MLX91220 Application Note

External Field Immunity

Contents

1. Scope

The MLX91220 is an Integrated Current Sensor that senses the current flowing through the leadframe of the SOIC package. By virtue of fixing the current conductor position with respect to the monolithic CMOS sensor, a fully integrated Hall-effect current sensor is obtained, that is factory calibrated.

Inside the package, the magnetic flux density generated by the current flow is sensed differentially by two sets of Hall plates. As a result, the influence of external disturbing fields originating from the dense power electronics surrounding the IC is minimized in the fast analog front-end.

Melexis differential sensing solution makes it one of the most robust solutions in the market regarding Common Mode. It is still important to understand the effects of an external disturbing field in order to optimize the design of the application as not only common mode can influence the output but also magnetic field gradients generated by. nearby current paths.

2. Theory

2.1. External Field Error Contributors

External field can impact sensor output in two ways.

1) The distance between the two Hall Plate clusters causes the two Hall Plates to see a different magnetic field originated from the same source (eg. Nearby current trace)

2) Due to the sensitivity mismatch between two Hall Plate clusters, a common-mode external field translates into a differential output signal

$$I_{error\_total} = I_{error\_gradient} \pm I_{error\_CM}$$

2.2. Gradient Induced Error

A current conductor generates magnetic field. If we consider the conductor long enough, we can derive the magnetic field at a distance r of the conductor according Ampere's Law:

$$B = \frac{\mu_{air}}{2\pi r}.I$$

In the MLX91220, the magnetic field is sensed differentially through the two sets of Hall plates.

$$\Delta B = \frac{\mu_{air}}{2\pi r_1}.I - \frac{\mu_{air}}{2\pi r_2}.I$$

Where r_1 is the distance to the first set of Hall plates and r_2 is the distance to the second set of Hall plates.

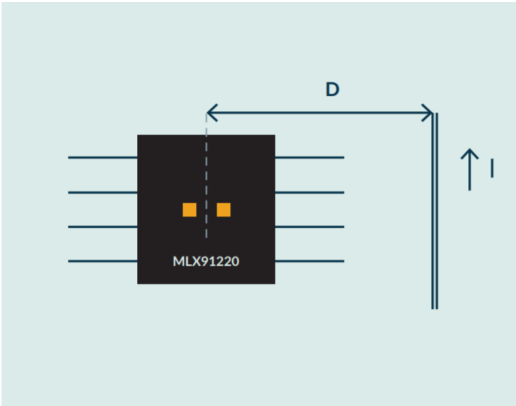


Figure 1: Current conductor placed parallel to package length, α = 90°

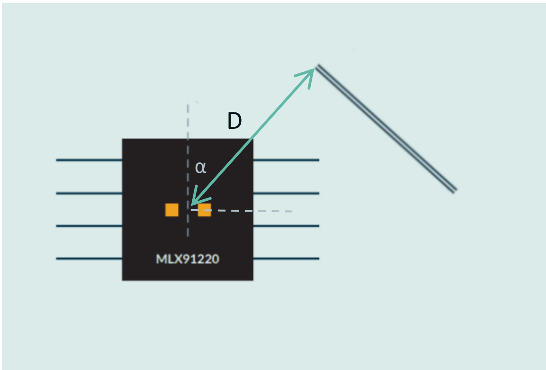


Figure 2: Current conductor placed with an angle α

D is the shortest distance between the wire and the center of the two sets of Hall plates and d is the distance between the Hall plates. Thus the magnetic field can be expressed as:

$$\Delta B = \frac{\mu_{air}}{2\pi}.I\left(\frac{1}{D-\frac{d}{2}\sin(\alpha)} - \frac{1}{D+\frac{d}{2}\sin(\alpha)}\right) = \frac{\mu_{air}}{2\pi}.I(\frac{d}{D^2-\left(\frac{d}{2}\sin(\alpha)\right)^2})$$

If α=0, the external field is completely rejected by the differential sensing system because the two Hall Plates are equidistant to the external current conductor. The only source of error originates from the sensitivity mismatch between the differential Hall Plates clusters. This error is expressed as the Common Mode Field Sensitivity (cf. 2.3 Common-Mode Susceptibility)

The gradient is maximal at the Hall plates if the current conductor is placed parallel to the length of the package (cf. Figure 1).

