Application Note for BBM-03-LV SERIES
Bus Bar Current Sensor Module – Design Guide AN_BBM-03_001

Engineers often face the problem of galvanically isolated current measurement using Hall magnetic field sensors. At the same time, they often do not have a feeling of how much magnetic field needs to be measured or how to correctly dimension the bus bar in order to achieve the best characteristics. Knowing the current being measured, the required geometry of the busbar can be determined, and then the required magnetic (or current) sensitivity of the applied sensor.

This application note provides guidance in sizing bus bars to obtain the desired BBM-03-LV Bus Bar Module sensitivity for DC currents. In addition, this guidance provides the basic recommendation on how to connect the sensor module in the signal conditioning circuit.

1. Sizing the bus bar to obtain the desired DC sensitivity

The BBM-03-LV sensor can be applied for AC current measurement, though in this case, the skin effect can cause the degradation of the frequency response. The BBM-03-LV determines the current in the bus bar by measuring on both sides of the bus bar, the magnetic field generated from the current through the bus bar. The magnitude of the magnetic field at the sensor is a function of the width and thickness of the bus bar as well as the current through the bus bar. This guide provides the output Sensitivity in mV/A for the BBM-03-LV as a function of bus bar width and thicknesses for various standard Imperial dimensioned bus bars.
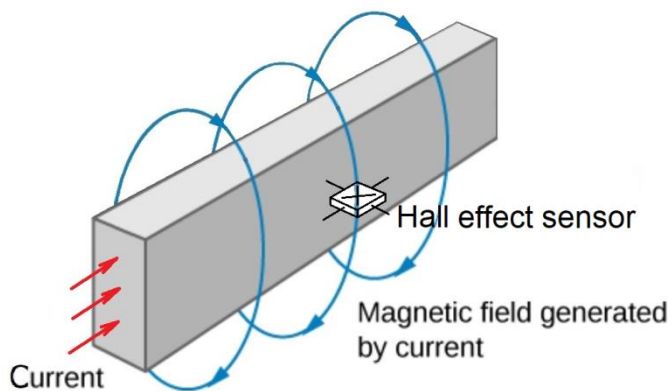

Figure 1.: Concept of a Bus Bar Current Sensor Module with a Hall sensor

The most important factor to consider when selecting the correct bus bar, is the current density in the bus bar. A number of factors determine this rating which include ambient temperature, mounting and desired maximum temperature rise. SENIS recommends a conservative current density of < 2000A/in2 (3A/mm2). Higher current densities can be achieved by using heat sinks or forced cooling.

Current flowing through a conductor creates a magnetic field in its surroundings as shown in the figure 1. The strength of the magnetic field H is proportional to the strength of the current I. If the conductor is not ferromagnetic, which is the most common case (copper or aluminium) and if there are no ferromagnetic objects in the environment, then the magnetic induction (i.e. the magnetic flux density) is proportional to the current in the bus bar. By measuring the magnetic induction B in the vicinity of the conductor and knowing the proportionality coefficient, the current through the

conductor is determined.

Using the fundamental laws of electrical engineering, the proportionality coefficient can be determined based on the busbar dimensions.

The magnetic field created by the strip conductor at the sensor location (Figure 2) is very roughly given by the following equation:
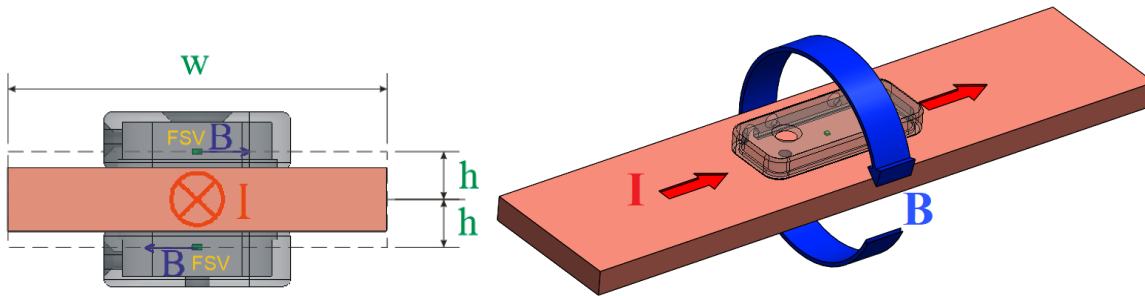
$$H(I, w, h) \approx \frac{I}{2(w + 2h)}$$

Figure 2.: Magnetic field around a strip bus bar

H depends on the thickness of the busbar and the distance to the magnetic field sensitive volume (FSV).
In vacuum (or air) the magnetic induction (flux density) is obtained by multiplying the vacuum magnetic permeability:

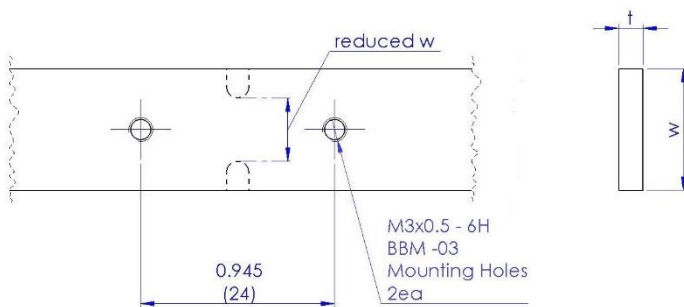$$B = \mu_0 H \qquad , \ \mu_0 = 4\pi \cdot 10^{-7} \frac{Vs}{Am}$$

Figure 3. Bus Bar Diagram

BBM-03-LV is intended for mounting on both sides of the busbar in order to suppress the influence of the external magnetic field. Figure 3 shows the dimensions and the position of the required holes on the busbar for mounting the BBM-03-LV.

Accurate determination of the current sensitivity of the bus bar current sensor module is given here using three sets of curves to cover bus bar widths ranging from 0.375 to 4.0 inches. Curves are given for Imperial industry standard busbar widths.
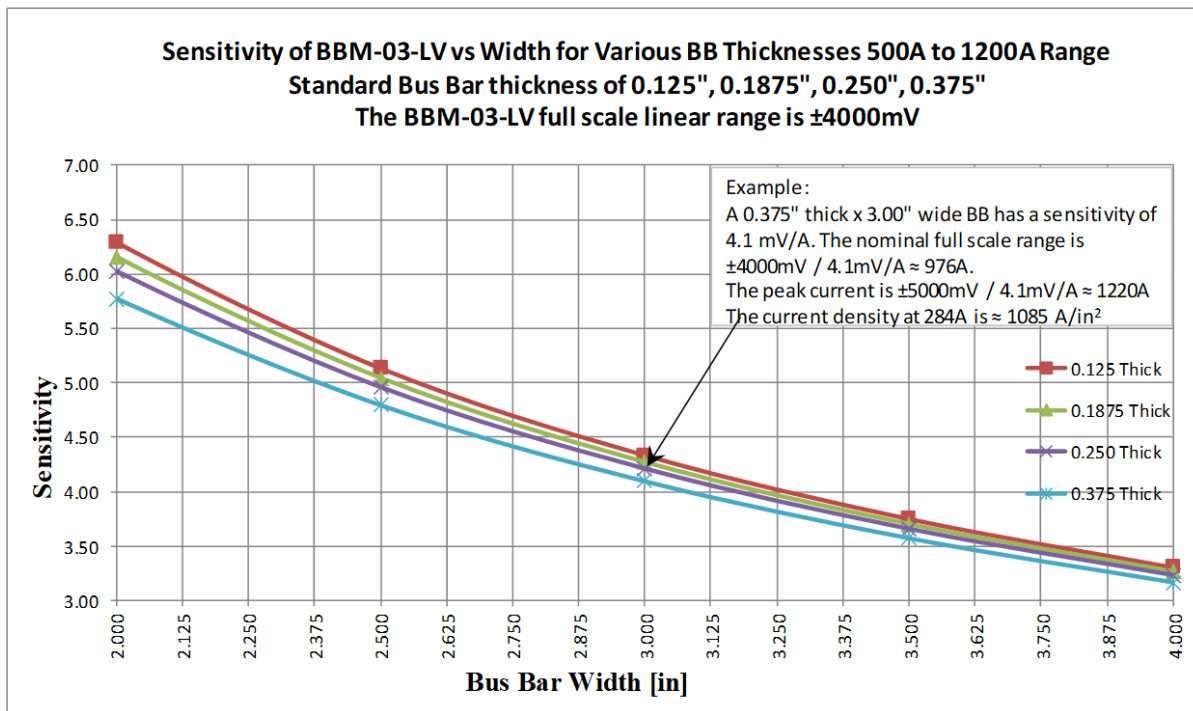If BBM-03-LV output sensitivities higher than achieved with the standard widths are desired, they can be obtained by incorporating slots in the bus bar to reduce the effective width "w" accordingly (see Figure 3).

