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Metal Alloy Resistors Offer Robustness And Other Benefits For Current Sensing

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For current-sensing applications, metal alloy resistors provide a more robust technology than thin film and thick film devices. This is due to the large current-carrying mass of their bulk alloy, which provides higher surge capability. Although metal alloy resistors have been around for decades, their capabilities have evolved so that they now offer higher power ratings, and/or extended resistance ranges.

Some also feature Kelvin connections for increased accuracy. One product series, Vishay's Power Metal Strip resistors, feature the Kelvin connection in combination with the ability to operate at very high temperature (275°C) and very tight tolerance (0.1%).

This article begins by reviewing the characteristics of the two main resistor technologies available for current sensing applications—thick film and metal alloy. It describes the specific features and benefits of Vishay's Power Metal Strip series, including the Kelvin connection, its stability at high temperature, and the thermal advantages associated with the resistors' elevated construction, low thermal EMF, and reduced CTE mismatch with standard FR4 pc board material.

Resistor Technologies

The two main resistor technologies used in current-sensing applications are thick film and metal alloy. Among the tradeoffs to be made in choosing between these two options is the level of robustness. There's another resistor technology—thin film—which generally is not used for current sensing. But understanding thin film characteristics provides further perspective on the thick film and metal alloy options, so we'll include it here in this discussion, which starts by examining the least robust technology and progresses through to the most robust technology.

Thin Film Resistors

These devices are not typically used for current-sense applications, but are included in this discussion to provide breadth to the topic. Generally, these resistive products are intended for precision applications due to their resistive layer, which ranges from 0.0000012 in. to 0.000004 in. thick. They are quite surge-tolerant in the appropriate application, but are not designed for the high currents typically associated with the applications mentioned in this article.

Thick Film Resistors

Thick film devices are typically 0.0005 in. to 0.002 in. thick, which is nearly 100 times that of thin film. The increased thickness equates to a greater mass that is better able to carry relatively high currents and dissipate the heat across the substrate, in addition to managing transients. Another advantage of thick film products is their flexibility; standard resistance values are available across a wide resistance range because of laser trimming and film composition. A tradeoff for thick film vs. thin film is that thick film is not capable of the very tight tolerances of thin film products.

Metal Alloy Resistors

Metal alloy has the greatest surge capability because of its large current-carrying mass. It is available in resistance values as low as 0.000005 Ω with low TCR, and is the best choice for high-current power supplies or where fault conditions can result in extreme currents. These products do not have as wide of a resistance range as thick film resistors, because the resistor alloy has limited resistivity and minimum alloy thickness to reach high range values.

Power Metal Strip Resistors Features and Benefits

Four-Terminal Or Kelvin Construction

High-current applications require very low resistance values to minimize power loss, while providing an appropriate voltage signal high enough to exceed the noise floor. The low ohmic values, typically <25 mΩ, oftentimes benefit from a four-terminal device that reduces measurement errors by separating the current flow from the voltage-sense locations (Fig. 1.) This reduces two types of errors: contact resistance as the part is mounted to the board, and the high temperature coefficient effects from the amount of in-circuit copper (3900 ppm/°C).

WSK0612	WSK2512	WSL3637	WSL2726	WSL4026
Kelvin-terminated wide-side terminal	Kelvin-terminated standard terminal	Kelvin-terminated wide-side terminal	Kelvin-terminated elevated construction	Kelvin-terminated elevated construction

Fig. 1. Examples of metal alloy resistors with four-terminal construction.

Four-terminal/Kelvin devices use a connection layout as illustrated by the WSL3637 and WSK2512 below in Fig. 2, where the smallest portion of the terminal (E1 and E2) is used for the voltage-signal measurement, while the large portion of the terminal (I1 and I2) is used for carrying current.

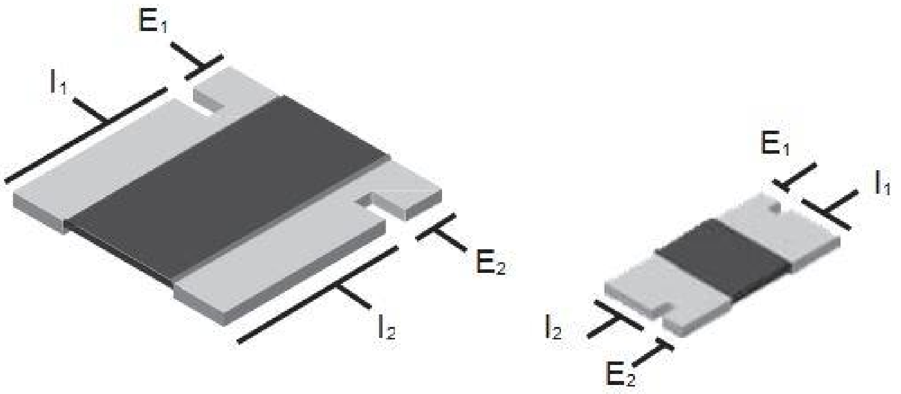

Fig. 2. E_1 and E_2 voltage connections and I_1 and I_2 current connections for the WSL3637 and WSK2512.

