

### Precautions

All product specifications and data are subject to change without prior notice. Be sure to request and confirm the latest technical specifications before you order or use a part.

*The following precautions apply to all products*

#### General

- In general, refer to the EIAJ RCR-1001A safety application guide for electronic parts, which is issue by JEITA

#### Application

- Confirm application parameters before the use of products, and please contact KOA in advance when products are to be used in critical, high-reliability equipment such as transportation (automobiles, airplanes, trains, boats, and ships), medical equipment, space equipment, energy, traffic, and information facilities. Unless the particular conditions and scope of liability is defined in mutually accepted contract documents, KOA will not be liable for issues arising from design or use in these applications.
- Consider sufficient fail-safe design if the products are used in high-reliability applications. Ensure the safety of the whole system by using proactive and redundant circuits to avoid unsafe operation due to a single product failure.

#### Environment for Use

- Unless otherwise specified, these products are not to be used in special environments. Examine and confirm performance and reliability before you use KOA products in any of the following environments:
  1. Under direct sunlight, exposed to the outside or to dust.
  2. In liquids such as water, oil, organic solvent, or liquid chemicals or in areas where these liquids are used.
  3. In locations where the products are exposed to salt-water breezes or corrosive gases, including SO<sub>2</sub>, H<sub>2</sub>S, Cl<sub>2</sub>, NH<sub>3</sub>, NO<sub>2</sub>, etc.
  4. In locations with high static electricity and strong electromagnetic waves.
  5. In locations subject to condensation from dew.
  6. When the products or PCBs are sealed and coated by resin or other coating materials.
  7. In locations where the products are exposed to the fumes of lubricating oil.

#### Sulfuration

- Products with silver-based electrodes may increase in resistance in atmospheres containing sulfur gases (H<sub>2</sub>S, SO<sub>2</sub>, etc.) or when exposed to sulfide compounds. Take anti-sulfur measures in these environments.

#### Anti-pulse Characteristics

- If transient overloads such as power pulse or voltage/current surges are applied to KOA products, performance and reliability may be degraded. Contact KOA for data on antipulse characteristics and design help.
- Pay attention to discharges between terminations (arc-over) when high voltages are applied.

#### Storage

- Store KOA products in dust-free areas and keep them away from extreme temperatures; moisture; condensation; direct sunlight; salt-water breezes; corrosive gases such as SO<sub>2</sub>, H<sub>2</sub>S, Cl<sub>2</sub>, NH<sub>3</sub>, NO<sub>2</sub>, etc.; or fumes from lubricating oil. Use desiccants if necessary.
- Please contact KOA for conditions and length of storage.

#### Storage of the Products with Lead-free Termination

- Solderability may degrade faster for products with Pb-free terminals than for products with Pb-bearing terminals.

#### Mounting

- Avoid physical damage or shock to the products, which may happen by holding them with hard tools like pliers or tweezers or by imperfect mounting-machine alignment. This damage may affect electrical characteristics or lead to disconnection or cracking.
- If the bottom point of the mounting nozzle is too low, a product could be pushed onto the PCB, which may deteriorate electrical characteristics or lead to cracking. Decelerate the nozzle just before mounting, and mount the product after correcting PCB deformations.
- Do not use products that have fallen during mounting or that have already been removed from a PCB.
- Contact KOA if PCBs are molded or sealed by coating material after component mounting.
- Do not stack PCBs after mounting, because this may damage the components.
- The electrical characteristics of film-type resistors and sensors may be changed by electrostatic overvoltage. Keep electrostatic discharge away from components when assembling and handling by monitoring machines and human contact.
- Prevent or eliminate the introduction of ionic substances like salt, salinity, or sweat, as these substances may degrade resistance due to moisture or corrosion.

#### Soldering

- Perform soldering within the temperature, time, and number of cycles specified for the product or its precautions. If a product is exposed to high temperatures for long periods of time, its color or electrical characteristics may change or disconnection may occur.
- Prevent any external force from being applied to the products until solder has cooled.
- Handle carefully to prevent mechanical stresses, such as from the bending or warping of a PCB, on the solder fillet.
- Confirm that solder flux residue does not affect the product.
- Confirm that components are in place when conductive adhesive is used in place of solder.

