

High-Power, Low-Ohmic Current Sense Resistors

Sense Resistor Basics

Measuring the electrical current flowing through a circuit can be done using a variety of techniques. One of the simplest and most common way is to use a dedicated sensing resistor.

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Such a resistor can be employed in two ways, as shown in the figure below. On the left is a shunt configuration, where the majority of current flows through the sensing resistor and a known ratio flows through an ammeter. The total circuit current can be calculated since this ratio is a function of the known ammeter resistance compared to the known shunt resistance. The configuration on the right depicts a series sensing topology, where all of the current flows through a relatively low resistance sensing resistor, and a high impedance meter measures the voltage across it. The total circuit current is readily calculated using Ohm's law.

between measurement accuracy and power dissipation must be carefully balanced to achieve satisfactory design performance.

Sense resistors must also be carefully selected based on the second-order effects at high temperatures. The resistance of the device itself increases with temperature, and this non-ideality must be accounted for in the measurements if the resistor cannot be adequately cooled. Similarly, as the sense resistor heats up, the total power it can safely dissipate must be derated after a particular temperature is reached. Careful selection of resistor construction, package geometry, and PCB layout can be used to mitigate this effect.

tude and range of sensing, and the thermal considerations for the resulting power dissipation must be thoroughly addressed. In the figure below, two common applications are shown, one for a relatively high current multi-phase motor driver, and the other for a low current battery monitor.

In the motor drive circuit on the left, the sense resistor is used to monitor the current sunk through each phase of the motor windings by the low side transistors. A differential amplifier is used to measure the sense voltage and feed it into an analog to digital converter (ADC) in a controller IC. The controller IC uses this voltage feedback to calculate the magnitude and phase of the motor current and in turn, control the timing of the transistor drivers.

In the battery monitor circuit on the right, the current flowing into and out of a lithium battery bank is being measured via an ADC on a dedicated battery management IC. This is typically used to control the charging of the battery, which must be carried out following a very specific current profile. In addition, this same resistor can be used to measure total charge leaving the battery to provide a fuel gauge read-out to an upstream user interface.

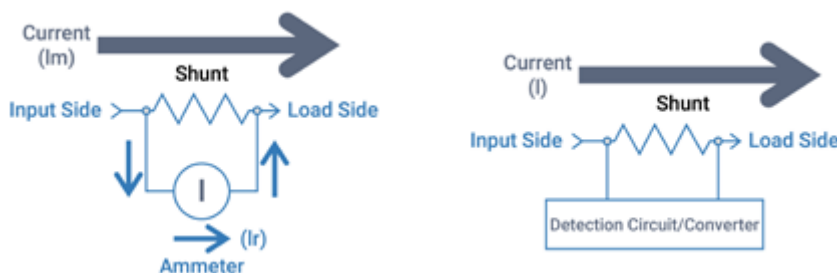


Figure 1: Shunt and series configurations for sense resistors

In both of these sense resistor topologies, it should be clear that the resistor will dissipate some amount of power in the form of heat. This power loss can be minimized by making the sense resistor as small as possible, the tradeoff being higher noise in the measurement circuitry. This balance

Sense Resistor Applications

Sense resistors are used in a myriad of applications ranging from low-current wearables to high-power electric vehicles. Regardless of the application however, the same general principles apply. The resistor must be sized to provide the appropriate magni-

Types of High-Power Sense Resistors

Sense resistors are manufactured in two different ways. The first is based on the traditional thick-film resistor structure shown below, where a resistive paste is screen

