Introduction of the Derating Curves Based on the Terminal Part Temperature

Background

Recently, the miniaturization, high power density and high temperature of the usage environment for the automotive devices have advanced. And requests for resistors to conform the high temperature is increasing. Figure 1 is the derating curve based on the terminal part temperature and this is introduced to realize these requests for the surface mount resistors safely. Rated terminal part temperature is the maximum terminal part temperature of the surface mount resistor at which the rated power may be applied continuously including the temperature rise by self heat generation.

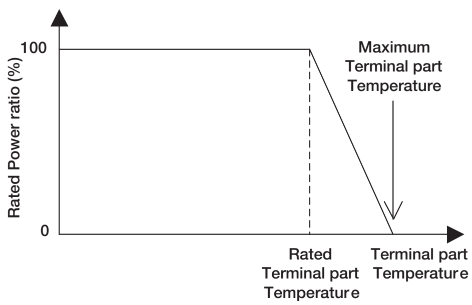


Figure 1. Derating curve based on the terminal part temperature

The derating curves based on the terminal part temperature is already used in the metal plate type ultra-low resistance value resistors for current sensing. It is because these resistors are used in sensing of large currents such as inverters and converters which the terminal part temperature rise irrelevantly from the ambient temperature because of the generated heat from the nearby switching elements or the large current applied to the copper pattern. This point of view was deployed to the general resistors as well.

Overview of the Establishment of the Derating Curves Based on Ambient Temperature

The traditional derating curve, which is based on ambient temperature, was defined by IEC and JIS during the vacuum tube era, long before the appearance of surface-mount resistors. At the time, there were no printed circuit boards, and cylindrical resistors with lead wires were held above the board by lug terminals, as shown in figure 2.

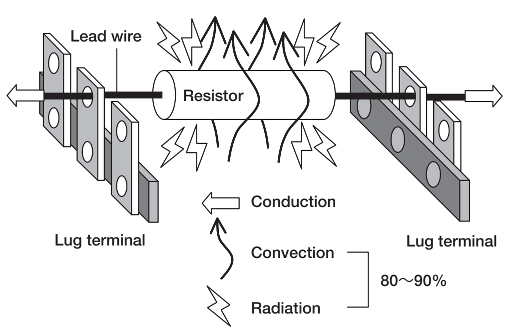


Figure 2. Heat dissipation of cylindrical resistors

The Joule heat that is generated in the resistor is dissipated in three pathways regardless of the shape of the resistor. The first path is conduction to the connected parts such as the terminal. The second path is convection including the heat transfer to the atmosphere by natural convection and airflow. The third path is radiation by infrared.

The larger the area connected to the resistor becomes, the larger the heat conduction will be. And the larger the surface area of the resistor becomes, larger the convection and radiation will be.

When cylindrical resistors with lead wires are mounted on lug terminals, the lead wire is long and thin, so the thermal resistance to conduction is high, and heat dissipation through that path is low. On the other hand, the dissipation of heat by convection and radiation is high, because the surface area of the resistor is large. Simulation shows that 80% to 90% of the heat from a cylindrical, lead-wire resistor is dissipated directly into the ambient air. The temperature of the resistor can be calculated by adding the temperature rise caused by self-heating to the ambient temperature. Because the ambient is sufficient to estimate the thermal resistance for most of the heat dissipation, the traditional derating curve was based on it.

Heat Dissipation of Surface Mount Resistors

Figure 3 shows the main heat dissipation paths for modern surface mount resistors. This type of resistor has only a small surface area, so convection and radiation have proportionally less heat dissipation. On the other hand, since the device is directly connected to the PCB pattern by a large part of the surface area, conduction will be the primary path for heat dissipation. In general, conduction through the terminal to the board represents over 90% of the heat dissipation, even when convection and radiation are presumed to be at their maximum levels. Therefore, the terminal temperature, on the main heat pathway, is the best location to monitor for controlling power dissipation.

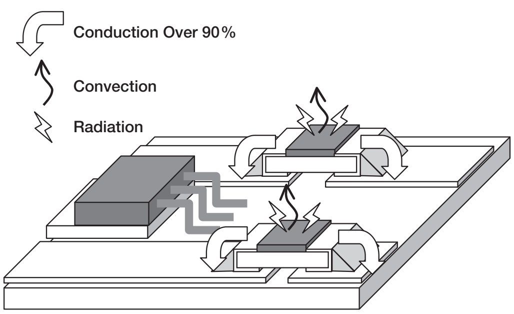


Figure 3. Heat dissipation of surface mount resistors

Derating Curve Suitable for the Surface Mount Resistor

As shown in figure 4, when a given amount of power is applied to the resistor, any given point on the resistor's surface will have the same temperature rise over the terminal temperature, regardless of ambient temperature. This is because there is very little heat dissipation from the resistor's surface to the ambient air.