As D > 3 mm, we can simplify the equation above as follows:

$$\boldsymbol{\Delta B = \frac{\mu_{air}}{2\pi}.I\left(\frac{d}{D^2}\right)}$$

The error in current is obtained by dividing the magnetic field by the field factor G expressed in T/A.

$$I_{error\_gradient} = \frac{B}{G} = \frac{\mu_{air}}{2\pi G}.I\left(\frac{d}{D^2}\right) = CT_{coeff}\frac{I}{D^2}$$

where $\mathrm{CT_{coeff}} = \frac{\mu_{air}}{2\pi}.\frac{d}{G} = \mathbf{5,71.10^{-8}\ m^2}$ for SOIC16 package and $\mathbf{6.70.10^{-8}\ m^2}$ for SOIC8

package.

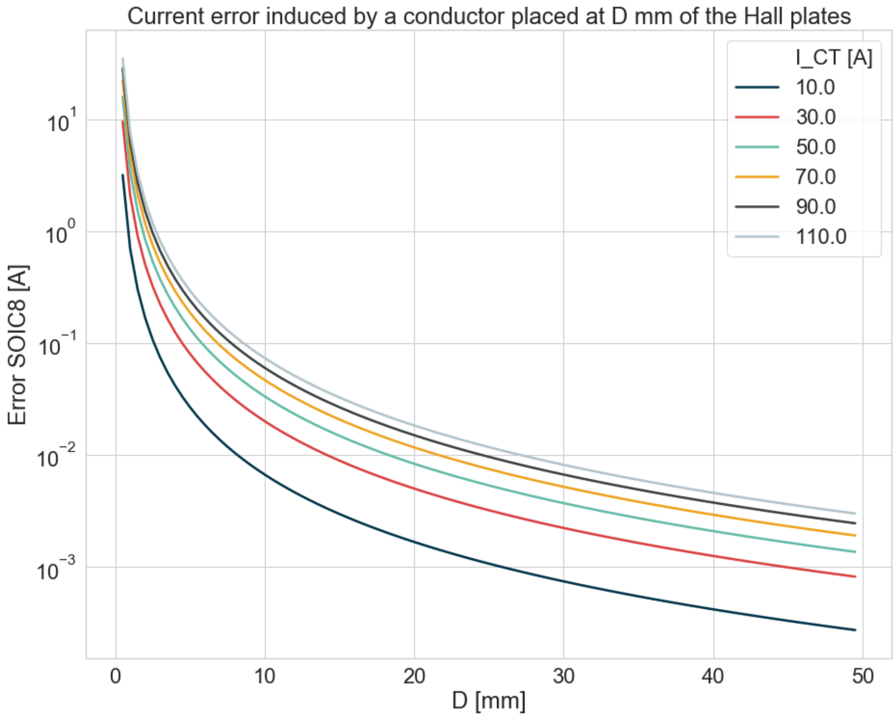


Figure 3: Current error induced by a conductor plated at D mm of the Hall Plate in a SOIC8 package

2.3. Common-Mode Susceptibility

Our differential measurement is based on two clusters of Hall Plates having the same sensitivity. By taking the differential output of the clusters, we should fully remove the common mode.

In reality, we observe a small sensitivity mismatch between the two clusters that translates into a differential output signal.

The susceptibility of the sensor to the common field is expressed through the Common Mode Field Sensitivity (CMFS).

Package	CMFS [mA/G]	CMFS [mA/mT]
SOIC16	0.4	4
SOIC8	0.4	4

Hence the error due to the common-mode is expressed as:

