm (angular sensor just above the magnet) and decreases as the distance between magnet and sensor increases.

Bmin and Bmax required are shown in the graph as a constant magnetic field value. The domain between the points were Bmax croses *Abs(B) @sensor* and Bmin croses *Abs(B) @sensor* define the air-gap range for which the angular sensor has its specified performance.

To reduce the required air-gap the remanence of the magnet has to decrease and/or the geometry (reduce magnet thickness and/or reduce magnet diameter). If bigger air-gaps are required then the remanence of the magnet has to increase and/or the geometry (increase magnet thickness and/or increase magnet diameter).

If larger air gap tolerances are required (broader distance between minimum and maximum air-gap) it is recommended to optimize the magnet design to be in the asymptotic part of the magnetic field curve *Abs(B) @sensor*.

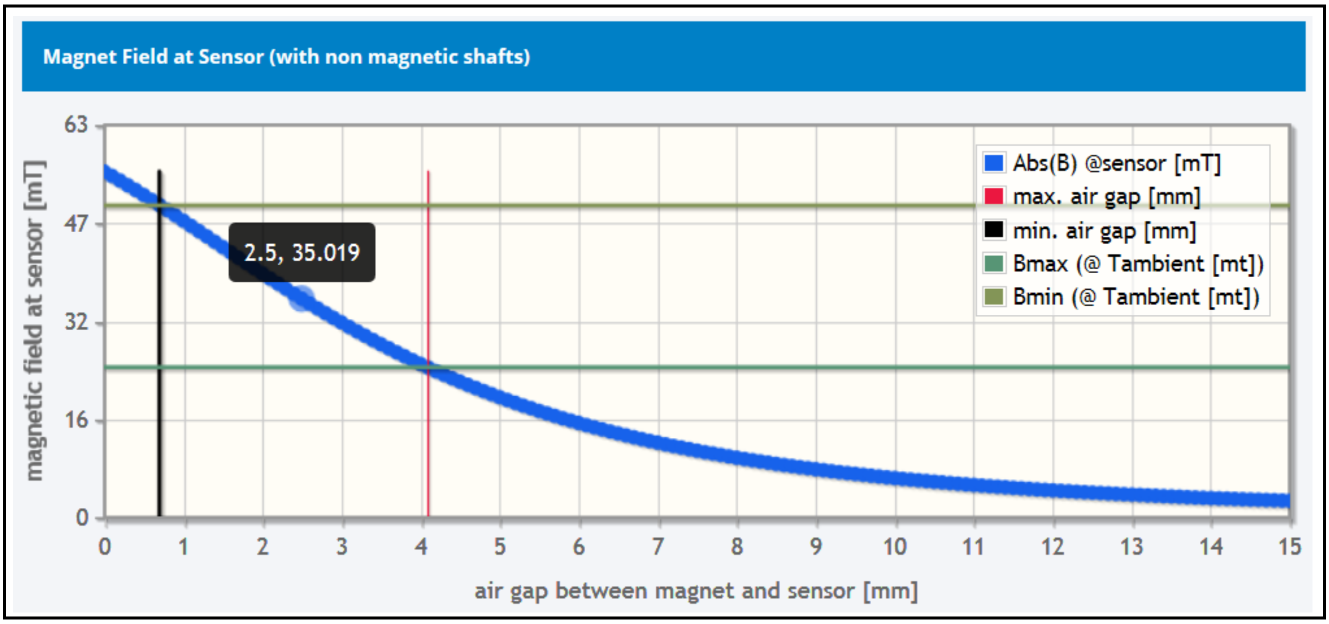

Figure 8 Magnet Field at Sensor (e.g. simulated magnet enables air gaps between 0.7mm and 4.1mm)

3.2 Worst Case Angle Error due to Assembly Tolerances

The assembly error calculated in the Magnetic Design Tool is an over-estimate of the real angle error due to assembly tolerances, therefore a worst case scenario is already considered and no additional safety margins are required. For further details on the methodology used and documentation on how to optimize the assembly error refer to the **AppNote_Magnet_Design**.

