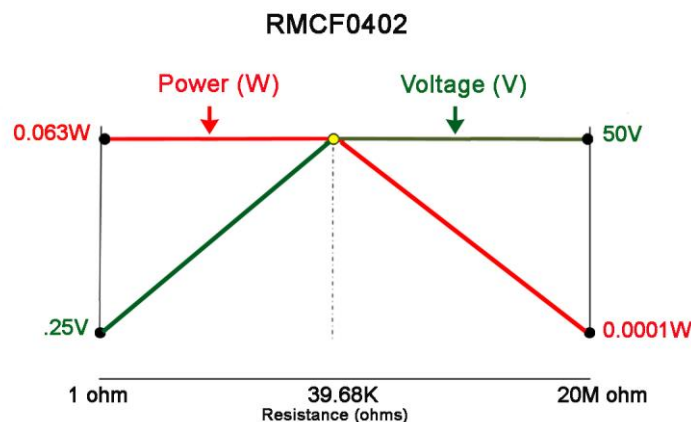


Keys to Understanding Resistor Specs

Used to protect, operate, or control circuits, resistors are straightforward in design and application. Resistors are most commonly used to limit current, divide current, or used in conjunction with other components like capacitors for RC filtering and more. Resistance values are understandably an important performance characteristic for design engineers. Although not a complex component, resistor specifications can be confusing, misleading, and misinterpreted. When specifying the different performance characteristics, it is important to review and understand the resistor test conditions so that the test results can be properly interpreted and applied to your design and application. There are potentially significant differences in data presented by resistor manufacturers and those differences can significantly affect performance.

Fig. 1 – Power / Voltage vs. Resistance Value



Resistor Power Ratings and Voltage Ratings

The power rating and voltage rating of a resistor are one common source of confusion. Simply put, the power rating is the amount of energy the resistor can dissipate in a given time at the designated ambient temperature.

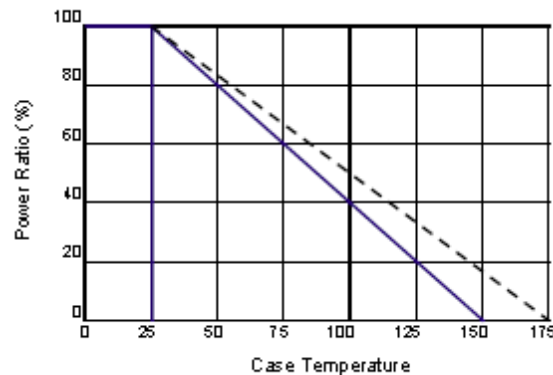
Multiple voltage ratings are typically provided on a datasheet, but most often the primary concern is the maximum working voltage. Maximum working voltage is the maximum amount of voltage the resistor can withstand constantly without arcing. Maximum working voltage is often expressed as “Vrms.”

It is critical to adhere to both the power rating and the maximum working voltage rating to avoid reliability problems. For example, if a 10 Ω 0402 chip resistor was subjected to the maximum working voltage of 50 volts, the resulting power through the part would be 250 watts. This far exceeds the power rating of the part.

Conversely, for high resistance values, the amount of electrical energy that the 0402 resistor can withstand is determined by the working voltage rating of 50 volts. If a 20M Ω 0402 was subjected to the maximum power of 0.063W, the voltage implied across the part would be 1122 volts, which surpasses the voltage handling of the part.

As shown in Fig.1 above, only at exactly 39.68K ohms can the 0402 resistor handle both 50 volts and 0.063W simultaneously. This value is known as the “critical resistance value”.

Fig. 2 – The Derating Curve



Another aspect of the power rating is the temperature at which heat dissipation is measured. Many resistors are rated at temperatures of at least 70 °C. This means the part can handle the designated power rating provided the ambient temperature around the part does not exceed 70 °C. However, there are some higher power resistors that are only rated for full power operation up to 25 °C. These power resistors typically require some type of external heat removal to operate at full rated power.

As can be seen from the derating curve in Fig 2 above, if the part associated with this derating curve is to be used at 70 °C, the power rating must be reduced to roughly 65% of its full value. Operating this part at full power and elevated temperature will lead to excessive resistance shifts and potentially failure of the resistor.

Performance Characteristic Information

Performance characteristics provide information about how a resistor performs in a test or a set of tests. Engineers will regularly use this information to compare parts from different manufacturers. When resistor series are tested to a common standard such as AEC-Q200, it is relatively easy to compare performance. However, even AEC compliant resistors may require some additional information. Some manufacturers will show compliance with the AEC testing and even provide all the supporting data from test done according to AEC, but at much smaller sample sizes. In some cases, these data files only show testing on 5 to 10 pieces for each size and in some cases only a single resistance value is chosen. For full AEC testing, most tests require at least 77 pieces from three distinctly different manufacturing lots in three different resistance values per size; high, low, and critical resistance value (or as close as the nearest standard resistance value can come).

