Scope

This application note describes the front-end compensation prior to the extraction of the angular position (arctangent interpolation) performed by the MLX90316 device.

Related Documents, Products and Tools

The documentation and information on the products and tools listed below can be found on Melexis website www.melexis.com

Related Products

MLX90316 Tria⊗is™ Rotary Position Sensor

Related Documents

Applications Note Back-End Calibration (Release in May 06)
Applications Note Magnet Selection for MLX90316
Applications Note Hall Applications Guide

Related Tools

PTC04 Programmer for Melexis PTC devices

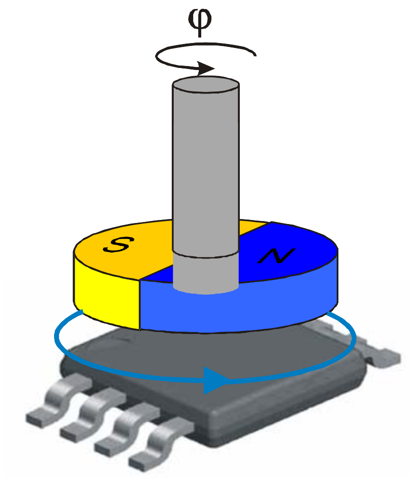


Figure 1 – MLX90316

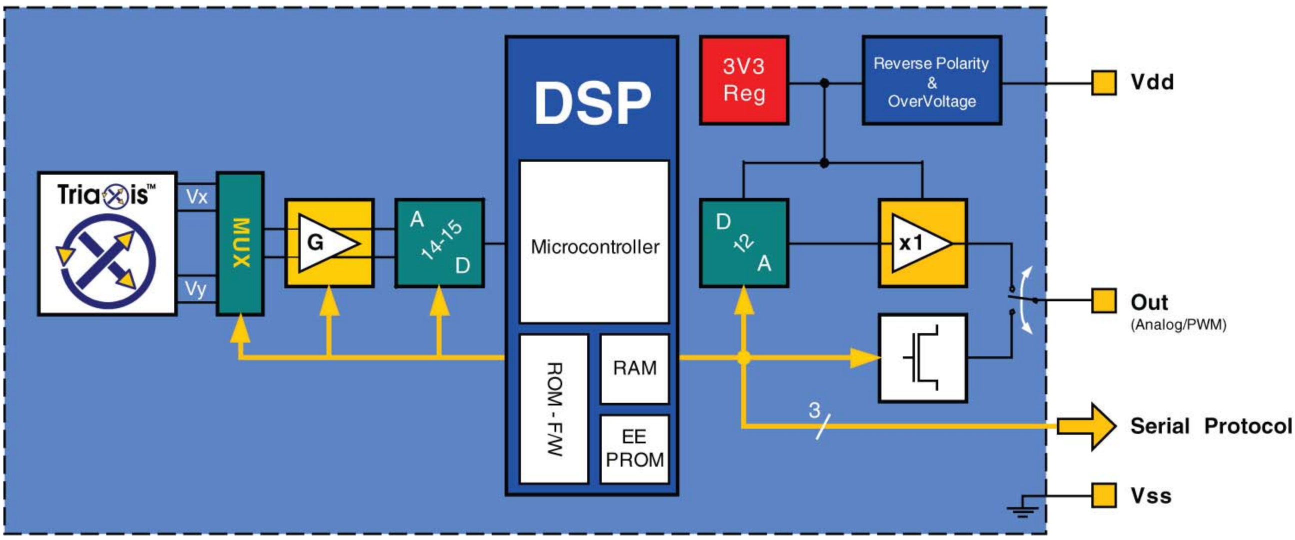


Figure 2 – MLX90316 Block Diagram

Description

As depicted in figures 1 and 2, if a magnet (diametrically magnetized) is rotating above the MLX90316, the Tria⊗is™ Hall Plates provide the two quadrature signals Vx and Vy (for the flux density along the X- and Y-axis respectively):

$$V_x \div \sin(90^\circ - \alpha) \div \cos\alpha \qquad \textbf{(1)}$$
$$V_y \div \sin\alpha$$

