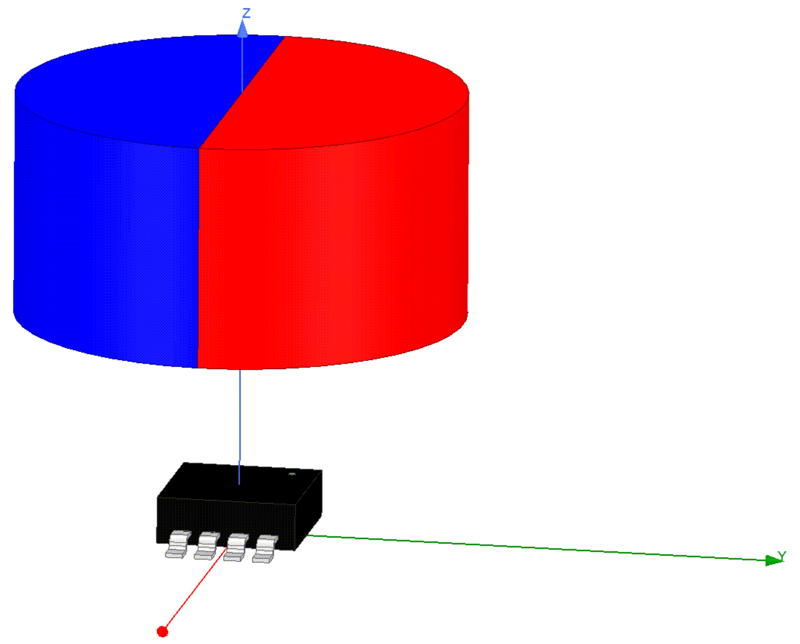
Specifications of Three Dimensional (3D) Hall Effect Sensors

TI Precision Labs – Magnetic Sensors

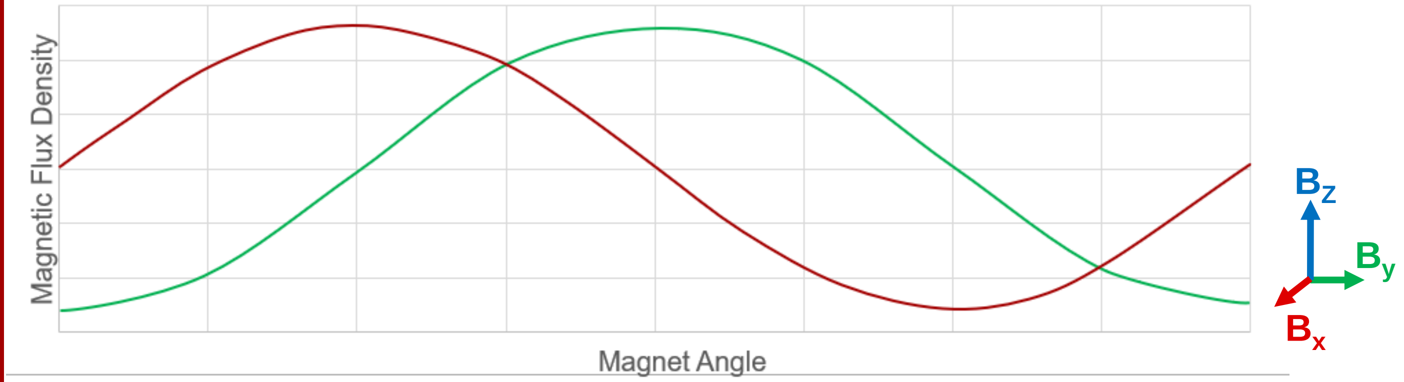
Presented and Prepared by Mekre Mesganaw

