CONTENT (alphabetical)

CONTENT (to continue on page 2)

DEFINITION OF TERMS

Nominal Resistor Value (R_N):	Nominal (printed) resistor value, i.e. 22R (value of the order).
Absolute Resistor Value:	Real resistor value of the resistor, i.e. 22R0253.
Tolerance:	Max. allowed deviation of the absolute resistor value from the nominal resistor value in percent from the nominal resistor value. (delivery tolerance), i.e. 22R ±1%
Accuracy:	Resolution / number of digits from the mantissa of the nominal resistor value, i.e. 5K045 (4 digits accuracy). The accuracy is not the tolerance even if there is a cohesion.
Stability:	Max. allowed change of the absolute resistor value depending from time and stress. Normally it is mentioned in percent from the absolute resistor value at t = 0 (reference value).
Temperature Change:	Change of the absolute resistor value dependency of the temperature at the resistance element. It is normally mentioned in ppm (parts per million) of the absolute resistor value at the reference temperature T_0 (relative change of temperature dR/R).
Temperature Coefficient (TC):	Relative change of temperature of the absolute resistor value at temperature T relative to the change of temperature ($T - T_0$). For Ultra-precision resistors the reference temperature T_0 is 25°C. It is stated in ppm/K.
TCR-Alignment (Tracking):	Max. allowed TC difference of different resistors. (i.e. double-resistors, pair resistors or networks)
Power Dissipation:	When applying an electric voltage in a resistor, the energy is converted into heat. The result of the energy per unit time is the power dissipation. ($P = W / t$, $P = U * I$, $P = R * I^2$, $P = U^2 / R$). Depending on the heat removal, there is a temperature rise of the resistance element.
Inherent Temperature:	Real temperature of the resistance element. The inherent temperature is the sum of the ambient temperature and the additional temperature of the power dissipation. (excess temperature dT_R).
Limiting Temperature:	Max. allowed inherent temperature in exceeding the limiting temperature it is possible to have non-reversible alteration of the resistance, a change in it properties or its demolition.
Nominal Power Dissipation:	Max. permanent allowed power dissipation without exceeding the limiting temperature of the resistance. The nominal power dissipation mentioned in the specifications belongs to these conditions: - Free-standing assembly. - Ambient temperature of 70°C without additional cooling or, - Assembled on a heatsink with optimal fixed mounting (pressurized and use of a heat conduction paste).

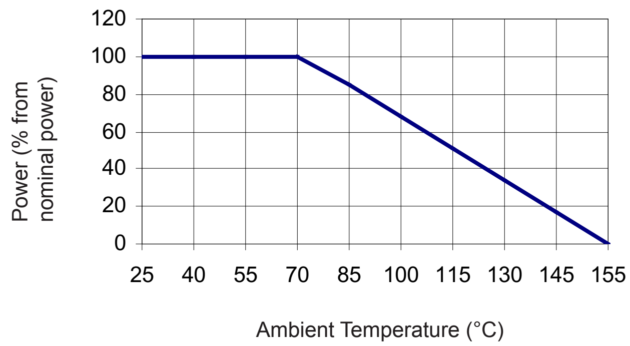
Thermal Resistance (Rth):	Factor of proportionality between power dissipation and over-temperature R_{th} = dT / P. The specifications mentioned in the data sheet for heatsink mounted resistors (R_{thj-c}) are defined as thermal resistance between the resistance element and case bottom plate.
Impulse Strength:	Max. allowed short-duration (impulse) electric energy, without exceeding the limiting temperature.
Limiting Voltage:	Also referred to dielectric strength; max. allowed voltage applied to the resistor.
Limiting Current:	Max. allowed current through the resistor.
Insulation Strength:	Also referred to breakdown rating; max. allowed voltage between the resistance element and the environment (i.e. chassis or heatsink).
Standard Conditions:	Measurement conditions for defining the absolute resistor value, tolerance and stability of the resistor. In the laboratory and production process the reference temperature is 25°C ± 2°C.

