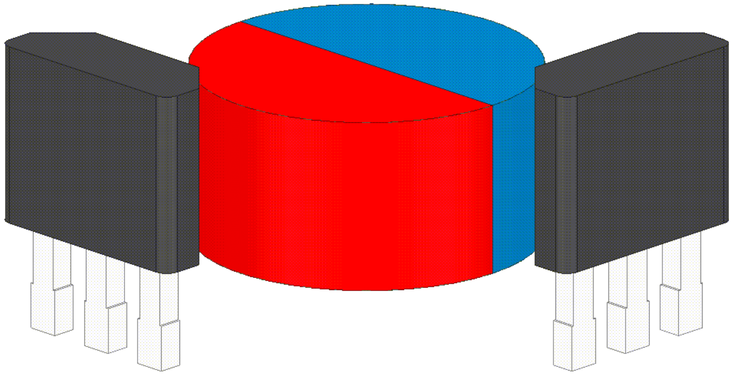
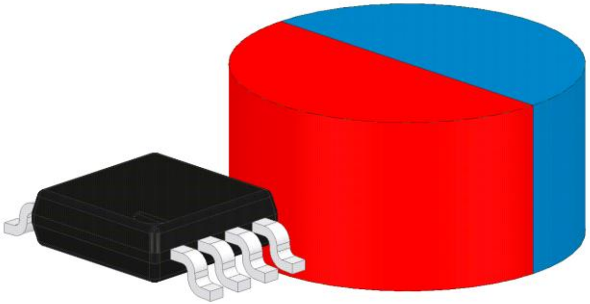
System calculation for precise angle measurements

TI Precision Labs – Magnetic sensors

Presented and prepared by Scott Bryson

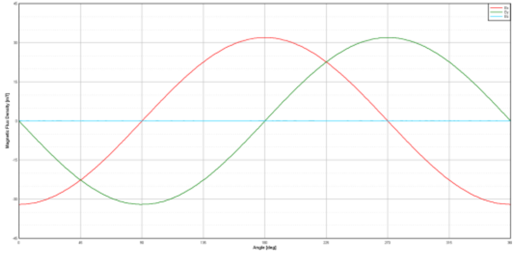
Angle detection



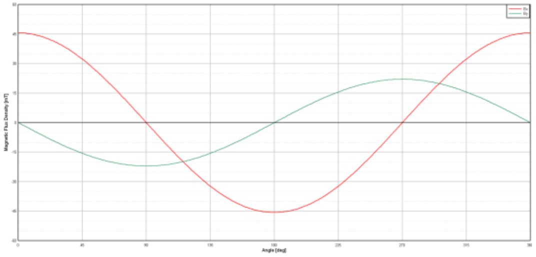


Angle detection

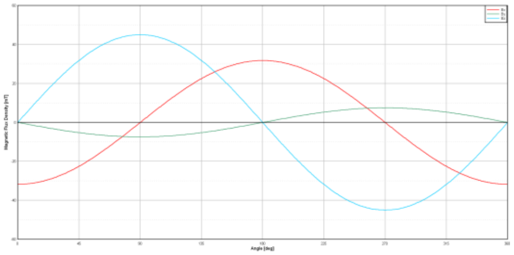
Angle detection



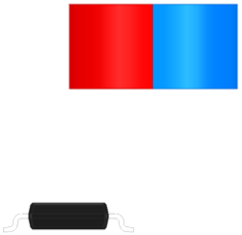
Sensor on-axis



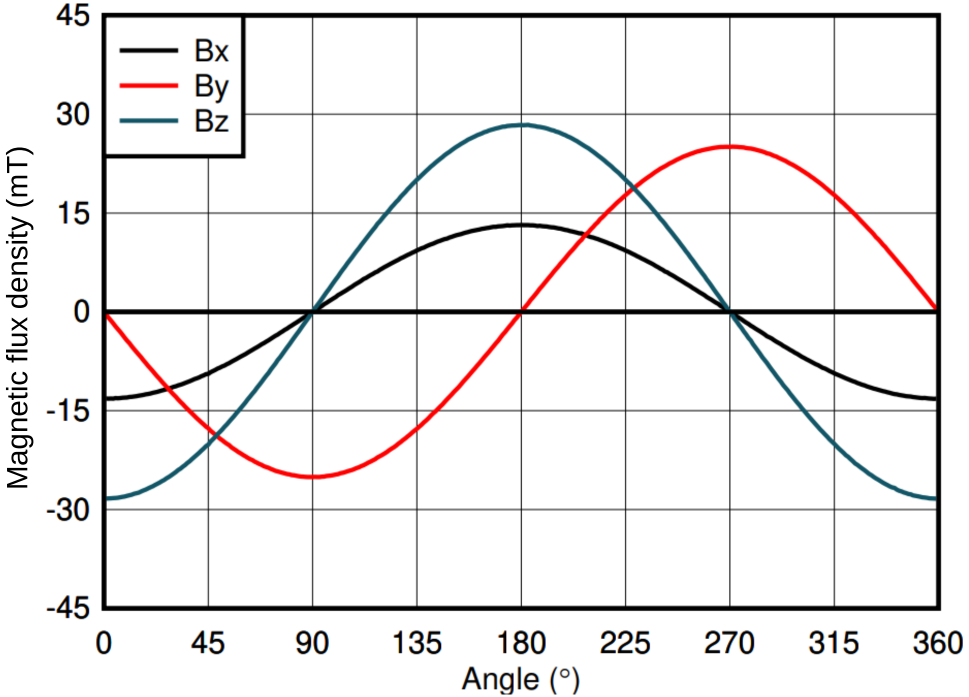
Sensor in-plane

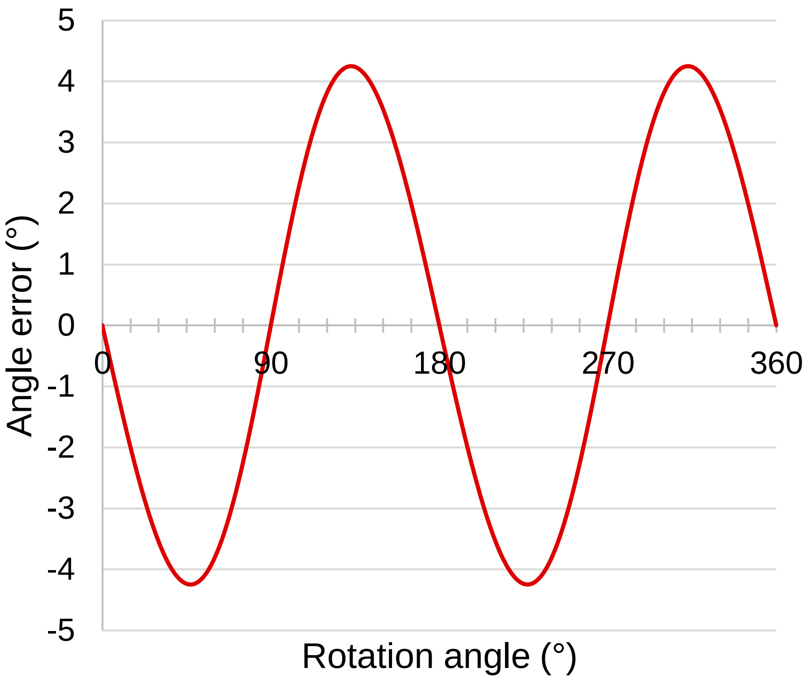


Sensor out-of-plane
(off-axis)

