

# Increasing Power Electronics Efficiency Using Current Sense Resistors

Author: Gabor Mark, Resistive Products Application Engineer at Bourns

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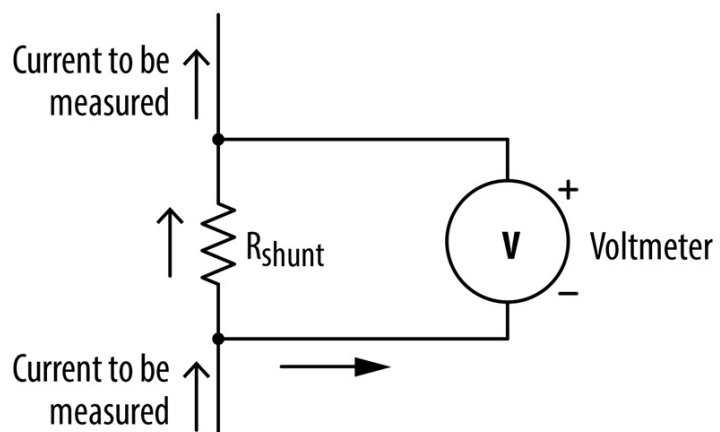
Tag: @Bourns #currentsense #resistors #psd #powerelectronics

In almost every market, there is an ongoing design goal to make electronic circuits more efficient in order to minimize power consumption and thermal issues

For circuit designers and systems operators, understanding what level of current is flowing through a circuit and being delivered is often a key requirement in many applications. Maximizing the operating performance of a battery, controlling motor speeds, and the ability to hot swap server units are examples of applications that can all benefit from the use of accurate current measurement.

Helping designers create more efficient circuit designs by precisely measuring and monitoring current flow is why current sense resistors are now important design

elements in a broad variety of power electronic applications. This article will cover how current sense resistors work and the testing methods necessary to evaluate and select the right resistor for a given application.



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Figure 1: Current sense resistors detect and convert current to voltage

## How Current Sense Resistors Work

Current sense resistors, also known as shunt resistors, are recognized as cost-effective components that help improve system efficiency and reduce losses due to their high measurement accuracy compared to other technologies. While they are used in all types of market segment applications, current sense resistors are growing in demand for precise current measurement in a whole range of new power electronics designs found in automotive, industrial and energy applications.

Current sense resistors work by detecting and converting current to voltage. These devices feature very low resistance values, and therefore, cause only an insignificant voltage drop of 10 to 130 mV in the application. Shunt resistors are placed in series with the electrical load whereby all the current to be measured will flow through it. Following Ohm's law, a voltage drop is generated across the resistor of known value, which is proportional to the current. The voltage drop across the resistor can be measured by various amplifier options such as operational, difference and instrumentation amplifiers.

## Selecting the Right Current Sense Resistor

In order to select the most appropriate current sense resistor for a given application, it is important to look at

the input common-mode voltage specification, which is the average voltage present at the input terminals of the amplifier.

As previously mentioned, shunt resistors sit in series with the load so they are able to directly measure current. This is in contrast to indirect current measurement techniques. Also, because shunt resistors use direct current sensing techniques, they allow power to be dissipated from the device, resulting in very low resistance values.

Current sense resistors also feature a very low Temperature Coefficient of Resistance (TCR). TCR defines drift with varying ambient temperature and helps to provide enhanced long term stability. These characteristics also contribute to the very high current measurement accuracy while the temperature dependency of the measurement is extremely low.

### Advantages of Kelvin Principle Measurement

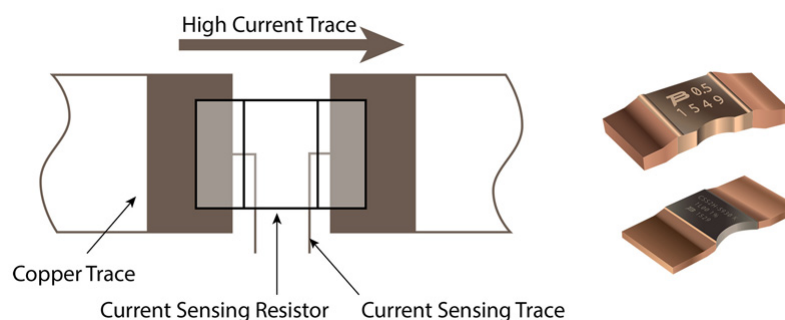
When evaluating a particular current sense resistor for a given application, designers will need to test their resistance value. So as to not get an incorrect failure analysis when testing the resistance, it is important to employ the proper test method for the most accurate results.