Magnetic specifications

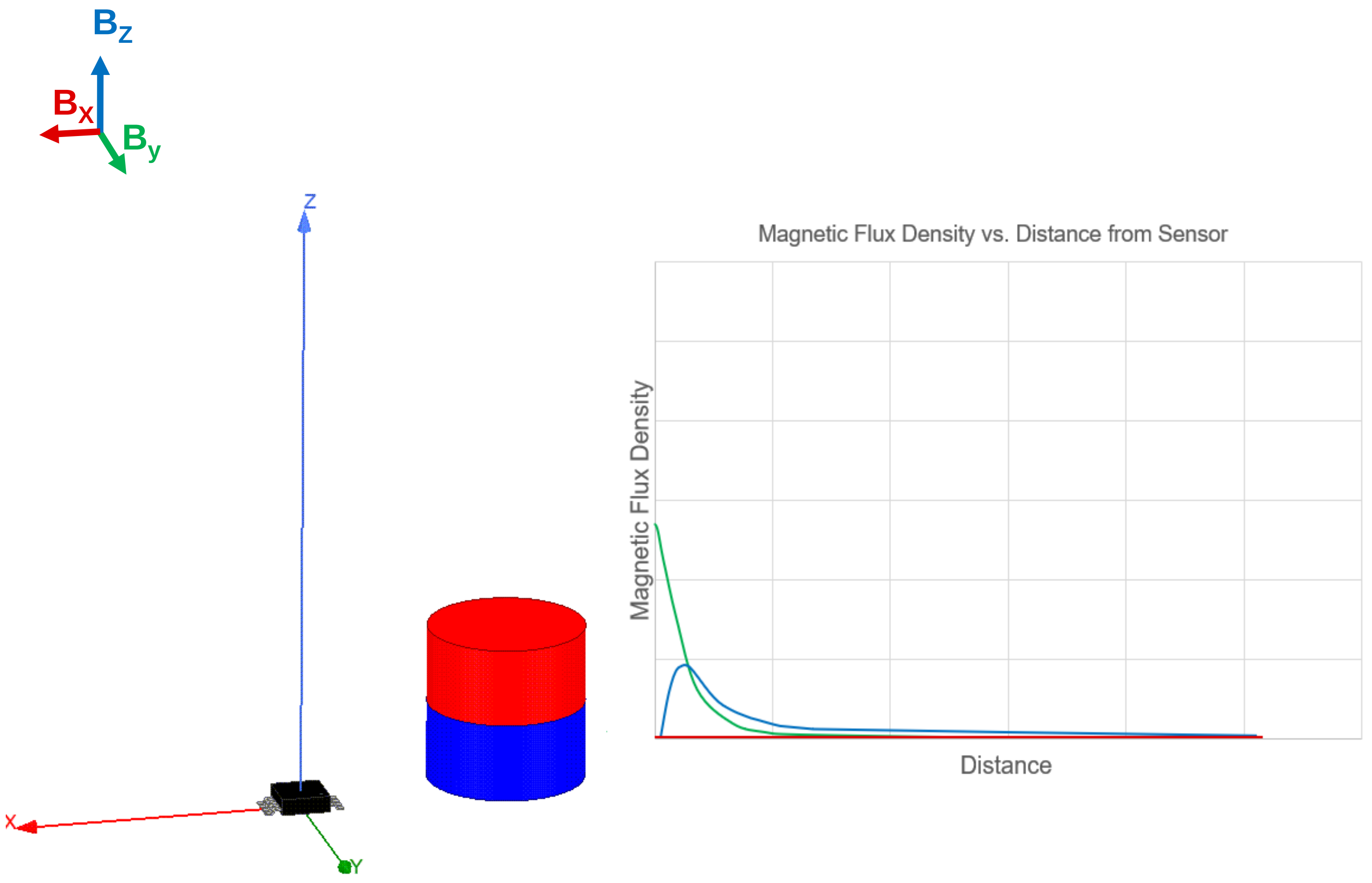
Angle measurement



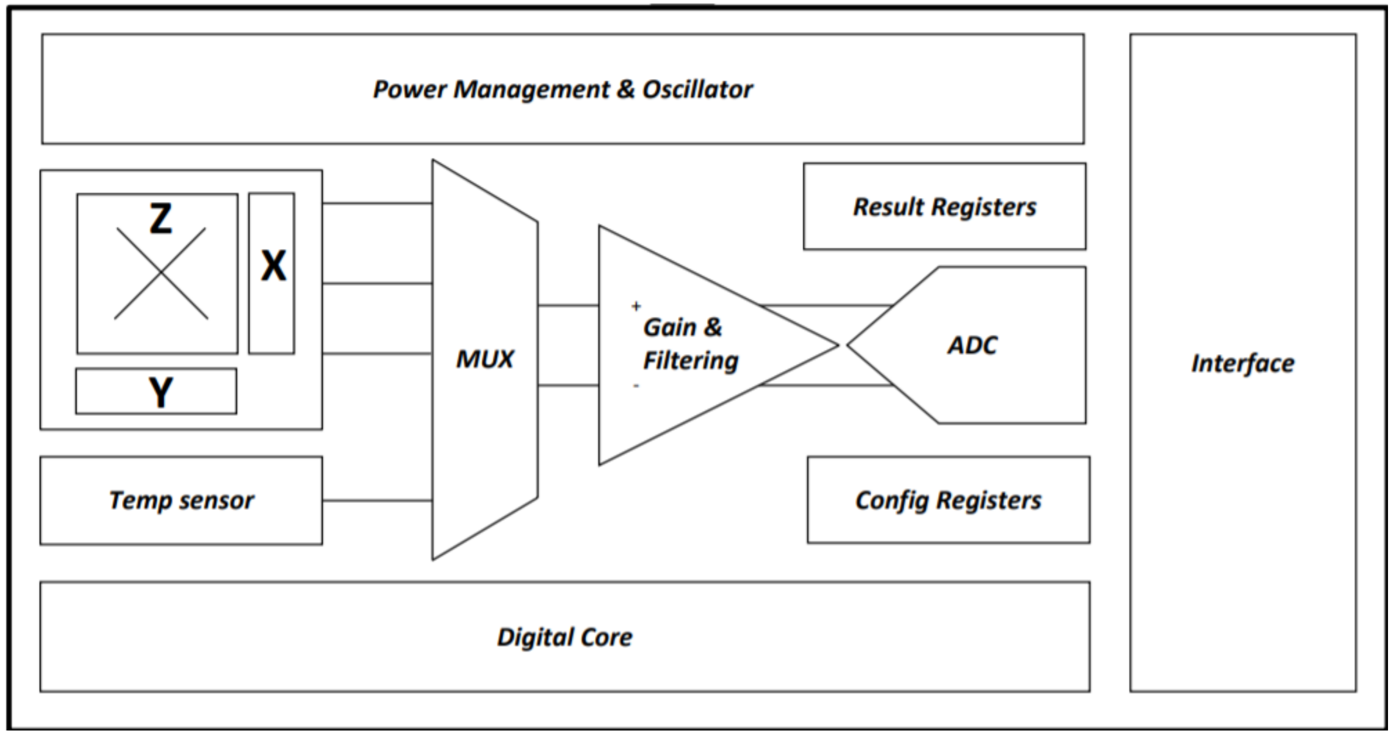
$$Magnet\ angle = arctan2(B_y, B_x)$$

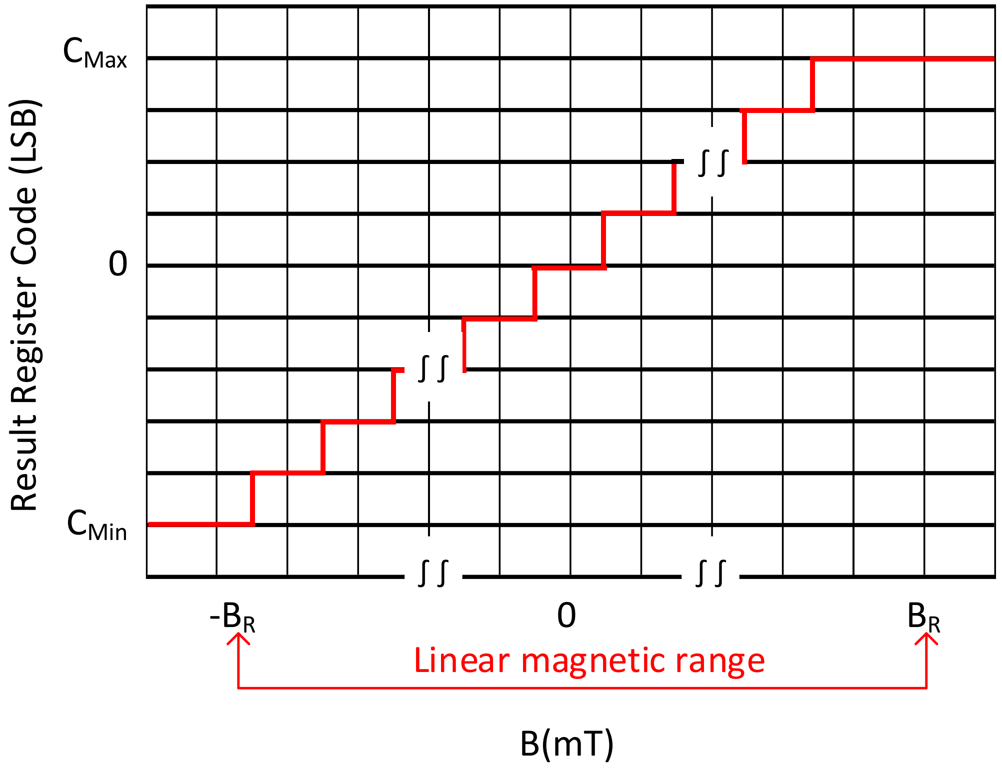


Distance measurement



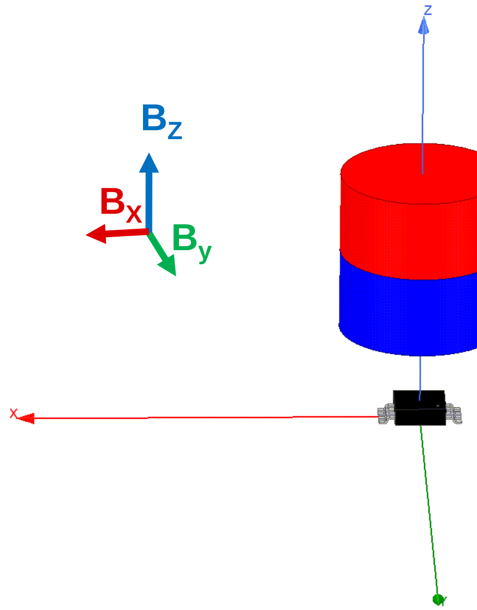
Linear magnetic range spec





PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
TMAG5170A1						
B_{IN_A1}	Linear magnetic range	x_RANGE =00b		±50		mT
		x_RANGE =01b		±25		mT
		x_RANGE =10b		±100		mT
TMAG5170A2						
B_{IN_A2}	Linear magnetic range	x_RANGE =00b		±200		mT
		x_RANGE =01b		±133		mT
		x_RANGE =10b		±300		mT

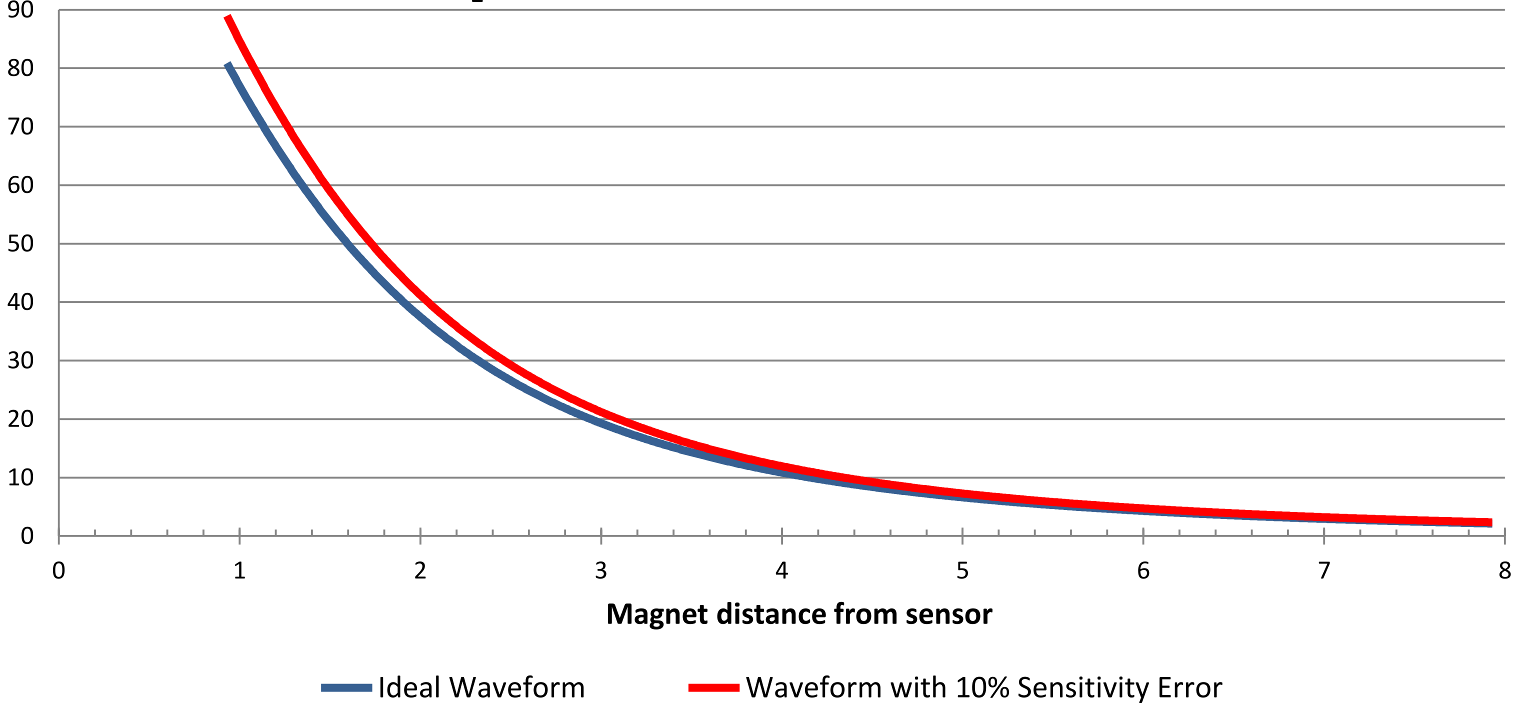
Sensitivity error effect on distance measurements