High Temperature

Hall effect and transistor current-sense measurements can be adversely affected by high temperatures that introduce non-linear measurement errors and compromise long-term measurement stability. Increased temperature can also affect active devices by increasing the availability of charge carriers, whereas a resistor solution is entirely based on fixed metallurgical properties.

Vishay Dale resistors use proprietary manufacturing processes that deliver products capable of long-term stable operation at temperatures up to 275°C (Fig. 3.) The high-temperature capability also enables a design to function at higher rated power for the same temperature than devices from other resistor manufacturers or comparable products with a similar design.

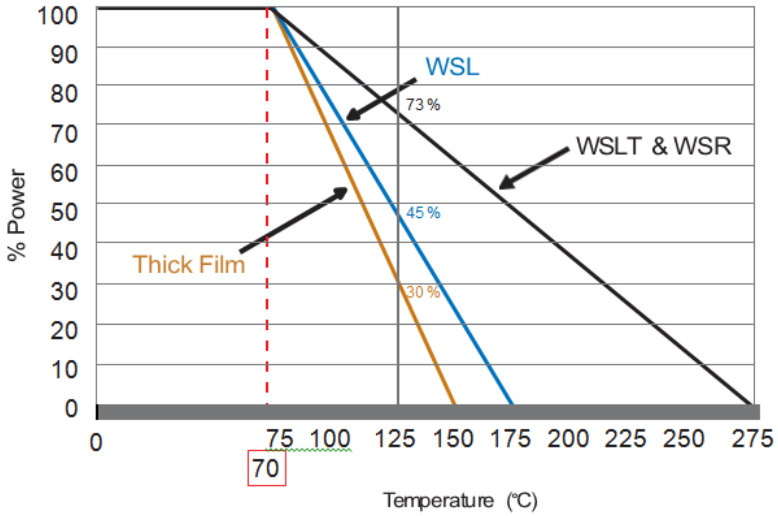

Fig. 3. Power Metal Strip high-temperature capability.

Thermal Performance

There are three key advantages of the Power Metal Strip resistor construction when it comes to thermal performance.

Degradation of the PCB material. Standard FR4 PCB material is only rated to 130°C; a typical power resistor that is against the board could cause damage to the material during power excursions or reduce the upper temperature performance of the circuit. A current-sense resistor with an elevated construction, such as the WSL2726 or WSL4026, prevents damage to the circuit material and can permit the solder joint to run cooler. The WSL offers a low profile, but still provides the board clearance to protect the PCB from hot spot exposure, as shown in Fig. 4.

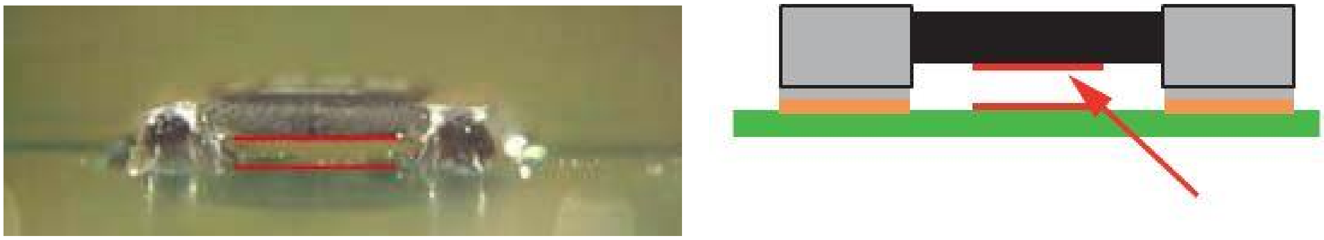

Fig. 4.Photo and diagram of resistor showing elevated construction.

The elevated design of the WSL2726 (see Fig 5.) and WSL4026 is unique among current-sense resistors because it protects the circuit board from direct exposure to the high temperatures of hot spots and places the hot spot in the available airstream, which dissipates the maximum amount of heat energy to the air instead of the PCB.

