DUAL-BRIDGE DESIGN GUIDELINES FOR ACS37610S

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INTRODUCTION

Allegro MicroSystems has pioneered coreless current sensing, which eliminates the need for bulky and expensive core-based solutions. The Allegro ACS37610 is a high-precision Hall-effect current-sensor IC designed for contactless current sensing in applications where current flows through a busbar or printed circuit board (PCB) (see Allegro application note ACS37610 Busbar Geometry and Design Techniques for Coreless Differential Current Sensors[1]). Traditionally, this capability requires a notched busbar or PCB, which presents mechanical design challenges, particularly in maintaining precise alignment between the sensor and the notch over temperature and across the sensor lifetime. The Allegro ACS37610S, in a single in-line package (SIP), addresses these challenges and enables more-flexible, robust mechanical designs. This application note details a novel dual-bridge busbar design specifically optimized for the ACS37610S to improve displacement error performance significantly.

DUAL-BRIDGE DESIGN AND SENSING CONCEPT

The dual-bridge design shown in Figure 1 features two parallel bridges with a central hole to accommodate the ACS37610S sensor.

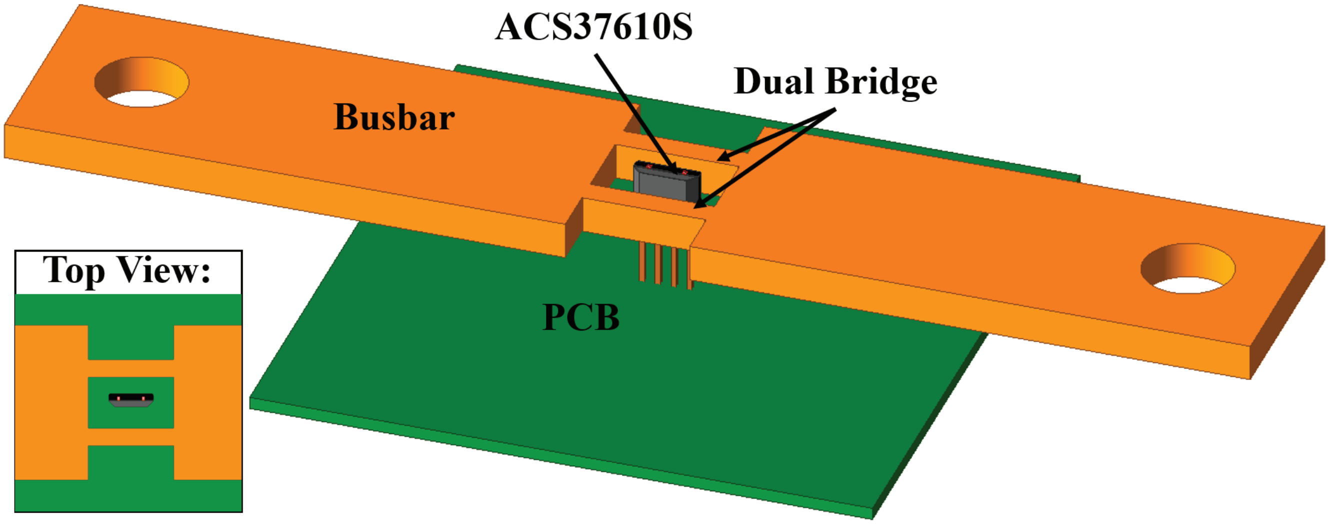

Figure 1: Concept of Dual-Bridge Design

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[1] https://www.allegromicro.com/-/media/files/application-notes/an296194-acs37610-busbar.pdf?sc_lang=en

The sensor is mounted vertically on the PCB, with the Hall plates aligned perpendicular to the PCB plane, as illustrated in Figure 2. Current flow through the busbar generates a magnetic field that "curls" around each bridge. The differential sensing of the magnetic field by the two Hall plates, sensitive to the Z-axis, cancels out the effects of stray magnetic fields to enable a robust measurement.

Output voltage, V_{out}, and sensitivity, Sens, can be calculated as:

Equation 1:

$$V_{out} = Sens \times (B_2 - B_1)$$
$$B_2 - B_1 = CF \times I$$
$$Sens = \frac{\Delta V}{\Delta I \times CF}$$

where CF is the coupling factor, ΔV is the output range, and ΔI is the total current range.

