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.

Matters common to all products

General

- For precautions in general, refer to “JEITA RCR-1001C Safety application guide on components for using electronic and electrical equipment” issued by JEITA.
- While the information and figures on the durability performance of the products we provide are accurate and highly reliable, based on fixed test conditions, please conduct advance testing with your own products. If you are unable to determine the suitability for each application, please be sure to contact us beforehand.

Disclaimer

- These products have been designed and manufactured for general use and are not intended for use in the following applications or those involving equivalent risks. When considering use of these products for these applications, etc., please be sure to contact us in advance. In addition, regarding the conditions such as the scope of the warranty provided to our customers, without special agreement in writing, we bear no responsibility whatsoever for any complaints, damage, etc. regarding these products when used for these applications, etc.
  1. Applications requiring high reliability (Ex.: gas/plumbing/electrical systems, etc., 24-hour continuous operation systems, settlement systems and other applications handling rights and assets, etc.)
  2. Applications requiring a high degree of safety (Ex.: automobiles, aerospace facilities, railway facilities, medical devices, safety equipment, other applications which may involve risk to life or limb, etc.)
  3. Applications in harsh environments (Ex.: equipment installed outdoors, equipment exposed to chemical pollution, equipment exposed to electromagnetic interference, equipment receiving vibration/impacts, etc.)
  4. Applications under conditions and/or in environments not listed in the Catalogs.
- Consider sufficient fail-safe design if the products are used in applications requiring high reliability. Ensure safety of a whole system by setting proactive circuits and redundant circuits to avoid the single failure of the product leading to unsafety of the equipment.

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_2, H_2S, Cl_2, NH_3, NO_2, 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 (SO_2, H_2S, 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 characterstics 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_2, H_2S, Cl_2, NH_3, NO_2, 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.

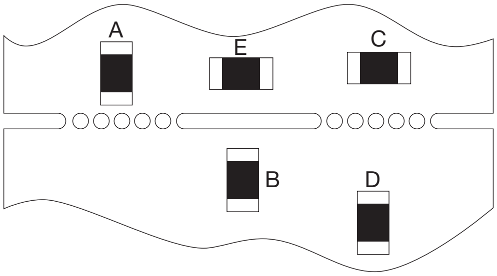
Dispose of the Products

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

The following precautions apply to surface mount devices

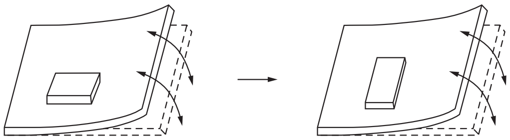
Precautions Related to PCB Bending Stress

- 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.



Large stress
Small stress

- 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 each land on right and left to have the same size. Different land size may change characteristics or cause cracks and tombstone effect while the solder is cooled down.

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 lead type 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.

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.

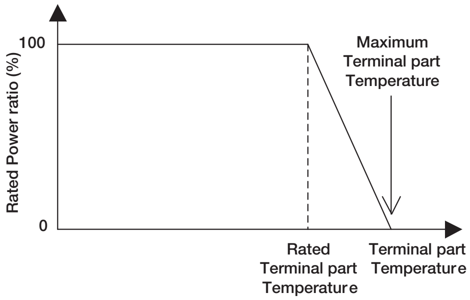


Figure 1. Derating curve based on the terminal part temperature

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.

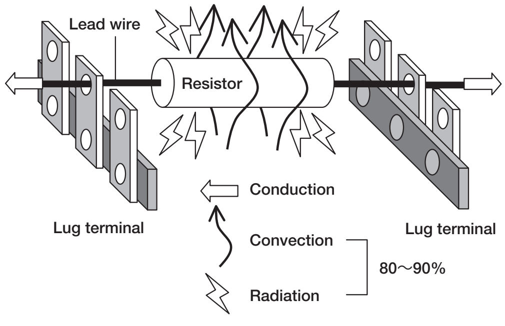


Figure 2. Heat dissipation of cylindrical resistors

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.

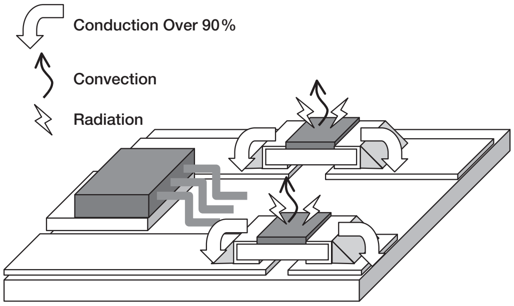


Figure 3. Heat dissipation of surface mount resistors

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.

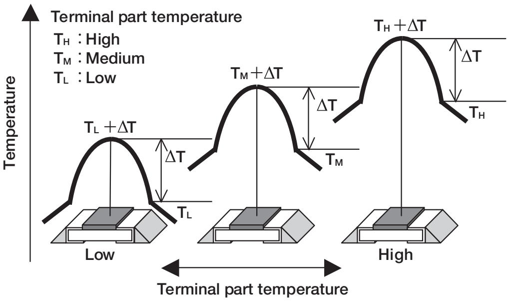


Figure 4. Contributing factor to the temperature of the surface mount resistor

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).