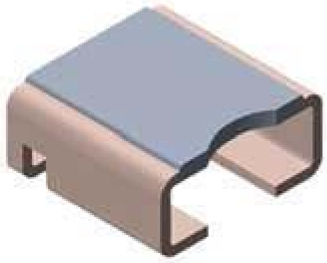

Fig. 5. The elevated design of the WSL2726 exposes the hot spot of the resistor to the available airflow.

Deterioration in performance of nearby power or semiconductor components. A portion of the heat will be dissipated to the air instead of the PCB, which can positively affect the performance of nearby heat-affected devices. These effects may include lifetime rating, power handling, LED luminous output lifetime, and accuracy; or more simply put, reliability.

Additionally, the low thermal EMF (< 3 µV/°C) of Power Metal Strip resistors assures that nearby power-/heat-generating components will minimize potential errors that can be introduced from thermal gradients across the resistor. Standard thick film resistors have a typical thermal EMF of 40 µV/°C to 50 µV/°C, and when multiplied by a 100°C temperature increase can introduce as much as 5 mV of error, which could exceed allowable measurement circuit error limits.

Coefficient of thermal expansion (CTE) mismatch. The all-metal welded construction of the Power Metal Strip series—in addition to a greater ability to flex due to its elevated design—minimizes solder joint stress that is a result of the CTE mismatch between the resistor and the circuit board. The cyclic stresses that result from the CTE mismatch due to a lifetime of thermal cycling can lead to fatigue stress cracks in the solder joint that can compromise long-term reliability.

The mismatch is a result of the FR4 circuit board material having a CTE of approximately 18 ppm/°C, while ceramic has a CTE of 5 ppm/°C, which is more rigid and less able to expand with the circuit board material. The Power Metal Strip construction provides a CTE of approximately 13 ppm/°C, which is more compatible with the 18 ppm/°C CTE of the FR4 material and therefore significantly reduces stress due CTE mismatch providing long-term reliability to your design.

Fig. 6 illustrates how the forces on each part are dissipated as a result of differences in the CTE between the current sense resistor and the circuit board material for the case where the resistor is a thick-film type versus a metal alloy resistor.

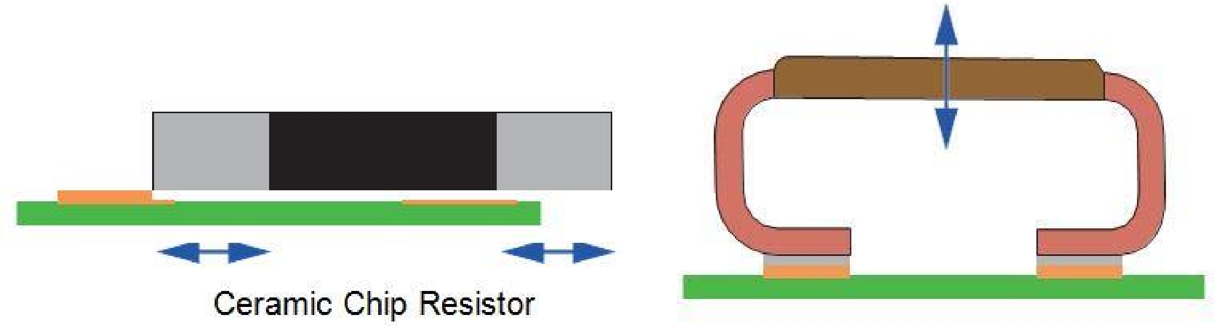

Fig. 6. Because of its construction, the elevated metal alloy resistor on the right experiences less stress with respect to its solder connections to the PCB than the thick film resistor shown at left.

Power Metal Strip metal alloy resistors offer a robust construction in a wide range of resistance values and configurations, and most are available with AEC-Q200 qualification. Devices in this family have been in production since 1993 and have provided long-term, reliable performance for many current sensing and protection applications for our automotive, medical, industrial, and military customers.

About The Author

Bryan Yarborough currently serves as a product marketing engineer for Vishay Intertechnology's Vishay Dale brand, specializing in surface-mount Power Metal Strip current-sense resistors. Previously, he has served as applications engineer at TT Electronics IRC and Saft Batteries. Yarborough holds a bachelor's of science degree in computer science and an MBA from Appalachian State University.

For further reading on current sensing, see the How2Power Design Guide, select the Advanced Search option, and enter "current sensing" in the keyword search.