Heat generation and temperature rise of chip resistors

§0 Overview

When current is applied to a resistor, the resistor heats up, and its temperature rises. The temperature of a surface-mount resistor is not primarily determined by the amount of power applied but varies depending on the heat dissipation capabilities of the environment absorbing the heat. In this Technical Note, we will explain the temperature rise resulting from the power applied to surface-mount resistors and the heat generated by it.

§1 Applied power and temperature rise in surface mount resistors

The rated power of a surface-mount resistor (hereinafter referred to as a “chip resistor”) is the maximum amount of power that can be continuously applied at the rated ambient temperature or rated terminal part temperature. The use of chip resistors began to spread in the 1980s, and recent years have seen a rapid increase in power ratings. In 2000, the rated power of 0805-inch-size (0805) chip resistors was 0.1 W, but currently the rated power is 0.25 W (2.5 times higher) for the RK73B series general-purpose chip resistors and 0.5 W (5 times higher) for the SG73P series high-rated power products. Our customers sometimes ask, “Since the rated power of the SG73P series is twice (0.5 W) that of the RK73B series, does this mean that the SG73P has better heat dissipation, and that the temperature rise is half that of the RK73B when the same power is applied?”
Figure 1 shows a graph of applied power and terminal part temperature rise when the 0805 size RK73B series general-purpose chip resistors and SG73P series high-rated power products are mounted on the same circuit board. The graph shows almost the same temperature rise. As you can see, even different chip resistors show the same temperature rise for the same applied power when mounted on the same printed-circuit-board(PCB) with the same heat dissipation capability.

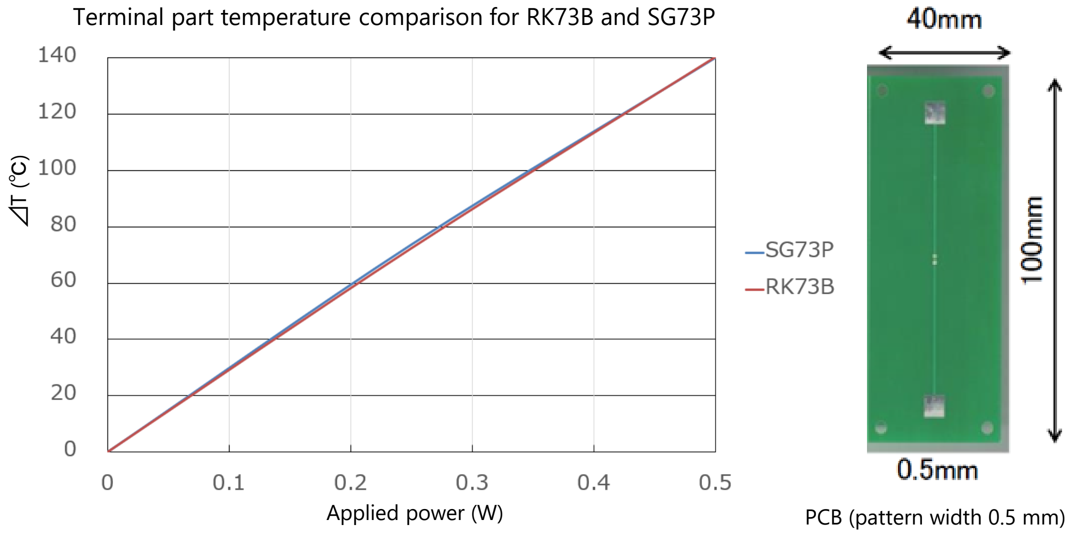

Figure 1 Applied power and temperature rise

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In both cases, the temperature rise is proportional to the applied power. This indicates that when applying the individual rated power to a part on a PCB with the same heat dissipation capability, the temperature rise is greater in the SG73P series than in the RK73B series. In other words, high-rated power products require more consideration for heat dissipation, so care must be taken.
Even for resistors made by different manufacturers, if the same power is applied, the temperature rise will be the same. Note that the 0805 size RK73B has a power rating of 0.25 W, but it was overloaded for the experiment. This experiment does not guarantee the same performance when overloaded.

§2 Heat generation and temperature rise

Our customers sometimes ask, "What is the terminal part temperature when the rated power is applied?" The terminal part temperature varies depending on the conditions of the PCB, even when the same power is applied. We will explain the relationship between power and heat generation and between heat generation and temperature rise.

