

# APPLICATION NOTE

## The Difference Between Current Sense Resistors and Hall Effect Sensors for Motor Control Applications

### Introduction

Current sensing is an essential design function that is necessary in a broad range of applications. For example, current sensing is needed to detect a battery's capacity, to measure current flow, or to calculate angles in motor control applications. Applications that can benefit from current sensing include Battery Management Systems (BMS), 3-Phase motor control units and On-Board Charging (OBC) Systems used in electric vehicles (EVs), as shown in Figure 1, and in other high energy charging-based designs.

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Current sensing is also advantageous in medical equipment to detect leakage current. Additionally, it is beneficial for equipment with grounding loops to effectively monitor the level of current flow. Adding current sensing to the design is a cost-effective way to help protect equipment from excessive electrical loads.

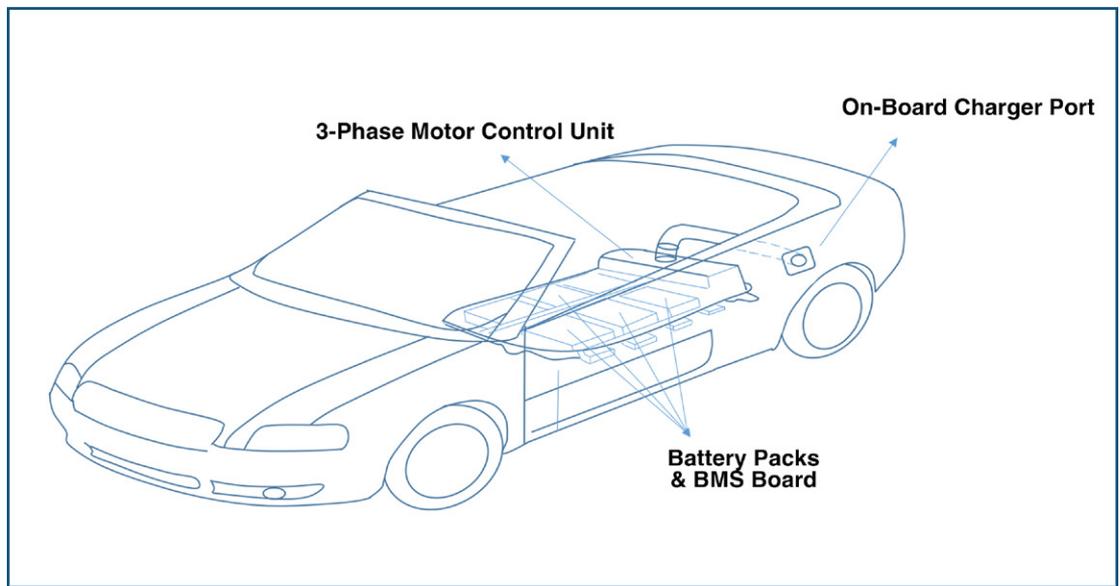


Figure 1. | An OBC, a 3-phase Motor Control and BMS in an EV Application

While there are various methods to detect current flow, the most commonly used methods in the industry are Hall effect current sensing, fluxgate current transformers, Rogowski coil transducers and current shunt resistors. This application note provides a comparison of Hall effect current sensors versus current shunt resistors. It details the pros and cons of using these two solutions for accurate current measurement in many types of motor control applications.

## Operational Basics of Hall effect Sensors

To better understand how Hall effect sensors work, Figure 2 shows a diagram of closed loop Hall effect current sensing. When the primary current ( $I_p$ ) goes through the core, the core will induce a magnetic field called B. Then, when the Hall effect sensor detects magnetics in field B, it will generate a voltage drop called a Hall Voltage (HV). There is typically an amplifier positioned after the Hall effect sensor. Thus, when HV is generated, the HV will feedback to the secondary coil after it is amplified. This event allows the Hall effect sensor to stay in a zero-flux environment due to its HV, which is relevant to the amplitude of magnetic field B and is precisely generated by the input current flow  $I_p$ . The amplitude of the current flow is proportional to the input current flow  $I_p$ .