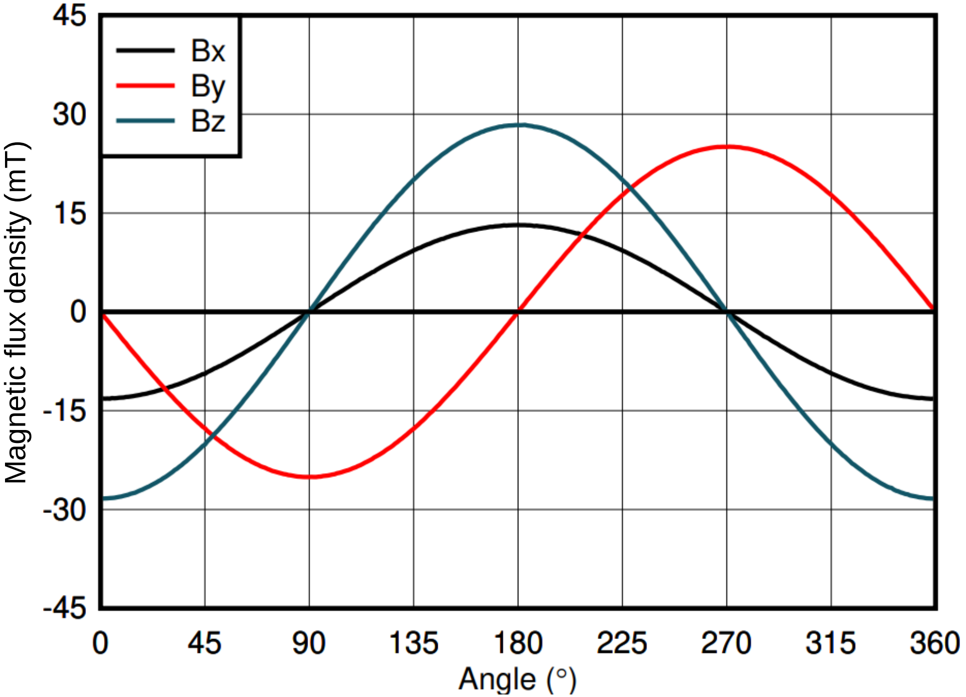


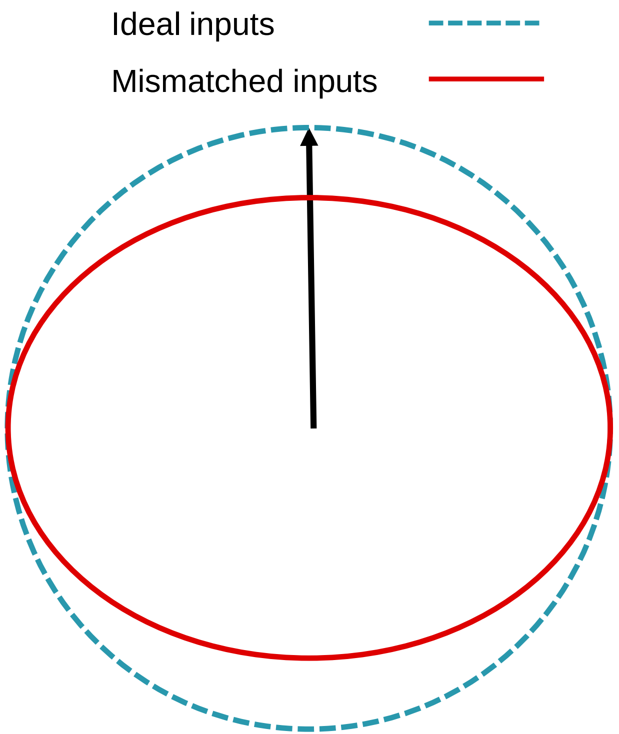
Angle detection



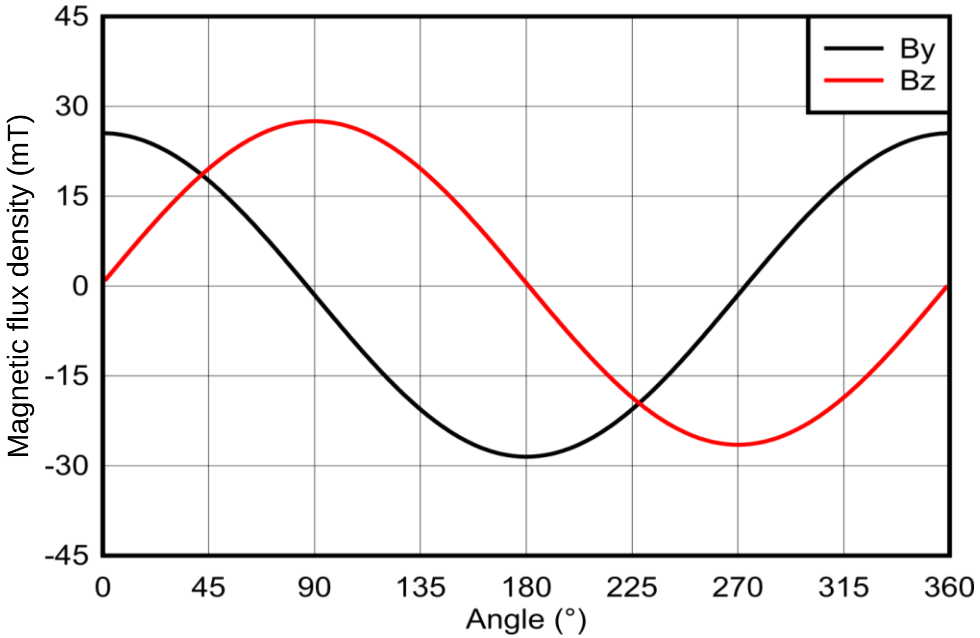


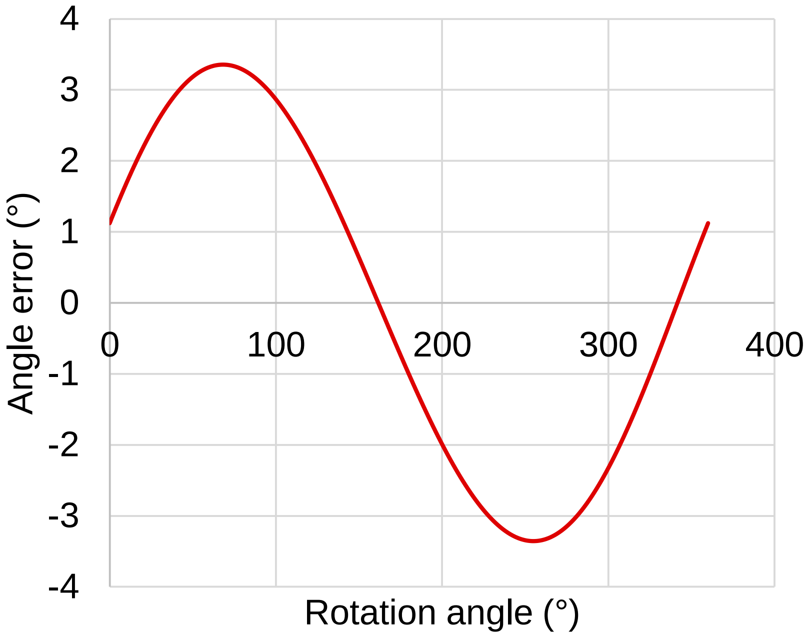
Angle detection





Angle detection





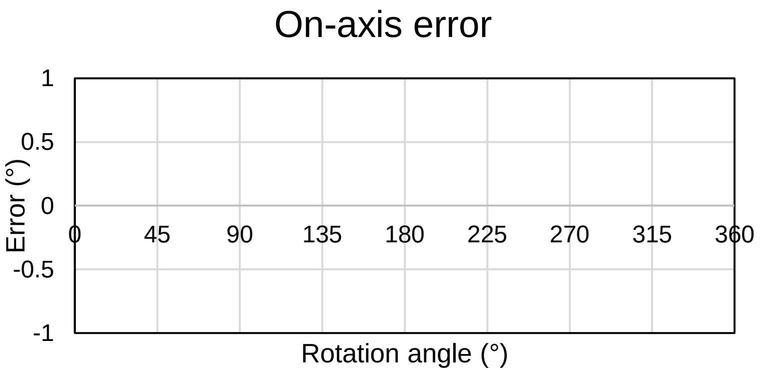
Texas Instruments

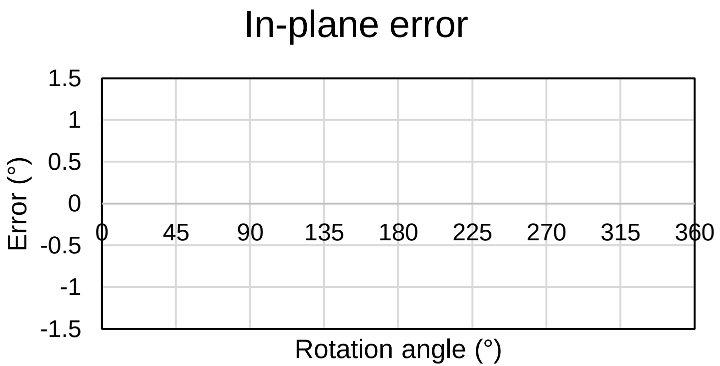
System error sources

Additional sources of error:

