Dual Bridge Design Guidelines for ACS37610S

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Introduction

Allegro Microsystems has pioneered coreless current sensing, eliminating the need for bulky and expensive core-based solutions. The ACS37610 is a high-precision Hall-effect current sensor IC designed for contactless current sensing in applications where current flows through a busbar or PCB (link to appnote). Traditionally, this requires a notched busbar or PCB, which present mechanical design challenges, particularly maintaining precise alignment between the sensor and the notch over temperature and across the sensor's lifetime. To address this, Allegro introduces the ACS37610S in a SIP, enabling more flexible and robust mechanical designs. This application note details a novel dual-bridge busbar design specifically optimized for the ACS37610S, significantly improving displacement error performance.

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.

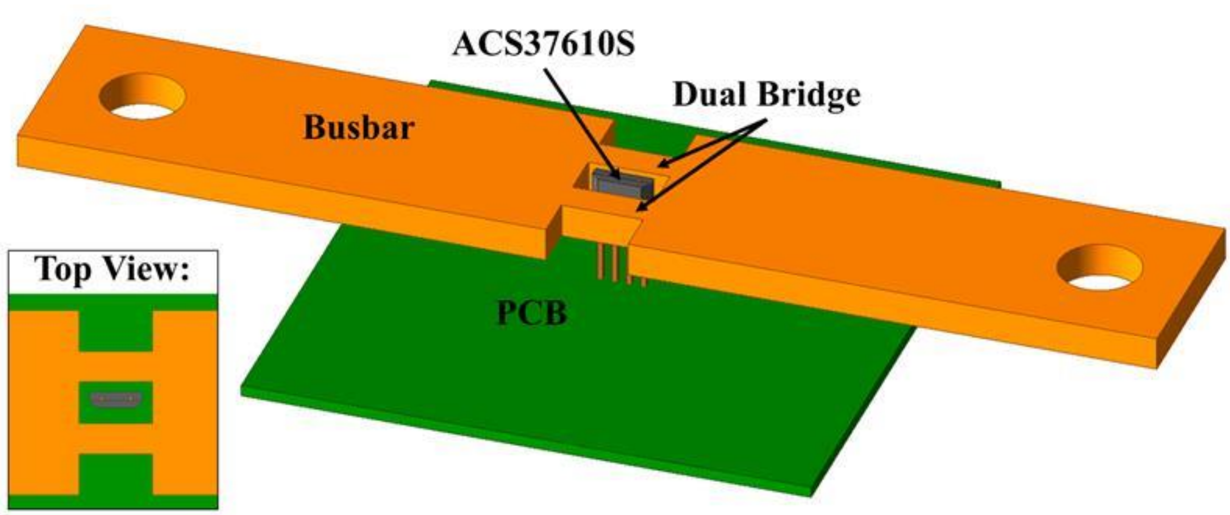


Figure 1: Concept of dual-bridge design.

The sensor is mounted vertically on the PCB, with the Hall plates aligned perpendicular to the PCB plane, as illustrated in Figure 2. Current flowing 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, enables a robust measurement by canceling out the effects of stray magnetic fields.

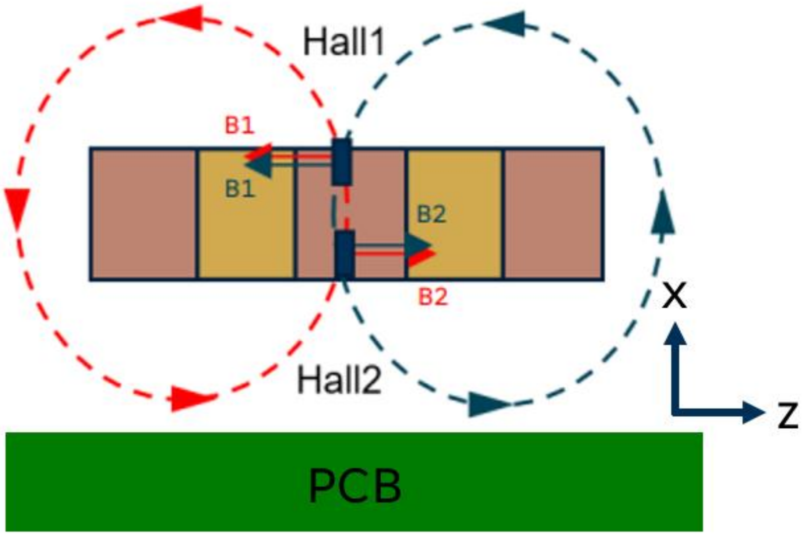


Figure 2: Sensing concept

The output voltage Vout and the sensitivity can be calculated with the following equations

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

Where CF is the coupling factor, ∆V is the output range and ∆I is the total current range.