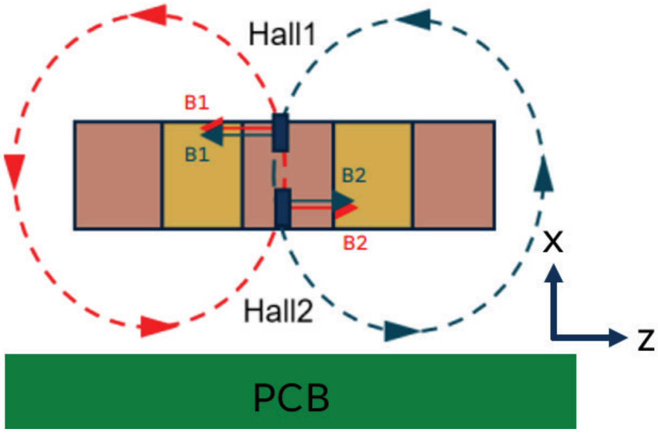


Figure 2: Sensing Concept

RECOMMENDED DESIGN AND PERFORMANCE

The recommended dual-bridge design is illustrated in Figure 3. This design uses 2 mm-wide bridges separated by 6 mm, each with a length of 10 mm. The sensor is positioned within the central hole, which ensures that the midpoint of the Hall plates aligns precisely with the center of the hole. Detailed technical drawings are provided in the product datasheet, which is available by request (contact Allegro MicroSystems).

A performance overview of the ACS37610S in combination with the recommended dual-bridge design for a peak current of 700 A is shown in Table 1. This peak-current value represents the typical maximum current observed in automotive applications. However, the sensitivity can be programmed to operate at different current ranges. Key performance parameters for busbar thicknesses that range from 1 mm to 3 mm are shown in Table 1. The parameters were obtained through magnetic simulations performed in Ansys Maxwell. The design geometry shows a robust coupling factor of 260 mG/A to 290 mG/A. This coupling factor is a crucial determinant of sensor sensitivity at the peak current, according to Equation 1.

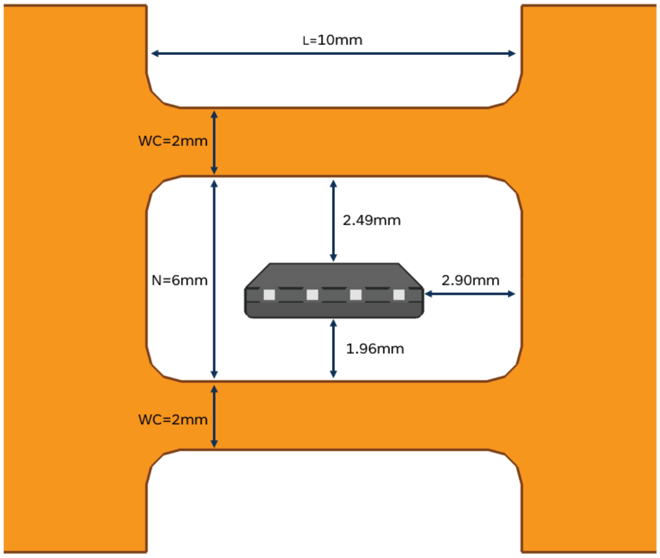


Figure 3: Recommended Design of the Dual Bridge

Table 1: Performance Overview of Recommended Dual-Bridge Design For Peak Current of 700 A and Different Busbar Thicknesses