2.1 Power and heat generation

The unit of power for chip resistors is the watt (W). In electrical engineering, this represents how fast electrical energy is applied to the resistor as the product of voltage (V) and current (A), where power (W) = voltage (V) × current (A). The generation rate of heat can also be measured in watts. Since a resistor is a component that converts electrical energy into heat, the electrical power applied to the resistor is equal to the generation rate of heat energy. In other words, even for different types and shapes of resistors, if the applied power is the same, the rate of heat generation will be the same. When power is applied continuously to a resistor, the resistor continues to generate heat during that time, so there is a need for the heat to dissipate. For a given heat generation rate, if the PCB has good heat dissipation capability, the resistor temperature rise will be low, but if the heat dissipation capability is poor, the temperature will rise, and it may cause ignition and other accidents. Heat generation density must also be taken into account for small electronic components. For a given applied power, the smaller the resistor, the higher the heat generation density, so local high temperature points are more likely to occur. Of the three types of heat dissipation (conduction, convection, and radiation), most of the heat generated by a chip resistor is dissipated to the PCB by conduction. This means that the heat dissipation capability of the PCB is a factor in determining the temperature of the chip resistor. (For more information, please see the heat dissipation destinations and heat dissipation ratio for resistors described in the technical note "Power Derating for Surface Mount Resistors").

2.2 Heat generation and temperature rise

The temperature of the chip resistor depends on the heat generation due to applied power and the heat dissipation capability of the heat dissipation destination. Using a PCB with different widths of copper foil patterning to change heat dissipation, the difference in the temperature rise of a chip resistor was measured using an infrared thermograph. Figure 2 shows information on the resistors used, the PCB, etc. Figure 3 shows the relationship between the pattern width and temperature rise.

