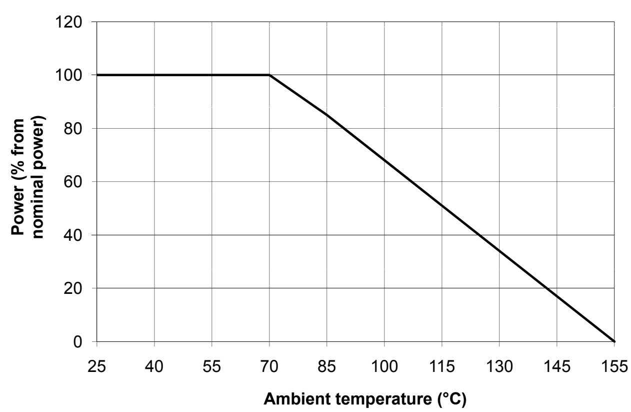
Technical Data Regarding Power and Heatsink Dimensioning

In our data sheets, the nominal power dissipation is given for all resistors. The data are mentioned for a free-standing assembly (i.e. a SMD assembled on a PCB). The ambient temperature is always +70°C. This means that the inherent temperature of the resistance element, without additional cooling, will reach the limiting temperature.

The inherent temperature is the sum of the ambient temperature and the created through power dissipation. If the ambient temperature is higher than +70°C, the power dissipation must be reduced to ensure that the resistance element will not exceed the limiting temperature. Otherwise, the element might be damaged. This necessary reduction of the power dissipation is denoted as "derating." In the data sheets a "derating curve" (Picture 5) is always given. The value of the specific power dissipation depends on the ambient temperature percentage of the nominal power dissipation.

Picture 5 – Derating curve of a free-standing resistor series (USR/USN, UNR, UHR, and UPW) without additional cooling.



If the ambient temperature reaches the limiting temperature of the element, it is not possible to electrically stress the element. If the ambient temperature is below +70°C, it is possible to stress the element with a higher power than that given in the data sheet.

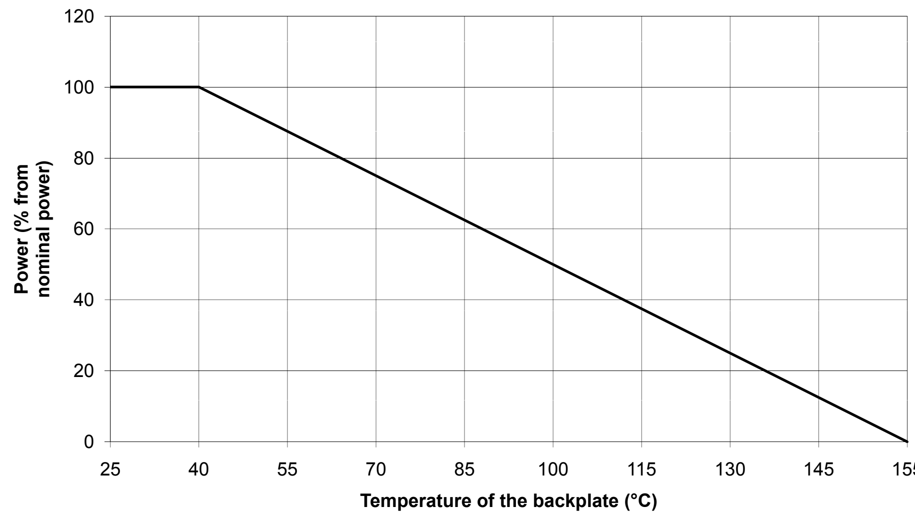
A supplementary increase of the power dissipation is possible if an additional cooling system is attached. The most effective method is a forced air blast with a ventilating fan. With this additional cooling, the heat convection of the resistor can be higher. In general, with a forced air blast of 3 m/s and an optimal construction, it is possible to double the power dissipation.

Another possibility is the use of a heatsink. With a heatsink the surface of the resistor is larger, resulting in higher convection. For all our resistor series we have constructed elements that allow a heatsink to be used, including packages such as the TO-220 and TO-218. In the data sheets, the nominal power dissipation is given for when a heatsink is used. The specifications are subject to these conditions:

- Assembly on a heatsink with optimal fixed mounting (pressurized and use of a heat conduction paste)
- Temperature of the heatsink is +25°C (+40°C for power resistors)

If the resistor is installed on a heatsink, the derating curve looks different from a free-standing assembly. The power dissipation depends on the temperature of the case's bottom plate (Picture 6)

Picture 6 – Derating curve of a resistor (optimal assembly on a heatsink)



The maximum allowed power dissipation depends on the temperature of the heatsink, because the inherent temperature is the sum of the heat from power dissipation and the heatsink temperature itself.

For the maximum allowed power dissipation, this condition is valid: Tresistor = $dT_R + T_{KK} = T_{limit}$.

The temperature of the heatsink results in the over-temperature of the heatsink itself (dTKK) and the ambient temperature of the whole application: $T_{limit} = dT_R + dT_{KK} + T_{ambient}$.

To protect electrical circuitry, we obtain the factor of proportionality between the power dissipation and the over-temperature: the thermal resistance $R_{th} = dT / P$.

For the resistor and the heatsink used, the following condition is valid:
RthR = dT_R / P or $R_{thKK} = dT_{KK} / P$.

In order to calculate the maximum power, we have to use the following equation which results from the former equations:

$$P_{max} = (T_{limit} - T_{ambient}) / (R_{thR} + R_{thKK}) \; ; (R_{thR} = R_{thAppl} + R_{thj\text{-}c}).$$

For all heatsink-mounted resistors, the given data for the thermal resistance are for an optimal assembly. The thermal resistance for the heatsink must be obtained from the heatsink manufacturer.

Example 1:

We are assembling a USR 2-T220 on a heatsink with a thermal resistance of 7 K/W. We want to know the maximal power dissipation (ambient temperature +25°C).

Solution:
P_{max} = (155°C - 25°C) / (13 K/W + 7 K/W) = 6.5 W
In a free-standing application, the maximal power dissipation is 2.3 W.

Another application for heatsink-mounted resistors is the possibility of reducing the change in the resistor value (through the temperature change) and to increase stability. The inherent temperature will be constant at the same power dissipation.

In order to calculate the inherent temperature (the power dissipation is fixed) we need the following equation:

$$T_{resistor} = P * (R_{thR} + R_{thKK}) + T_{ambient}.$$

In order to calculate the thermal resistance of a heatsink (application is fixed), we have this equation:

$$R_{thKK} = (T_{resistor} - T_{ambient}) / P - R_{thR}.$$

Example 2:

The temperature change of a 2.5 Ohm measuring resistor must be lower than 40 ppm if there is a stress current of 1 A. To reach this we are using a resistor in the USR series with a TCR of 1. The maximal inherent temperature of this resistor is +60°C. The ambient temperature in the application (measurement equipment) is +35°C. The question is which resistor type and which heatsink do we have to use?

Solution:
The power dissipation is $P = R * I^2 = 2.5$ W.
The first resistor we are choosing is the USR 4-T220.
The thermal resistance of the heatsink we have to use results in the following equation:
$R_{thkk} \leq (60°C - 35°C) / 2.5 W - 13 K/W = -3 K/W$.
A heatsink with this thermal resistance is not possible.

One solution is to use a water-cooled heatsink to reduce the temperature below the ambient temperature. This solution is very expensive and not possible for normal applications.

It is better to use the resistor type UNR4-4020 TK1. The thermal resistance is 2.7 K/W. The thermal resistance of the heatsink we have to use with this resistor is ≤7.3 K/W.