$$I_{error\_CM} = CMFS\,.B = \; B = CMFS.\frac{\mu_{air}}{2\pi D}.I$$

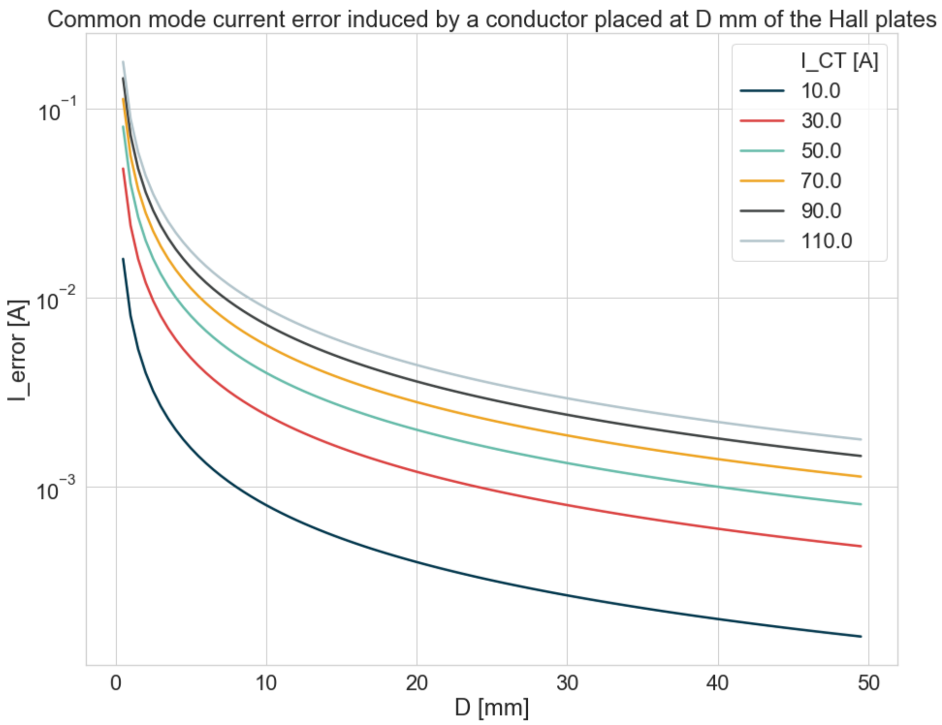


Figure 4: Common mode current error induced by a conductor placed at D mm of the Hall plates

In the worst case the common mode error adds up to the gradient error, in the best case it compensates it. This depends on the placement of the wire conductor and the way that the Hall Plates clusters are mismatched.

2.4. Conclusion

Based on Figure 3 and Figure 4, at close distance, the dominant contributor to the error is due to the gradient. At bigger distance, both errors are negligible.

3. Measurements

3.1. Setup

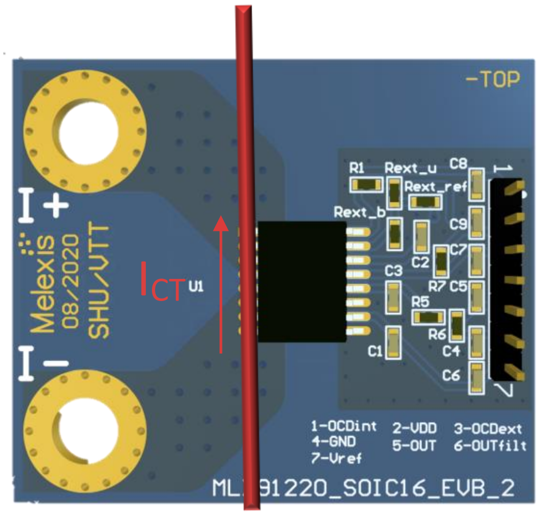


Figure 5: Cross-Talk Measurement Setup

Cross-talk measurements were conducted by placing a current conducting wire as close as possible to a MLX91220 sensor. The distance between the wire and the center of the IC is around 4.9 mm. No current is flown through the IC.

The IC was programmed with the highest gain (120 mV/A).

