New Performance Requirements for Resistors

in aeronautics applications

By
Dominique Vignolo
(Vishay)

The designs of today’s aircrafts are being driven by two primary goals: increasing aircraft fuel efficiency and conforming to anti-pollution regulations. The humble resistor can be helpful, provided some of its key specifications are given close consideration.

In order to increase fuel efficiency, the weight of the aircraft is decreased by reducing cabling, which can be achieved by moving electronics close to their function. To comply with anti-pollution regulations, electric engines are being used to move the aircraft on the ground.

In addition to changing design, the new demands placed on aircraft manufacturers have also created new performance requirements for electronic components, including resistors. In this article, we will explore the required parameters for different types of resistors, including high-temperature capabilities for stringent operating conditions and long-term stability.

A history of high-temperature components in aeronautics applications

Over the past eight years, aircraft manufacturers have used high-temperature parts in a number of applications. One of these was landing and braking monitoring systems, where brake temperatures were measured, and Wheatstone bridges were used to monitor hydraulic and tire pressure. In this type of application, the electronics were located in the wheel, and high temperatures reached them within an hour.

In terms of performance, these systems required components with operating temperature ranges from –55 °C to +175 °C, but this quickly needed to be expanded to +200 °C. Components with good long-term stability were also required, as the measurements had to remain stable for the life of the aircraft. The expected drift after several thousand hours of life could not exceed a given percent. Finally, the components had to exhibit good behavior during acceleration, vibration, and harsh environments. SMD products were shown to be the best under such conditions.

Like the aircraft braking monitoring systems, this sensor required components with an operating temperature range from –55 °C to +200 °C, very good long-term stability, and excellent behavior during acceleration, vibration, and harsh environments. The application utilized SMD wraparound chip resistors.

New regulations

With new regulations aimed at reducing pollution and saving fuel, more and more high- temperature applications are showing up. For example, engine temperatures are monitored so they can be regulated by a computer. This means electronics can be found inside the engine, where temperature can be very high. Taking into account that the average life of an aircraft is 25 to 30 years, the load-life stability of the components used at high temperatures is a key parameter for aeronautics applications. The goal is to find the best compromise between handling the power and enhancing long-term stability.

Likewise, sensors can be used to measure temperature of helicopter turbines.

Thermal management

Referring to **Figure 1**, resistor manufacturers need only take care of $R_{th(jsp)}$, but must carefully consider their choice of material, the resistor pattern, terminations, etc. Manufacturers who also improve thermal stability can offer resistors that can withstand higher and higher temperatures without undergoing significant drifts. This removes limitations on T_j.

The control of all the others parameters — namely T_a, P_d, and $R_{th(spa)}$ — are addressed by the customer’s assembly designers. Designers must take the PCB material, the thickness and layout of the copper tracks, the cooling system, and the interaction between surrounding components into consideration.

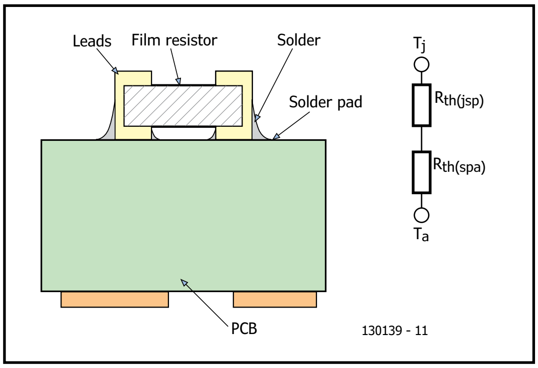


Figure 1.
Thermal parameters for a wraparound chip resistor.

A poor thermal management might induce melting or reduced reliability of the solder joints; reduce PCB performance (even burn-out); and lower chip resistor performance.

$R_{th(jsp)}$ and experimental data

To use the thermal model above, manufacturers need to provide $R_{th(jsp)}$ for standard termination parts, in addition to experimental data relevant to chip resistors of standard sizes mounted on various PCBs. These PCB should be chosen to represent the standard and best cases in terms of thermal resistance.

In the experimental data collected in **Table 1**, we have:

- PCB sCu — A PCB with a thickness of 1.6 mm, double sided, 35 µm thick copper (minimum), at least 50 % copper coverage both sides
- PCB MCu — A PCB with a thickness of 1.6 mm, double sided, 70 µm thick copper (minimum), at least 80 % copper coverage both sides
- Temperature versus drift was plotted against time and appears in **Figure 1**.

Derating curve of a basic thermal model

The derating curve in **Figure 2** is a representation of a basic thermal model:

Table 1. Load-Life drifts after 15,000 hours at various temperatures (experimental data).