TECHNICAL DATA REGARDING POWER AND HEAT SINK DIMENSIONING

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

The inherent temperature is the sum of the ambient temperature and the temperature through the power dissipation. If the ambient temperature is higher than 70°C the power dissipation must be reduced to secure that the resistance element will not exceed the limiting temperature. Otherwise the element will 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 mentioned. The value of the specific power dissipation depends on the ambient temperature in % of the nominal power dissipation.

Picture 5 - Derating-Curve of a free standing resistor series USR/USN, UNR, UHR, UPW without additional cooling



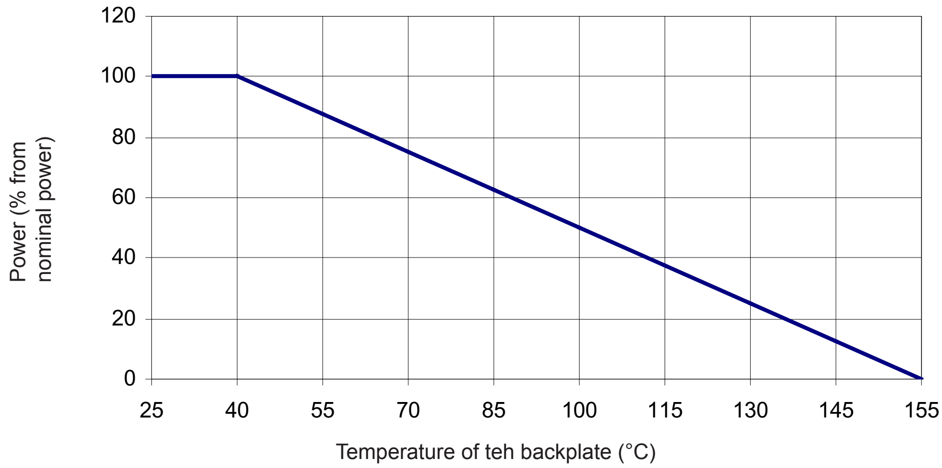
If the ambient temperature reaches the limiting temperature of the element, it is not possible to electrically stress the element. If the ambient temperature is below 70°C, it is possible to stress the element with a higher power than mentioned in the data.
A supplementary increase of the power dissipation is possible, if an additional cooling system is attached (i.e. heat-sink, forced air blast).
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, a forced air blast of 3 m/s and an optimal placed 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 resistor series we have constructed elements with a possibility to use a heatsink (i.e. housings like TO 220 and TO 218).
In the data sheets the nominal power dissipation in use with a heatsink is mentioned. The specifications belong to these conditions:

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

If the resistor is installed on a heatsink, the derating curve looks different from the freestanding assembly. The power dissipation depends on the temperature of the case bottom plate (picture 6).

Picture 6 - Derating-Curve of a resistor (optimal assembling on a heatsink)



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

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

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

In protection to the electrical technology 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 used heatsink the following condition is valid: $R_{thR} = dT_R / P$ or $R_{thKK} = dT_{KK} / P$

In order to calculate the max. power we have to use 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 mounting resistors the mentioned data for the thermal resistance are for an optimal assemblage. The thermal resistance for the heatsink must be optained from the manufacturer of the heatsink.

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 freestanding application the maximal power dissipation is 2.3 W.

Another application for heatsink mounted resistors is the possibility to reduce the change of the resistor value (through the temperature change) and to increase the 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 an 2.5Ohm measuring resistor must be lower than 40ppm if there is a stress current of 1A. To reach this we are using a resistor of the series USR with TCR 1. The maximal inherent temperature of this resistor is 60°C. The ambient temperature in the application (i.e. 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 for normal applications not possible.

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.