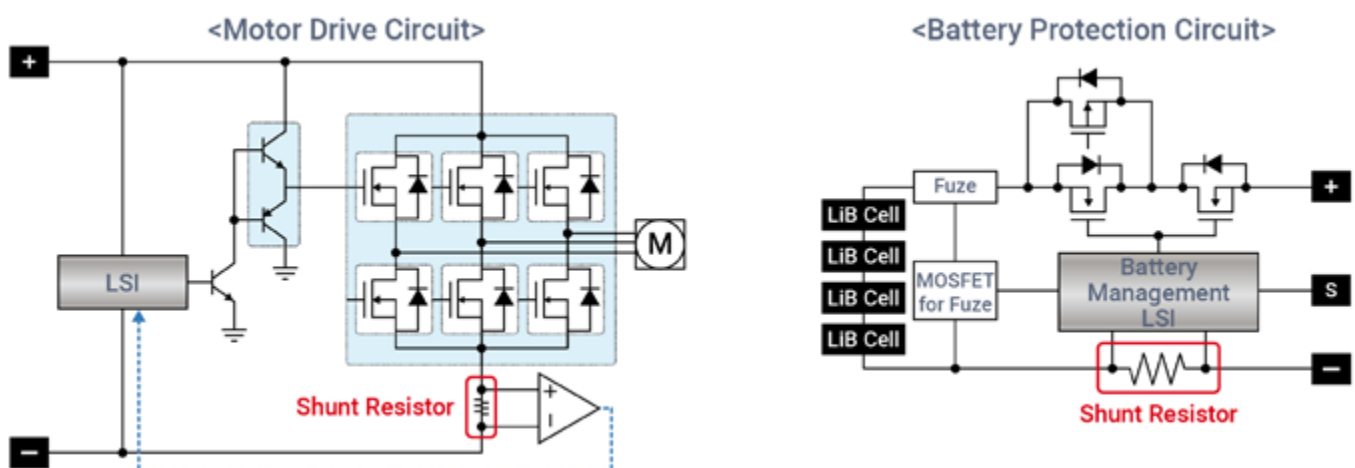


Figure 2: Shunt resistors for motor drive and battery monitoring applications

printed onto a ceramic substrate. After firing, the resistive area is laser trimmed to a specific value, and then coated and contacted to achieve the final surface mount device as shown in Figure 3.

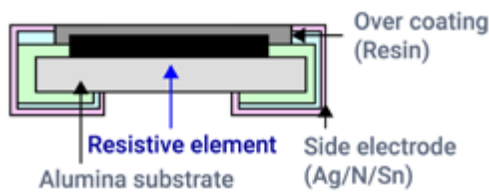


Figure 3: Thick film resistor construction

The second method utilizes a metal alloy as the resistive structure which is welded directly to the contact electrodes. The alloy formula is critical to determining the resistance and its thermal characteristics. This offers excellent power and thermal performance, but can be more costly to construct. An example is shown in the figure 4.

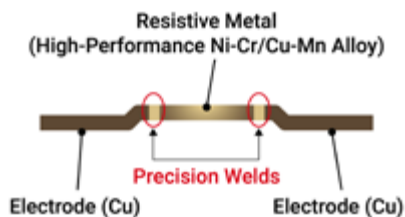


Figure 4: Metal plate resistor structure

In addition to the fundamental structure, sense resistors come in a variety of packages for different applications. As shown in the figure below, traditional top mount packages provide the lowest cost option but also exhibit the lowest power rating. Rear mount packages create a direct thermal contact between the resistive element and the underlying PCB to provide enhanced thermal performance. Finally, wide terminal devices use a reverse aspect ratio for maximizing the surface area of the terminals. Since the terminals provide an excellent path for heat transfer, these devices offer the highest power ratings of any sense resistor.