Size	**$R_{th(jsp)}$ (°C/W)**	**PCB sCu**	**PCB Mcu**
		$R_{th(ja)}$ (°C/W)	**$R_{th(ja)}$ (°C/W)**
0603	27	200	67
1206	20	110	60
2010	12	95	52
2512	11	95	51

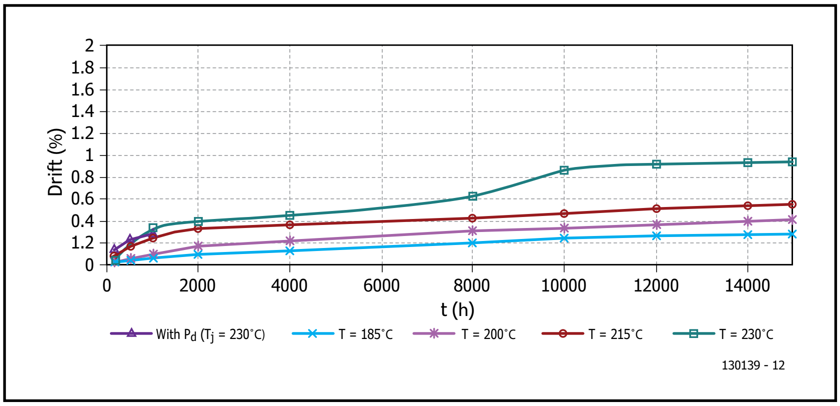


Figure 2.
High-temperature drift vs. time.

$T_c = T_a + R_{th} \times P_d$

where

T_c = temperature to be controlled;
T_a = ambient temperature;
P_d = maximum allowed power dissipation;
R_{th} = thermal resistance between the surface of the resistor at temperature T_c, and the ambient.

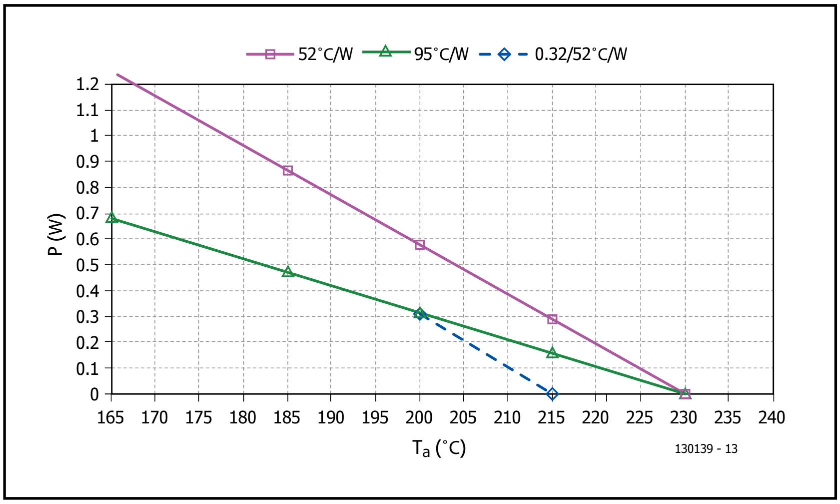
The model can be written as $P_d = (T_c - T_a) / R_{th}$. Per Table 1 we get: R_{thja} = 52 °C/W for a P2010 chip on a MCu PCB, and R_{thja} = 95 °C/W for a P2010 chip on an sCu PCB.

Using the derating curve

Providing $T_{j\ max}$ = +230 °C, the maximum power dissipation of the resistor at T_a = +200 °C will be:

- 0.57 W for R_{thp} = 52 °C/W — This is the *best assembly*.
- 0.32 W for R_{thp} = 95 °C/W — This is the *standard assembly*.

Figure 3.
Example of a derating curve (P2010).



The first way to use the derating curve is to check the maximum power rating that can be applied at a given temperature. For instance, if a customer uses the *best assembly* (52 °C/W), the maximum power at +200 °C will be 0.57 W. The second way is to reduce drifts by limiting the temperature at the surface of the resistor. In this example, the best assembly is used, but the customer limits the power to 0.32 W. This moves the 52 °C/W curve down and the junction temperature will be +215 °C instead of +230 °C as with the 52 °C/W curve.

Conclusion

From an analysis of temperature-induced drifts, we have pointed out some specific features of our thin film resistors that give them advantages for high-temperature applications.

The irreversible drifts other than load life are negligible. The load-life drift depends on T_j, however it is reached; by pure ambient temperature or the sum of ambient temperature and power dissipation ($T_j = T_a + R_{thja} \times P_d$). This is valid, providing some P_d limitations given in the datasheets. From an analysis of actual stability data and drifts versus time for various temperatures, it is obvious that even for T_j as high as +230 °C, drifts are under control and rather predictable from manufacturing data processes.

To help assembly designers we developed a thermal model showing thermal resistance figures necessary to use this model. The derating curves illustrate how good thermal management leads to load-life drift minimization.

From the above derating curves, it is clear that the load-life stability of the resistor or of the resistor network is enhanced by properly controlling the temperature at the surface of the resistor, thus increasing the life of the components in extreme operating conditions. Such conditions are becoming more common as electronics in aeronautics applications move closer to their functions.

(130139)

Reproduced with permission from Elektor International Media.