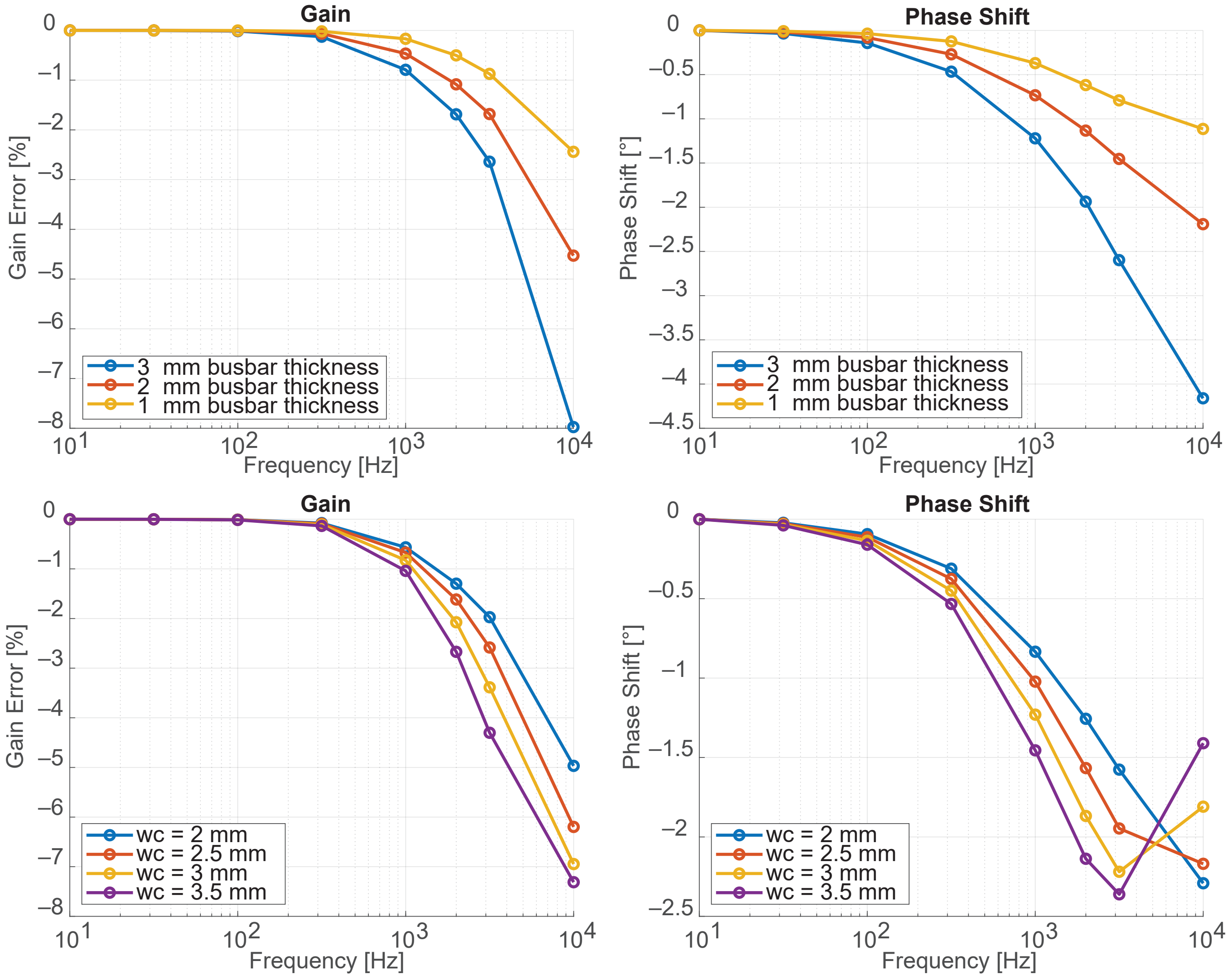
Parameter	**Conditions**	**Busbar Thickness**			
		3 mm	**2 mm**	**1 mm**	**Units**
Coupling Factor		259	277	288	mG/A
Sensitivity	700 A	11.0	10.3	9.92	mV/G
Displacement Tolerance	dx = 0.1 mm	–0.2	–0.1	–0.2	%
	dx = 0.3 mm	–1.2	–1.3	–1.4	%
	dy = 0.1 mm	0	0	0	%
	dy = 0.3 mm	0.2	0	0	%
	dz = 0.1 mm	0.1	0.2	0.2	%
	dz = 0.3 mm	1.1	1.2	1.4	%
Busbar Tolerance	±0.1 mm	0.5	0.6	0.5	%
Gain Error	at 1 kHz	–0.8	–0.6	–0.2	%
Phase Shift	at 1 kHz	–1.2	–0.8	–0.4	°

Displacement errors are shown in Table 1 for displacements of ±0.1 mm and ±0.3 mm in all directions. (For the coordinate system, refer to Figure 3.) For the given range of ±0.3 mm: Influence is not observed along the Y-axis; and displacment errors of 1.2% and 1.4% are observed along the X- and Z-axes, respectively. These errors are much less than those observed with notched busbar geometry, where 0.1 mm of displacement along the Z-axis results in a 5% influence on the measurement.

The initial displacement error introduced during sensor placement within the dual bridge can be effectively eliminated through end-of-line calibration. This calibration typically involves application of a known current and adjustments to the sensor output to match the current. After calibration, the primary concern shifts to the displacement that occurs during operation, which is usually significantly less than the initial displacement.

Similarly, the busbar tolerance, which represents the manufacturing variation in the width of each bridge, can also be compensated during end-of-line calibration. The analysis considers a deviation of ±0.1 mm, which results in approximately 0.5% influence on the measurement.