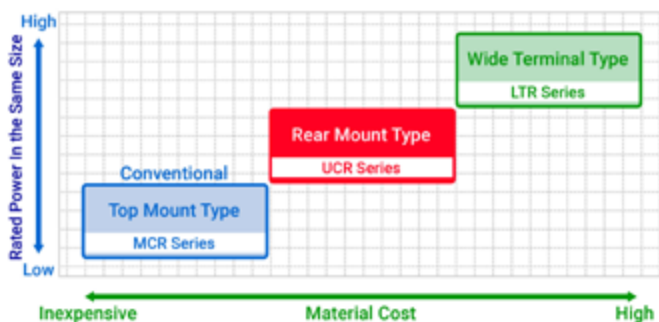


Figure 5: Tradeoff of mounting and terminal styles between cost and power rating

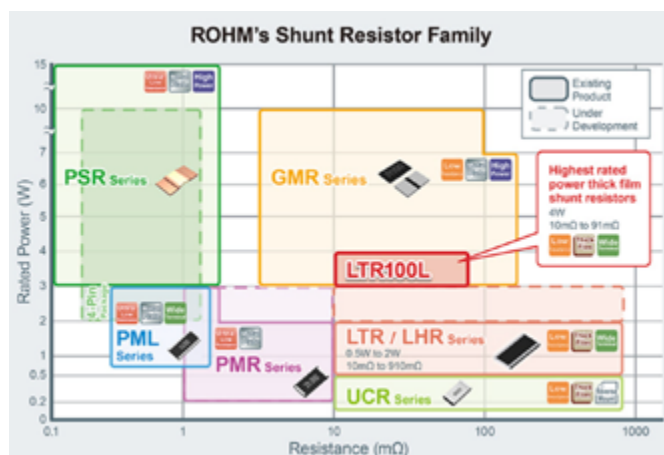


Figure 6: ROHM's shunt resistor product family

ROHM's High-Power Lineup

When considering the performance variables of rated power and resistance, ROHM offers a wide selection of devices to fit virtually any application need. Shown in the figure below are the various families of ROHM shunt resistors along with their performance envelope.

For metal alloy shunt resistors, ROHM's lineup can be segmented into the PS, GM, and PM series. The PS is focused on high-current, ultra-low ohmic resistors in the range of 0.1 to 2 milliohms. The GMR is geared toward a larger range of resistance, from about 3 to 200 milliohms, and offers excellent temperature characteristics. The PM series spans the largest resistance range and is a general purpose design for lower power applications.

For thick film shunt resistors, ROHM offers the LTR100L, LTR/LHR, and the UCR series of devices. LTR resistors are low power devices between 1 and 4 watts featuring excellent temperature characteristics. The LTR/LHR series enhance temperature characteristics even further while still targeting the low power application space. And the UCR devices are general purpose for sub-2W designs.

ROHM has developed and deployed a host of novel structures and design techniques to create devices that vastly outperform their competitors. One example is the thermal performance of the GMR series resistors, which incorporate a proprietary contact structure and a unique alloy for excellent temperature coefficients. When compared to an equivalent competitor, the ROHM device exhibits 57% lower surface temperature at 3W of power dissipation. This directly translates to space savings and cost reduction as a lower temperature derating can be applied at the design phase.

Similarly, ROHM has developed special packaging techniques such as wide-terminal and face-down assembly. Wide terminal devices, as shown in the figure below, create an improved thermal path for contact heat dissipation into the surrounding traces. This allows for higher power ratings and improved derating curves for temperature.

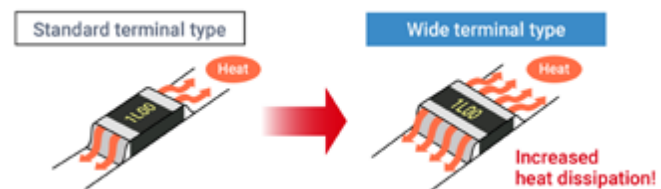


Figure 7: Wide terminal style packages deliver improved thermal performance

Conclusion

Sense resistors are commonplace circuit elements used for monitoring current in numerous electronic devices. ROHM has developed materials, structures, and packaging techniques to create families of sense resistors for any application, from low-power general purpose designs to high-current high-precision configurations. Considering total power, total resistance, and temperature coefficient, one can choose between thick-film and metal topologies. Within each of these families, aspect ratio and package structure can be optimized to minimize total cost and board area while maximizing performance. To learn more, visit: <https://www.rohm.com/products/resistors/current-detection-resistors>

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