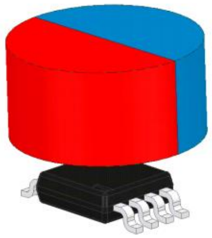
- Magnet tilt (wobble)
- Magnet centering
- Sensor alignment
- Measurement noise

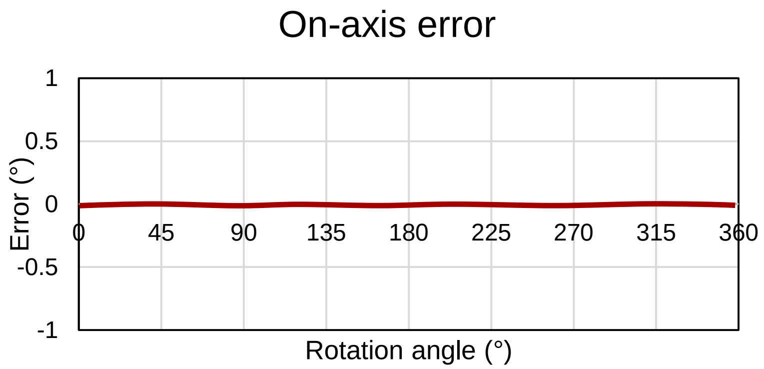
Magnet tilt

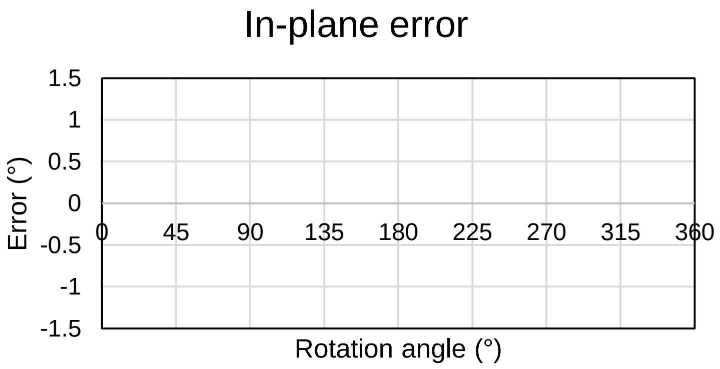

On-axis error
1
0.5
0
-0.5
-1
Error (°)
0
45
90
135
180
225
270
315
360
Rotation angle (°)


In-plane error
1.5
1
0.5
0
-0.5
-1
-1.5
Error (°)
0
45
90
135
180
225
270
315
360
Rotation angle (°)

