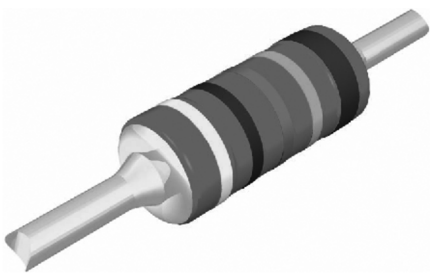
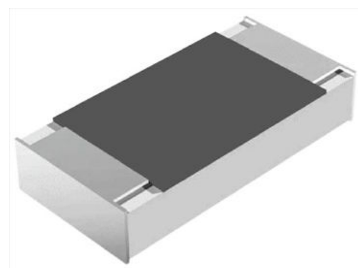
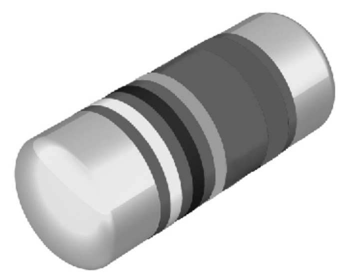
Resistive Products | Technical Note

Drift Calculation for Thin Film Resistors

1. MODEL CALCULATION FOR DRIFT OF THIN FILM RESISTORS

All resistors share one property: they change the resistance value with the film temperature experienced through an applied electrical load and with the duration of that load. The degree of change and of its predictability varies substantially with the resistor technology, i.e. the materials used to build the resistive element and the terminations.

There is a great advantage with resistors of pure metal or special metal alloys of applicable laws of physics and related equations that support precise predictions.

For resistors manufactured in thin film technology, the law of Arrhenius leads to the widely accepted statement:

$$\frac{\Delta R}{R_{(t,\,\vartheta_j)}} = 2^{\frac{\vartheta_j - \vartheta_0}{30\mathrm{K}}} \times \sqrt[3]{\frac{t}{t_0}} \times \frac{\Delta R}{R_{(t_0,\,\vartheta_0)}}$$

$\frac{\Delta R}{R_{(t_0,\,\vartheta_0)}}$ Reference resistance drift

t Actual time of operation

t_0 Reference time of operation

ϑ_0 Reference film temperature

ϑ_j Actual film temperature

Based on this equation, the drift of a thin film resistor:
- doubles for every 30 K temperature rise
- increases with the cube root of the load durations

Relevant for these considerations is the temperature on the resistive film and even more on hot spots in the resistive element, if any. The rise of the resistive film temperature is determined by the laws of heat conduction, convection, and radiation. All three of these physical laws are simply described with the thermal resistance R_{th} of a resistor.

If the thermal resistance, ambient temperature ϑ_{amb}, and power load P are known, the film temperature can be calculated with the following equation:

$$\vartheta_j = \vartheta_{amb} + \Delta\vartheta$$
$$\vartheta_j = \vartheta_{amb} + R_{th} \times P$$

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It is clear that the temperature of the resistive element depends not only on the applied electrical power, but heat transfer conditions and ambient temperature have major influences, as well. The heat transfer conditions are described by means of a thermal resistance that strongly depends on the type of printed circuit board, its material, and the distribution of copper tracks and pads next to the individual resistor. Hardly more than 20 % of the dissipated heat of an SMD resistor are transferred through radiation and convection. Unfortunately, the real conditions are too complex to be described in simple formula, thus the perfect design too often depends on experiments and experience.

N.B. The individual drift values shown on page 2 are examples. The designer will find the relevant details for the specific circuit in the datasheet of the selected product.

2. OPERATION MODES OF THIN FILM RESISTORS

The operation modes specified in the datasheets are related to the specified resistor. The same specified resistor can be driven under the following operation modes under relationship to the long-term stability and specified lifetime.

2.1. Standard Operation Mode

Under normal operating conditions in a typical circuit environment, a thin film SMD resistor would be operated with not more than 125 °C film temperature by not exceeding a suited maximum electrical load. The result would be a drift performance as outlined here:

Thin film SMD resistor • standard operation

Loaded with P_{70}, for a film temperature at 125 °C			
Load duration	1000 h	8000 h	225 000 h
Drift $\Delta R/R$	≤ 0.25 %	≤ 0.5 %	≤ 1.5 %

It is obvious that an SMD resistor operated under this condition is usable for over 20 years without causing trouble due to an excessive change of its value.

Historically, a normal operating condition for leaded thin film resistors has been considered different. Here, a maximum film temperature of 155 °C is permitted, leading to an assumption for a useful lifetime of about ten years.

Leaded thin film resistor • standard operation

Loaded with P_{70}, for a film temperature at 155 °C			
Load duration	1000 h	8000 h	225 000 h
Drift $\Delta R/R$	≤ 0.5 %	≤ 1 %	≤ 3 %

2.2. Long-Term Operation Mode

Since a medium-term operation period for leaded resistors was considered standard, the request for advanced professional electronics with extended lifetime demanded a new load definition. As used later with the standard operation of SMD resistors, the limitation to film temperatures not exceeding 125 °C provided the required stability.

Leaded thin film resistor • long-term operation

Loaded with P_{70}, for a film temperature at 125 °C			
Load duration	1000 h	8000 h	225 000 h
Drift $\Delta R/R$	≤ 0.25 %	≤ 0.5 %	≤ 1.5 %

Hence, one single resistor product proves to be suitable for two completely different classes of application just by choice of the operating mode and the individually permitted power dissipation.

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2.3. Power Operation Mode

Not all applications of SMD resistors require the same life expectancy of over 20 years. Quite often, lifetimes of ten years are considered enough. This leads to a higher permissible drift and thus to the higher permissible film temperature of 155 °C.

Thin film SMD resistor • power operation

Loaded with P_{70}, for a film temperature at 155 °C			
Load duration	1000 h	8000 h	225 000 h
Drift $\Delta R/R$	≤ 0.5 %	≤ 1 %	≤ 3 %

Again, one single resistor product is suitable for two different classes of application by choice of the operating mode and the permitted power dissipation.

Caution: SMD resistors are situated much closer to the printed circuit board than leaded resistors. Thus, a higher film temperature is more likely to influence the printed circuit board and the solder joints. Designs of certain SMD resistors in power operation mode may require a special printed circuit board design in order to provide good thermal management.

2.4. Precision Operation Mode

When an increased film temperature caused by higher load leads to higher drift figures, the opposite consideration applies as well: a limitation to less power dissipation and thus to lower film temperatures - a typical limit is set at 85 °C - provides a much improved stability of the resistance value. This greatly supports the application of precision resistors with very tight tolerances.

Thin film resistor • precision operation

Loaded with P_{70}, for a film temperature at 85 °C			
Load duration	1000 h	8000 h	225 000 h
Drift $\Delta R/R$	≤ 0.05 %	≤ 0.1 %	≤ 0.3 %

These drift figures provide confidence that an expensive precision resistor will remain precise for the designed operational lifetime.

3. RANDOM OPERATING CONDITIONS

It is obvious that the drift characteristics (i.e. the stability of the resistance value) are under full control of the circuit designer. The designer may estimate the performance of the particular resistor application or set certain load and temperature limits in order to maintain a desired stability.