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Because Hall effect sensors are contactless, they provide the advantage of no insertion loss on the input side. The disadvantage is that the size of the Hall effect sensor must be proportional to the amplitude of magnetic field B.

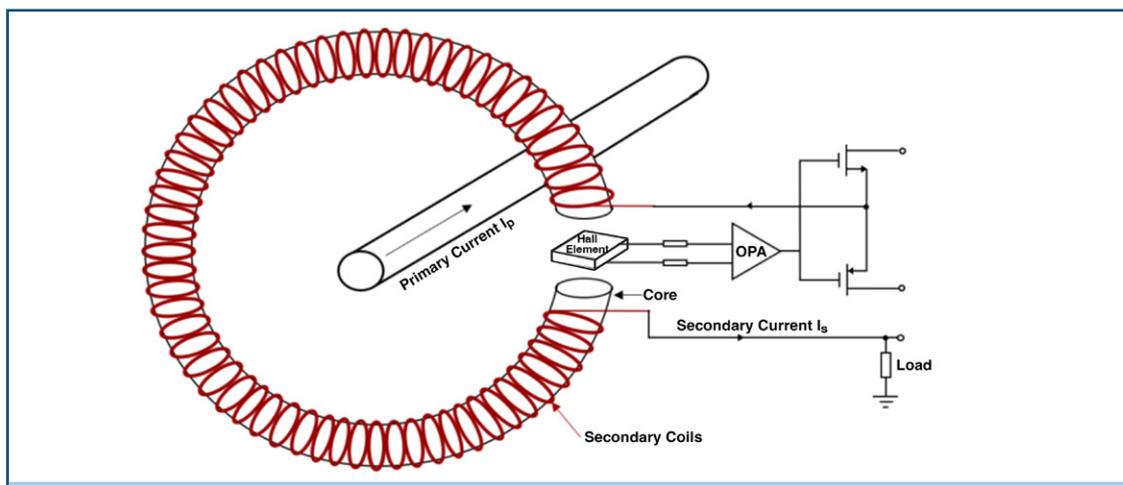


Figure 2. | Hall effect Sensor

As shown in Figure 2, there are many factors that affect Hall effect sensor operation. It is important to note that all the components, including OPA (Operational Amplifier), MOSFETs/transistors and Hall effect sensors, will require extra power sources to maintain operation in the initial stage to sense the voltage generated by the magnetic field or their signals can be lost. And, as a magnetic field's strength is increased, the saturation level of the Hall sensor will be reached. This value will be high enough to drive internal circuitry to turn itself on, whereas, when the magnetic field disappears, the internal circuitry is turned off. The differential between the internal circuitry being turned on and turned off is called hysteresis deviation. The value of the hysteresis deviation depends upon the magnetic material used and its magnetic strength, size, the distance between the magnetic material and the Hall effect sensor and the operating temperature. And, because the HV is sensed and generated by a magnetic field, the secondary coil may also be affected by external magnetic fields.

## How Current Sense Resistors Work

Current sense resistors work differently than Hall effect sensors. Figure 3 illustrates how a current sense resistor can be employed in a BMS application. When a battery or a power source connects the load with a current sense resistor, the current flow  $I_p$  can be directly measured by the device's four-terminal current shunt. Based on Ohm's law, the voltage drop across the current sense resistor will be measured, then amplified by an OPA. The benefits of using a current sense resistor are that it provides simplified operation, quicker response time, is smaller in size compared to a Hall effect sensor and is capable of operating in a wider temperature range when measuring high current flow.