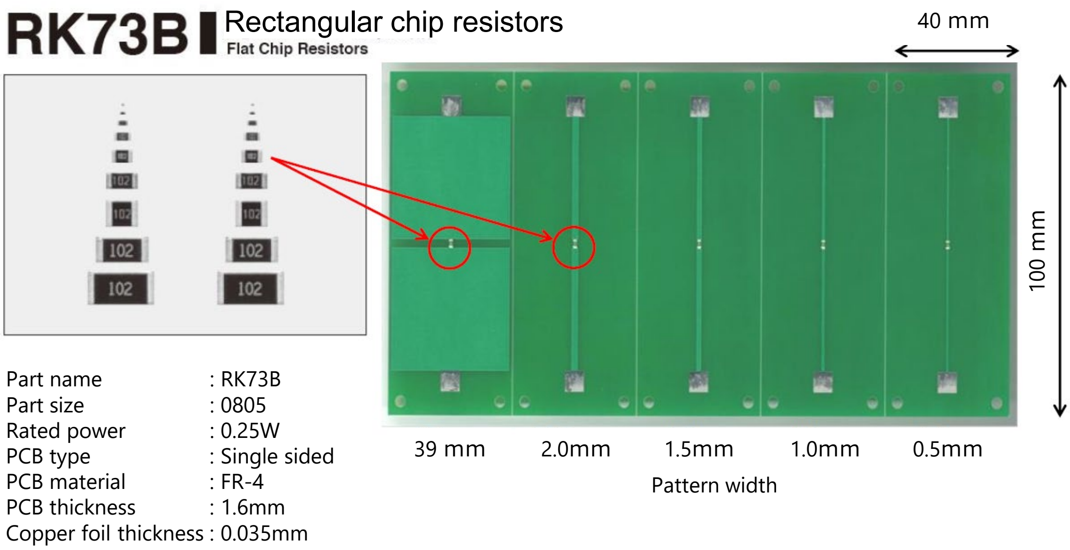

Figure 2 Information on PCB and resistors used

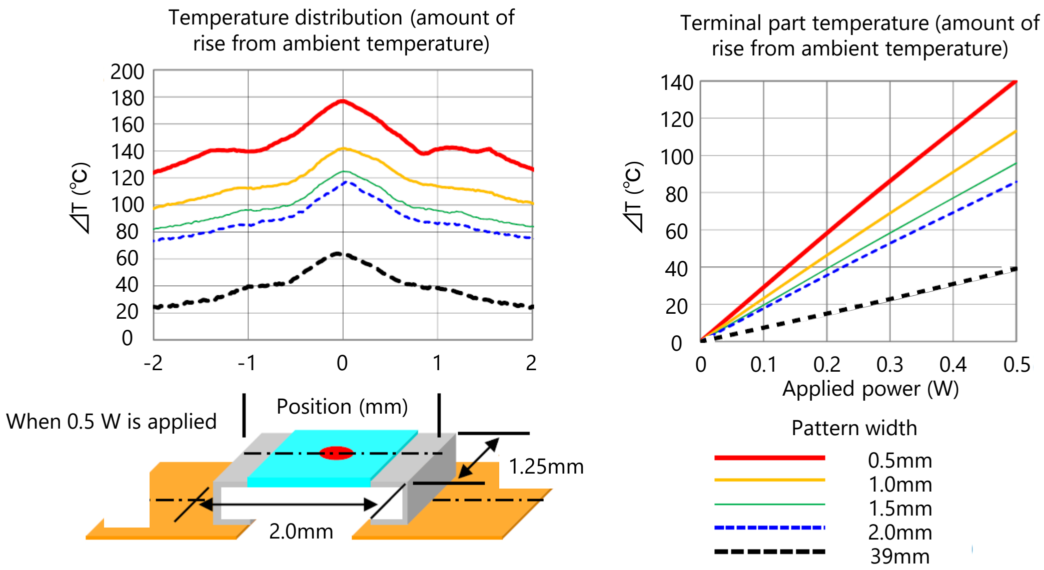

Figure 3 Relationship between pattern width and temperature rise

The graph on the right side of figure 3 shows the applied power and terminal part temperature rise. When using a pattern width of 0.5 mm, the temperature rise from ambient temperature is about 58°C when the applied power is 0.2 W, about 115°C when the applied power is 0.4 W, and about 140°C when the applied power is 0.5 W, indicating that power and temperature rise are proportional. From the same graph, we can understand that when the applied power is 0.25 W, the temperature rise from ambient temperature is about 70°C when the pattern width is 0.5 mm, about 50°C when the pattern width is 1.5 mm, and about 20°C when the pattern width is 39 mm, indicating that chip resistor temperature rise varies depending on the pattern width even at the same applied power. In other words, if the circuit board has a high heat dissipation capability, the temperature rise can be lowered even if the applied power is the same. Note that this size of RK73B has a power rating of 0.25 W, but it was overloaded for the experiment; long-term stability is not guaranteed above the power rating.

§3 Heat generation and temperature rise for high-rated power products

High-rated power chip resistors are designed to perform at their best by controlling the terminal part temperature through proper heat dissipation on a PCB with high heat dissipation capability, so the heat dissipation design must be taken into consideration. In particular, wide-terminal chip resistors such as the WK73R series are designed for terminal part temperature control. Figure 4 shows the temperature rise when 1 W of rated power is applied to the 0508 (0.05” x 0.08”) WK73R series without an appropriate heat dissipation design. In this case, the terminal part temperature was about 220℃, which exceeded the maximum operating temperature of the resistor. In addition, the heat resistance temperature of FR-4, a common PCB material, is generally listed as 120°C, and this temperature was also exceeded. Furthermore, the back surface of the PCB was burnt and discolored, and continued use in this condition could result in an accident.

Part name : WK73R series
Part size : 0508
Rated power : 1 W
PCB type : Single sided
PCB size : 60 x 60 mm
PCB material : FR-4
PCB thickness : 1.6 mm
Copper foil thickness : 0.035 mm

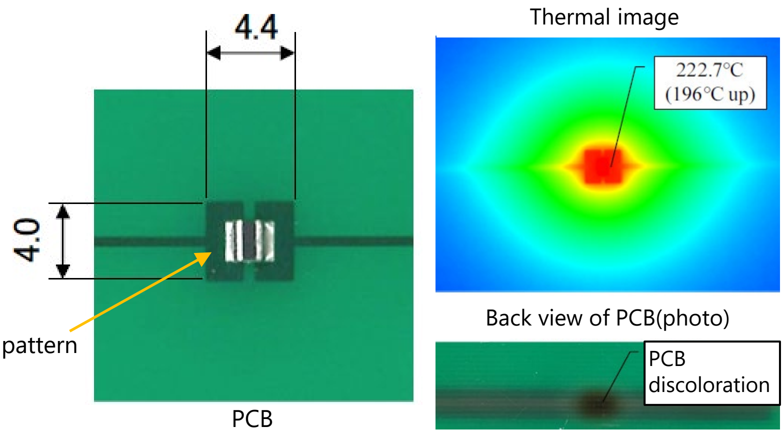

Figure 4 Temperature rise without appropriate heat dissipation design

Heat generation and temperature rise of chip resistors

Figure 5 shows an example of heat dissipation design for use with high-power resistors. One heat dissipation measure is the use of a multilayer circuit board (in this case, a 6-layer circuit board) and thermal vias, and the other is a heat dissipation measure in which heat from the same multilayer circuit board is dissipated into an aluminum housing through a thermal interface material (TIM) for a wall-mounted board. The circuit board size and copper foil pattern of the top surface of the 6-layer circuit board are the same as in figure 4, but for the other layers, the copper foil pattern part footprint is recreated, and a copper foil pattern separated from that part is arranged over the rest of the layer surface. In addition, eight 0.4 mm diameter thermal vias are arranged in the copper foil footprint pattern to connect all layers. An image of the copper foil pattern of the circuit board is shown in figure 5(a). The configuration of the circuit board connected to an aluminum housing through TIM is shown in figure 5(b).