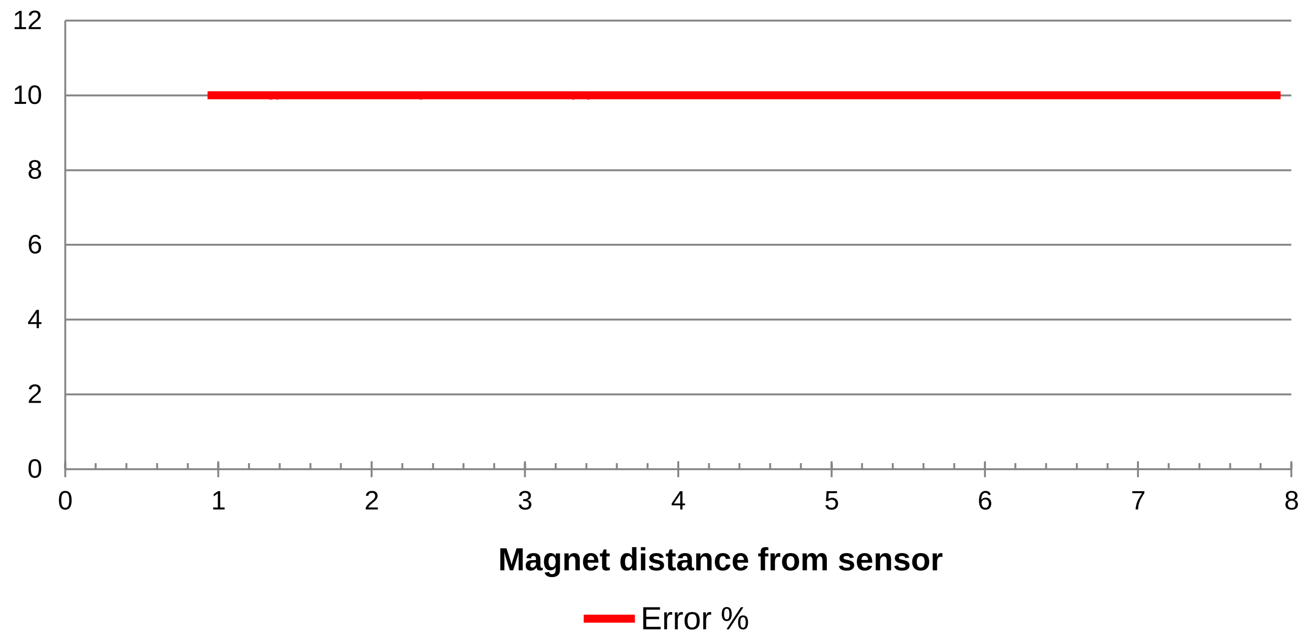
$$Sensitivity\ (LSB/mT) = \frac{Result\_register\_value}{B} = \frac{326\ LSB}{1\ mT}$$

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
TMAG5170A1						
$SENS_{50\_A1}$	Sensitivity, X, Y, or Z axis	x_RANGE =00b		654		LSB/mT
$SENS_{25\_A1}$		x_RANGE =01b		1308		LSB/mT
$SENS_{100\_A1}$		x_RANGE =10b		326		LSB/mT
$SENS_{ER\_25C\_A1}$	Sensitivity error, X, Y, Z axis	T_A = 25°C	–1.1%	±0.1%	1.1%	

B_z Magnetic Flux Density (mT)

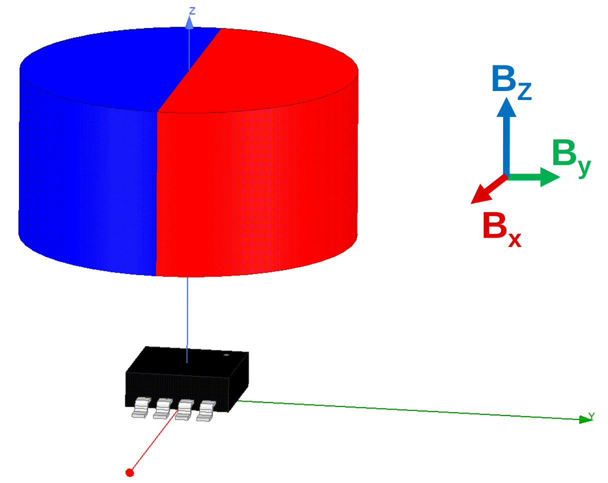


Error (%)



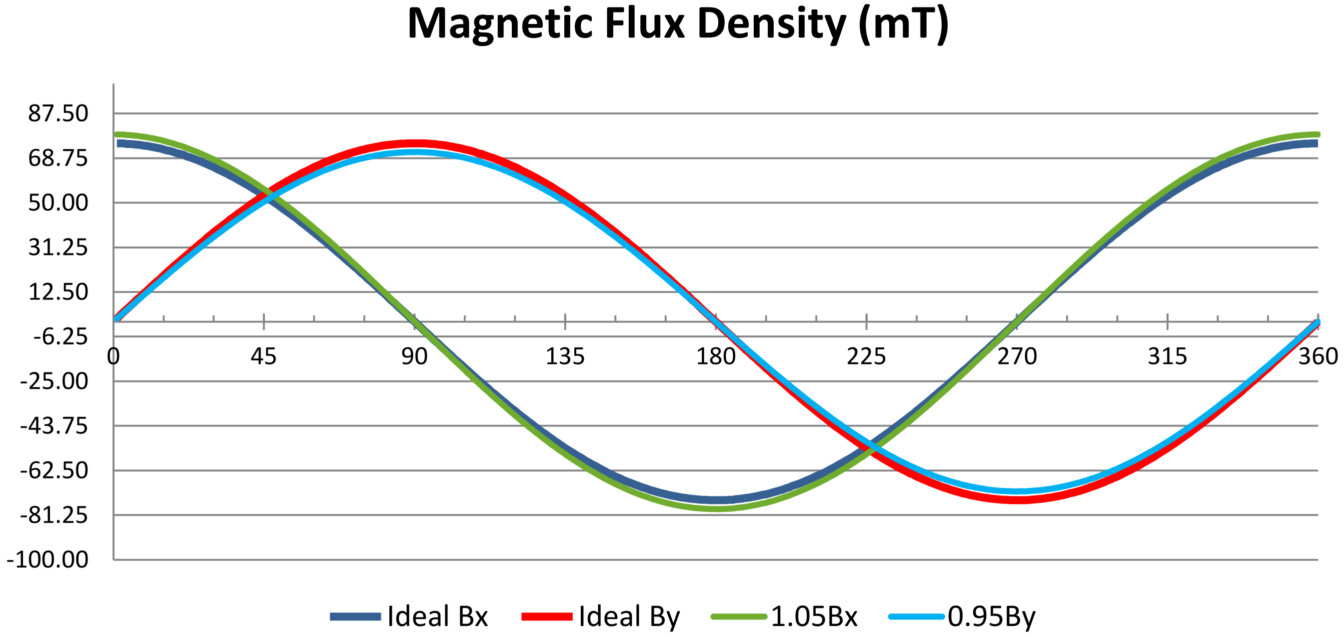
$$Sensitivity_{Actual} = \frac{k_{Sensitivity\_error} + 100}{100} \times Sensitivity_{Ideal}$$

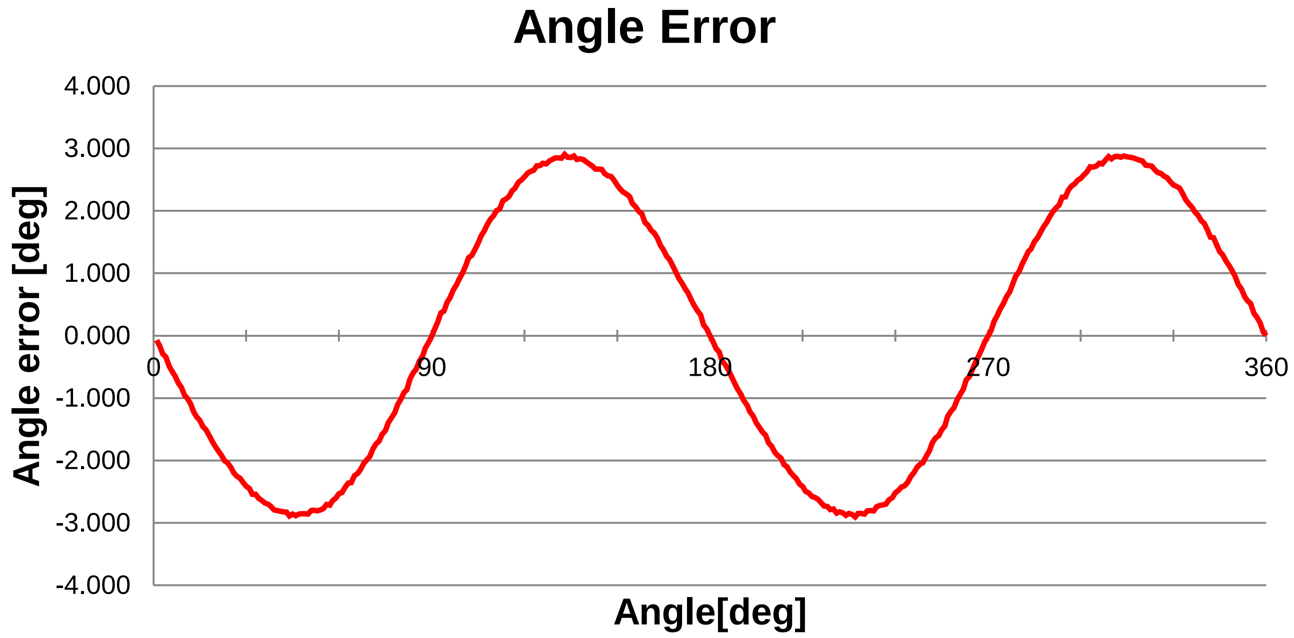
Sensitivity mismatch effect on angle measurement