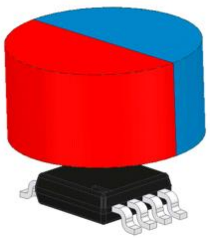
Magnet tilt

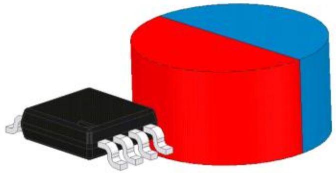


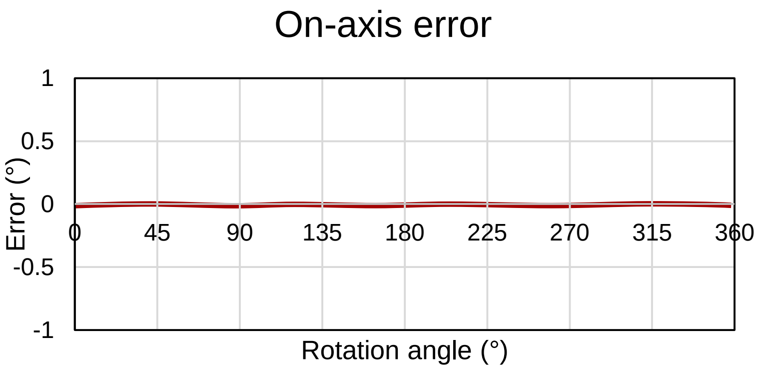

On-axis error
1
0.5
0
-0.5
-1
Error (°)
0
45
90
135
180
225
270
315
360
Rotation angle (°)

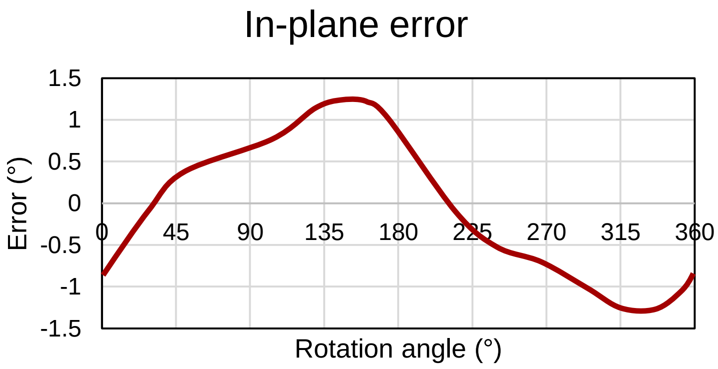

In-plane error
1.5
1
0.5
0
-0.5
-1
-1.5
Error (°)
0
45
90
135
180
225
270
315
360
Rotation angle (°)

Magnet tilt

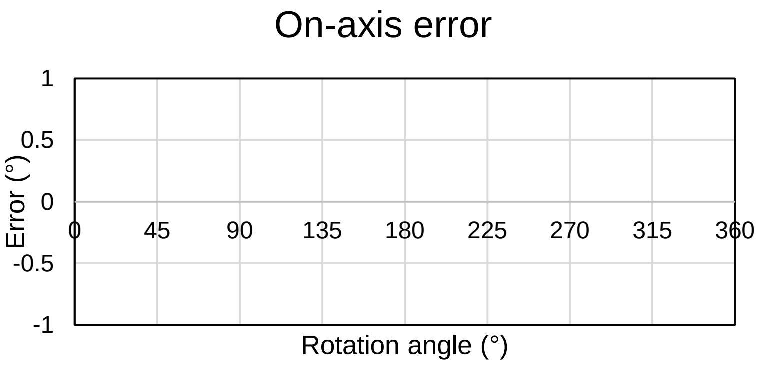


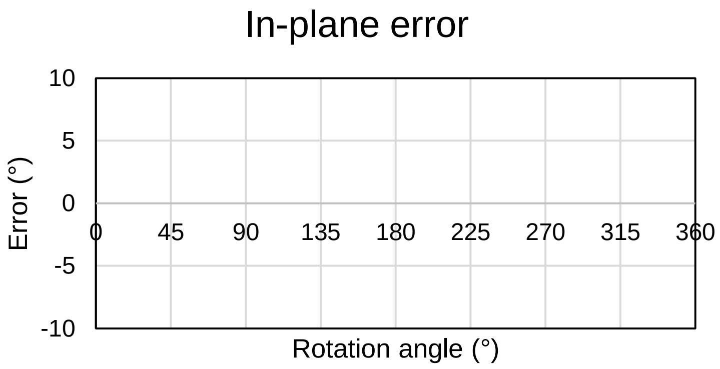



On-axis error
1
0.5
0
-0.5
-1
Error (°)
0
45
90
135
180
225
270
315
360
Rotation angle (°)

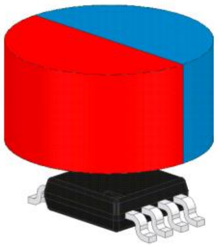

In-plane error
1.5
1
0.5
0
-0.5
-1
-1.5
Error (°)
0
45
90
135
180
225
270
315
360
Rotation angle (°)

