Thermal Challenges When Using Resistors With Higher Power Ratings

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The electronics industry continues to push component suppliers for smaller sizes. In some cases, the smaller sizes come with economies of scale which allow for those sizes to be less expensive. In other cases, the size reduction is necessary to either downsize the product or to add functions or features to the device. In response, resistor manufacturers are offering common size resistors with higher power ratings. While it may seem easy to downsize a design by simply putting in a smaller size resistor of the same power rating, it is important to consider the thermal impact of this resistor size reduction.

2512 Chip Resistor Example

Chip resistor technology is evolving rapidly. Different materials used in the construction of the part will have a major impact on how quickly and efficiently the part deals with the thermal energy created by the part. The amount of heat that a particular resistor can dissipate is dependent on the specific heat of the element materials and is proportional to the mass of the material used. For example, metal alloy resistors, whether wirewound or low resistance alloys for current sensing, will have both better thermal conduction and more mass than similar sized resistors with film elements. These resistors typically have higher power ratings.

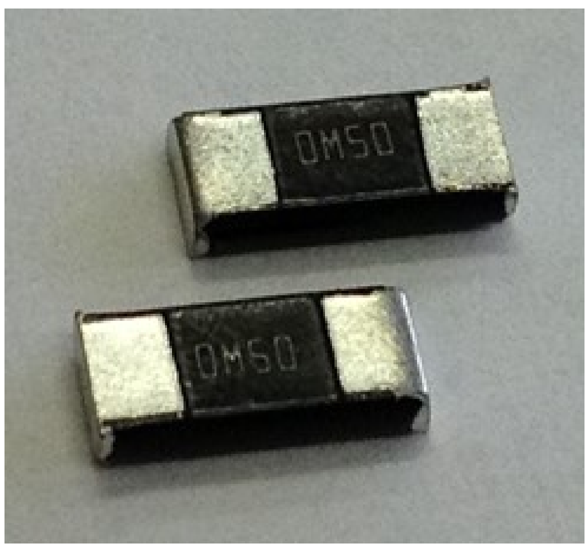

Fig. 1 2512 Size 50 Milliohm Chip Resistor

What is more interesting, however, is the recent improvements in rated power for chip resistors of a given size. If we assume a 2512 size chip resistor with a metal element, there are currently power rating options ranging from 1W to 3W. In some cases, manufacturers may add a heat sink to the body of the part or may increase the thickness of the material to better handle the increased heat. But in most cases the element, and the part itself are largely the same for the 1W part and the higher power rating versions. Given the earlier statement that the amount of heat a chip resistor can dissipate depends on the materials used, and the amount of materials present, the fact that essentially the same part can be rated at 1W and 3W seems illogical. The key factor to understand is how hot will the part get in the application and whether the part can withstand this level of heat.