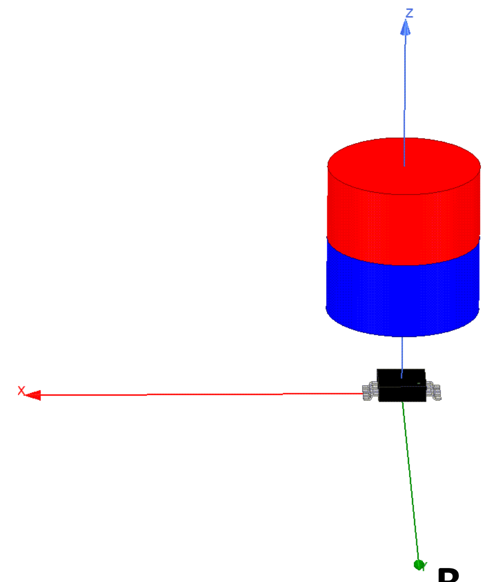
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$SENS_{MS\_XY\_A1}$	Sensitivity mismatch among X-Y axes	T_A = 25°C	–1.1%	±0.15%	1.1%	
$SENS_{MS\_Z\_A1}$	Sensitivity mismatch among Y-Z, or X-Z axes	T_A = 25°C		±0.15%		
$SENS_{MS\_DR\_XY\_A1}$	Sensitivity mismatch drift X-Y axes	T_A = –40°C to 150°C		±0.2%		
$SENS_{MS\_DR\_Z\_A1}$	Sensitivity mismatch drift Y-Z, or X-Z axes			±0.2%		

$$Mismatch_{XY}[\%] = \left(\left(\frac{Sensitivity\_Actual,y}{Sensitivity\_Actual,x}\right) - 1\right) \times 100 \ , \quad arctan\left(\frac{B_y}{B_x}\right) = arctan\left(\frac{(100+k_{Sensitivity\_error,x}) \times Result\_register\_value_y}{(100+k_{Sensitivity\_error,y}) \times Result\_register\_value_x}\right) = arctan\left(\frac{100 \times Result\_register\_value_y}{(100+Mismatch_{XY}) \times Result\_register\_value_x}\right)$$