For example, testing for designs that use very low ohmic 2-terminal surface mount resistors can show that the contact resistance of the solder pad and the traces of the printed circuit board (R<sub>lead</sub>) are uncertain and usually higher than the resistance of the current sense shunt itself. These conditions can lead to inaccuracies in the current measurement. Additionally, the TCR of copper trace of the printed circuit board (3900 ppm/°C) is also much higher than the TCR of the shunt resistive element (< 50 ppm/°C). These issues can many times cause the resistance value change of the leads to be much higher than the resistance value change of the resistance element. The result is the temperature dependency of the current circuit tends to be very high.

Another disadvantage of this measurement testing method is that it is not only the component but the total resistance of the circuit that is measured. This method provides the total resistance of the measuring cables, connectors, fixtures and clips as typically 5 to 100 milliohm, which would be incorrectly added to the measuring result.

In order to mitigate these negative effects, designers can use current sense resistors implementing the 4-wire Kelvin principle. This method employs additional leads for current measurement independent from the main current flow. By using a 4-wire connection, the test current (main current) is forced through the component under test via a pair of wires while the voltage drop across the subject component is measured through another pair of cables (sense current).

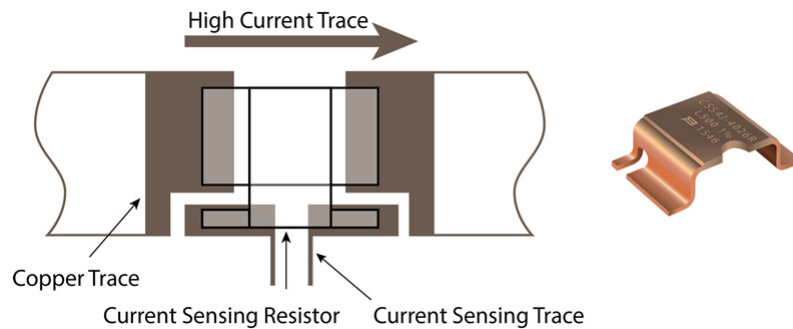
A 2-terminal resistor can also employ the 4-wire Kelvin principle method. By separating the current path through the resistor, this test directly senses the voltage drop across the resistor, thereby improving the measurement accuracy. Unless extreme precision is required, the 2-terminal resistor is the economical choice with PCB traces added to provide the 4-terminal connection.



[Click image to enlarge](#)

*Figure 2: A 2-wire resistor can use the 4-wire Kelvin principle test method to improve measurement accuracy*

If the design budget permits, however, it is recommended to utilize a 4-terminal current sense resistor with the 4-wire Kelvin principle to allow separate terminations for current flow and voltage drop measurement. Adopting this approach helps ensure higher current measurement accuracy. An additional advantage of utilizing the Kelvin principle is to reduce the effect of TCR by providing improved stability of the sense amplifier as the temperature rises. And, this method of measuring resistance also helps prevent the influence of any damaged wires or probes on the resistance measurement.