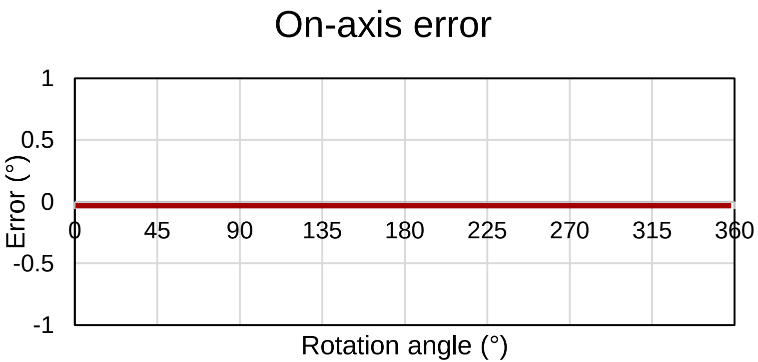
Magnet centering

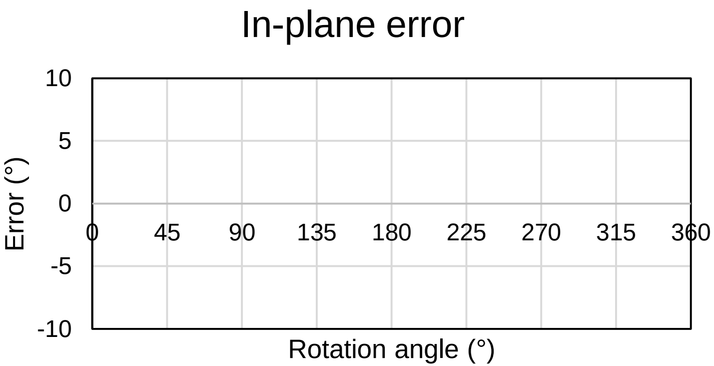




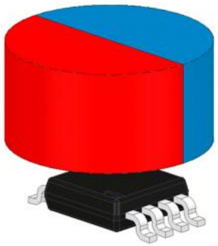
Magnet centering

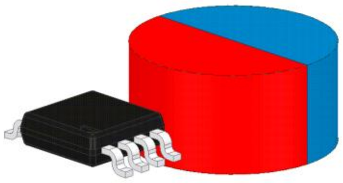


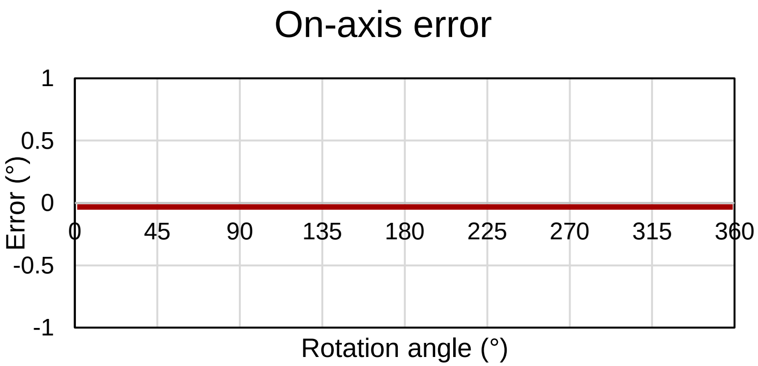


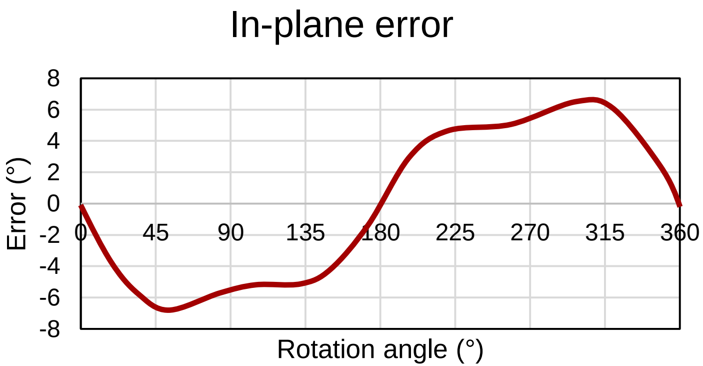


Magnet centering

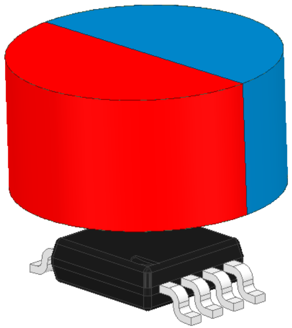


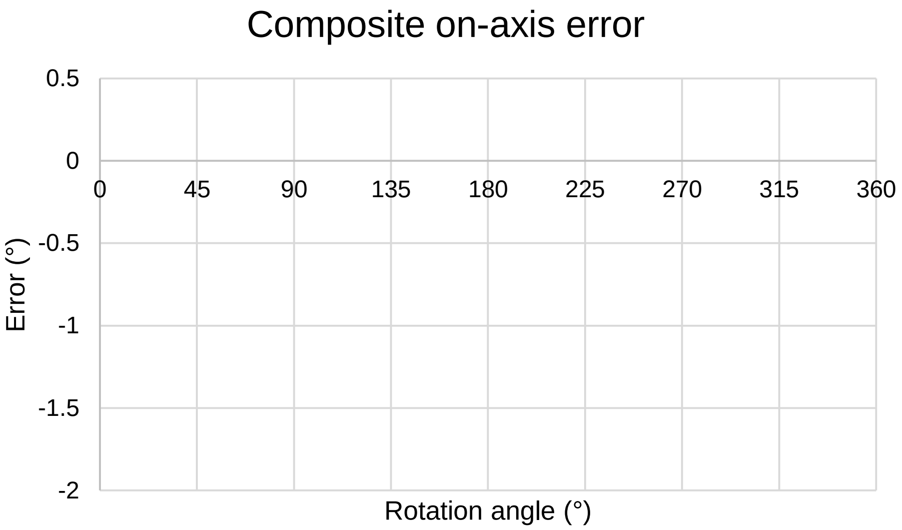




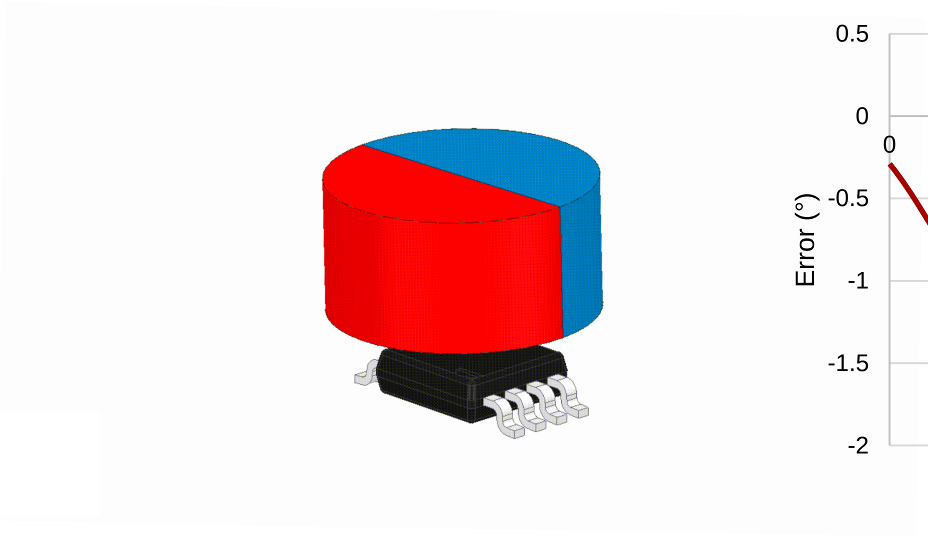


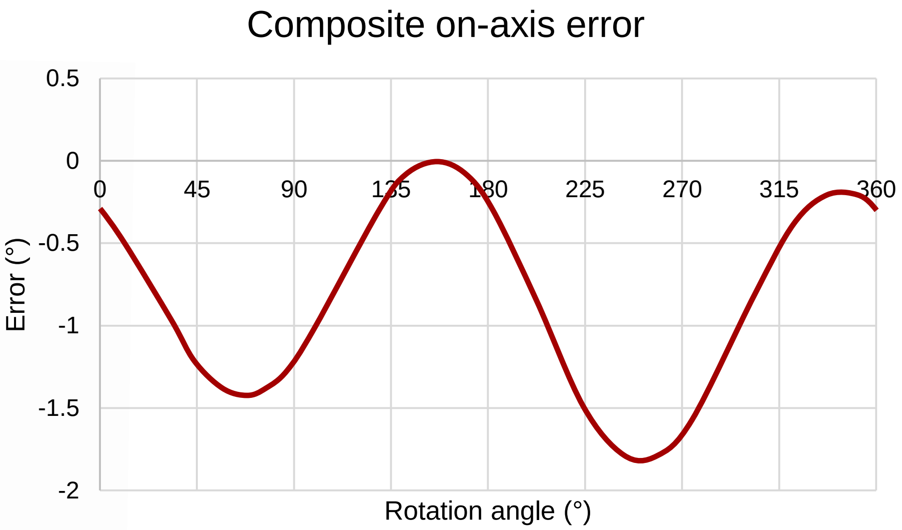
Sensor alignment



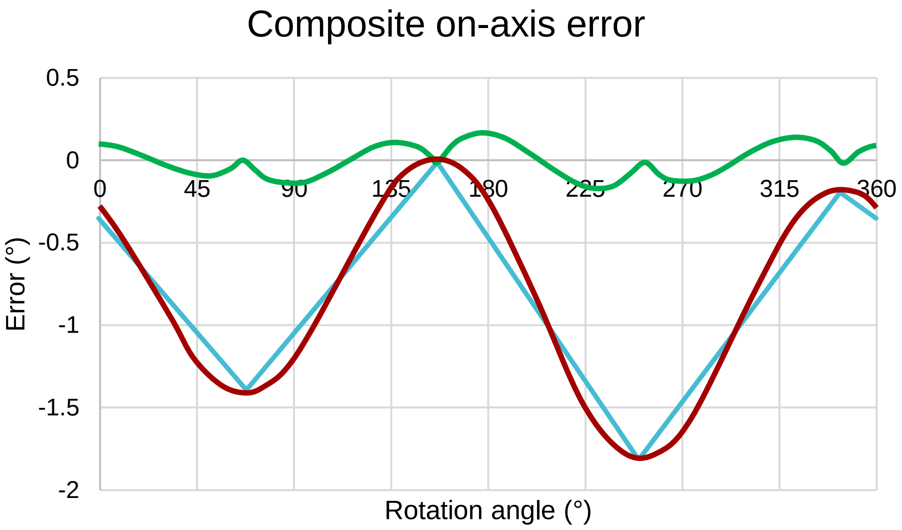


Sensor alignment





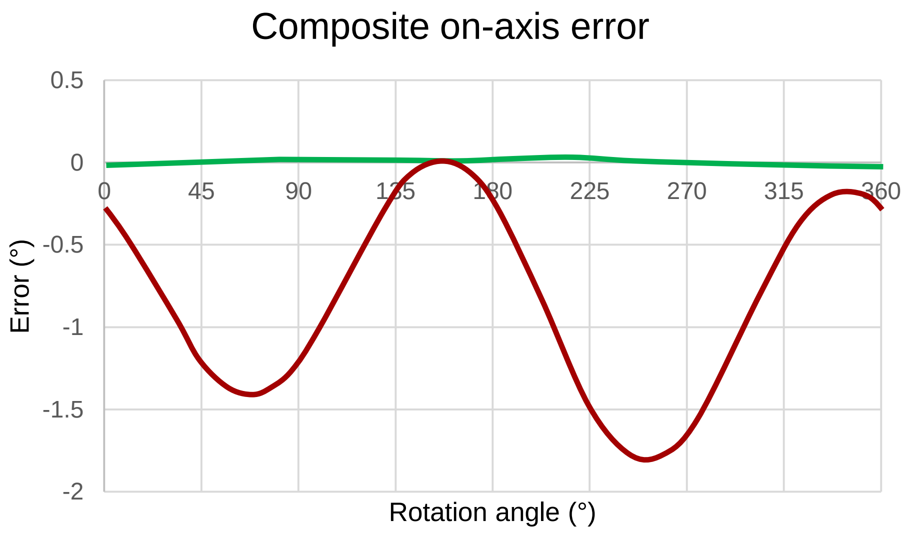
Calibration - Linearization



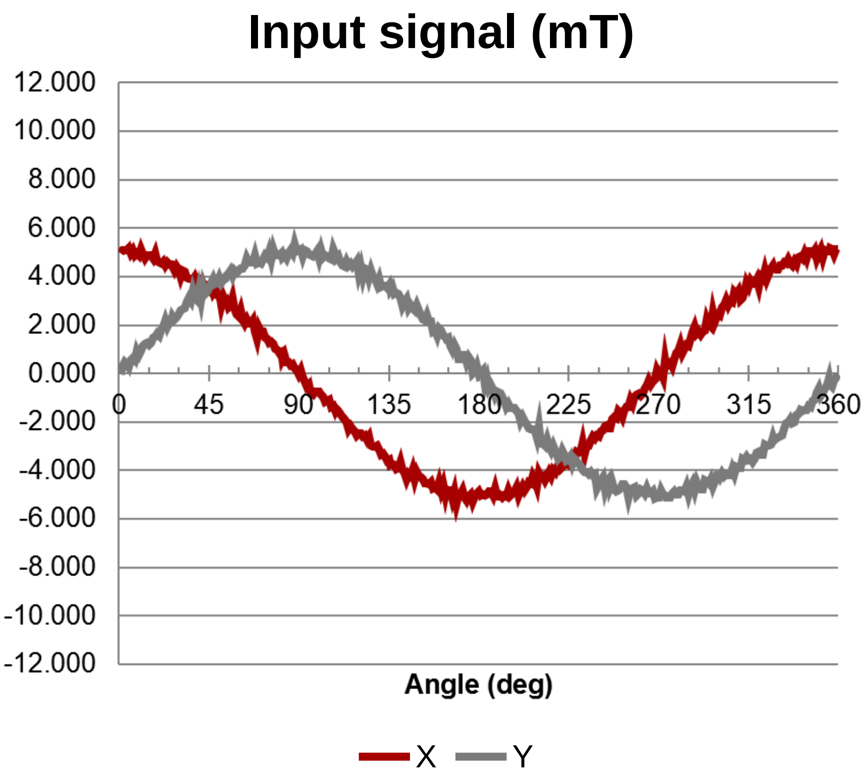
Calibration - Harmonics

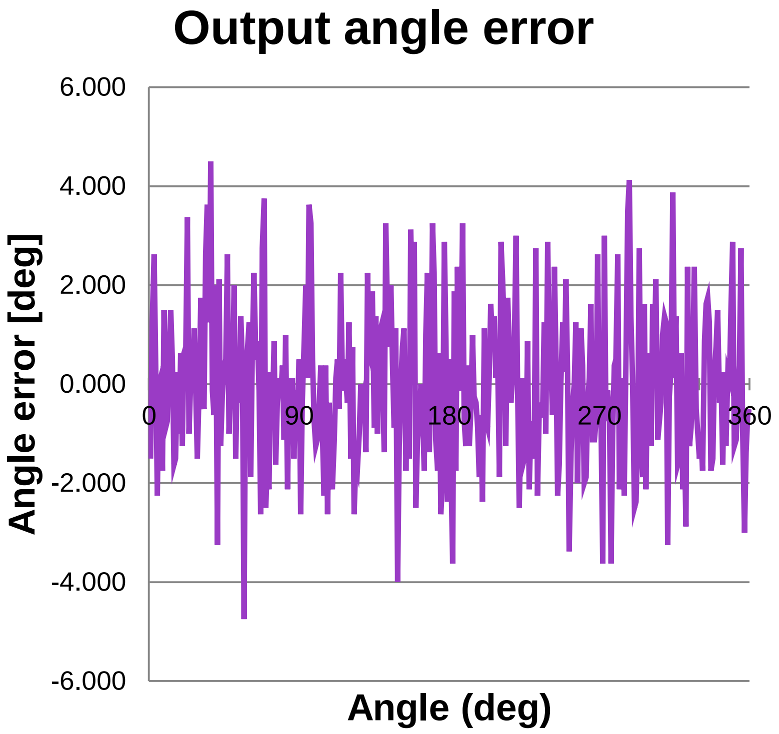
Calibration factor = $\sigma + \sum_{i=1}^{n} \alpha_i * \sin(i * \theta + \delta_i)$

σ = fixed angle offset
α_i = harmonic magnitude scalar
i = harmonic number
n = number of harmonics to correct
θ = output angle
δ_i = harmonic phase offset

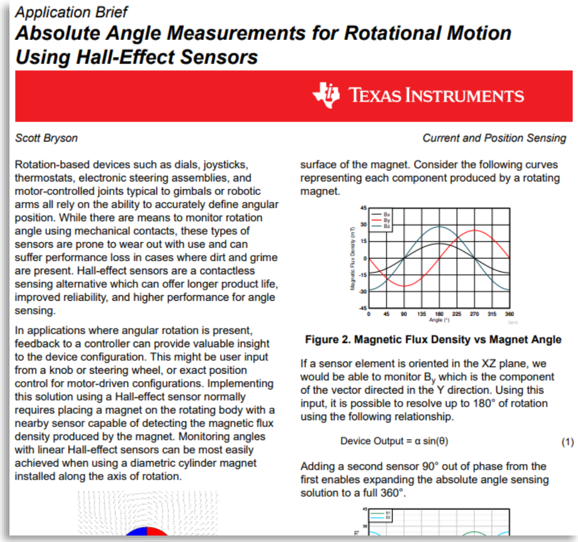


Noise


Input signal (mT)
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