#### Precautions for Soldering with Lead-free Solder

- In Pb-free soldering, temperature may be higher than in the use of eutectic solder. Confirm that soldering is acceptable under actual conditions.
- Solder fillets may lift off double-sided boards with through holes. Confirm the solder strength on actual board material before assembly.

#### Washing

- Confirm that solder flux residue does not remain after washing, because it may cause deterioration of moisture and corrosion resistance.
- Confirm reliability in advance when using no-clean solder, water, or a soluble agent.
- Since Pb-free solder may contain many ionic materials, use RMA type solder or flux or wash sufficiently.
- Wash thoroughly after soldering to remove ionic substances like sweat and salinity. Control the washing agent appropriately to remove all ionic substances. Consult KOA when using a washing agent such as acid, alkaline, or organic solvent other than alcohol.
- Ultrasonic washing may damage products due to vibration resonance. High hydraulic pressure may also damage products. Ask KOA in advance for washing conditions.
- Dry products thoroughly after washing.

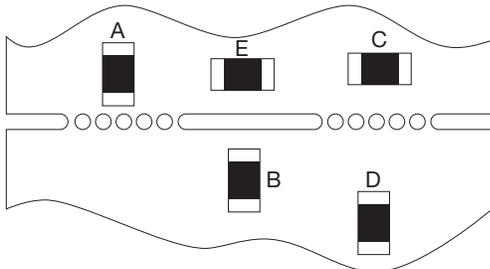
#### Dispose of the Products

- Observe appropriate laws and regulations for handling and disposal of products or packing materials.

The following precautions apply to surface mount devices

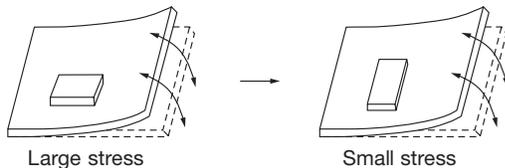
### Precautions Related to PCB Bending Stress

- Arrange the long side of chip components parallel with the direction of the smaller coefficient of thermal expansion in anisotropic PCBs.
- Cracking of the solder fillet may occur with thermal cycling, because of mismatch of coefficients of thermal expansion between the board and the component. Pad size, amount of solder, and amount of heat radiating from the PCB must be designed carefully, especially with large components of 5 mm x 2.5 mm or larger.
- If products are mounted near a depaneling line, the termination or component may be damaged by large stresses during depaneling. Mount the products as shown in the following figure to minimize depaneling stress.



The level of stress on terminations  $A > B \neq C > D > E$

- Use proper layouts to avoid stress from warping, bending, or deformation of the board in order to avoid solder cracking or component damage.



- Pay careful attention to products mounted near the edge of the board or near connectors, since stresses may happen during connection.
- Pay careful attention to layout when products are mounted near large components, when solder solidifies, it creates a stress in directions based on the large components, and cracking may occur.
- Design solder pads to be equal. If solder pads differ in size, they may change electrical characteristics or cause cracking and tombstoning when solder is cooling.

### Mounting and Soldering

- Poor mounting machine adjustment may cause cracking, chipping, or alignment errors. Check and inspect the mounting machine in advance.
- Set backup pins in an appropriate layout to avoid damage to components mounted on the back of the board. Do not set these pins at nozzle positions.
- Adjust the bottom dead point of a dispenser away from the board when you apply adhesive to avoid damage to components mounted on the back of the board.
- Confirm that products solder properly if wave soldering is used.
- Pay close attention to amount of solder, since an improper amount may create a large stress on the component and cause cracking or malfunctions.

### Soldering with a Soldering Iron

- Solder using a soldering iron at the temperature specified in the technical specifications or precautions for each product.
- Perform preheating as much as possible.
- Keep the tip of the soldering iron away from the body and the product terminal.
- Avoid physical damage or shock to components when using hard tools like pliers and tweezers.

The following precautions apply to through-hole devices

### Mechanical Stress

- Play close attention to vibration resonance after mounting.
- Do not add additional bending or twisting stresses to the product.
- Fix large components firmly.
- When lead wires are to be bent, use a large radius of curvature to avoid excessive stress on the terminal joint. Excessive stresses may cause the lead wire to separate from the electrode cap and damage the product.
- Do not add excessive stresses to the product body when lead wires are cut or held by the mounting machine.

### Temperature Rise

- Pay close attention to heat radiation and interaction with other components, since large resistors general a large amount of heat when the rated power is applied.