3.2. Results

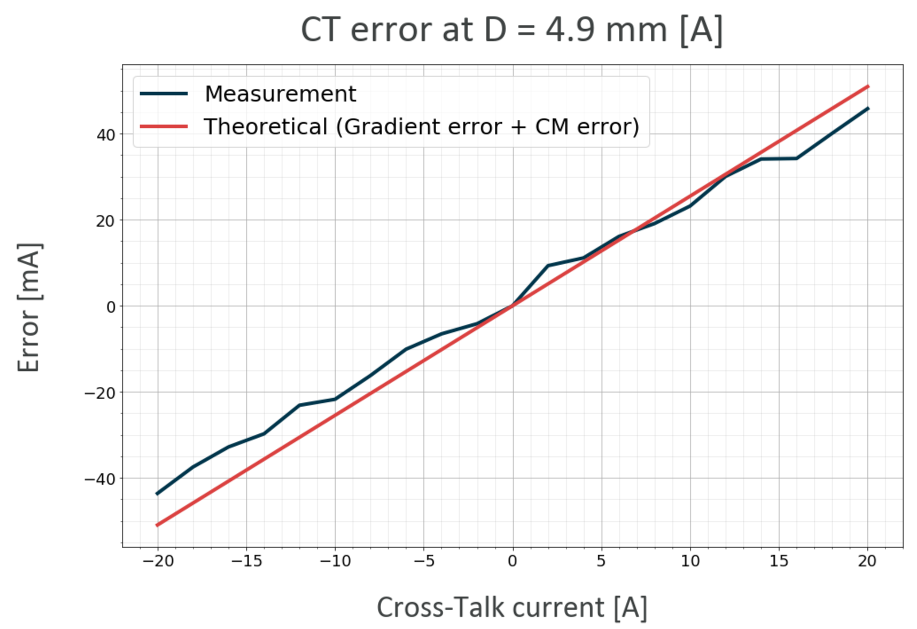


Figure 6: Error [A] induced by current conductor placed at 4.9 mm from the sensor central point. Worst case scenario, when the Common-Mode error adds up to the gradient error

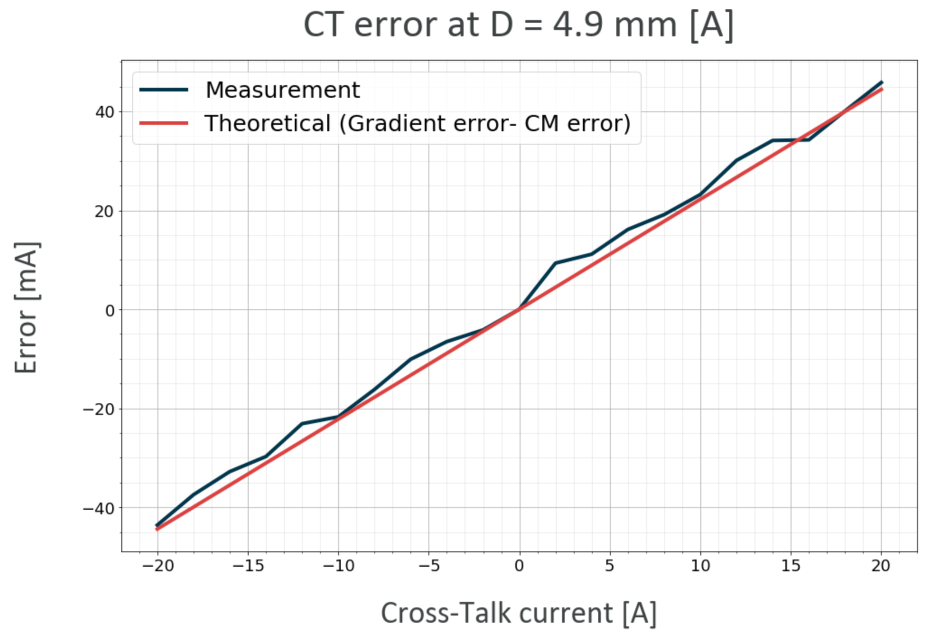


Figure 7: Error [A] induced by current conductor placed at 4.9 mm from the sensor central point. Best case scenario, when the Common-Mode error compensates the gradient error

3.3. Conclusion

For the sample used in this measurement, the error due to the common mode compensates the error due to the gradient.

Figure 6 and Figure 7 displays the effect of the Common-Mode induced error and the difference appears to be limited. The measurements confirm that the current error induced by the gradient is dominant compared to the error induced by the Common Mode.