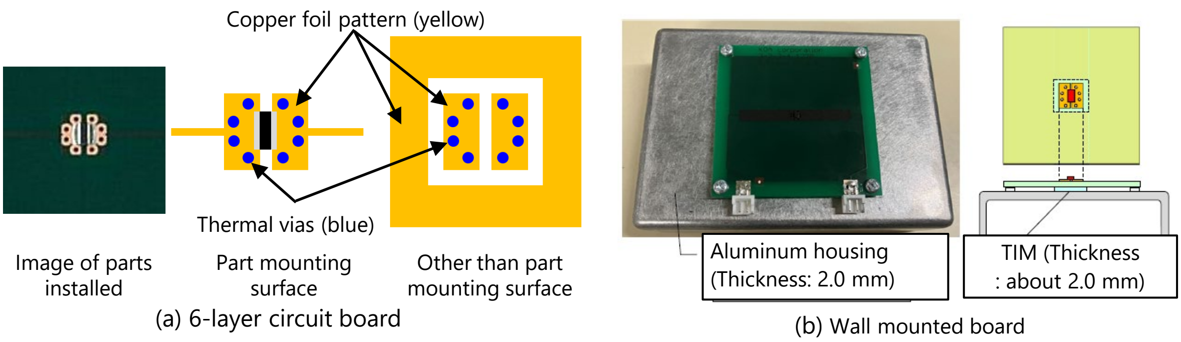

Figure 5 Example of heat dissipation design

Figure 6 shows the temperature rise when the heat dissipation design is used. The same power was applied as in figure 4, but the temperature rise was 84.6°C for the 6-layer circuit board and 45.3°C for the wall-mounted board. Compared to the temperature rise of approximately 200°C for the single sided circuit board, the temperature rise of each was considerably reduced. This shows that appropriate heat dissipation design is important when using high-rated power products.

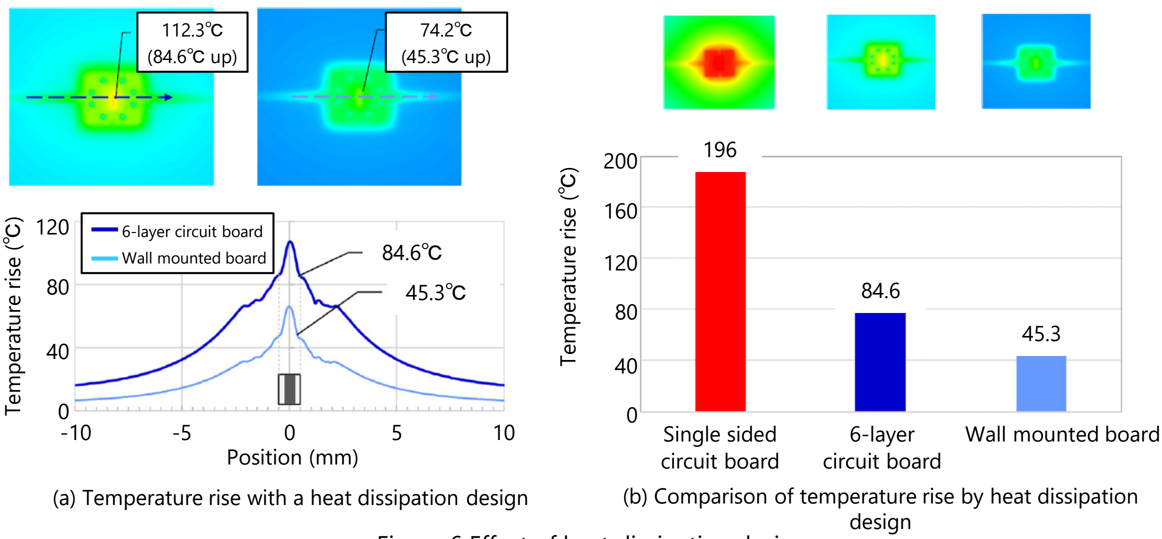

Figure 6 Effect of heat dissipation design

§4 Summary

Chip resistors generate heat according to the applied power, and the heat is dissipated through the terminals to the PCB. Since terminal part temperature varies depending on the heat dissipation capability of the PCB, it is important to control the terminal part temperature with appropriate heat dissipation design. Particular attention should be paid to high-rated power products, which are designed to perform through appropriate heat dissipation on a PCB with high heat dissipation capability. KOA provides various types of support, including videos on our website. Please feel free to contact us for inquiries.