Recommended Design and Performance

The recommended dual bridge design, illustrated in Figure 3, uses 2 mm wide bridges separated by 6 mm, each with a length of 10 mm. The sensor is positioned within the central hole, ensuring the midpoint of the Hall plates aligns precisely with the hole's center (refer to the datasheet for detailed technical drawings).

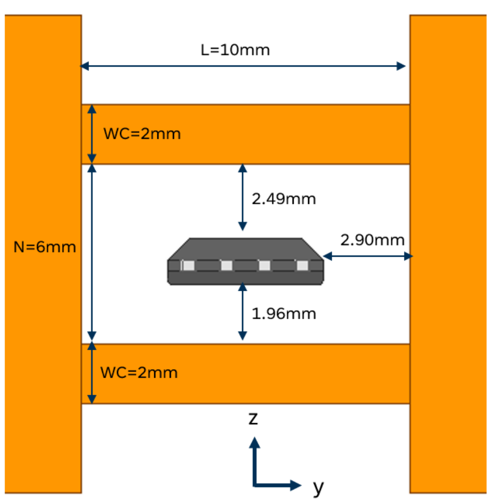


Figure 3: Recommended design of the dual bridge

Table 1 shows the performance overview of the ACS37610S in combination with the recommended dual bridge design for a peak current of 700A. This peak current value represents a typical maximum current observed in automotive applications. However, the sensitivity can be programmed to operate at different current ranges. The table shows key performance parameters for different busbar thicknesses (T) ranging from 1mm to 3mm. The parameters were obtained by doing magnetic simulations in Ansys Maxwell. The geometry shows a robust coupling factor of 260-290 mG/A. This coupling factor is crucial for determining the sensor's sensitivity at the peak current according to the above-mentioned equations.

Table 1: Performance overview of the recommended dual bridge design for a peak current of 700 A and for different busbar thicknesses.

	T = 3 mm	T = 2mm	T = 1 mm
Coupling Factor [mG/A]	259	277	288
Sensitivity for 700 A [mV/G]	11.0	10.3	9.92
Displacement tolerance dx = 0.1/0.3 mm [%]	-0.2/-1.2	-0.1/-1.3	-0.2/-1.4
Displacement tolerance dy = 0.1/0.3 mm [%]	0/0.2	0/0	0/0
Displacement tolerance dz = 0.1/0.3 mm [%]	0.1/1.1	0.2/1.2	0.2/1.4
Busbar tolerance (±0.1mm) [%]	0.5	0.6	0.5
Gain error @ 1 kHz [%]	-0.8	-0.6	-0.2
Phase shift @ 1 kHz [°]	-1.2	-0.8	-0.4

The displacement errors are shown for ±0.1 and ±0.3 mm in all directions. Please refer to Figure 3 for a coordinate system. There is no influence for the given range of ±0.3 mm along the y-axis. There is an error of 1.2 and 1.4 % for a displacement of 0.3 mm along the x- and z-axes. This is much smaller than the displacement error of the notch geometry which is 5 % for only 0.1 mm along the z-axis.

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 applying a known current and adjusting the sensor output to match the current. After calibration, the primary concern shifts to displacement occurring during operation, which is usually significantly smaller than the initial displacement.

Similarly, the busbar tolerance, representing the manufacturing variation in the width of each bridge, can also be compensated during end-of-line calibration. The analysis considered a ±0.1 mm deviation, resulting in an approximate 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. Thinner busbars exhibit a flatter frequency response. For instance, reducing the 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°. Figure 4 provides a detailed illustration of the frequency response for various busbar thicknesses (top row) and bridge widths (bottom row).