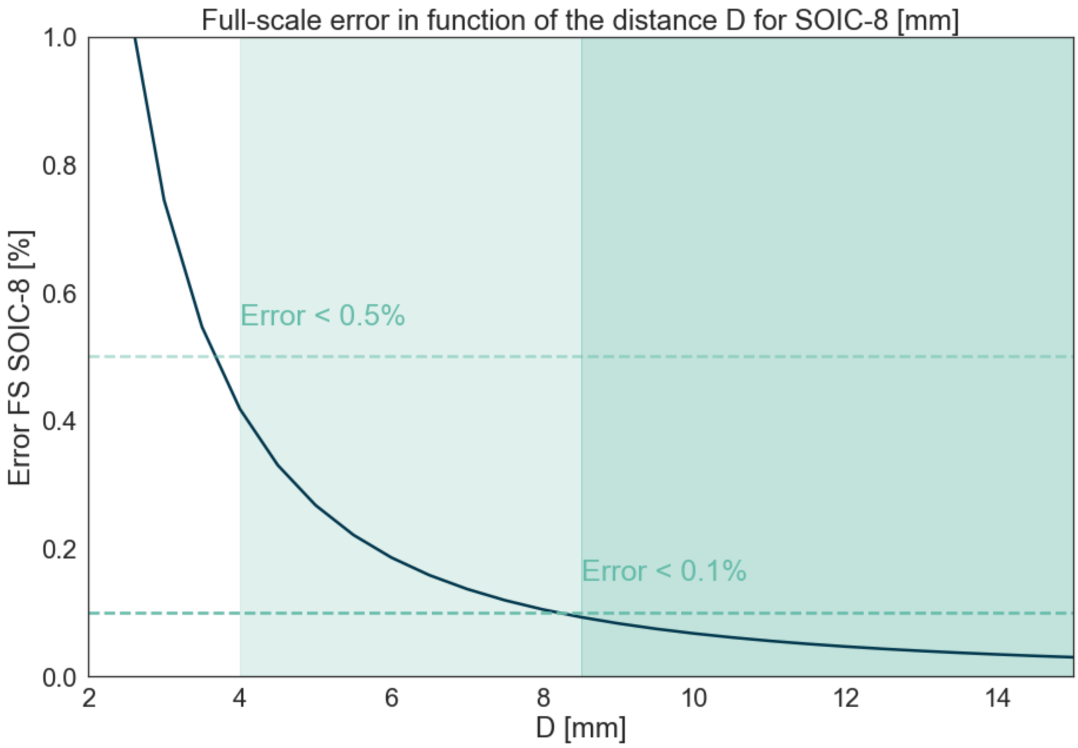
4. Application examples

To estimate to which extent an external field will disturb the output signal, it is useful to compare it to the current injected on the primary side of the current sensor IC.

With I_{prim} the current injected in the current sensor IC and I_{error} the error generated by the external field we can define the full-scale crosstalk error in % as follows:

$$Error_{FS}\,[\%] = 100.\left(1 - \frac{I_{prim} - I_{error}}{I_{prim}}\right)$$

I_{error} is proportional to the crosstalk current. It means that if $I_{prim} = I_{CT}$, the behavior of the error in function of the distance D will be the same regardless I_{CT} value. We considered here the worst case, where the common-mode field error is added on top of the gradient error and the current conductor is parallel to the package length (If α=90°).



In this example, $D_{0.5\%} = 4\,mm$ is the minimum distance between the current sensor IC's center and the external current conductor that provides a crosstalk effect of less than 0.5%. And having $D = D_{0.1\%} = 8.5\,mm$ provides a crosstalk effect of less than 0.1%.

Naturally if $I_{prim} < I_{CT}$, $D_{0.5\%}$ and $D_{0.1\%}$ will be higher.

As an example, the table below shows $D_{0.5\%}$ and $D_{0.1\%}$ for $I_{prim} = 50\ A$.

Table 1: Full-scale error for $I_{prim} = 50\ A$

I_{CT} [A]	SOIC-8		SOIC-16	
	$D_{0.5\%}$ [mm]	$D_{0.1\%}$ [mm]	$D_{0.5\%}$ [mm]	$D_{0.1\%}$ [mm]
10	2.0	4.0	2.0	3.5
30	3.0	6.5	3.0	6.0
50	4.0	8.5	3.5	8.0
70	4.5	10.0	4.5	9.0
90	5	11.0	5.0	10.5
110	5.5	12.5	5.5	11.5

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6. Revision history table

Revision	Date	Description/comments
1.0	December 2020	Initial release