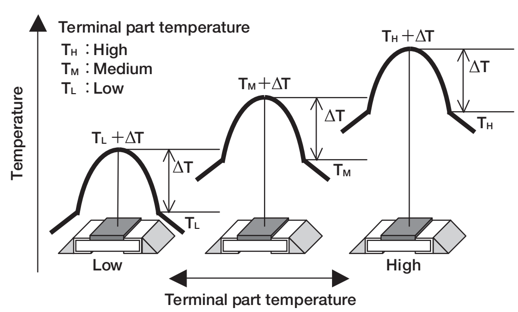


Figure 4. Contributing factor to the temperature of the surface mount resistor

However, surface temperatures at a given power will differ between different PCB designs, since the terminal temperature will be different. When resistors are mounted close to each other or other heat-generating devices, as shown in figure 5, there is a possibility that the temperature will be higher than the 70°C ambient temperature threshold used in the traditional JIS/IEC derating curve.

The traditional derating curve based on ambient temperature usually uses 70°C as the ambient temperature above which parts are to be derated. There will be no problem if resistors are used with sufficient electrical and thermal margin, but recent trends to miniaturization, high power density, and high-temperature use have reduced margins on design.

Redefining derating based on terminal temperature is a way to better represent the capabilities of the part. KOA will provide a derating curve suitable for surface mount resistors, based on testing under conditions where power rating is defined in terms of terminal temperature (as seen in terms & definitions).

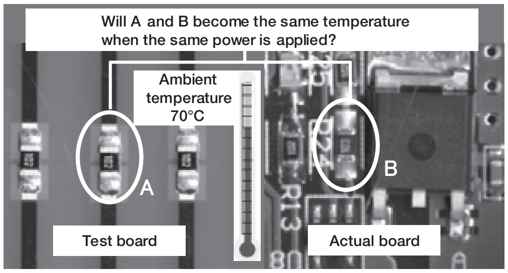


Figure 5. Temperature differs depending on the board

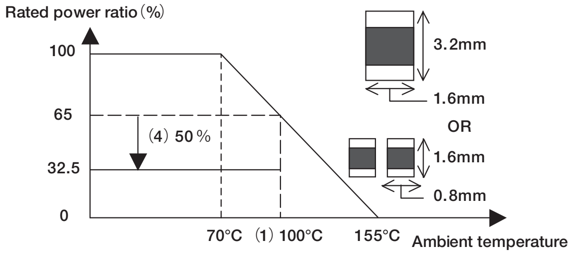
How to Use the Derating Curve Based on the Terminal Part Temperature

Here are some examples on using terminal temperature derating that lead to greater factors of safety, reduction in number of resistors, or use of a smaller component. The prior conditions will be the following (Be aware that the terminal part temperature does not always become 120°C when the ambient temperature is 100°C):

(1) Ambient temperature of the board: 100°C

(2) Terminal temperature of the surface mount resistor: 120°C

(3) Actual power load: 0.05W



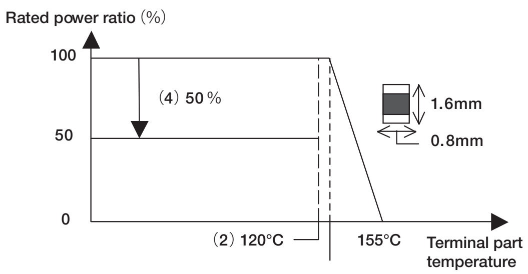
Necessary rated power= (3) 0.05/0.325=0.154W
1 piece of 2A (2012mm rated power 0.25W)
2 pieces of 1E size (1005mm rated power 0.1W)

Figure 6. Selection by the traditional derating curve

(4) Required margin of safety below rating according to designer's internal guidelines: 50%

The required power rating for the resistor using the ambient-temperature derating curve is calculated from conditions (1), (3), and (4). Figure 6 shows this result. For KOA's RK73B resistor series, one piece of 2A size, or two pieces of 1W size will be required.