### Higher Power Ratings

In some cases, KOA will increase the power rating for a given component. Often, the older power rating and newer power rating are both given on the specification, in order to create a transition period. During this time, the new power rating will often have a note asking for discussion with KOA.

A higher power rating is based on appropriate resistance stability, but other ratings and parameters still require attention. For example, voltage rating is based on a separate failure mechanism and will not be increased in the same ratio. In mid- and high-value resistors, power dissipation will still be kept lower than the new rating by the voltage limit. In addition, using a resistor at a higher power than its previous rating will create a greater rise in temperature on the surface of the component. This temperature rise should be checked for acceptability and to make sure that the layout does not place the resistor near a board material or component that could be damaged by greater heat.

### Introduction of the Derating Curves Based on the Terminal Part Temperature

#### Background

Recent studies have led to better practices for miniaturizing high-power components in high-temperature automotive environments. Applications that require high-temperature resistors have increased dramatically. Recently, derating guidelines based on the resistor's terminal temperature, such as the diagram in figure 1, have been introduced to respond to these requirements.

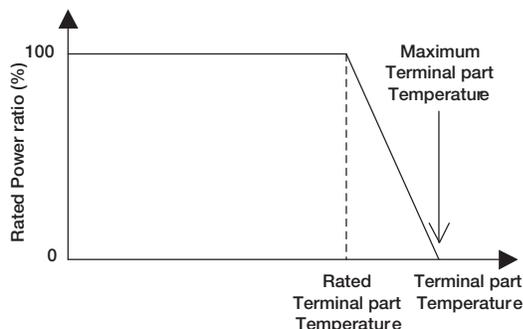


Figure 1. Derating curve based on the terminal part temperature

Derating by terminal temperature has already been used for metal-plate current-sense resistors with very low resistance values (such as the PSB and PSE series). These resistors are used to sense large currents in inverters and converters, and nearby switching elements or high-current conductors can lead to a local temperature increase at the resistor terminal beyond the temperature generated by the resistor itself. The techniques learned in designing these applications are now being extended to general-purpose components.

#### 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.

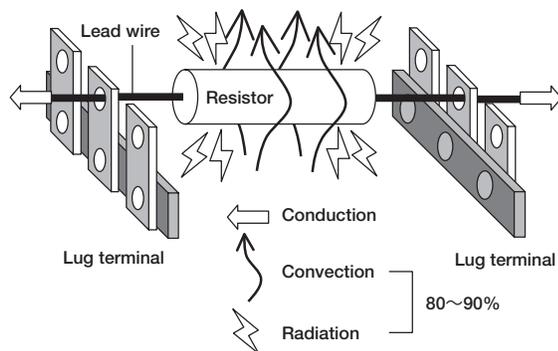


Figure 2. Heat dissipation of cylindrical resistors

Regardless of the shape of the resistor, the heat generated by its use is dissipated through three pathways. One path is conduction through solids such as the terminal. The second path is convection, usually heat transfer into the air by natural convection. The third path is radiation of infrared. Of these pathways, conduction increases with the area of solid connected the resistor. Convection and radiation increase with the total surface area of the resistor.

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.

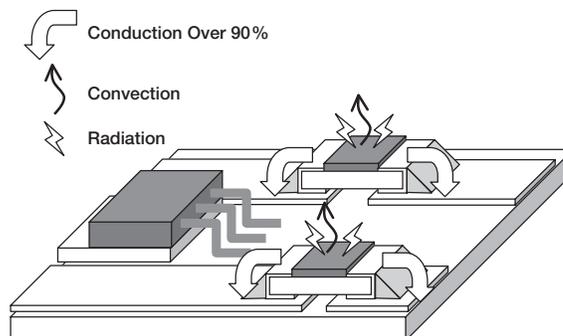


Figure 3. Heat dissipation of surface mount resistors

### 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.

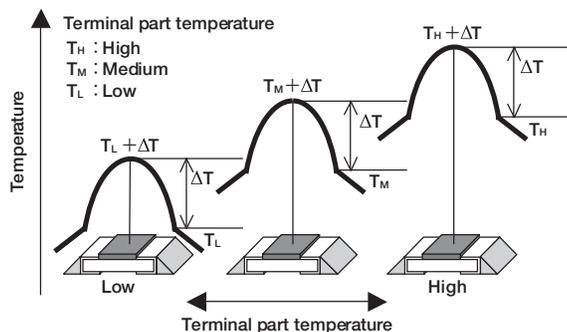


Figure 4. Contributing factor to the temperature of the surface mount resistor

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).