Those Hall signals are processed through a fully differential analog chain featuring the classic offset cancellation technique. The conditioned analog signals are converted through an ADC (configurable 14 or 15 bits) and provided to a DSP block for further processing. The basic function of the DSP is performing the following calculation:

$$\alpha = \arctan\left(\frac{V_y}{V_x}\right) \qquad \textbf{(2)}$$

In reality, Vx and Vy are given by:

$$V_x = V_{x,0}(T) + A_x(\alpha)\sin(90^\circ - \alpha + \beta) \qquad \textbf{(3)}$$
$$V_y = V_{y,0}(T) + A_y(\alpha)\sin\alpha$$

where:

T is the temperature.

$V_{y,0}(T)$ is the Y-offset (temperature dependent).

$V_{x,0}(T)$ is the X-offset (temperature dependent).

β is the orthogonality error (phase error).

A_x is the X-sensitivity.

A_y is the Y-sensitivity.

Before the arctangent extraction, the DSP will perform the front-end compensation in order to cancel some non ideal behaviors of the sine and cosine signals. Those non ideal behaviors can be split in four main categories:

- Offset ($V_{x,0}(T) \neq 0, V_{y,0}(T) \neq 0$)
- Sensitivity Mismatch ($A_x \neq A_y$)
- Orthogonality Error ($\beta \neq 0$)
- Signal Non Linearity ($A_x = A_x(\alpha)$ and $A_y = A_y(\alpha)$)

A very important step during final test is the magnetic calibration of these 3 first items. Since this calibration is performed only once at Melexis, the following sections are not critical in the use of the MLX90316 sensor. Nevertheless, they represent very useful information to anybody interested in achievable performance in term of angular error.

Offset

Though the on-chip dynamic offset cancellation mechanism (Hall plate quadrature spinning and chopper stabilized amplifier), the analog signals may show a residual offset. The representation of this offset on a sinusoidal signal is shown in figure 3 where both X0 and Y0-Offset are magnified (X0 and Y0 are the digital representation of the analog levels $V_{x,0}$ and $V_{y,0}$). The value of the offset is generally very small and temperature dependent.

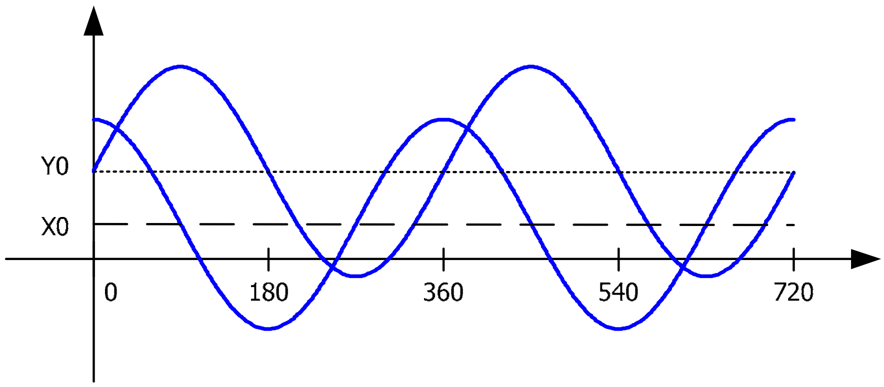
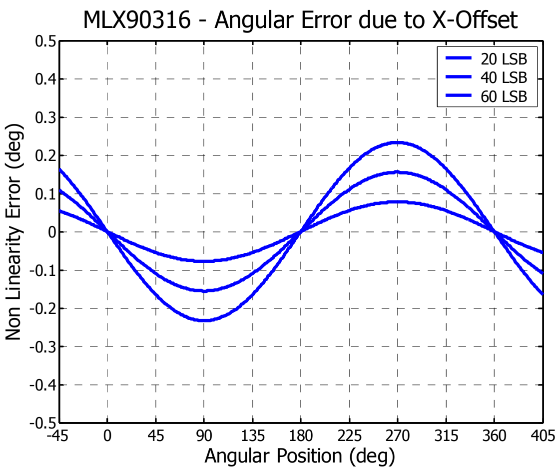
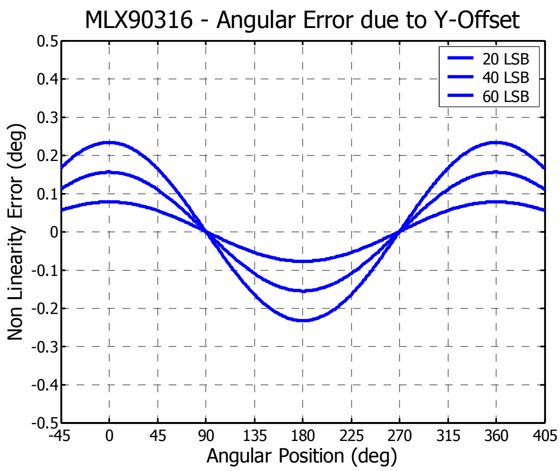