TEMPERATURE DEPENDENCE AND TC OF THE RESISTOR

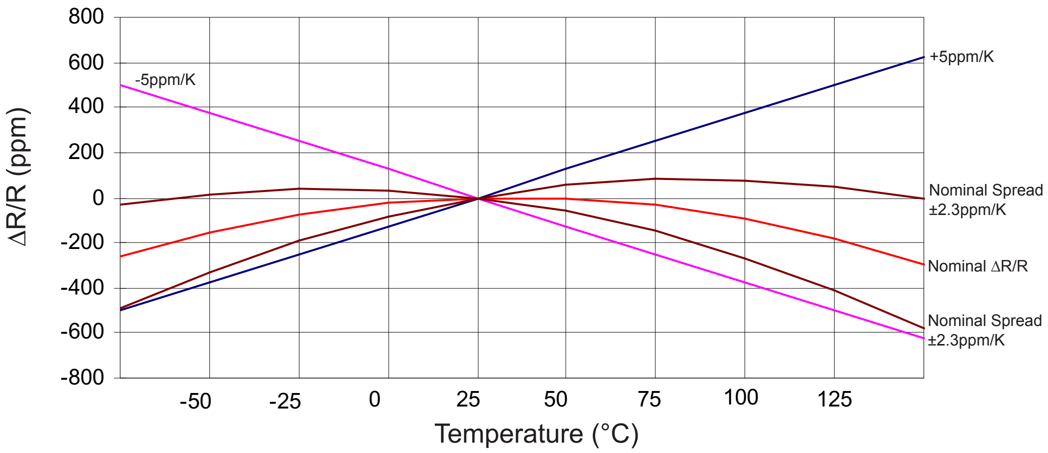
The absolute ohmic value of a resistor is temperature-dependent.

In today's modern fields of measurement and electronics, particularly in such industries as heating and ventilation (HVAC), medical technology, and military applications: precision, stability, and dependability are important criterions. Here the highest demands are made on every component; for this reason, the precision and ultra-precision resistors have been developed. The base of the resistance element is a special resistive film.

With the use of special technological steps we are able to synchronize the substrate and the resistor material. This means that we can produce resistors with a very low temperature coefficient.

1. Ultra-precision-resistors (series USR/USN, UNR, UHR and UPW)

Picture 1 - dR/R (T) for the series USR/USN, UNR and UHR



The TC adjustment is per charge at the reference temperature of 25°C (T0).

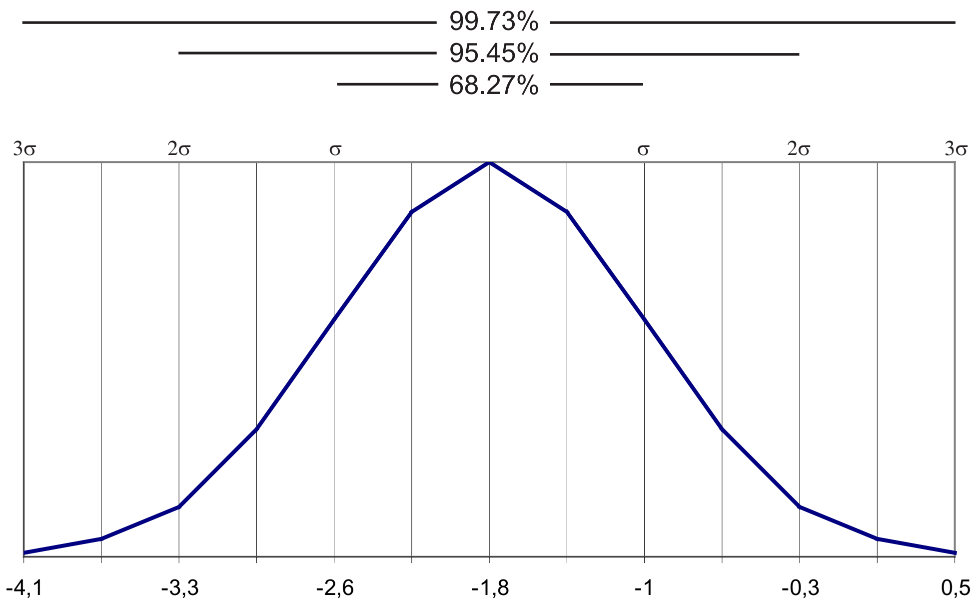
For the series USR/USN as well as UNR and UHR when adjusting the dR/R (T) -curve, we are able to reach a TC1 of -1.8 ppm/K with an inherent temperature of 125°C (T1) and a TC2 of +2.2 ppm/K with an inherent temperature of -55°C (T2). These curves are mentioned as the nominal dR/R-curves or the nominal TCs (Picture 1)