[Current Sense Resistors](#)

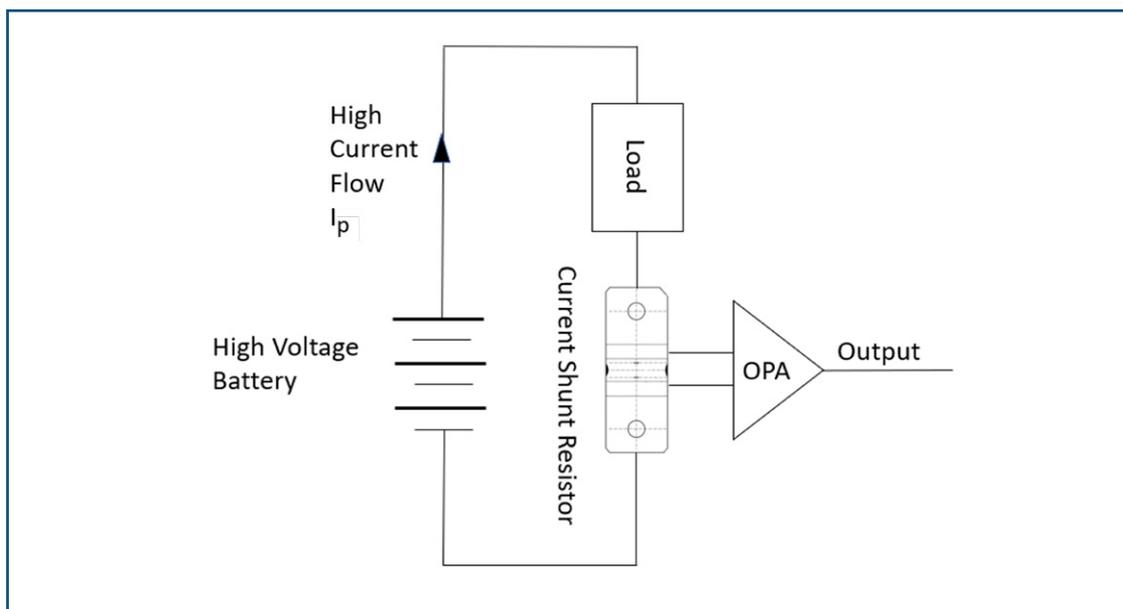


Figure 3. | A Current Sense Resistor Employed in a BMS Application

The accuracy and quick response time of current measurement are very important to motor control and BMS applications in EVs because monitoring this measurement helps to protect the circuit from sudden current spikes. Accurate and fast current measurements are also critical for sensing current flow in other motor control applications, this is to help sensing the inrush current and determining input and output current flow in DC-DC applications.. Resistors that offer fast and accurate measurements are also necessary for sensing current flow in harnessing when power is transmitted via cables.

### How Current Sense Resistors Work (Continued)

[Current Sense Resistors](#)