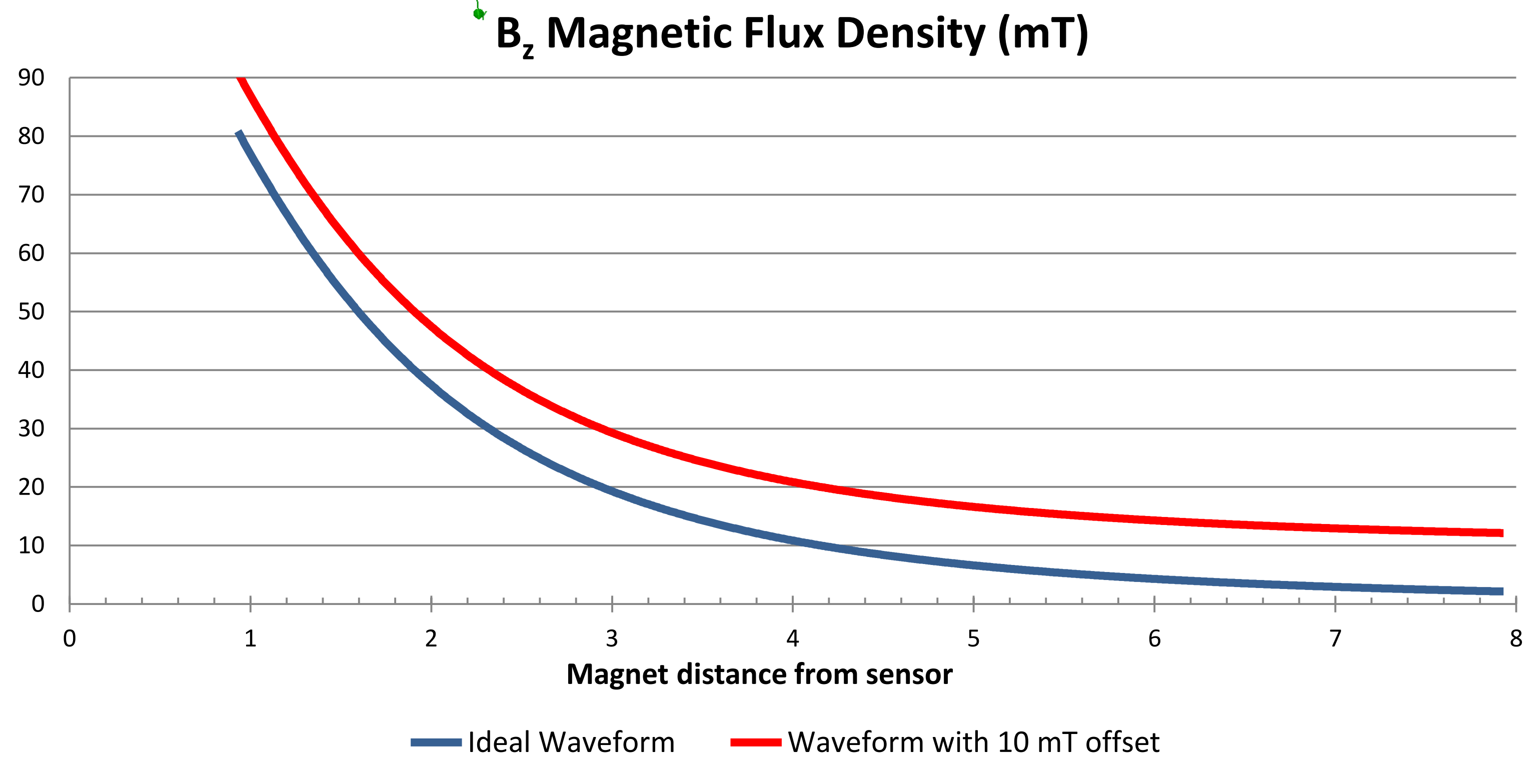


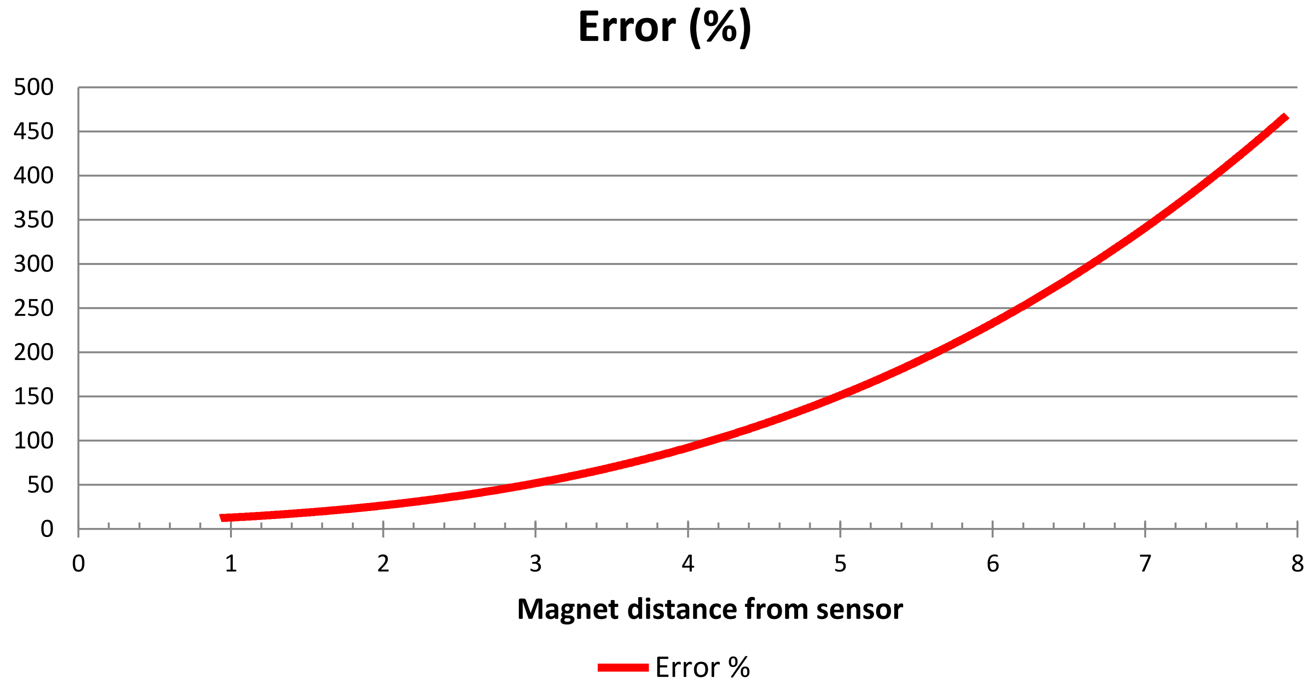


Offset effect on distance measurements



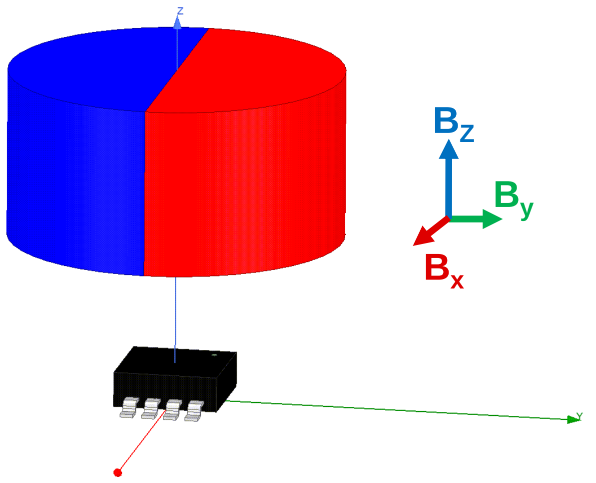
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
TMAG5170A1						
B_{off_A1}	Offset	x_RANGE - 00, T_A = 25℃		±0.15		mT
$B_{off\_TC\_A1}$	Offset drift from value at T_A = 25℃	T_A =-40℃ to 150℃		-2		μT/°C





$$Output_{Actual} = C_{offset\_error} + Output_{Ideal}$$

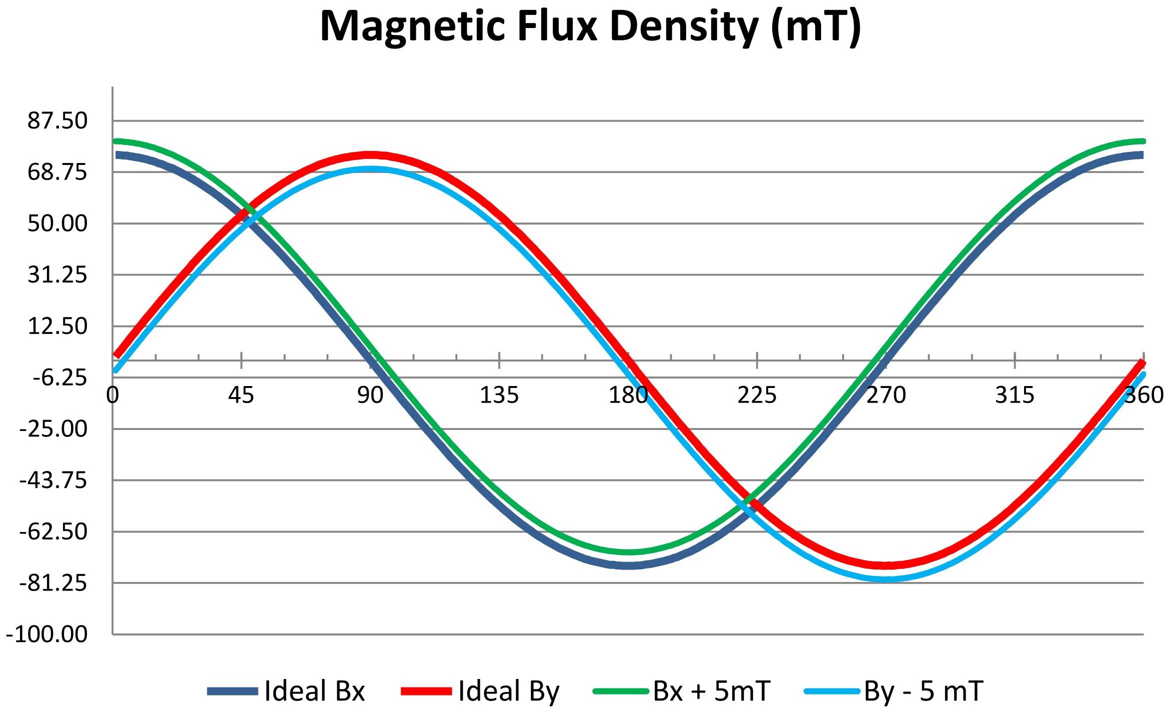
Offset effect on angle measurement

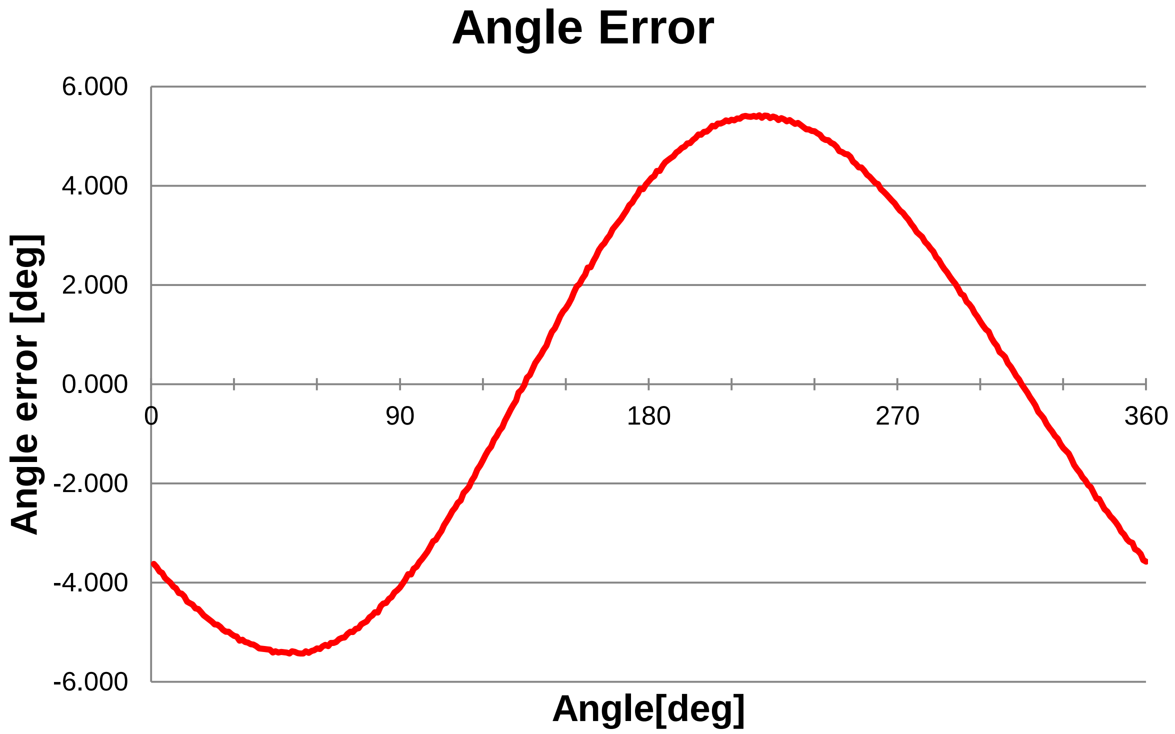


$$B_x = \; + B_{Ideal,x} + C_{offset\_error,x}$$

$$B_y = \; + B_{Ideal,y} + C_{offset\_error,y}$$

$$arctan\left(\frac{B_y}{B_x}\right) = arctan\left(\frac{B_{Ideal,y} + C_{offset\_error,y}}{B_{Ideal,x} + C_{offset\_error,x}}\right)$$





Noise specs

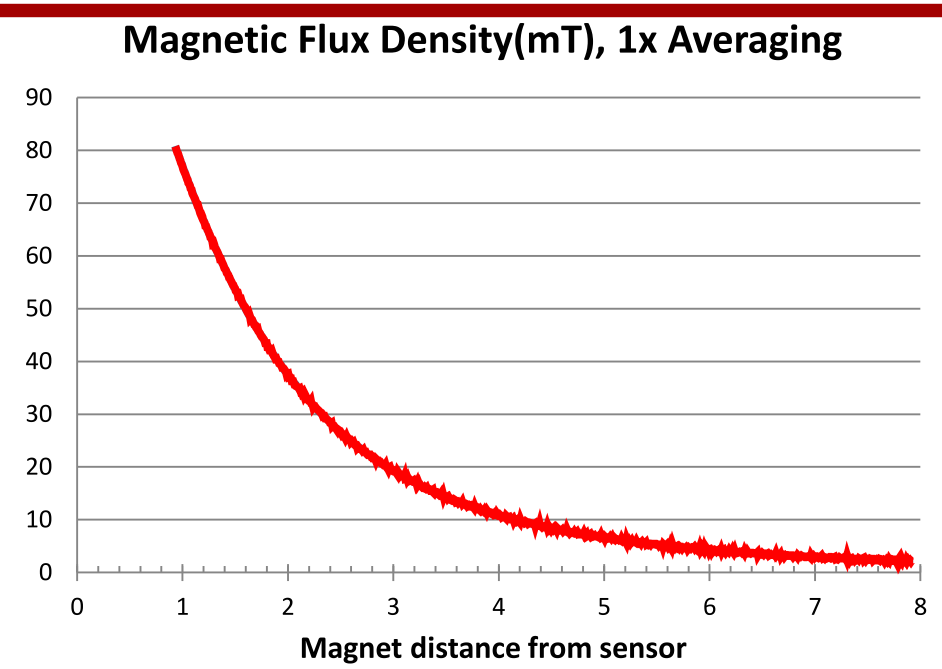
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
TMAG5170A1							
$N_{RMS\_XY\_FAST\_A1}$	RMS (1 Sigma) magnetic noise (X or Y-axis)	CONV_AVG = 000, T_A = 25°C		±0.140		mT	1x averaging
$N_{RMS\_XY\_SLOW\_A1}$	RMS (1 Sigma) magnetic noise (X or Y-axis)	CONV_AVG = 101, T_A = 25°C		±0.025		mT	32x averaging
$N_{RMS\_Z\_FAST\_A1}$	RMS (1 Sigma) magnetic noise (Z axis)	CONV_AVG = 000, T_A = 25°C		±0.064		mT	1x averaging
$N_{RMS\_Z\_SLOW\_A1}$	RMS (1 Sigma) magnetic noise (Z axis)	CONV_AVG = 101, T_A = 25°C		±0.011		mT	32x averaging

