TI TechNotes

Design Considerations for Dual DRV425 Bus Bar Application

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This document is a supplement to the Bus Bar Theory of Operation Application Report (SLOA237) and the DRV425 Bus Bar App Magnetic Field Calculator (SBOC480).

There are several different ways to sense current. The majority of applications are based on measuring the voltage across a shunt resistor. This approach is difficult at high currents (>100A) and/or high voltages (>100V). Magnetic field based current sensing is a common solution for designs extending beyond these levels. In a magnetic field based solution, the measured magnetic field (B) is proportional to the current (I) and inversely proportional to the distance (r) from the current carrying conductor (Ampere's Law), as shown in Figure 1.

$$B = \frac{\mu_0 I}{2\pi r}$$

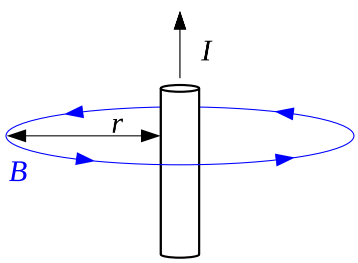

Figure 1. Ampere's Law

Measuring high current through a bus bar can be accomplished using two (2) DRV425 Integrated Fluxgate Magnetic Field Sensors placed in a cutout in the center of a bus bar. As the current is split into equal parts around the cutout, a magnetic field gradient is generated around each side of the cutout. The magnetic field lines present inside the cutout flow in opposite directions. The DRV425 device has a maximum magnetic field sensing range of 2mT. System level considerations need to be investigated when designing with this implementation as to not exceed this maximum range. The performance of the design is affected by the cutout configuration, DRV425 device PCB layout orientation and location of stray/interfering magnetic fields.

The TI recommended implementation is a hole placed in the center of a bus bar with the DRV425 devices axis of sensitivity oriented vertically on the PCB, as shown in Figure 2. When a hole is placed in the center of a bus bar the current is split into equal parts around the hole. Since the magnetic field is perpendicular to the current flow, a hole provides an amplification of the magnetic field inside of the hole as the current flows around it. The size of the hole needs to be as small as possible but at least larger than the width of the PCB designed for the dual DRV425 devices. The smaller the hole, the larger the magnetic field generated by each side of the cutout. The magnetic fields around each side of the hole are elliptical in shape and are in opposite direction to each other inside the cutout. The magnitude of the magnetic fields generated by each side of the cutout will be 0 in the center of the cutout and increase as you move toward the edges of the cutout. The magnitude of each magnetic field will be largest in the y-axis inside the cutout. This allows each DRV425 device in the vertical PCB orientation to see a larger magnitude of the desired magnetic field. Each devices axis of sensitivity is oriented in opposite directions on the PCB enabling a doubling of the desired magnetic field to be measured. Another benefit of this orientation is it reduces or cancels the effect of any stray magnetic fields since they only flow in one direction inside the cutout.

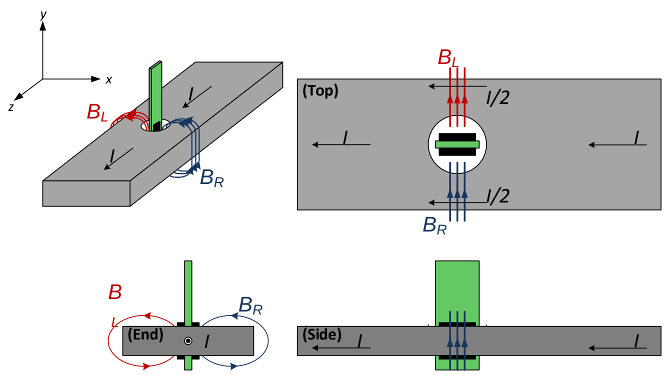

Figure 2. Recommended Configuration

This configuration, however, does not work for all systems. Looking at all magnetic field influences of the design becomes critical for optimal performance. Below we will investigate possible reasons for selecting a different configuration.

Hole vs Slot

A hole is recommended due to the amplification of the magnetic field as the current wraps around the hole. Because stray magnetic fields do not get any amplification due the hole, this configuration provides a better signal-to-noise level. Here are two reasons for using the alternative slot configuration.