The *cylindrical magnet* shows the assembly error given the magnet described in Magnetic Properties and the Assembly Tolerances (Air-Gap, β, λ, δ, ε). The diameter described in Magnetic Properties is not used in this calculation and an assembly error (y-axis) function of the diameter (x-axis) is provided. The diameter of the magnet in the x-axis is provided in m (meter).

The smaller the magnet's diameter the bigger the assembly error. With diameters above 10mm the assembly error becomes relatively small. It is also possible to reduce the assembly error by optimizing the air gap.

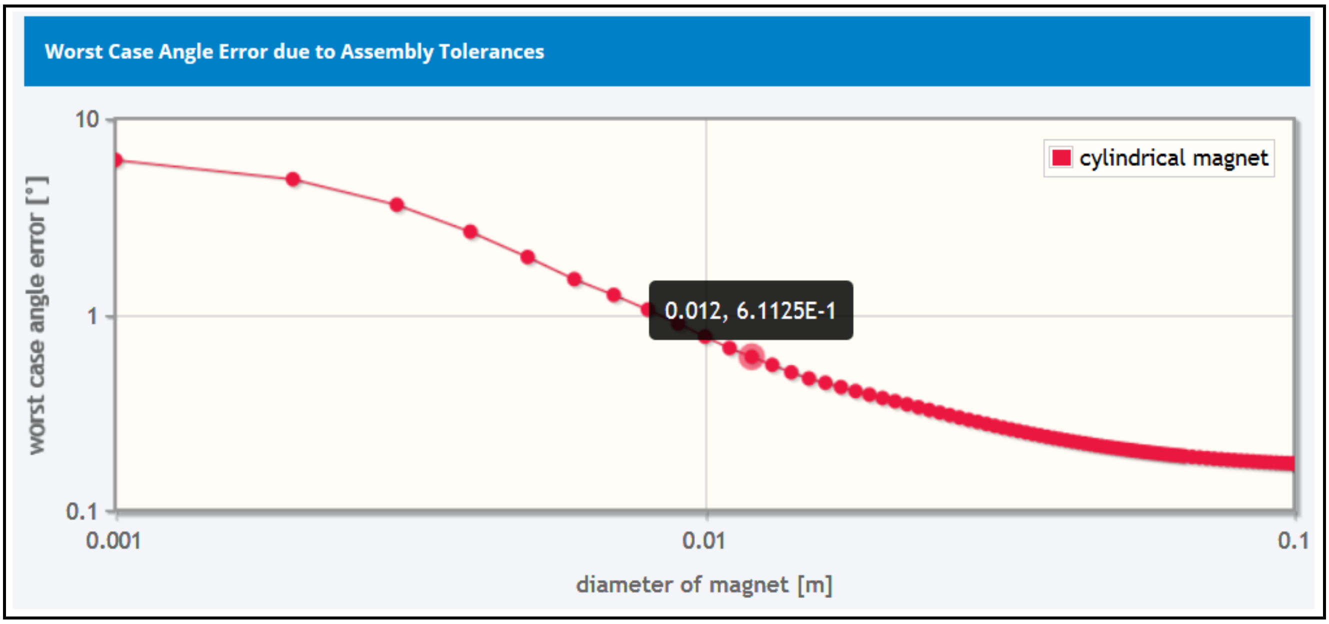

Figure 9 Angle Error due to Assembly Tolerances (e.g. 0.61° assembly error with a 12mm diameter)

References

[1] U.Ausserlechner, “Inaccuracies of Giant Magneto-Resistive Angle Sensors due to Assembly Tolerances”, IEEE Trans. Magn., May 2009, vol. 45, no. 5, pp. 2165-2174

[2] U.Ausserlechner, “Inaccuracies of Anisotropic Magneto-Resistant Angle Sensors due to Assembly Tolerances”, PIER B (Progress in Electromagnetics Research B), 2012, Vol. 40, pages 79-99

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