-4.000
-6.000
-8.000
-10.000
-12.000
0
45
90
135
180
225
270
315
360
Angle (deg)
X
Y


Output angle error
6.000
4.000
2.000
0.000
-2.000
-4.000
-6.000
Angle error [deg]
0
90
180
270
360
Angle (deg)

Resources



Application Brief

Absolute Angle Measurements for Rotational Motion Using Hall-Effect Sensors

TEXAS INSTRUMENTS

Scott Bryson — *Current and Position Sensing*

Rotation-based devices such as dials, joysticks, thermostats, electronic steering assemblies, and motor-controlled joints typical to gimbals or robotic arms all rely on the ability to accurately define angular position. While there are means to monitor rotation angle using mechanical contacts, these types of sensors are prone to wear out with use and can suffer performance loss in cases where dirt and grime are present. Hall-effect sensors are a contactless sensing alternative which can offer longer product life, improved reliability, and higher performance for angle sensing.

In applications where angular rotation is present, feedback to a controller can provide valuable insight to the device configuration. This might be user input from a knob or steering wheel, or exact position control for motor-driven configurations. Implementing this solution using a Hall-effect sensor normally requires placing a magnet on the rotating body with a nearby sensor capable of detecting the magnetic flux density produced by the magnet. Monitoring angles with linear Hall-effect sensors can be most easily achieved when using a diametric cylinder magnet installed along the axis of rotation.

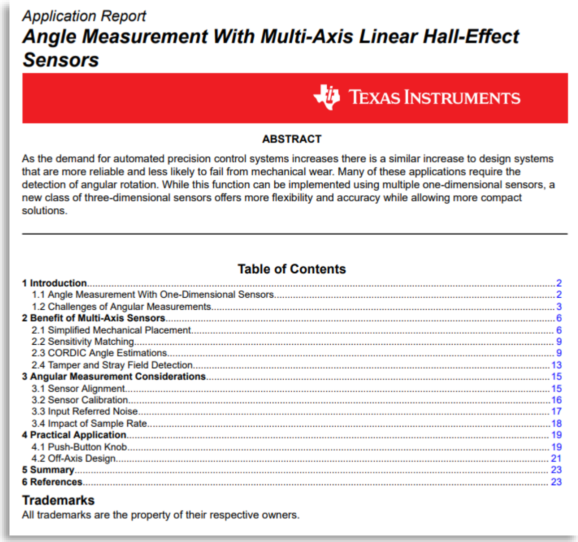
surface of the magnet. Consider the following curves representing each component produced by a rotating magnet.

Figure 2. Magnetic Flux Density vs Magnet Angle

If a sensor element is oriented in the XZ plane, we would be able to monitor B_y which is the component of the vector directed in the Y direction. Using this input, it is possible to resolve up to 180° of rotation using the following relationship.

$$\text{Device Output} = \alpha \sin(\theta) \quad (1)$$

Adding a second sensor 90° out of phase from the first enables expanding the absolute angle sensing solution to a full 360°.