1. Low current/small bus bar. A slot configuration will allow for a narrower opening when using the vertical PCB device layout orientation if the bus bar is not large enough to accommodate a hole. A smaller opening creates a larger magnetic field differential seen by the dual DRV425 devices.
2. Large current/large bus bar. Since the slot does not have the amplification effect of the hole, a slot will produce a smaller magnetic field for the same current and cutout width.

Vertical vs Horizontal

Vertical and horizontal describe the PCB layout orientation of the axis of sensitivity of the fluxgate sensor internal to the DRV425. In the vertical layout, the axis of sensitivity for each DRV425 device are placed in the y-axis. Each device measures the y-axis component of any magnetic field. Similarly, in the horizontal layout, the axis of sensitivity for each DRV425 device are placed in the x-axis and measures the x-axis component of any magnetic field. Interestingly, the final values for the desired differential magnetic field seen by each device in both orientations is very similar. However the larger values seen by each DRV425 device inside the cutout in the vertical PCB layout orientation is the reason why it is the recommended PCB layout. Here is a reason for using a horizontal PCB device layout orientation.

1. Large stray magnetic fields in the y-axis. As shown in Figure 3. The magnitude of the stray magnetic fields are seen entirely by each DRV425 device before being subtracted out. While the difference of the 2 DRV425 devices may be small, there is a possibility that the total magnetic field seen by one or both DRV425 devices may exceed the 2mT magnetic field range limit. This would result in an invalid measurement. Since the strength of the magnetic field is inversely proportional to the distance, the spacing from stray field sources (like another bus bar) needs to be evaluated at the system level to ensure saturation of either DRV425 does not occur.

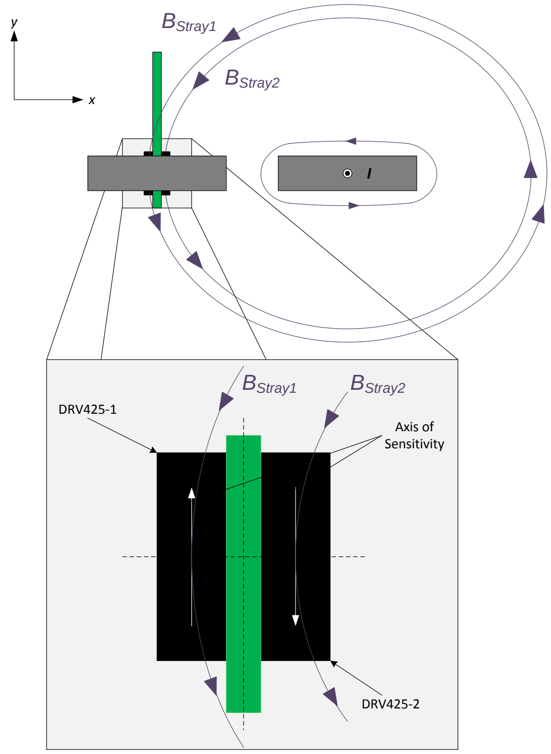

Figure 3. Stray Field

Understanding the system level influences for any magnetic field measurement is critical to achieve the best performing system. Stray magnetic fields cannot be eliminated but their influence can be minimized.

Alternative Device Recommendations

Based on system requirements, alternate devices are available that can provide the needed performance and functionality. The DRV421 provides a closed loop isolated current measurement with an external core and compensation coils. The AMC1305 provides on-board isolation using an external shunt resistor.

Table 1. Alternative Device Recommendations

Device	Optimized Parameters	Performance Trade-Off
DRV421	Precision Integrated Fluxgate Sensor	Requires External Core and Compensation Coils
AMC1305x	High Precision, Reinforced Isolated Delta-Sigma Modulator	Slightly Higher Cost

Table 2. Adjacent Tech Notes

SBOA179	Integrated, Current Sensing Analog-to-Digital Converter
SBOA168	Monitoring Current for Multiple Out-of-Range Conditions
SBOA160	Low-Drift, Precision, In-Line Motor Current Measurements With PWM Rejection

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