Figure 3 – Representation of the offset

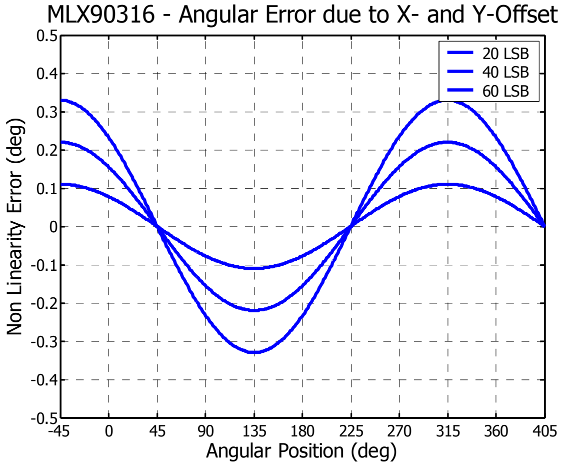
Figure 4 shows the influence of the offset on the angular error for various values of offset (20 LSB, 40LSB and 60LSB). The worst case is naturally when both X0 and Y0 are different from zero, this leads to an angular error of ≈ 0.1, 0.2 and 0.3 degree respectively. The signature of the offset error is one period over 360 degrees.



(a)



(b)



(c)

Figure 4 – Typical Non Linearity Error due to offset (20LSB, 40LSB and 60LSB).
(a) X-Offset, (b) Y-Offset and (c) X-Offset + Y-Offset

Sensitivity Mismatch

Although both Hall signals (Vx and Vy) are generated by matched Hall Plates and amplified though a common multiplexed amplification chain, the two signals may show a residual difference in amplitude. The two main reasons for this mismatch are the non perfect alignment of the IMC with respect to the Hall Plates constellation and a difference between the sensitivity of the different Tria⊗is™ Hall Plates. Illustration of the amplitudes mismatch is shown in figure 5.

