INNOVATION WITH PURPOSE

CROSSTALK ERROR ESTIMATION AND REDUCTION THROUGH BUSBAR DESIGN FOR THE ACS37610 CORELESS CURRENT SENSOR

By Christian Kasparek
Allegro MicroSystems

INTRODUCTION

The ACS37610 is a highly accurate, differential coreless current sensor with robust stray-field immunity to common-mode magnetic fields—no concentrator such as a C-core or a U-shield is required, and therefore cost and complexity are reduced. Differential sensing allows for immunity to magnetic stray fields.

A common application for the ACS37610 is AC current sensing in a three-phase inverter. To save space and increase power density, the phases are typically densely packed. A common concern is how the current flowing through one phase affects the current measurement of the adjacent phase. This is called crosstalk. This application note provides an estimation of the crosstalk error for a standard notched busbar and varying busbar distances in combination with the ACS37610. In addition, a busbar design is proposed in which the busbars can be close to each other without showing a crosstalk error.

CROSSTALK ERROR FOR NOTCHED BUSBAR

A notched busbar is a typical design for AC applications. Figure 1 shows the geometry of two adjacent busbars with a notch width of 3.2 mm. The sensor (white) and the Hall plates (green squares) are centered over the notch with an air gap of 1.5 mm. The air gap is defined as the distance from the busbar surface to the Hall plates of the sensor. The busbar width is 20 mm, and the distance between the busbars is varied.

To assess the crosstalk error, a current flowing through busbar 1 is simulated, and the coupling factor is calculated. The coupling factor is the ratio of generated differential magnetic field per current applied to busbar 1. Similarly, the coupling factor of the sensor of the second busbar is calculated. The only difference is that there is no current flowing through its primary, i.e., the second busbar. The crosstalk error is then calculated by the relative ratio of the coupling factors:

$$\mathrm{Crosstalk} = ((\mathrm{CF}_2 \,/\, \mathrm{CF}_1) - 1) \times 100$$

Crosstalk is not fully compensated by differential sensing because in this geometry one Hall plate of sensor 2 is closer to busbar 1 than the other. Since the magnetic field is proportional to r^{-3} with the distance r between the Hall plate and the source of the magnetic field, the Hall plate that is closer to busbar 1 measures a higher magnetic field than the Hall plate that is further away.

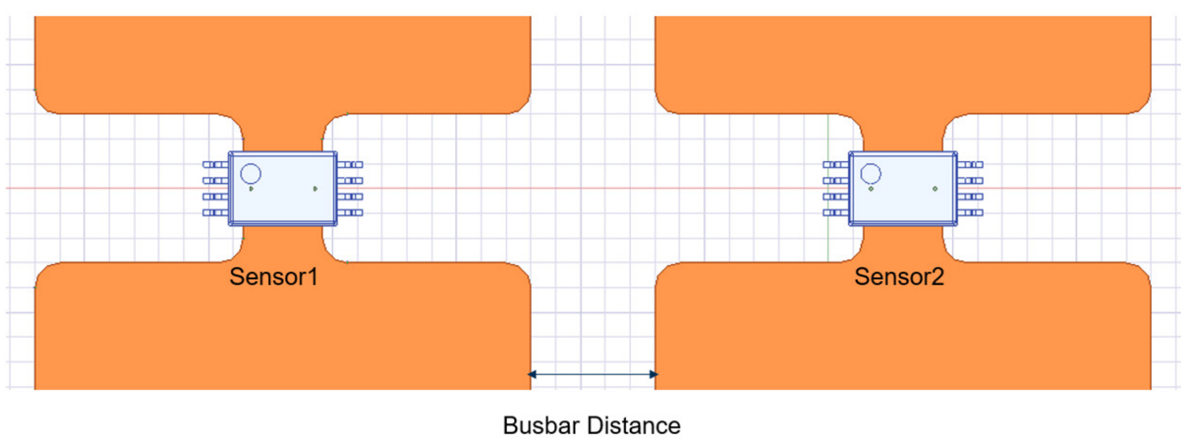

Figure 1: Geometry of a standard notch showing the sensor and Hall plate (green squares) alignment perpendicular to the length of the busbar.

By varying the distance between the busbars and calculating the crosstalk for each distance, the crosstalk can be estimated for different application cases. Figure 2 shows the crosstalk error as a function of the busbar distance for a notch in blue. Crosstalk has been calculated for three different air gaps: 0.5 mm, 1.5 mm, and 2.5 mm. The crosstalk error depends on both the air gap and the distance between the busbars. If the busbars are as close as 5 mm, the crosstalk error is between 1% and 3% depending on the air gap. If the air gap is small, the coupling factor is larger, and thus the influence of the adjacent busbar is smaller as compared to a larger air gap.

By increasing the distance between the busbars, the magnetic field generated by the current flowing in busbar 1 at sensor 2 decreases; therefore, the crosstalk error decreases. For a typical distance between the busbars of 40 to 50 mm, the crosstalk error is in the range of 0.3 to 0.6%.