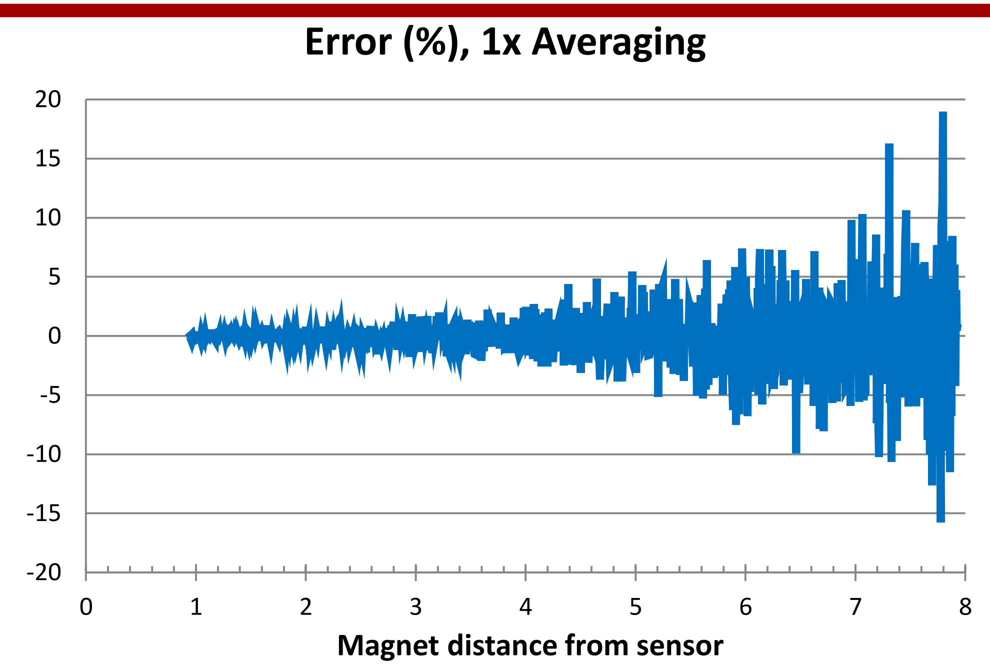
$$N_{avg} = \frac{N}{\sqrt{Number\ of\ samples}} = \frac{0.14}{\sqrt{32}} = 0.025\ mT$$

Increasing averaging interval reduces noise but also reduces maximum sampling frequency!

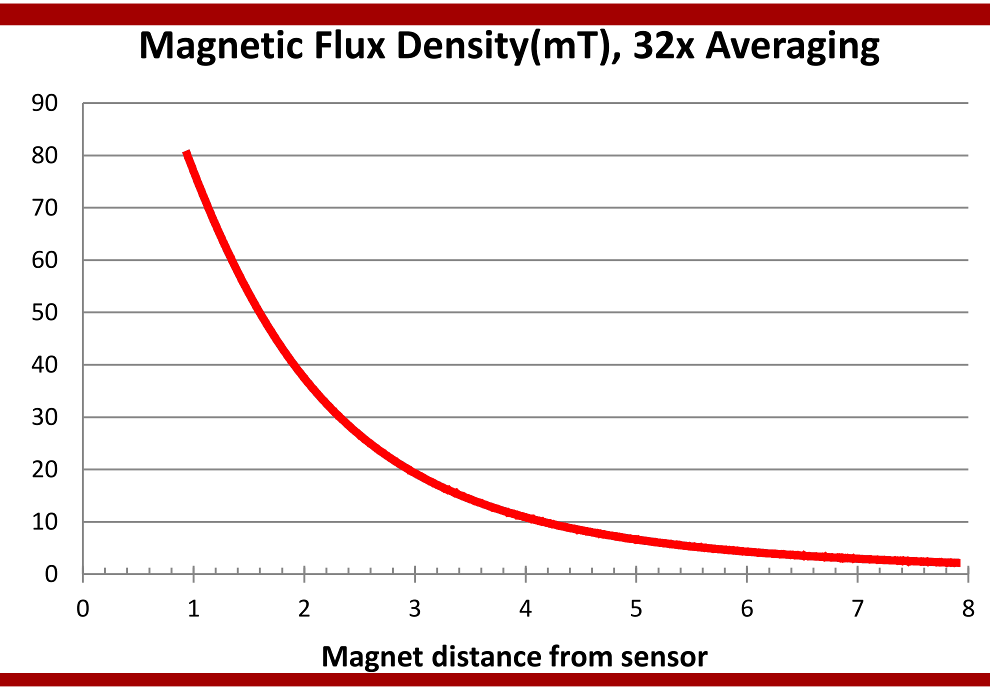
Effect of noise on linear distance measurement