Sensitivity of BBM-03-LV vs Width for Various BB Thicknesses 100A to 300A Range
Standard Bus Bar thickness of 0.0625", 0.125", 0.1875", 0.250", 0.375"
The BBM-03-LV full scale linear range is ±4000mV
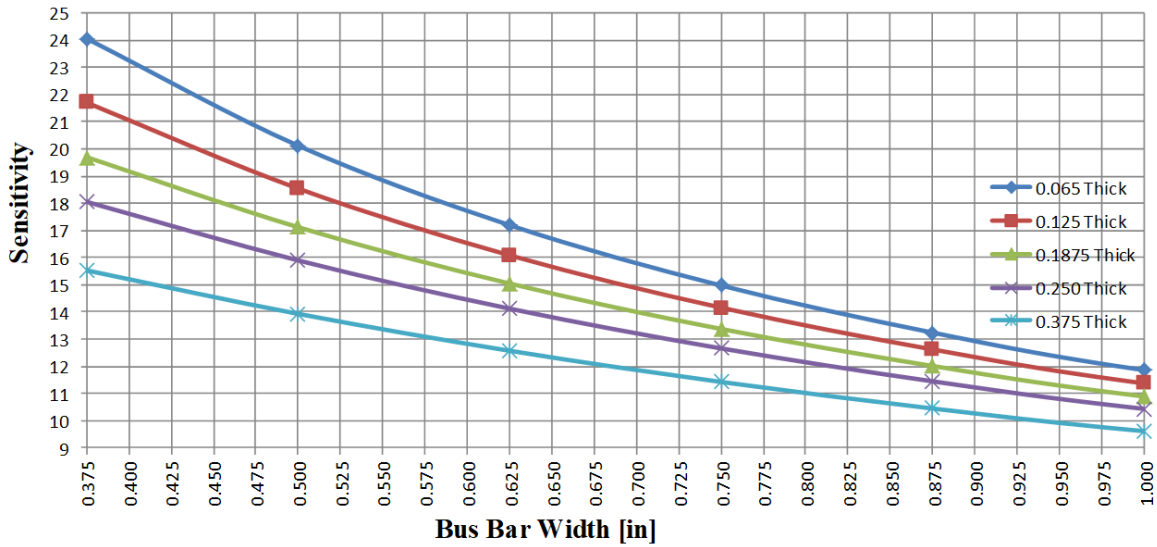
Sensitivity of BBM-03-LV vs Width for Various BB Thicknesses 300A to 600A Range
Standard Bus Bar thickness of 0.125", 0.1875", 0.250", 0.375"
The BBM-03-LV full scale linear range is ±4000mV

Example:
A 0.250" thick x 1.5" wide BB has a sensitivity of 7.6 mV/A. The nominal full scale range is ±4000mV / 7.6mV/A ≈ 526A.
The peak current is ±5000mV / 7.6mV/A ≈ 658A
The current density at 284A is ≈ 1755 A/in²

Sensitivity of BBM-03-LV vs Width for Various BB Thicknesses 500A to 1200A Range
Standard Bus Bar thickness of 0.125", 0.1875", 0.250", 0.375"
The BBM-03-LV full scale linear range is ±4000mV

Example:
A 0.375" thick x 3.00" wide BB has a sensitivity of 4.1 mV/A. The nominal full scale range is ±4000mV / 4.1mV/A ≈ 976A.
The peak current is ±5000mV / 4.1mV/A ≈ 1220A
The current density at 284A is ≈ 1085 A/in²

- ■ 0.125 Thick
- ▲ 0.1875 Thick
- ✕ 0.250 Thick
- ✱ 0.375 Thick

Sensitivity (y-axis), *Bus Bar Width [in]* (x-axis)

2. Recommendation on how to connect the bus bar sensor module

The most common case is that the output of the magnetic sensor is connected to the input of the A/D converter. Therefore, the maximal output voltage from the sensor should be equal to the maximal input voltage of the applied A/D converter (usually ±5V).
On the other hand, the maximal output voltage of the sensor is obtained for the maximal expected magnetic field, and it is achieved with the maximal applied current:

$$B_{max} = C \cdot I_{max}$$

The required magnetic sensitivity of the sensor for a maximal input voltage of the applied A/D converter of 5V can be calculated as:

$$S_M = 5.0V / B_{max}.$$

Busbar

A/D converter

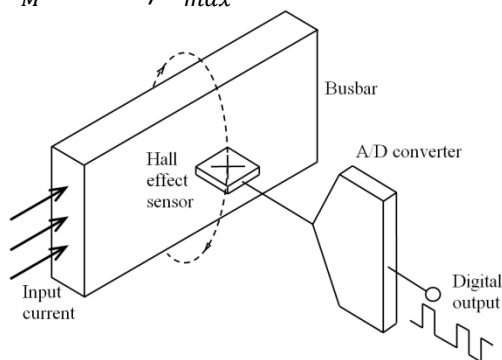Hall effect sensor

Input current

Digital output

Figure 4. Concept of signal conditioning of a Bus Bar current sensor module

The output signal from BBM-03-LV is a symmetrical differential voltage with the common mode of 2.5V, i.e. the half of the supply voltage (the supply voltage of the current sensor module is 5.0V). Each output of the differential pair of BBM-03-LV can have a value in the linear range of Uout = 2.5V ±2V (±2V is the linear range of the BBM-03-LV).
Such an output from the current sensor can be directly fed to the A/D converter with differential

inputs and with the full-scale input voltage ±5V.

If customer end-application doesn't have an A/D converter with a differential input but single-end A/D instead, then it is necessary to add a differential-to-single-ended converter between the BBM-03-LV and the A/D converter.

3. General Recommendations

To fix the sensor on a bus bar the use of non-magnetic screws is highly recommended, particularly the use of high-performance plastic screws is recommended.