The AC performance of the sensor, characterized by gain error and phase shift at 1 kHz, is influenced by the busbar thickness. A thinner busbar exhibits a flatter frequency response. For instance, a reduction in busbar thickness from 3 mm to 1 mm improves the gain error at 1 kHz by 0.6% and reduces the phase shift by 0.8°. A detailed illustration of the frequency response is shown in Figure 4 for various busbar thicknesses (top row) and bridge widths (bottom row).



**Top row shows the frequency response for different busbar thicknesses: Thinner busbars show a flatter curve.
Bottom row shows the frequency response for different bridge widths: Thinner bridges show a flatter curve.**

Figure 4: Frequency Response by Busbar Thicknesses (Top) and Bridge Width (Bottom)

To evaluate the thermal capacity of the dual-bridge design, a 700 A (DC) current was applied for 5 minutes to both a solid 3 mm-thick busbar and the 3 mm-thick dual-bridge structure. The ambient temperature was maintained at 25°C. The solid copper busbar, with dimensions of 18 mm × 3 mm (width × thickness), reached a temperature of 130°C. Despite the significant reduction in copper in the dual-bridge design, the measured temperature of 140°C is only 10°C higher than the solid busbar. Importantly, the narrower bridges do not exhibit localized overheating and do not act as hot spots.

CONCLUSION

The dual-bridge design, combined with the ACS37610S SIP, offers a robust, high-performance solution for contactless current sensing. Its key advantages include improved displacement error tolerance, flexibility in mechanical design, and good thermal performance. For further assistance, for samples, or to discuss specific application requirements, contact Allegro MicroSystems.

ACKNOWLEDGEMENT

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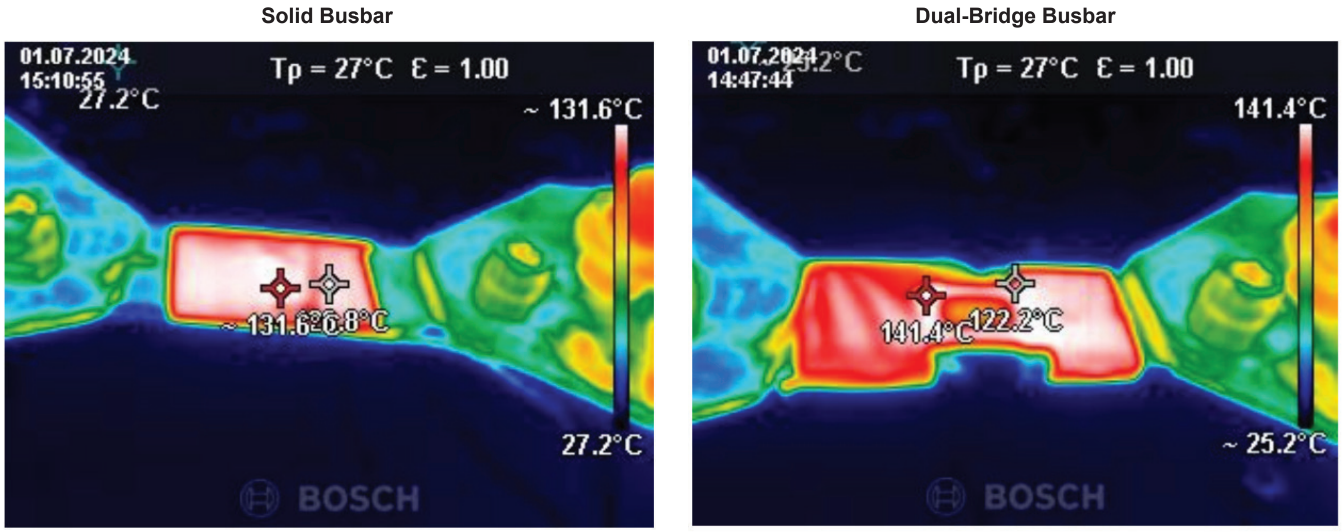
Solid Busbar

Dual-Bridge Busbar

700 A (DC) applied for 5 minutes; dual-bridge busbar shows less than 10°C higher (131.6°C vs. 141.4°C)

Figure 5: Application of 700 A on 3 mm-Thick Busbars (Cooling System not Used)

Revision History

Number	Date	Description	Responsibility
–	March 5, 2025	Initial release	C. Kasparek