The specific TC is mathematical the rise of the secant between dR/R (T1;2) and dR/R (T0).

Normally there is a spread of values when the TC-adjustment is made. The reason for this belongs to the technical process and the normal difference in the materials. Therefore it is possible that the real dR/R (T)-curves, the TK1 and TK2 of all the resistors varies from the nominal mentioned parameters.

In the normal production process and big charges the TCs of all resistors are within the Gaussian distributian.
For the series USR/USN as well as UNR and UHR the nominal spread is ± 2.3 ppm/K (for TK1 as well as TK2).
This is the 3σ - area.
The TCs of 99.73% of all resistors in one charge belong to this area (Picture 2).

Picture 2 - nominal distribution of the TCs - series USR/USN and UNR



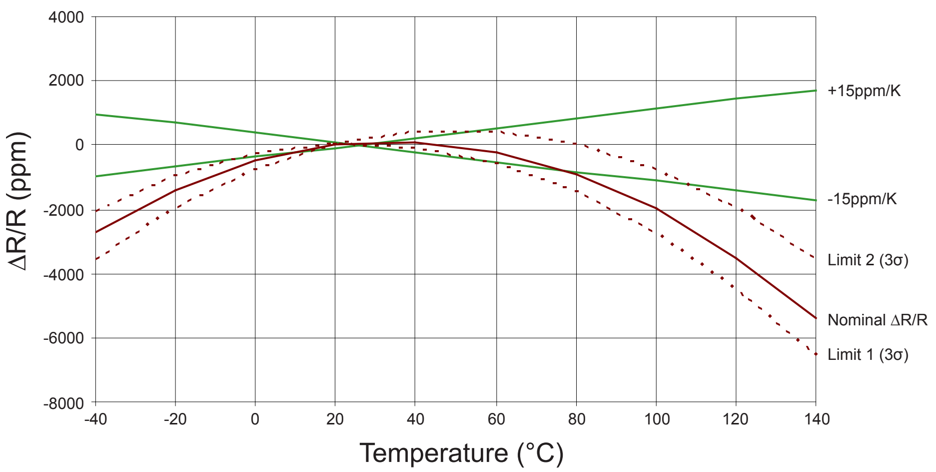
For a reduced temperature range from 0...60°C the nominal TCs are -0.6 ppm/K / +0.6 ppm/K and the nominal spread (3σ-area) of one charge is at ±2.5 ppm/K.

Upon customer request we can measure each resistor to secure that the TC in the temperature range of 25...60°C of all delivered resistors is ±1.0 ppm/K.

For the series UPW the TK1 is -3.6 ppm/K and the TK2 is +4.4 ppm/K. The nominal spread of the TCs of all resistors of one charge is at 25°C ±2.8 ppm/K.

2. Precision-Resistors (series FPR/FPN, FHR/FHN and FNR/FNN)

Picture 3 - dR/R (T) for the series FPR/FPN, FHR/FHN and FNR/FNN



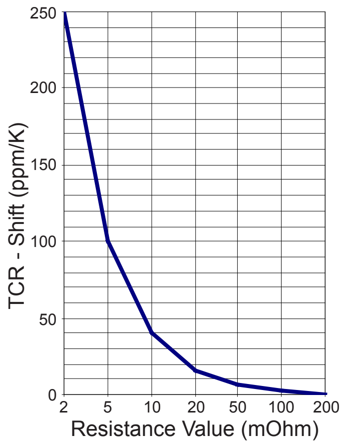
The dR/R (T)-curve of the precision-resistors series FPR, FHR and FNR as well as the precision-networks series FPN, FHN and FNN compared with the ultra-precision-resistor series USR/USN, UNR and UHR is more curved.