When common test standards are not followed, both test conditions and the way in which test results are stated, can vary widely. These variations can lead to misleading performance statements. For example, nichrome based thin film resistors are susceptible to moisture corrosion. Some manufacturers will tout their nichrome elements as having superior moisture resistance, citing extremely low resistance shifts to biased humidity testing.

When examining those test conditions, the load or bias on the resistor is a critical factor. At full rated power, most resistors will generate enough heat that moisture will not condense on the part, making it appear robust in terms of moisture. But in many applications, precision nichrome thin film resistors will only see a fraction of the rated power. In these cases, the part will generate much less heat and the possibility of moisture condensing and collecting on the part increases. The resistance shift could be significantly different under a lower bias condition, such as 10% rated power. The test conditions is critical to understanding the results and ultimately resistor performance.

Fig 3 - Example of Performance Characteristics

Performance Characteristics		
Test	Test Specifications	Test Conditions (JIS-C 5202)
Short Time Overload	$\pm(2\%+0.1\Omega)$	2.5x rated voltage for 5 seconds
Dielectric Withstanding Voltage	$\pm(1\%+0.05\Omega)$	100 VAC, 1 minute
Resistance to Soldering Heat	$\pm 1\%$	260°C $\pm$ 5°C, for 10 sec. $\pm$ 0.5 sec. (Solder Bath)
Solderability	95% coverage, minimum	235°C $\pm$ 5°C, for 2 sec. $\pm$ 0.5 sec. (Colophonium flux)
Temperature Cycle	$\pm(1\%+0.05\Omega)$ Jumper (<0.05 Ω)	-65°C: 30 min. 25°C: 2 to 3 min. 155°C: 30 min. 25°C: 2 to 3 min. (5 Cycles)
Endurance (Damp load)	$\pm(3\%+0.1\Omega)$ Jumper (<0.05 Ω)	40°C $\pm$ 2°C, 90% RH, Rated Load 90 min. On, 30 min. Off for 1,000 hrs. -0hrs./+48hrs.
Endurance (Rated load)	$\pm(3\%+0.1\Omega)$ Jumper (<0.05 Ω)	70°C $\pm$ 2°C, Rated Load 90 min. On, 30 min. Off for 1,000 hrs. -0hrs./+48hrs.
Voltage Coefficient	± 100 (ppm/V)	1/10 rated voltage for 3 sec. max. then rated voltage for 3 sec. max.
Robustness of Termination	$\pm(1\%+0.05 \text{ Ohm})$	Bend of 3mm for 5 $\pm$ 1 sec.

Another frequently asked question about performance characteristics is how to interpret the accumulated variation or tolerance stack-ups from the different potential sources of variation. Adding the maximum potential shift from all the relevant tests provides the maximum expected resistance shift or worst-case scenario.

In practice, this is unnecessarily conservative for most applications and may result in the selection of a more expensive resistor with a tighter tolerance or lower TCR. It is important to remember that each performance characteristic test is independent. Some of these tests will typically have a positive shift in resistance and some will typically have a negative shift in resistance. In addition, the typical test performance will differ from one resistor technology to the next. In most cases, the actual resistance shift experienced in the circuit or application is a fraction of the sum of the individual test tolerances. It is advisable to contact the factory about specific stability requirements over the life of a given circuit or application for a resistor or series of resistors.

It is also important to understand if the change in resistance shown in the performance characteristics is typical performance, or absolute maximum limits. Some manufacturers will show typical results and not state it explicitly unless they are asked specifically by the customer. Typical results are usually 2 to 3 times better than the actual test specification. This creates the false impression that their part is superior to other similar products when the actual performance is no better and, in some cases, inferior.

Summary

Effective electronic designs can be achieved when critical resistor specifications are considered. When selecting resistors, the design must not violate the power rating or the voltage rating of a given device; these are resistance dependent parameters. Power ratings must be reconciled with the appropriate operating temperature. If the circuit operates at temperatures above the rated temperature of the resistor, then the power handling of the resistor must be derated appropriately.

Performance characteristic testing must be closely examined to determine what tests are relevant to the application. Test specifications must be reviewed to ensure the test conditions are the same, and test results must be properly interpreted. Test results must be verified as actual maximum possible shifts or typical performance to ensure a balanced comparison. Only then should a decision be made on the actual performance of each resistor.

Finally, when considering tolerance stack-ups, the accumulated variance or worst-case scenario does not consider the distribution of the individual, independent variables. This can lead to an unnecessarily constraining design and would make typical commodity resistors impractical to use. Whenever there is a question about whether a resistor is suitable for a design, it is recommended to have factory engineers examine the design in detail to ensure the correct product is chosen.

More Information and Data Sheets Available At: www.seielect.com