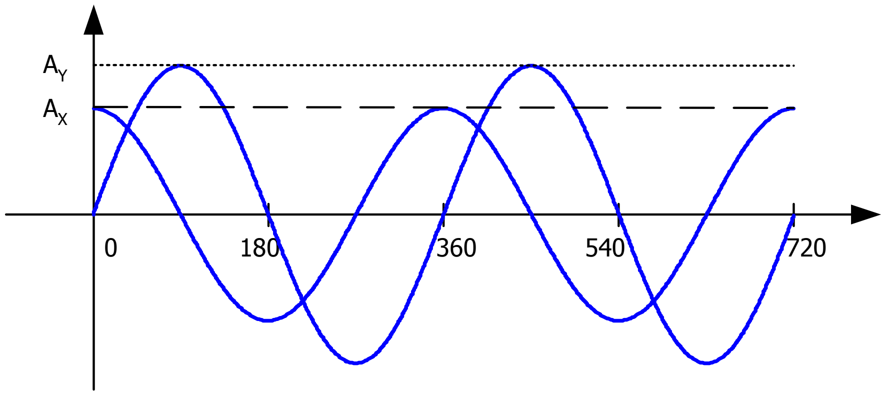


Figure 5 – Representation of the Sensitivity Mismatch

The compensation performed by the DSP consists in adjusting continuously one of the amplitude signals to get it match with the other.
Figure 6 shows some typical non linearity error prior to the compensation. The sensitivity mismatch is generally expressed in percent of the amplitude (in our example: 0.1%, 0.5% and 1% lead to 0.03, 0.15 and 0.3 degree of angular error). The signature is a double period and bipolar over 360 degrees.
The thermal variation of sensitivity mismatch is negligible.

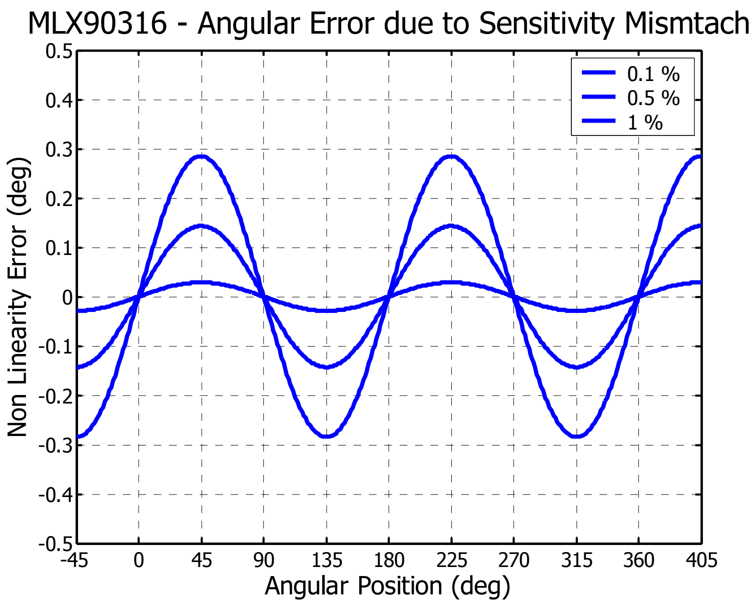


Figure 6 – Typical Non Linearity Error due to Sensitivity Mismatch (0.1%, 0.5% and 1%)

Orthogonality

The quadrature error, also called the orthogonality error, is a phase error between the sine and cosine signals. This means that the phase separation of these two signals is not exactly 90 degrees.

The DSP of the sensor will continuously adjust the sine versus the cosine to have a constant phase separation of 90 degrees.
Figure 7 shows the effect on the non linearity ehrror (the angular error is equal to the phase error). It translates into a double-period signal like the sensitivity mismatch error but in this case it is unipolar.