However, when a resistor is selected using the terminal-temperature derating curve, which is better suited to surface-mount parts, conditions (2), (3), and (4) show that a single 1E (0402) size RK73B resistor would be sufficient.



100% until terminal part temperature is 125°C

Necessary rated power= (3) 0.05/0.5=0.1W
1 piece of 1E size (1005mm) rated power 0.1W

Figure 7. Selection using a terminal-temperature derating curve

As seen above, the number of resistors and the mounting area can be reasonably reduced by using the proper derating curve based on terminal temperature, and this will lead to cost savings.

Type	Power Rating	Rated Ambient Temp.	Rated Terminal Part Temp.
SG73S 2A	0.25W	70°C	125°C
SG73P 2A	0.5W	70°C	100°C

Table 1. Rating column of products with 2 rated power

Derating curve suitable for the surface mount resistor

As shown in Table 1, for the surface mount resistors, there are products that have 2 rated powers for the same type in the rating column. The high rated power is basically available and applicable only to boards with adequate heat dissipation design for example multilayer boards, DCB (direct copper bonding) boards and single layer boards with wide heat dissipation area land. Therefore, the horizontal axis of the derating curve for high rated power is only defined with the terminal part temperature and please be careful that the conventional derating curve defined by the ambient temperature cannot be used in this case. For these products, "-" will be shown in the rated ambient temperature column which means "Not Applicable."

In addition, we implement load life tests for the products with high rated power by using a test board that can specially control the terminal part temperature.

In the case of Table 1, there will be 3 derating curves as shown from Figure 8 to Figure 10.

How to use each derating curve is shown as the following.

When 0.25W is the rated power

When the terminal part temperature can be measured:

The derating curve in Figure 8 can be applicable and it can be used with rated power 0.25W up to terminal part temperature 125°C. The derating curve with the horizontal axis based on the terminal part temperature supersedes the conventional derating curve with the horizontal axis based on the ambient temperature. Therefore, even when the ambient temperature exceeds 100°C, it can be used with rated power 0.25W as long as the terminal part temperature is below 125°C.

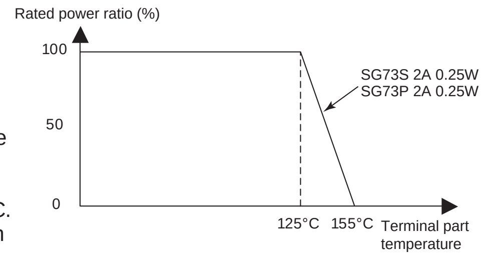


Figure 8. Derating curve of 0.25W rated power based on terminal part temperature

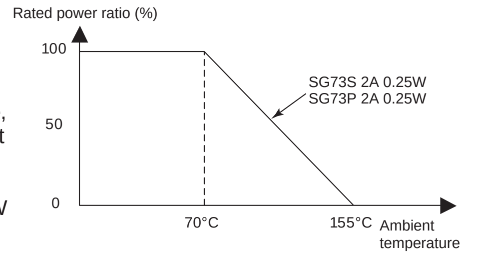


Figure 9. Derating curve of 0.25W rated power based on ambient temperature

When the terminal part temperature is not measured and only the ambient temperature is measured:

The product may be used by derating the load power from the ambient temperature 70°C according to the conventional derating curve shown in Figure 9. However, as mentioned in the past descriptions, the temperature of the resistor differs according to the wiring patterns and heat generating components nearby, even when the ambient temperature is the same, so it is not a derating method with good precision.

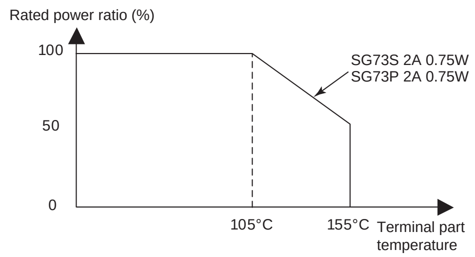


Figure 10. Derating curve of 0.75W rated power based on terminal part temperature

When 0.75W is the rated power

Managing the terminal part temperature is the requirement to apply the rated power 0.75W. Only the derating curve with the horizontal axis based on the terminal part temperature as shown in Fig.10 can be used but it can assure up to the high power. The product can be used with 0.75W if the terminal part temperature is below 105°C.

Reference: IEC TR 63091:2017 "Study for the derating curve of surface mount fixed resistors-derating curves based on the thermal part temperature."