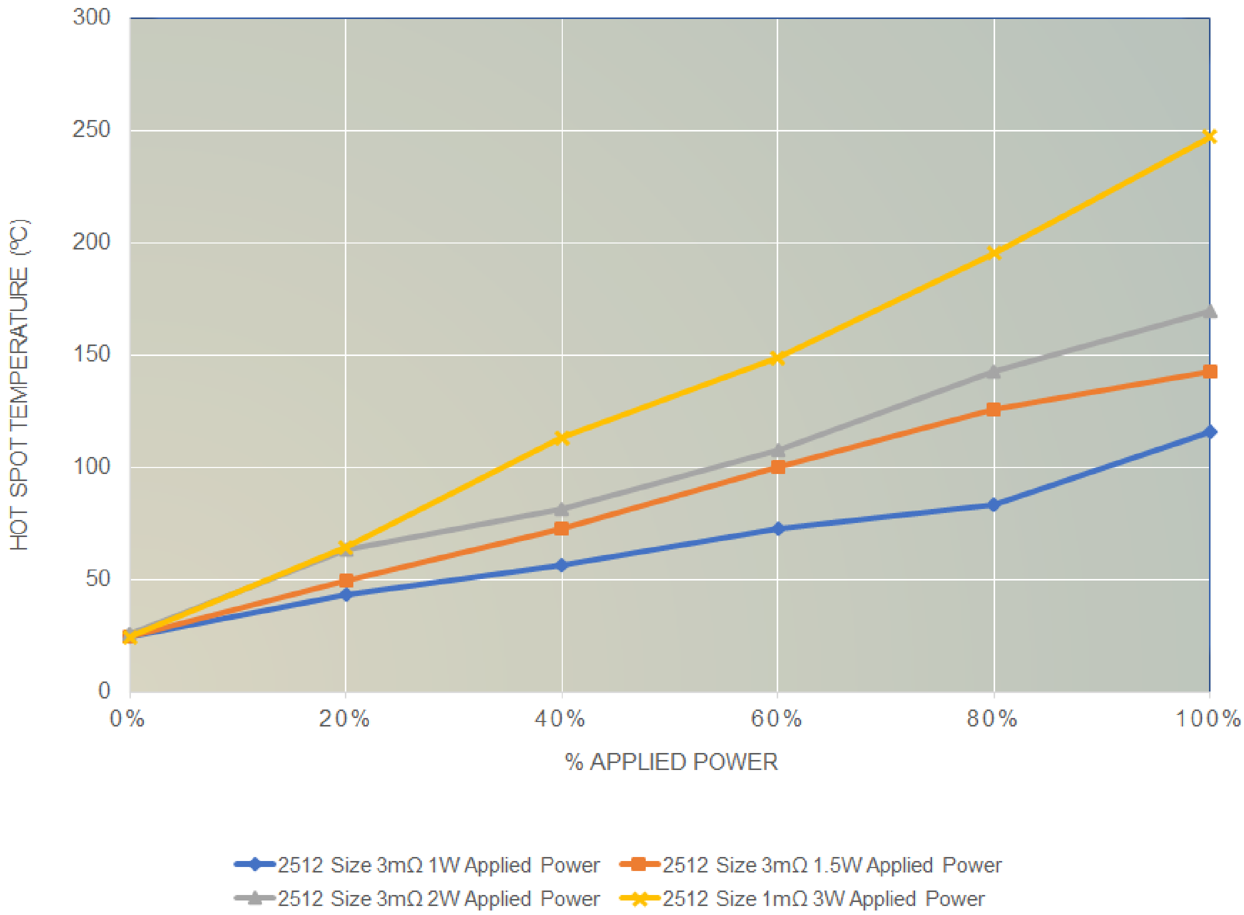

Fig. 2 2512 Size Chip Resistor Hot Spot Temps.

The above chart shows the hot spot temperature of a 2512 size all metal current sense resistor. 2512 size chip resistors, even under 1W of power will generate enough heat to create some PCB design and layout challenges. Most manufacturers recommend a hot spot / terminal temperature of between 105ºC and 125ºC depending on the element material. Film resistors will typically have recommended terminal temperatures at the lower end of the spectrum while metal element resistors such as shown here will typically have higher allowable part temperatures. At 1 watt, the resistor may see temperatures of 115ºC, which is acceptable for robust metal element sense resistors. However, the 1.5W, 2W, and 3W rated parts show hot spot temperatures well above 125ºC. This implies that to use these parts at the higher power ratings, thermal reduction techniques must be employed.

Thermal reduction strategies vary widely in cost and the effectiveness of each varies with application and surroundings. Air movement over a board from fans may be practical in some industrial machinery applications, but not in small consumer electronic devices. Other methods such as the use of larger solder pads, heavier copper weight, larger traces, vias through the PCB, and heat sinks may be used to lower the overall heat generated from high power chip resistors. Care must be taken so that surrounding components that either absorb (transformers or large inductors) or are adversely affected by heat (semiconductors with low heat tolerance) are sufficiently far away from resistors running at high power. For designs that require small footprints or downsizing, there may not be enough room to accomplish this. In this case more robust semiconductors may be used along with every possible heat reduction method possible.