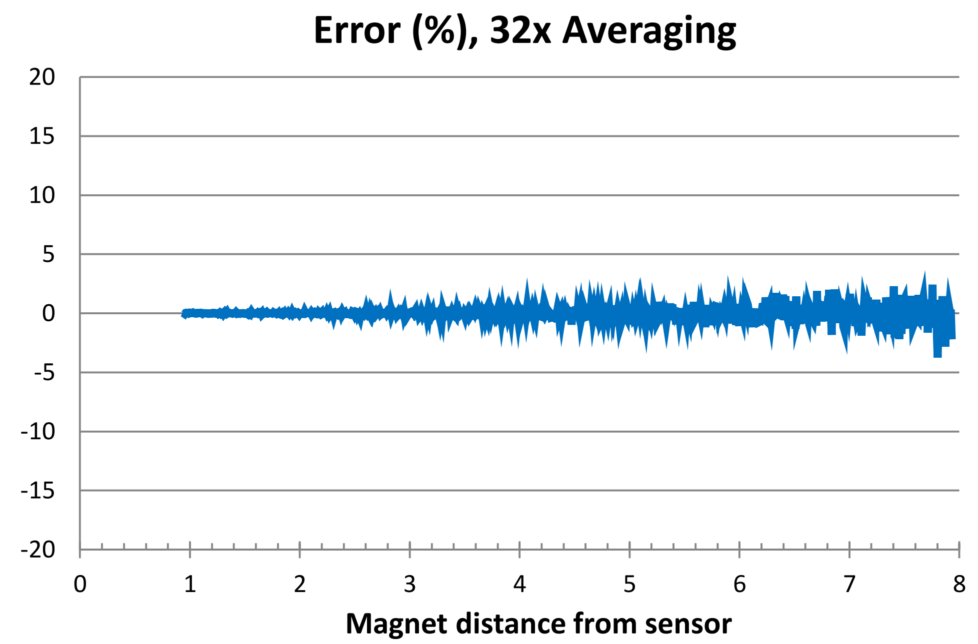
1x Averaging





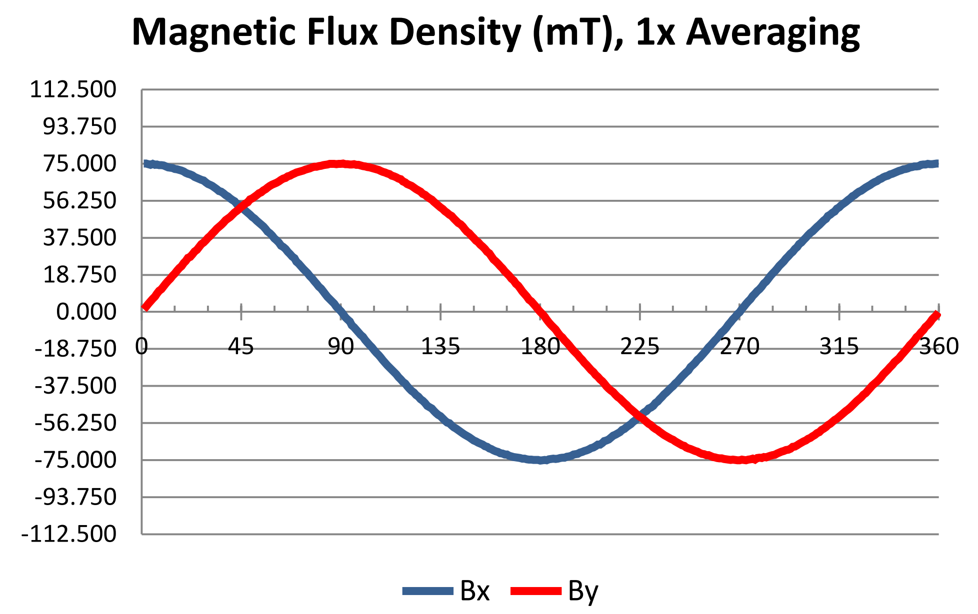
32x Averaging

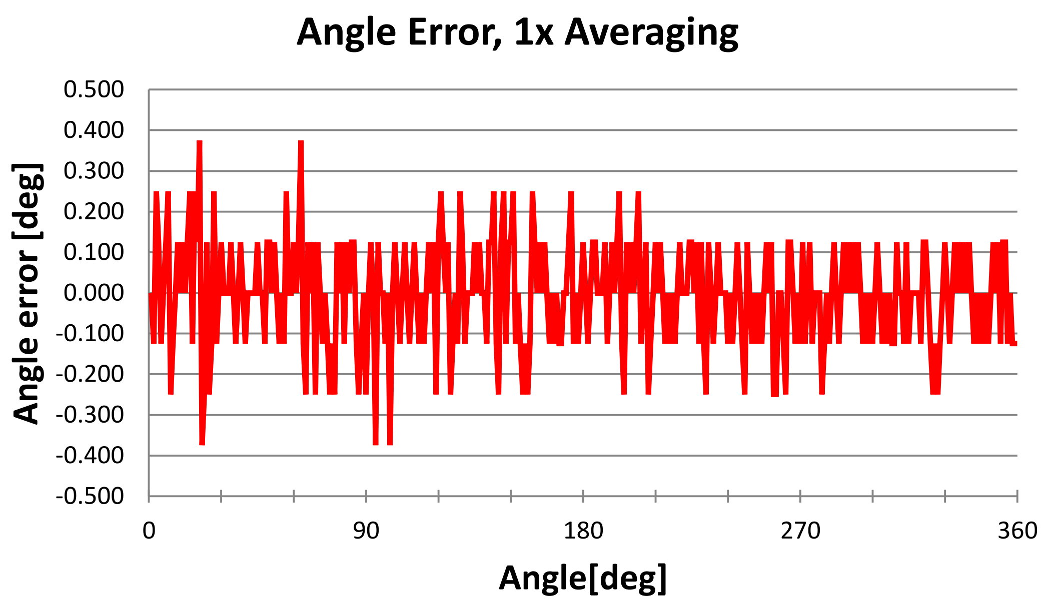




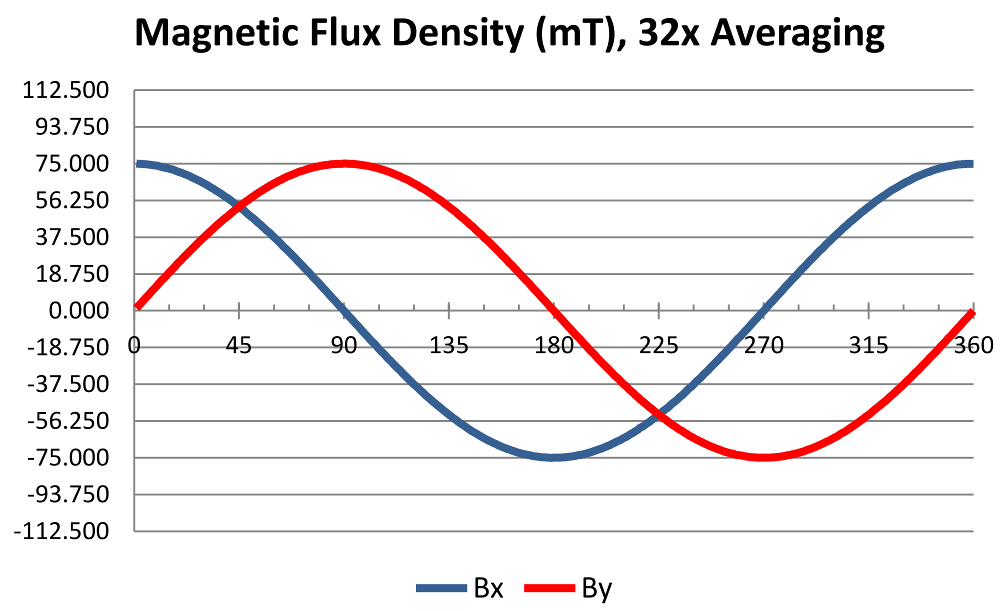
Effect of noise on angle measurements

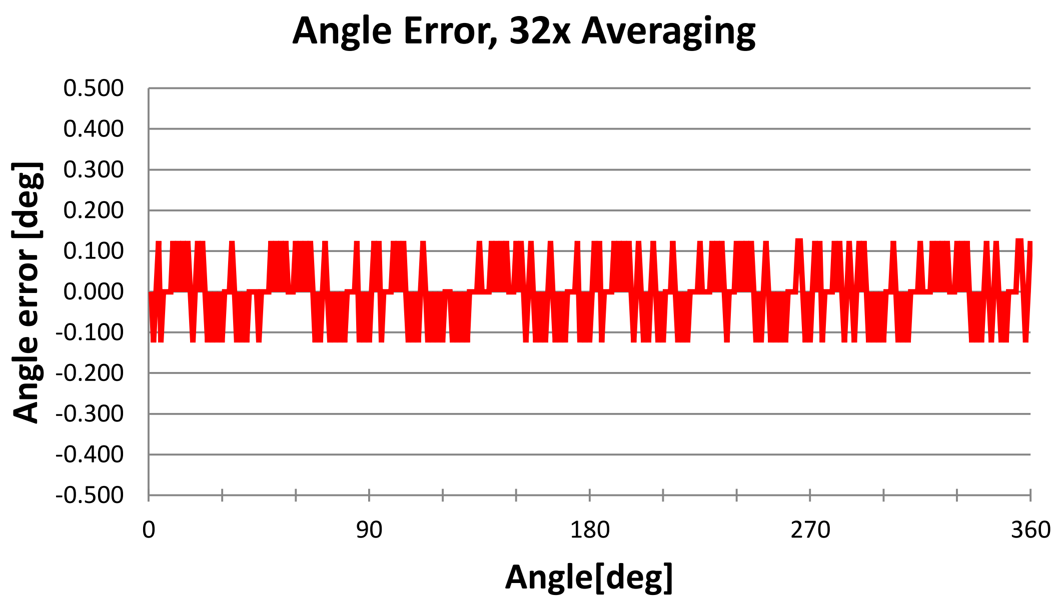
1x Averaging





32x Averaging

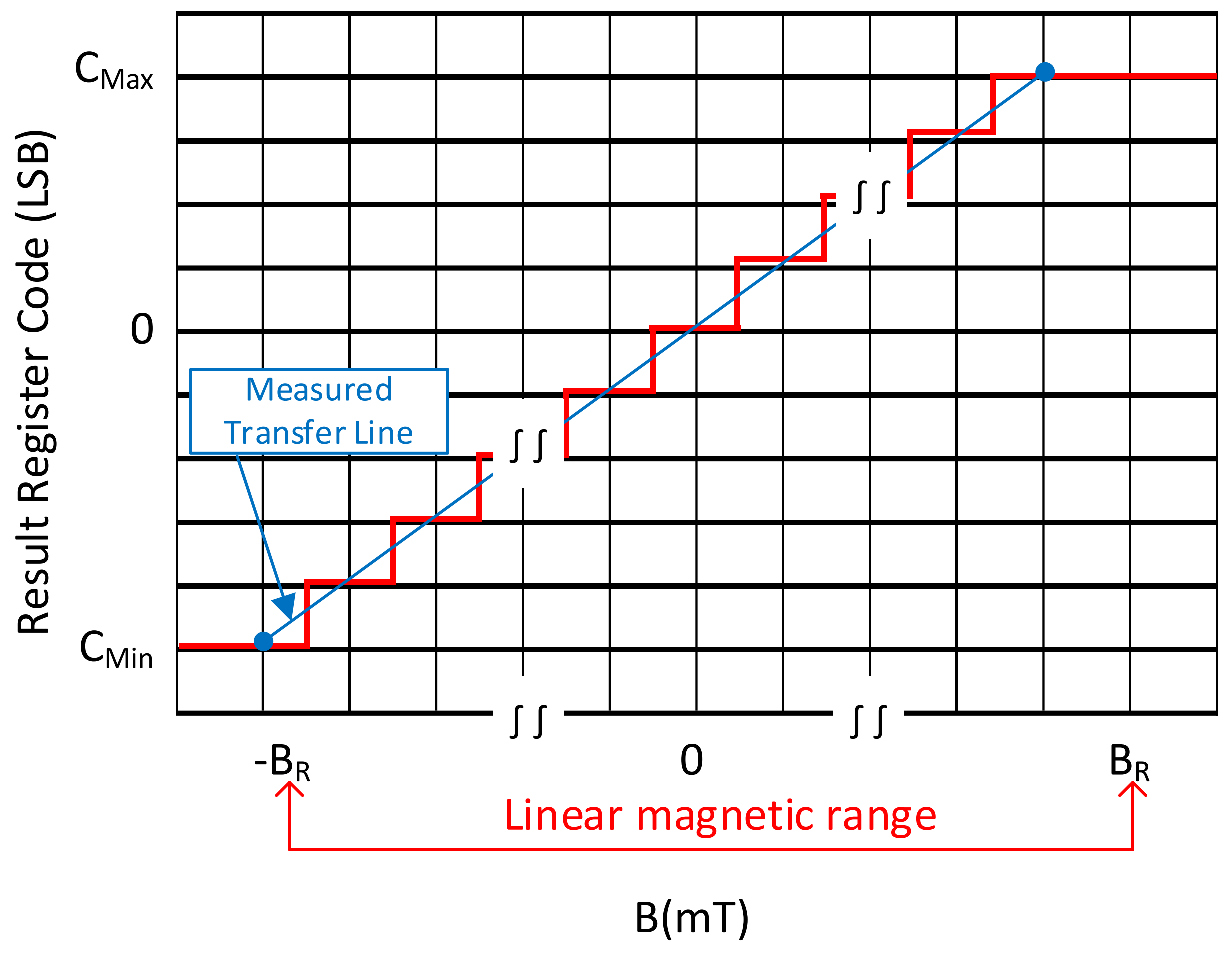




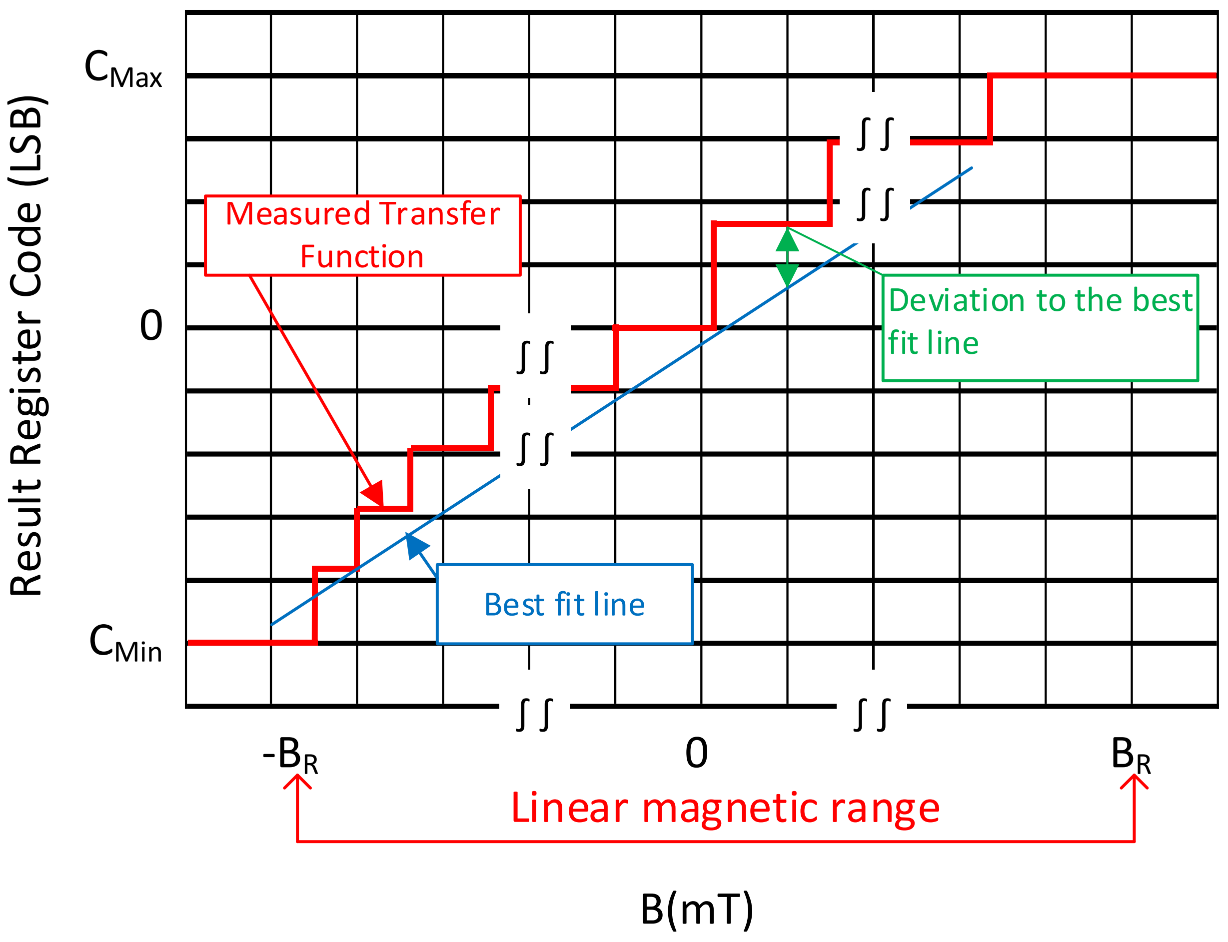
Sensitivity linearity error

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
TMAG5170A1						
$SENS_{LER\_XY\_A1}$	Sensitivity Linearity Error, X, Y-axis	T_A = 25℃		±0.1%		
$SENS_{LER\_Z\_A1}$	Sensitivity Linearity Error, Z axis			±0.05%		

Perfectly Linear(No linearity error)



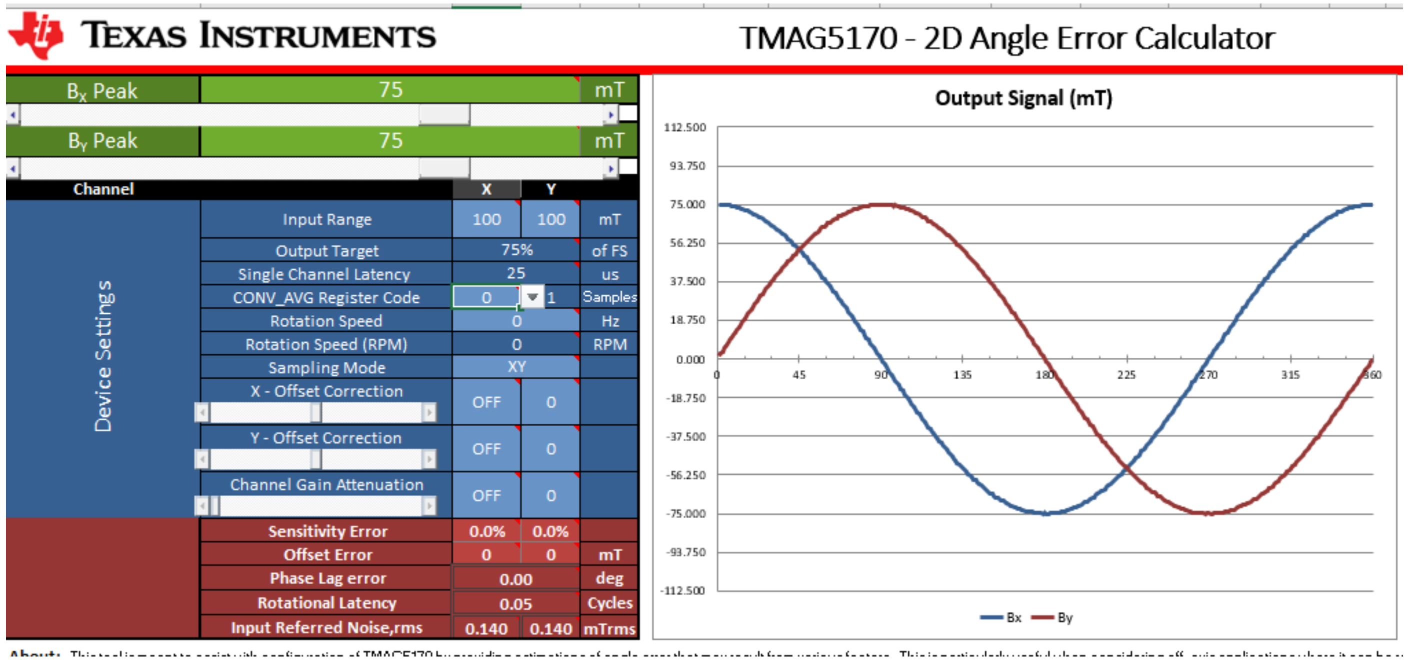
Linearity Error Present



Summary

- Errors that affect magnetic field measurement accuracy: sensitivity error, sensitivity mismatch, offset error, noise, and linearity error.
- Noise error may be able to reduced by averaging multiple samples at the cost of reduced sampling frequency.
- Sensitivity error, sensitivity mismatch, and offset error can be calibrated out.
  - Requires additional work, especially if accuracy across temperature must be maintained.
  - Linearity error and magnetic noise may affect effectiveness of calibration.
  - May not be necessary if 3D Hall sensor has good specs for these parameters.

TMAG5170 2D Angle Error Calculator Tool



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