REDUCING CROSSTALK ERROR WITH S-NOTCH BUSBAR DESIGN

If the crosstalk error is too high for the overall requirements or if the busbars must be close to each other, the ACS37610 in combination with an S-notch can significantly reduce the crosstalk error.

Figure 4 shows the geometry of an S-notch. The notch is designed in an S-shape and the sensor is rotated by 90° as compared to the standard notch. The Hall plates are aligned parallel to the busbar length and normal to the magnetic field gradient from the secondary busbar. In contrast to a standard notch where one Hall plate of sensor 2 is closer to busbar 1, the Hall plates have the same distance to busbar 1 in the case of the S-notch. The differential sensing method allows for the cancelling out almost all the magnetic field generated in the adjacent busbar. Figure 2 shows the crosstalk error of an S-notch as a function of busbar distance and for different air gaps. For a busbar distance of 5 mm, the crosstalk error is a maximum of 0.3%—a remarkable improvement compared to a standard notch. If the busbar distance is larger than 15 mm, the crosstalk error is reduced to a negligible amount.

Figure 3 shows the crosstalk error for a notch (blue) and S-notch (red) over frequency for a busbar distance of 40 mm. The crosstalk error is largely independent of the frequency.

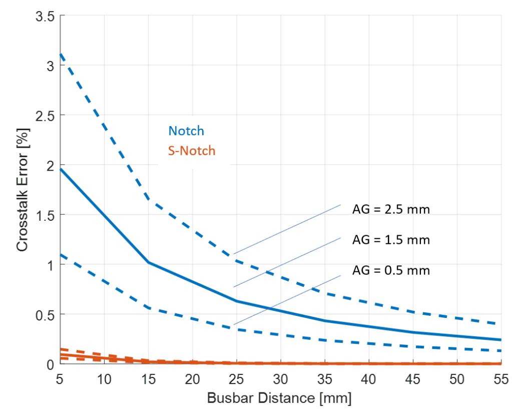

Figure 2: Crosstalk error for a notch (blue) and S-notch (red) as a function of the distance between busbars and for different air gaps

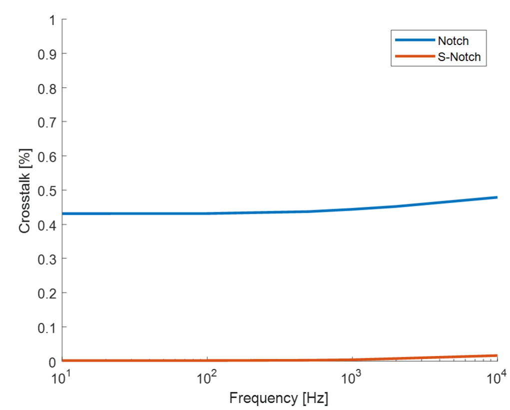

Figure 3: Crosstalk error for a notch (blue) and S-notch (red) as a function of the frequency showing that the crosstalk error does not depend on the frequency. The busbar distance is 40 mm.

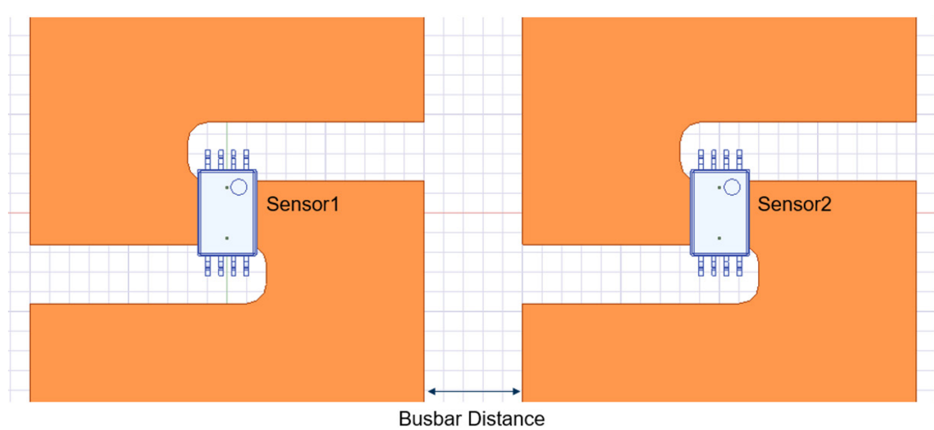

Figure 4: Geometry of S-Notch showing the sensor and Hall plate (green squares) alignment parallel to the length of the busbar.

CONCLUSION

This application note can be used to estimate the crosstalk error for adjacent notched busbars in combination with the ACS37610 coreless differential Hall sensor. This information can be useful when designing, for example, the three phases of a traction inverter. For typical distances between the busbars (40 to 50 mm), the crosstalk error is in the range of 0.7 to 0.3%, depending on the air gap. Further, an S-notch busbar design is proposed that reduces the crosstalk error significantly even for more compact designs.

Revision History

Number	Date	Description
–	August 25, 2023	Initial release

955 PERIMETER ROAD • MANCHESTER, NH 03103 • USA
+1-603-626-2300 • FAX: +1-603-641-5336 • ALLEGROMICRO.COM