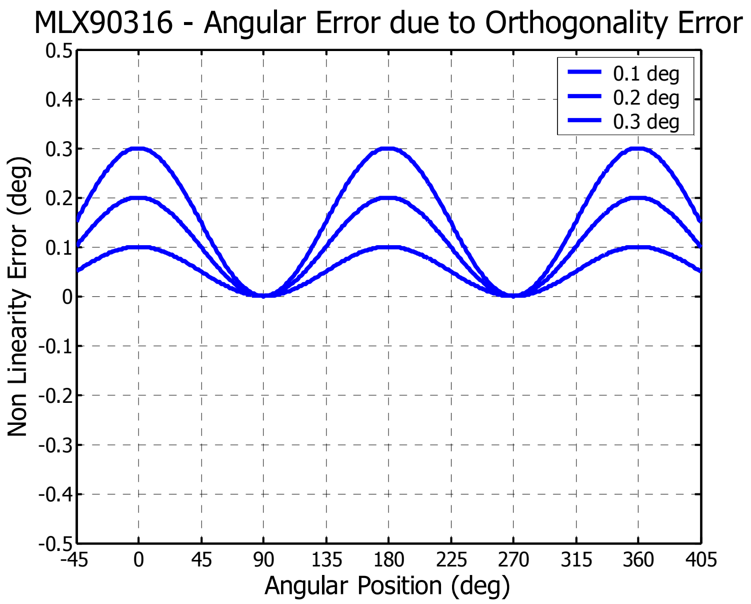
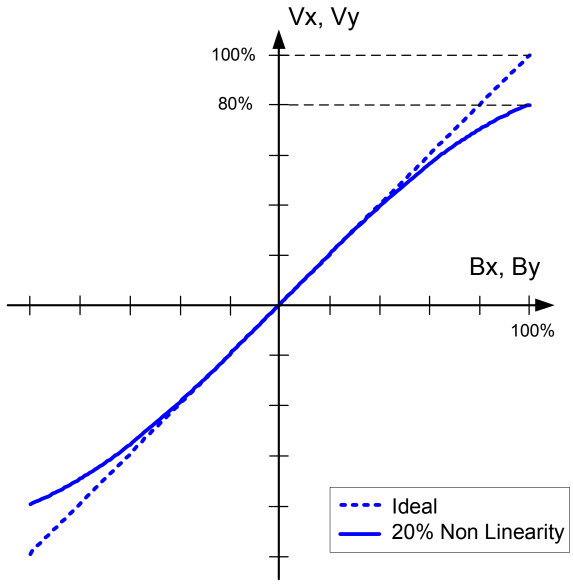


Figure 7 – Typical Non Linearity Error due to Orthogonality Error (0.1deg, 0.2 deg and 0.3deg)

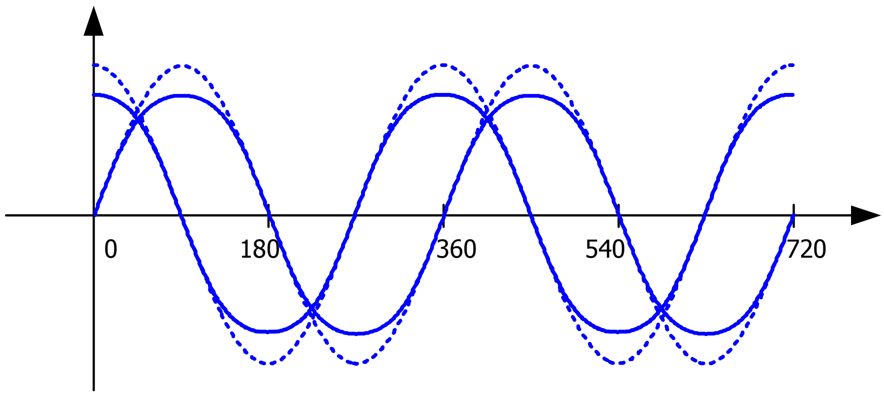
Signal Non Linearity

In normal operation, the signal non linearity is negligible. Its signature is easily recognizable: four periods over 360 degrees. Consequently, it allows tackling the main source of non linearity, i.e. the magnetic saturation (the applied field on the IMC location is greater than 70mT).

Figure 8(a) illustrates a 20% non linearity on the voltages Vx and Vy. This non linearity is clearly exaggerated. Figure 8(b) applies this transfer curve to the sinusoidal signals.



(a)



(b)

Figure 8 – Representation of the Non Linearity (20 %).