Even then we can reach nominal-TCs in a temperature range of 20...60°C smaller than ±15 ppm/K and in a temperature range of 20...40°C smaller than ±10 ppm/K. This is possible through the use of a 4-pol technology. The current intake and the voltage tapping are separated (Kelvin-connection).

In picture 3 the middle nominal dR/R (T)-curve as well as the border-curves of the nominal spread (3σ - area) are mentioned. These curves are only for low-ohm values used with a 4-pol connection.

For 2-pol resistors the influence of the contact-elements to the TCs of the complete resistance is very big. In picture 4 the change of the TC for 2-pol resistors is mentioned (depending on the nominal resistor value).

Picture 4 - TC-shift (low-ohm 2-pol resistors)



Different thermal resistances of heatsink-mounted resistors within real applications

Important in the applications of heatsink-mounted power resistors is the question of 'what exact power dissipation can be reached' for 'real' applications. Also, what is the maximum temperature of the resistance element when appearing under a defined stress. If we know these two data points, it is possible to determine the change of the resistance through stress, the long-term stability, and the failure rate for a given product.

An important factor for the answer of the above question is: 'what is the thermal resistance of the element against the heatsink?' If we know this answer, then it is possible to calculate the inherent temperature of the resistance element under stress with the following equation:

$$T_{resistor} = P * R_{thR} + T_{heatsink}$$

Our data sheets state the thermal resistance for all our heatsink-mounted resistors in K/W . These data should only be used for reference. The specifications are for a pressurized assembly and use of a recommended heat conduction paste. Also the mentioned nominal power dissipation is related to such applications where the heatsink-temperature is 25°C or 40°C.

With this data to hand, it is necessary to pay attention to the real heatsink-temperature. This is reliant on the thermal resistance of the heatsink, the total power balance (sum of all power dissipations from the parts assembled to the heatsink), and the ambient temperature.

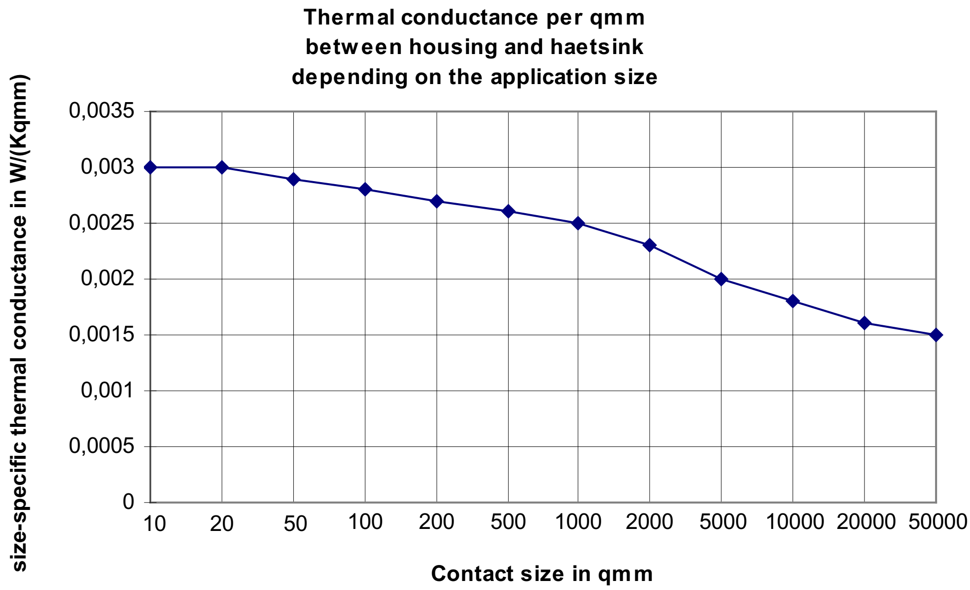
The thermal resistance R_{thR} is the result of the thermal resistance between the resistance element and the mounting plate (R_{thj-c}), inherent in design, and the thermal resistance between the mounting plate and the heatsink ($R_{thRAppl}$), depending on the application. The R_{thj-c} is fixed from the manufacturer of the resistor. The RthRAppl depends from the mounting possibilities, the size of the mounting plate, type of the fixing (i.e. number of the location holes or fixing strap), the force the resistor is assembled to the heatsink and the specialized experience of the customer for the application.