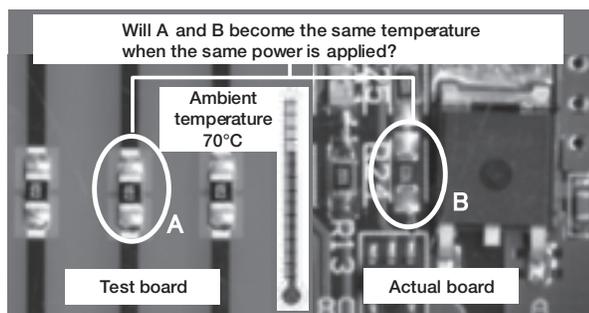


Figure 5. Temperature differs depending on the board

### 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 conditions for these examples are:

- (1) Ambient temperature of the board: 100°C
- (2) Terminal temperature of the surface mount resistor: 120°C
- (3) Actual power load: 0.05 W
- (4) Required margin of safety below rating according to designer's internal guidelines: 50%

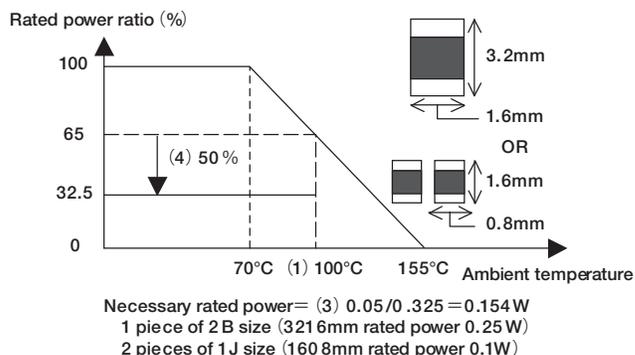


Figure 6. Selection by the traditional derating curve

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, either a single 2B (1206) size resistor or two 1J (0603) size resistors 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 1J (0603) size RK73B resistor would be sufficient.

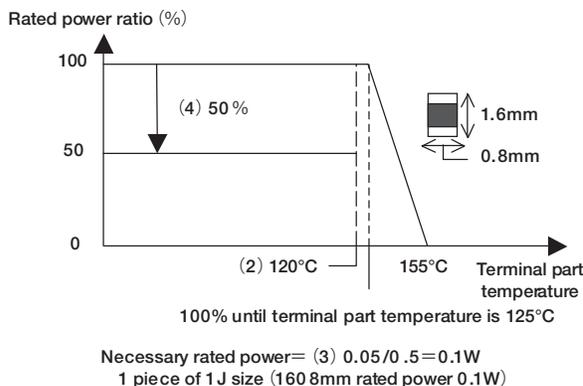


Figure 7. Selection using a terminal-temperature derating curve

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.

## Precautions for the Resistors

Refer to the precautions of common matters for all products in the beginning of this catalog.

### General in Fixed Resistors

- For basic precautions of using resistors, refer to the technical report "EIAJ RCR-2121A Guideline of notabilia for fixed resistors for use in electronic equipment" issued by JEITA.
- When the resistors are operated in ambient temperature above the rated temperature, the power rating must be derated according to the derating curve.
- Resistors in general may emit flame, fire or smoke when overload is applied.
- Flame retardant resistors may emit smoke or appear red hot when overload is applied but are unlikely to emit flame or fire.
- When the resistors are sealed and coated by coating materials such as resin, deterioration of the resistor by thermal stress or resin may affect the characteristics. Confirm with KOA for the performance and reliability specifications in advance.

When the resin absorbs moisture, the resistance to moisture and corrosion of the resistor may deteriorate, so be aware.