(a) Transfer Characteristics – (b) Non Linearity on the Sinusoidal Shapes

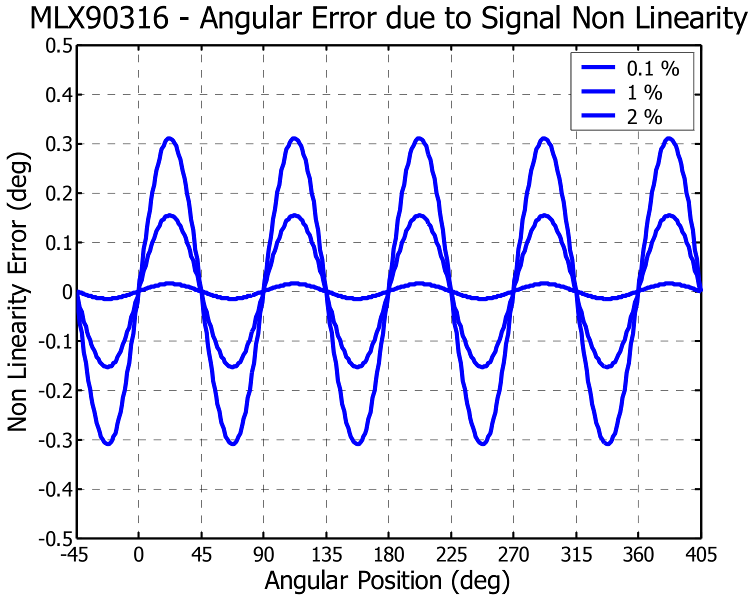


Figure 9 – Non Linearity Error due to Signal Non Linearity

Figure 9 shows the typical non linear error resulting from the signal non linearity (A non-linearity of 0.1, 1 and 2% lead to an angular error of 0.02, 0.15 and 0.3 degree respectively).

As mentioned before, the main non linearity is linked to the saturation of the IMC while the applied flux density is higher than 70mT. Some typical values are: 1% of signal non linearity is due to field strength of 80mT, 2% with 90mT, 7% with 100mTÖ

Overall System Accuracy

The following table gives the typical values of error that can remain after the calibration.

Test Conditions	Parameter	Symbol	Min	Typ	Max	Units
Room temperature	X0 and Y0-Offset	X0 & Y0	-60 -0.32	±40 ±0.2	60 +0.32	LSB Deg
	Sensitivity Mismatch	SMISM	-1 -0.3	0 0	+1 +0.3	% Deg
	Orthogonality Error	ORTH	-0.1	0	0.1	Deg
	Raw Signals Non Linearity	NL	-0.1	0	0.1	Deg
Thermal Drift	X0 and Y0-Offset thermal drift	ΔX0 & ΔY0	-60 -0.32	±40 ±0.2	60 +0.32	LSB Deg
	Sensitivity Mismatch	ΔSMISM	-0.3 -0.1	0 0	+0.3 +0.1	% Deg
	Orthogonality Error	ΔORTH	Not measurable			Deg
	Raw Signals Non Linearity	ΔNL	Not measurable			Deg
Hysteresis		Hyst	Not measurable			Deg

Table 1 ñ Front End Calibration Specification for a 360Deg-Application

The worst case is the sum of the maximum *angular* error:

$$
\begin{aligned}
Err_{\max}(25^{\circ}) &= X0 \,\&\, Y0 + SMISM + ORTH + NL \\
&= 0.32 + 0.3 + 0.1 + 0.1 \\
&= \pm 0.82 Deg \\
Err_{\max}(\Delta T) &= \Delta X0 \,\&\, \Delta Y0 + \Delta SMISM + \Delta ORTH + \Delta NL \\
&= 0.32 + 0.1 \\
&= \pm 0.42 Deg
\end{aligned}
$$

Conclusion

The front-end calibration is a very important step performed during final test. Melexis perform the adequate measurements for the customer to compensate all the errors included in (3) and get back to the ideal basic equations in (1).

The results, given in this application note, concern only the angular linearity error (the front end) over 360 degrees. This is the error that can be expected when the SPI or PWM is used. If the analog output is used, the back-end (D/A + output buffer) error has to be added (INL, DNL and thermal offset drift).

Moreover, the angular linearity error can be significantly reduced though the multiple points (2, 3, 4) output calibration, especially for an angular span lower than 360 degrees.

Please refer to the MLX90316 datasheet (*MLX90316 Accuracy Specification*) for the latest specifications.