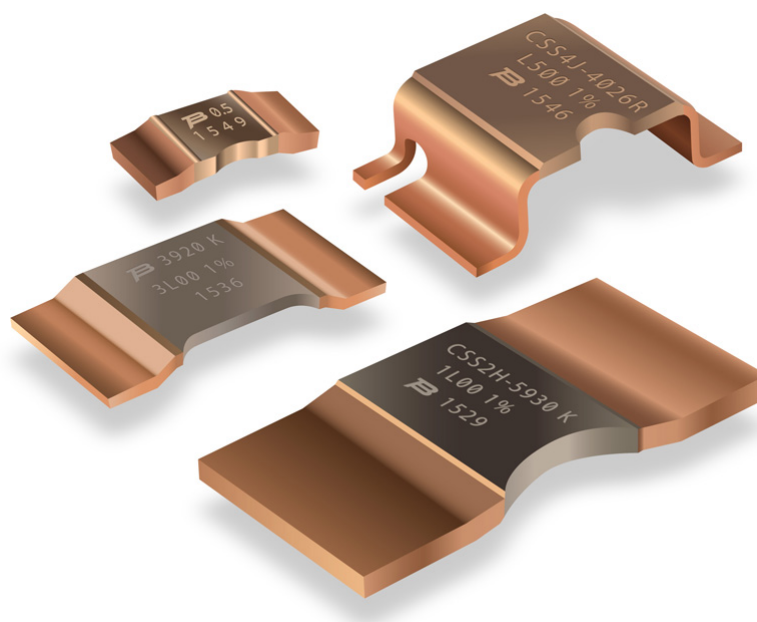


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*Figure 3: Using the 4-wire Kelvin principle method on a 4-terminal current sense resistor accommodates separate terminations for current flow/voltage drop resulting in more precise current measurement accuracy*

## Features to Look For

For today's power electronics designs, it is recommended to source advanced current sense resistor models that feature very low resistance, low thermal electromagnetic field (EMF), low TCR, very high power and excellent long term stability. And for applications that require even higher measurement accuracy, designers may want to look for 4-terminal current sense resistor solutions. Manufacturers such as Bourns offer a 4-terminal series that features low thermal EMF that in-turn delivers a low voltage drop and higher measuring accuracy along with outstanding long term stability with rated power at 130 °C.



[Click image to enlarge](#)

*Figure 4: Bourns® Model CSS and CSM series high power current sense resistors are manufactured using an electron beam-welded metal strip with iron chrome or manganese copper alloy resistive element giving them excellent electrical characteristics. Their very low resistance levels, low thermal EMF and high power handling capabilities make them ideal solutions for BMS, switch mode power supplies and motor drives*

Other current sense resistor capabilities that may be quite advantageous for next-generation power designs are those that are automotive grade AEC-Q200 compliant. These resistors are tested to handle high current requirements with very low resistance (0.2 to 5 milliohms), and typically feature permanent power ratings from 36 W to 50 W and resistance values from 25 to 200 microohms. They also tend to provide a very low drift of resistance with temperature due to their low TCR.

## **Putting Current Sense Resistors to Work - Application Examples**

### **Battery Management Systems**

Proper battery management requires the continuous monitoring of current flow through the electrical circuit. The status of the battery is essential in automotive and other market segments where rechargeable batteries are used.

Selecting an advanced current sense resistor model that features low ohms of less than a milliohm helps to meet BMS requirements for low voltage drop and high accuracy. In automotive applications, it is also recommended to source a current sense resistor that is able to handle the high current of a 100-1000 amp engine starter. Plus, a current sense resistor that features a low TCR is particularly well-suited for automotive applications because of the high temperature fluctuation.

### **DC-DC Converters**

High performance power supplies have growing importance for the rapidly increasing market of mobile devices, especially in consumer and IT segments. The efficiency needed in switching power supplies used in current-mode DC-DC converters is higher than traditional linear power supplies. High stability and power efficiency is extremely important to ensuring the safety of the sensitive circuits and also helps to extend valuable battery life. So is finding a resistor with tight tolerance of resistance values.

Current sense resistors for DC-DC converters must offer a low resistance value of less than 10 - 20 milliohms for low power loss. Their low TCR and low thermal EMF minimizes or even eliminates the negative impact of self-heating of the devices and effects of various ambient temperatures.

Meeting the accurate current measurement needs in a growing range of power electronics, current sense resistors provide a simple and cost-effective direct method solution. As stated previously, these devices offer additional benefits including a low TCR, low thermal EMF and long-term stability. Low resistance electron beam-welded metal alloy-based current sense products, such as the Bourns® CSS and CSM Series, offer exceptional electrical characteristics and surge performance for efficient and highly reliable protection from short circuit and overcurrent threats.

**Bourns**