- When the resistor is coated, potted or molded by resin materials, the curing stress could cause peeling of protective coating and cracking of solder fillet, resulting in resistance change and disconnection. Do not coat nor seal the flame retardant coated resistors.
- Allow enough time for cooling after mounting metal film resistors, before washing off the flux. Residues of ionic substances may deteriorate resistances to moisture and corrosion.
- KOA can only guarantee safety when the average power is below the rated power. When power, exceeding the rated power, is applied for a short duration, please contact us with the surge voltage or current waveform for advice.
- Cylindrical film resistors have inductance due to the spiral trimming. Please be aware when using in a high-frequency circuit.
- The flame retardant resistors are weak against mechanical stress compared with the general resistors due to the special coating. Please do not apply impact, vibration or pinching with pliers, tweezers to the resistor body. Do not apply any external force to the protective coating until drying is fully completed after washing.

### Chip Resistor Array and Networks

- Misalignment of the mounting, abnormal solder amount or a loading direction mistake in the flow soldering process could cause a solder bridge to the neighboring terminations.
- Adhesive of ionic residuals on the resistor or board could cause migration between the neighboring terminations.

### Wirewound Type Resistors

- Wirewound type resistors have inductances and parasitic capacitances resulting from the winding structure. Therefore, they could resonate when used in a high frequency circuit.

### Fusing Resistors

- Confirm beforehand that the overload condition of the abnormal situations are within the fusing characteristics.
- Contact KOA in advance when excess overload above the rated voltage is continuously applied, since there is a possibility of damage accumulated in the resistor.
- The arc phenomenon may occur when high voltage is applied again after fusing by over current. Make sure to use the product below the maximum open circuit voltage.
- Contact KOA about the maximum open circuit voltage, it varies depending on the product type and resistance.
- The fusing characteristics could change when the resistors are coated, potted and molded by resin materials.

## Terms and Definitions

### Nominal Resistance

- Designed resistance value usually indicated on the resistor.

### Power Rating

- Maximum allowable power at rated temperature. Some of our chip resistor arrays and networks specify the power rating for the entire package, as opposed to each element.

### Rated Temperature

- Maximum ambient temperature at which the power rating may be applied continuously. The rated ambient temperature refers to the temperature around the resistor mounted inside the equipment, not to the air temperature outside the equipment.

### Derating Curve

- Plot that expresses the relation between ambient temperature and the maximum allowable power, which is generally expressed in percentage.

### Rated Voltage

- Maximum allowable D.C. or A.C. voltage (rms), to be continuously applied to a resistor or a resistor element.

Rated Voltage (V) =  $\sqrt{\text{Rated Power (W)} \times \text{Nominal Resistance Value } (\Omega)}$   
 Rated voltage shall be the calculated value or max. working voltage, whichever is lower.

### Critical Resistance

- The maximum nominal resistance value at which the rated power can be applied without exceeding the maximum working voltage. The rated voltage is equal to the max. working voltage at the critical resistance value.

### Max. Working Voltage

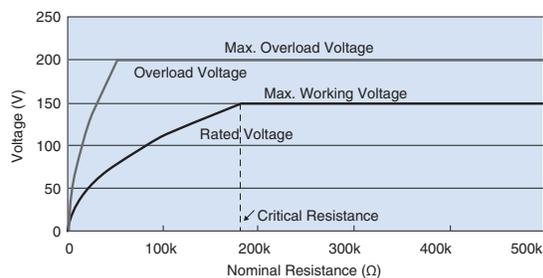
- Maximum D.C. or A.C. voltage (rms) that can be continuously applied to the terminations of a resistor. However, the maximum value of the applicable voltage is the rated voltage at the critical resistance value or lower.

### Overload Voltage

- Allowable voltage which is applied for 5 sec. according to the short time overload test. Overload voltage shall be 2.5 times of rated voltage or max. overload voltage, whichever is lower.

### Maximum Overload Voltage

- Largest value of overload voltage



Example of Various Voltage of RK73 2A

### Dielectric Withstanding Voltage

- A.C. voltage (rms) that can be applied to a designated spot between the electrode and the outer coating for one minute according to the proof test.

### Temperature Coefficient of Resistance (T.C.R.)

- Relative variation of resistance between two given temperatures when temperature is changed by 1K, which is calculated by the following formula.

$$\text{T.C.R. } (\times 10^{-6}/\text{K}) = \frac{R - R_0}{R_0} \times \frac{1 \times 10^6}{T - T_0}$$

R : Resistance value (Ω) at T

R<sub>0</sub> : Resistance value (Ω) at T<sub>0</sub>

T : Measured test temperature (°C)

T<sub>0</sub> : Measured base temperature (°C)