The following diagrams (picture 1 and picture 2) show the reachable average thermal conductance (optimal application) and the absolute thermal resistance ($R_{thRAppl}$) dependency from the mounting point (with normal heat conduction paste).

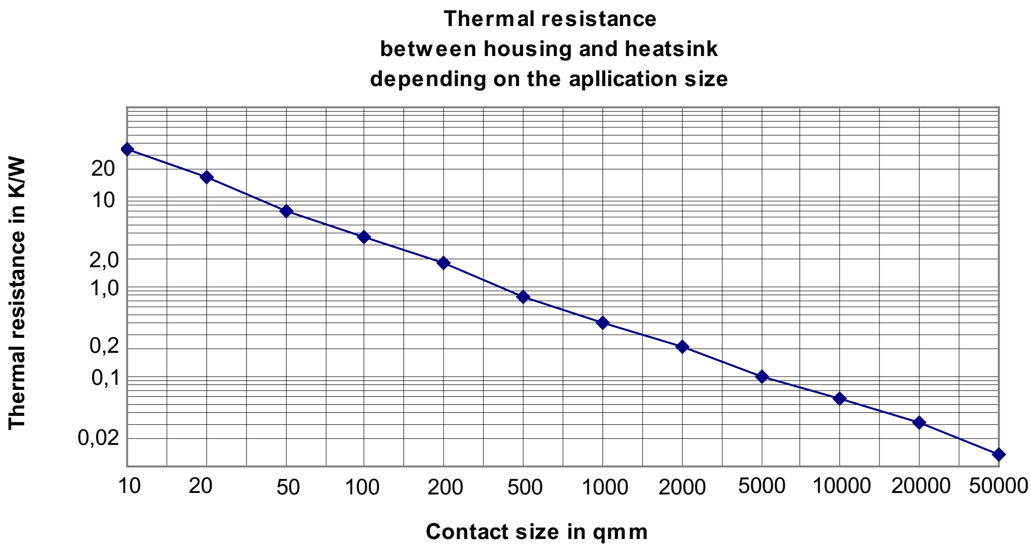
The decrease of the heat conductivity (depending on the surface) within big mounting areas, results in the problem that it is virtually impossible to reach an optimal constant pressure to fix the elements on the heatsink.

Approximated guide values for thermal paste with 1W/mK

Picture 1:



Picture 2:



The results of these calculations are the thermal resistances between the mounting-plate and the surface of the heatsink ($R_{thRAppl}$) for the most important heatsink-mountable resistors within our product portfolio. The specific inherent thermal resistance of each resistor (resistance element / mounting-plate) R_{thj-c} is also mentioned:

type/size	$R_{thRAppl}$ (guide value)	R_{thj-c}
USR T220	2.2 K/W	10.8 K/W
UNR T220	2.2 K/W	6.8 K/W
USR 3425	0.5 K/W	3.5 K/W
UNR 3425	0.5 K/W	2.1 K/W
USR 4020	0.5 K/W	3.6 K/W
UNR 4020	0.5 K/W	2.2 K/W
FPR T220	1.8 K/W	4.8 K/W
FPR T218	1.0 K/W	2.5 K/W
FHR 3025	0.52 K/W	2.0 K/W
FHR 3825	0.46 K/W	1.6 K/W
FHR T238	0.42 K/W	1.3 K/W
FNR T238	0.42 K/W	1.0 K/W
FPR T227	0.2 K/W	1.3 K/W
FNR T227	0.2 K/W	1.0 K/W
FHR 8065	0.096 K/W	0.16 K/W
FHR 80110	0.060 K/W	0.09 K/W
FHR 80216	0.036 K/W	0.04 K/W
FHR 80320	0.025 K/W	0.026 K/W
FHR 80370	0.02 K/W	0.022 K/W
NPR T220 / T221	0.6 K/W	3.5 K/W
KPR T218	0.3 K/W	2.1 K/W
NHR T220 / T221	0.6 K/W	2.1 K/W
KHR T218	0.3 K/W	0.8 K/W
KPR T227	0.2 K/W	0.7 K/W
KHR T227	0.2 K/W	0.35 K/W

With these specifications it is possible to calculate the maximal allowed power dissipation. It is only necessary to define the temperature of the housing (i.e. 85°C at the mounting-plate). This temperature must be secured by the application.

$$P_{max} = (T_{limit} - T_{housing}) / R_{thj-c}$$

An additional increase of the heat dissipation can be reached with the use of a heat adhesive agent. The disadvantage is that it is difficult to remove at a later time fixed resistor.

Resistor series F (CuNiMn-Foil)

Measurements	Standard	Test Condition	Max. Change
Load Stability	DIN IEC 115 Part 1	1000h / 70°C / 0.75 P_n 90 min / 30 min	0.05%
	DIN IEC 115 Part 1	1000h / 70°C / P_n 90 min / 30 min	0.1%
Dry Heat	DIN IEC 115 Part 1	16h / 130°C	0.1%
Coldness	DIN IEC 115 Part 1	2h / -40°C	0.1%
Fast Temperature-cycle test	DIN IEC 115 Part 1	5 Cycles / -40°C / +130°C / 30 min	0.1%
Moisture resistance	DIN IEC 115 Part 1	56 days / 40°C / 93% rh	0.05%
Resistance to soldering heat	DIN IEC 115 Part 1	250°C / 5s (Method B)	0.05%
Terminal Strength	DIN IEC 115 Part 1	Test condition depends on contact	0.1%

Resistor series U (NiCr-Foil)

Measurements	Standard	Test Condition	Max. Change
Load Stability	DIN IEC 115 Part 1	1000h / 70°C / 0.75 P_n 90 min / 30 min	0.005%
Dry Heat	DIN IEC 115 Part 1	16h / 155°C	0.01%
Coldness	DIN IEC 115 Part 1	2h / -55°C	0.01%
Fast Temperature-cycle test	DIN IEC 115 Part 1	5 Cycles / -55°C / +155°C / 30 min	0.01%
Moisture resistance	DIN IEC 115 Part 1	56 days / 40°C / 93% rh	0.05%
Resistance to soldering heat	DIN IEC 115 Part 1	250°C / 5s (Method B)	0.01%
Terminal Strength	DIN IEC 115 Part 1	Test condition depends on contact	0.01%

Resistor series K and N (Thickfilm)

Measurements	Standard	Test Condition	Max. Change
Load Stability	DIN IEC 115 Part 1	2000h / 70°C / 0.75 P_n 90 min / 30 min	1.0%
Short Overload	DIN IEC 115 Part 1	5s / 2.5 x P_{rated} or U_{max}	0.5%
Dry Heat	DIN IEC 115 Part 1	16h / 155°C	0.25%
Coldness	DIN IEC 115 Part 1	2h / -55°C	0.25%
Fast Temperature-cycle test	DIN IEC 115 Part 1	5 Cycles / -55°C / +155°C / 30 min	0.25%
Moisture resistance	DIN IEC 115 Part 1	56 days / 40°C / 93% rh	0.25%
Resistance to soldering heat	DIN IEC 115 Part 1	250°C / 5s (Method B)	0.1%
Terminal Strength	DIN IEC 115 Part 1	Test condition depends on contact	0.1%