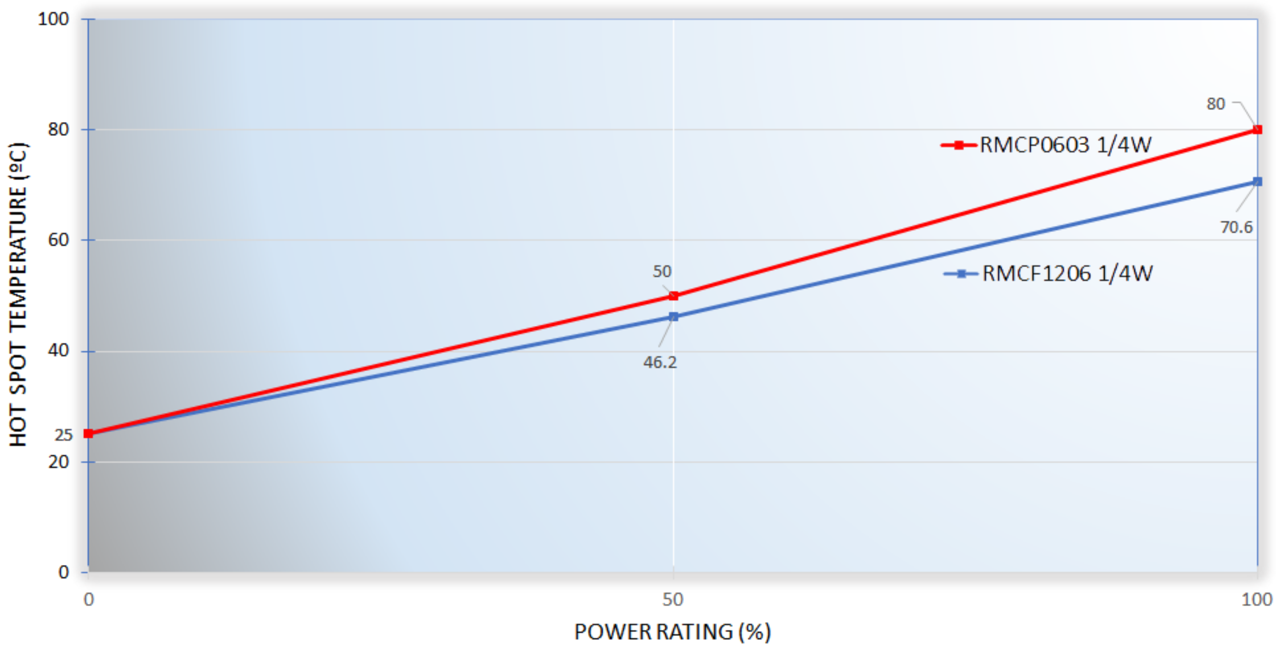

Fig. 3 Hot Spot Comparison Between 1/4W 1206 and 1/4W 0603 Sizes

Similar design considerations are required when using a downsized chip resistor to reduce the area of a circuit design. For thick film materials, if a ¼ watt power rating is required, a standard 1206 size chip may be used. However, high power 0603 size chip resistors are now readily available which reduce the overall size needed (including solder pads and traces) by 66% or more depending on manufacturer recommendations. While the significance of this size savings for a single part depends on the total circuit area and other factors such as trace routing, when multiple parts are replaced in this manner the size reduction can be dramatic.

A similar relationship holds for the heat increase with this size reduction. The chart in figure 3 shows the net increase in hot spot temperature to only be around 10ºC. However, if 5 such resistors are downsized, the aggregate thermal impact would typically be greater than 5 times the individual delta, especially if those resistors are placed near each other. The amount of heat generated by the individual parts is magnified by co-heating from neighboring resistors, as well as heat absorbing components such as large wound transformers or toroidal inductors. Depending on the board design, layout, and construction replacing multiple chip resistors with high power smaller versions can easily add 15 to 40 degrees of heat in addition to the added heat from the use of the smaller case size the circuit needs to deal with. For high density applications it may be impossible to deal with this kind of heat increase with any reasonable combination of heat reduction methods. For those high density applications, replacing many resistors with higher power chips in smaller case sizes simply isn't feasible.

Summary

Current trends in personal electronic devices continue to push for smaller and smaller component sizes to reduce overall circuit real estate. While smaller size components with higher power ratings are now readily available, considerations must be made so that the associated thermal increase can be accounted for and maintain the overall recommended hot spot temperatures for surface mount chip resistors of 105ºC to 125ºC. Maintaining this absolute maximum terminal temperature ensures stable operation and longer usable circuit lifetime.