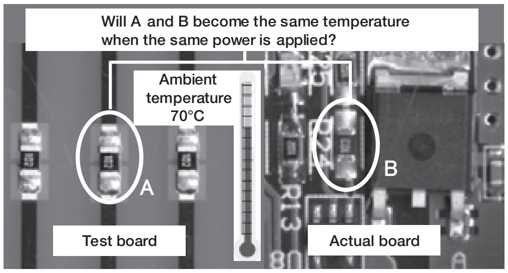


Figure 5. Temperature differs depending on the board

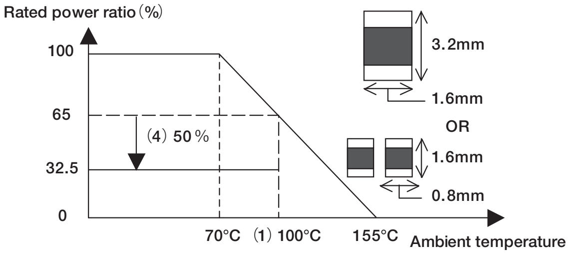
How to Use the Derating Curve Based on the Terminal Part Temperature

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



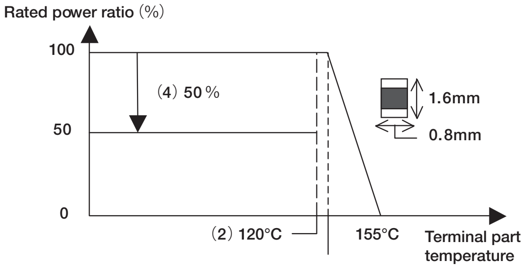
Necessary rated power= (3) 0.05/0.325=0.154W
1 piece of 2A (2012mm rated power 0.25W)
2 pieces of 1E size (1005mm rated power 0.1W)

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.

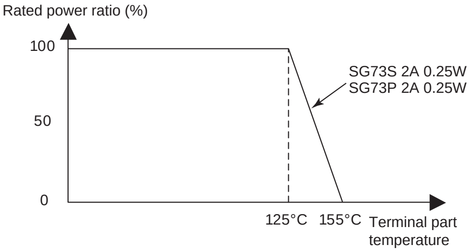


Figure 8. Derating curve of 0.25W rated power based on terminal part temperature

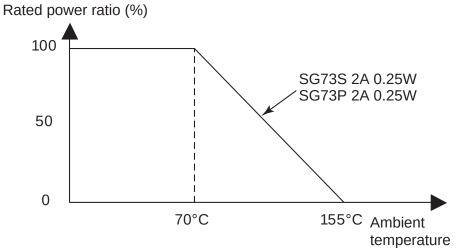


Figure 9. Derating curve of 0.25W rated power based on ambient temperature

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.

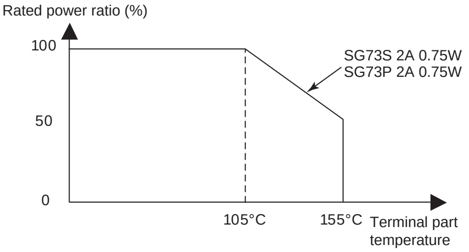


Figure 10. Derating curve of 0.75W rated power based on terminal part temperature

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."

Caution & Terms

Precautions for the Resistors

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

General in Fixed Resistors

- 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.
- 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.

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.

Reference

- For the basic precautions of using resistors, refer to the technical report, "JEITA RCR-2121A Safety application guide for fixed resistors for use in electronic equipment", issued by JEITA.

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 Ambient 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.

Rated Terminal Part Temperature
- Maximum terminal part temperature of the surface mount resistor at which the power rating may be applied continuously. Includes the temperature rise by self heat generation.

Derating Curve
- Curve that expresses the relation between ambient temperature or terminal part temperature and the maximum allowable power, which is generally expressed in percentage.

Rated Voltage
- Maximum allowable D.C. or A.C. voltage, to be continuously applied to a resistor or a resistor element.

  $\text{Rated Voltage (V)} = \sqrt{\text{Rated Power (W) X Nominal Resistance Value (}\Omega\text{)}}$

  Rated voltage shall be the calculated value or max. working voltage, whichever is lower.

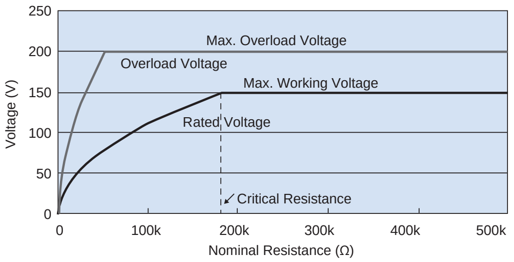
Critical Resistance
- The maximum nominal resistance value at which the rated power can be applied without exceeding the maximum working voltage. The rated voltage is equal to the max. working voltage at the critical resistance value.

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.

  Maximum working voltage and rated voltage are calculated D.C. voltage based on rated power. Sine wave is assumed for the A.C. voltage so the peak voltage should be $\sqrt{2}$ times the maximum working voltage. When the wave form is not a sine wave, or when the resistance value exceeds the critical resistance, please contact us for the applicable peak voltage.

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 RK73G 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_0 : Resistance value (Ω) at T_0
T : Measured test temperature (°C)
T_0 : Measured base temperature (°C)