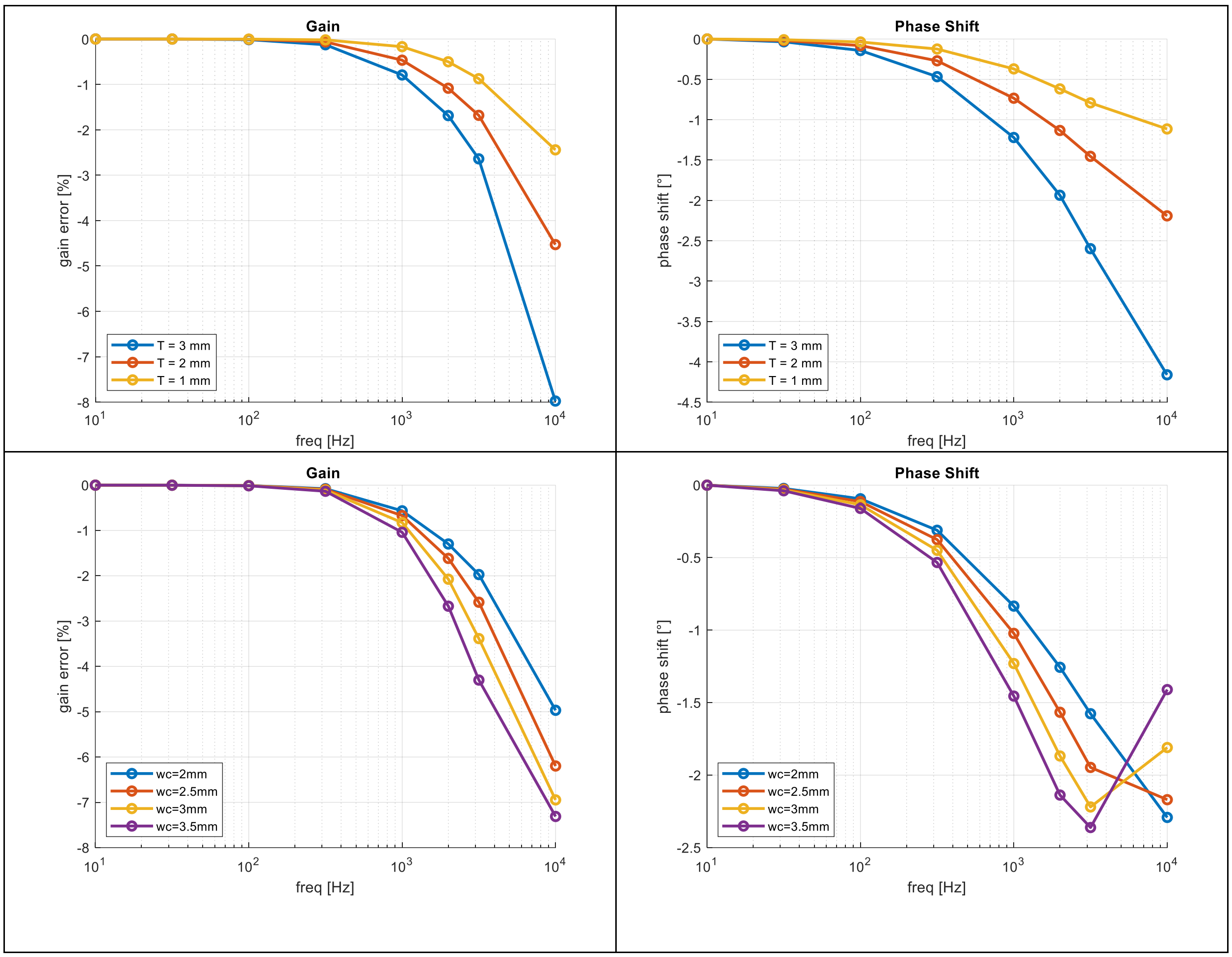
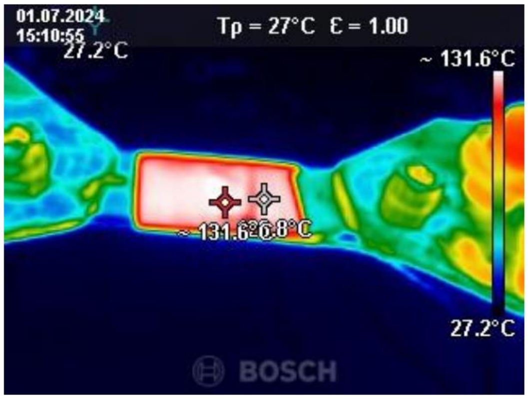


Figure 4: Top row shows the frequency response for different busbar thicknesses. Thinner busbars show a flatter curve. Bottom row shows the frequency response for different bridge widths. Thinner bridges show a flatter curve.

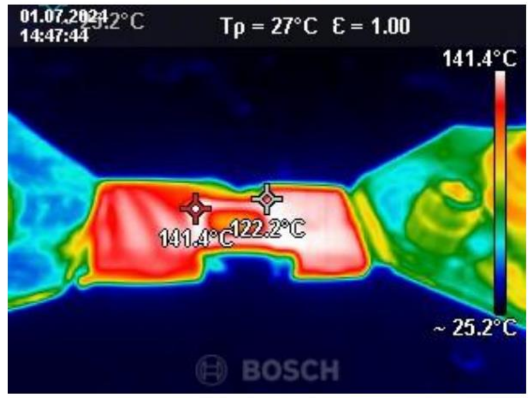
To evaluate the thermal capacity of the dual bridge design, a 700 A (DC) current was applied for 5 minutes to both a solid 3 mm thick busbar and the 3 mm thick dual bridge structure. The ambient temperature was maintained at 25°C. The solid copper busbar, with dimensions of $18x3\ mm^2$ (Width x Thickness), reached a temperature of 130°C. Despite the significant reduction in copper in the dual bridge design, the measured temperature was only 10°C higher, reaching 140°C. Importantly, the narrower bridges did not exhibit localized overheating or act as hotspots.

700A applied on 3mm thick Busbars (no cooling system)

Solid busbar



Dual Bridge Busbar



- 700A (DC) applied for 5minutes: Dual Bridge Busbar shows less than 10°C higher (131.6°C vs 141.4°C)

Conclusion

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