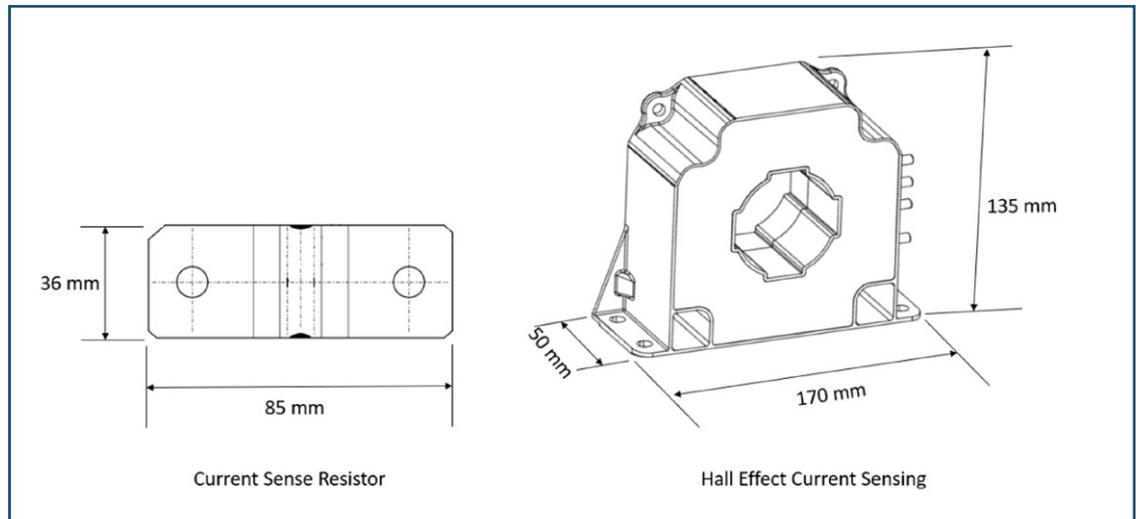


Figure 4. | A Comparison of the Difference in Size and Typical Packaging of Current Sense Resistors Compared to Hall Effect Sensors

Current sense resistors are constructed of metal strips, which enables them to have very low thermal Electromagnetic Field (EMF) and inductance. There are also newer current sense resistor designs available with 4-terminal traces that deliver higher accuracy measurement.

Table 1. | A Helpful Comparison Of The Current Sensing Advantages And Disadvantages Of Hall Effect Sensors And Current Sense Resistors

Product Type	Advantages	Disadvantages
<b>Hall effect Sensor</b>	<ul style="list-style-type: none"> <li>• Lower insertion loss</li> <li>• Accurate</li> <li>• Good isolation capability</li> <li>• Can measure AC and DC current</li> </ul>	<ul style="list-style-type: none"> <li>• Larger size</li> <li>• Slower response time compared to current sense resistors</li> <li>• Residual voltage issues</li> <li>• Hysteresis deviation</li> <li>• Needs an extra current source for Hall effect sensor and extra voltage source for transistors</li> <li>• Consumes current flow</li> <li>• Typically higher cost</li> <li>• Reliability can be impacted when operated in high temperature</li> </ul>
<b>Current Sense Resistor</b>	<ul style="list-style-type: none"> <li>• Low inductance</li> <li>• Cost-effective</li> <li>• Smaller size</li> <li>• Simple to use</li> <li>• Has no inherent phase drift</li> <li>• Fast response time</li> <li>• Low impact on reliability when operated at high temperature</li> </ul>	<ul style="list-style-type: none"> <li>• Power dissipation</li> <li>• Needs isolation</li> <li>• Insertion loss from metal components connected in series</li> </ul>

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### Selecting the Right Current Sense Resistor

There is no “one size fits all” current sense solution. That is why Bourns offers a broad portfolio of advanced current sense resistors ranging in size from 0402 to 8536. To match a variety of application needs, Bourns® current sense resistors, which are optimal solutions to withstand the higher current flow from batteries or other power sources in a variety of motor control applications, feature power ratings from 0.1 W to 50 W. Essential features designers need to consider also include the maximum current that flows through the current sense resistor, the operating environment and ambient temperature of the application, the total thermal resistance of the PCB, the current paths for current measuring and the required resistance value of the current sense resistor.

[Current Sense Resistors](#)

Current measurement sensing is gaining more and more attention due to the increasing usage of portable devices and other applications that require battery or motor power monitoring. This paper has highlighted why current sensing is important for BMS or on OBC, and why these systems can be supported with today’s advanced precise shunt resistors. For example, a device’s response time in a vehicle application is vital when measuring current flow in BMS or OBC applications to help ensure the safety of the vehicle occupants whenever in charging/discharging mode or during driving. Because of this essential requirement for fast device response time, the quicker response time of a current sense resistor compared to a Hall effect solution makes it the better choice in this type of application.

There are many metrologies that can be implemented to achieve very accurate current measurements based on a customer’s application requirements. With the material and process advancements that it can provide, Bourns® current sense resistors are proven, high quality and cost-effective solutions that offer reliable and precise performance for today’s higher power designs.

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