Application Report

Angle Measurement With Multi-Axis Linear Hall-Effect Sensors

TEXAS INSTRUMENTS

ABSTRACT

As the demand for automated precision control systems increases there is a similar increase to design systems that are more reliable and less likely to fail from mechanical wear. Many of these applications require the detection of angular rotation. While this function can be implemented using multiple one-dimensional sensors, a new class of three-dimensional sensors offers more flexibility and accuracy while allowing more compact solutions.

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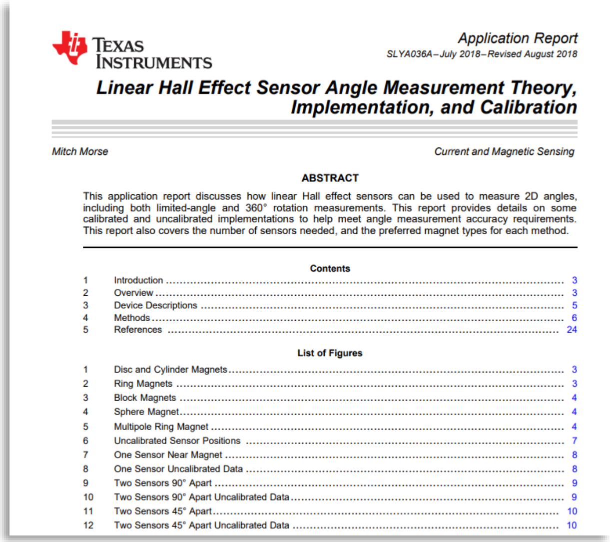

TEXAS INSTRUMENTS

Application Report
SLYA036A – July 2018 – Revised August 2018

Linear Hall Effect Sensor Angle Measurement Theory, Implementation, and Calibration

Mitch Morse — *Current and Magnetic Sensing*

ABSTRACT

This application report discusses how linear Hall effect sensors can be used to measure 2D angles, including both limited-angle and 360° rotation measurements. This report provides details on some calibrated and uncalibrated implementations to help meet angle measurement accuracy requirements. This report also covers the number of sensors needed, and the preferred magnet types for each method.

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TEXAS INSTRUMENTS

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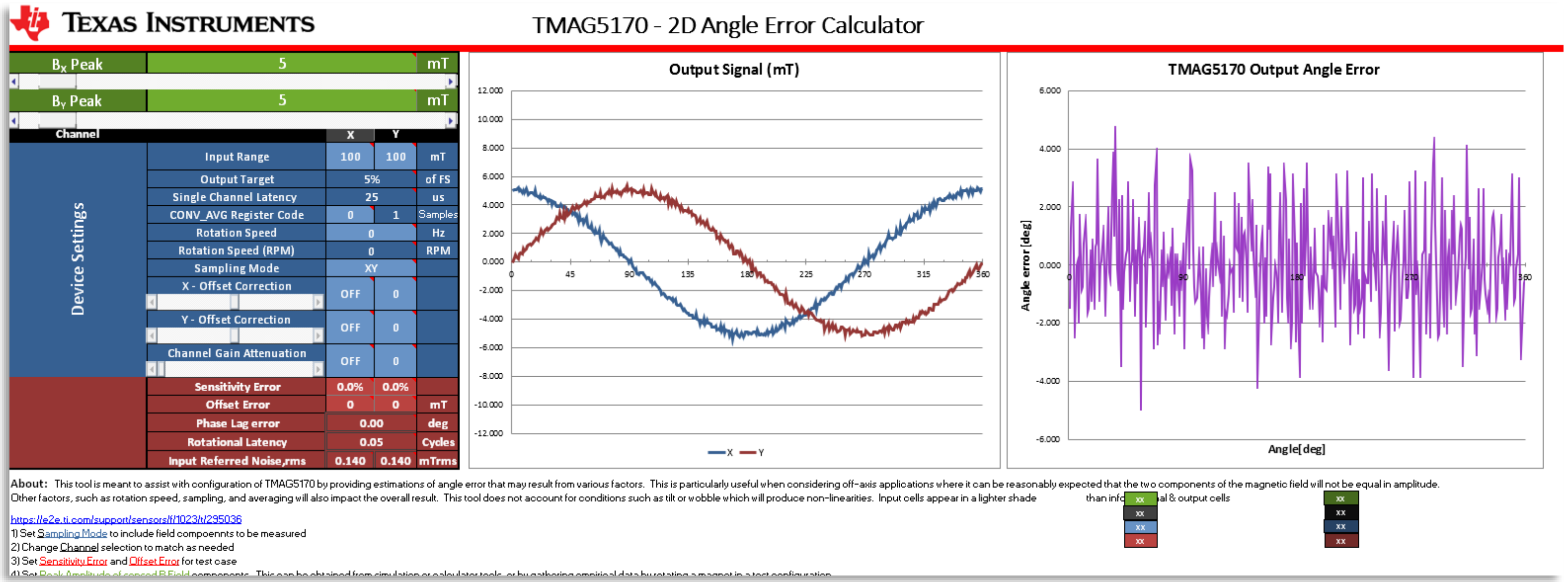

Texas Instruments
TMAG5170 - 2D Angle Error Calculator
Bx Peak 5 mT
By Peak 5 mT
Channel X Y
Device Settings
Input Range 100 100 mT
Output Target 5% of FS
Single Channel Latency 25 us
CONV_AVG Register Code 0 1 Samples
Rotation Speed 0 Hz
Rotation Speed (RPM) 0 RPM
Sampling Mode XY
X - Offset Correction OFF 0
Y - Offset Correction OFF 0
Channel Gain Attenuation OFF 0
Sensitivity Error 0.0% 0.0%
Offset Error 0 0 mT
Phase Lag error 0.00 deg
Rotational Latency 0.05 Cycles
Input Referred Noise,rms 0.140 0.140 mTrms
Output Signal (mT)
X
Y
TMAG5170 Output Angle Error
Angle error [deg]
Angle[deg]
About: This tool is meant to assist with configuration of TMAG5170 by providing estimations of angle error that may result from various factors. This is particularly useful when considering off-axis applications where it can be reasonably expected that the two components of the magnetic field will not be equal in amplitude.
Other factors, such as rotation speed, sampling, and averaging will also impact the overall result. This tool does not account for conditions such as tilt or wobble which will produce non-linearities. Input cells appear in a lighter shade
al & output cells
https://e2e.ti.com/support/sensors/f/1023/t/295036
1) Set Sampling Mode to include field compoennts to be measured
2) Change Channel selection to match as needed
3) Set Sensitivity Error and Offset Error for test case

To find more magnetic position sensing technical resources and search products, visit **ti.com/halleffect**.