Stackpole Electronics, Inc.
Resistive Product Solutions

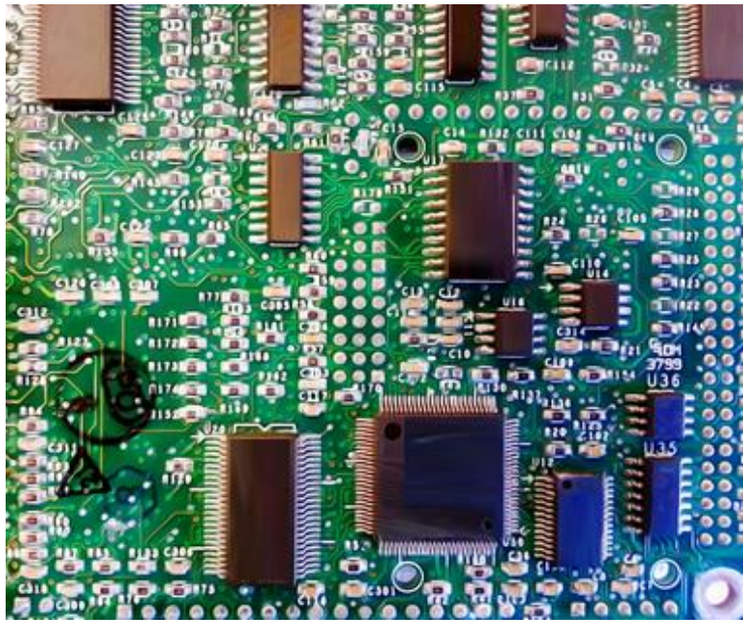
Technical Article

Service Tolerance Versus Purchase Tolerance for Resistors

Joe Biernacki
VP Operations/Quality
jbiernacki@seielect.com

Good circuit design requires that all the components in the circuit function together within their expected performance parameters to assure that the device functions as expected. This means that the components must meet their specified parameter, resistance in the case of resistors, within the required tolerance band over time.

Two key factors related to the expected performance of resistors are their specified tolerance (maximum allowable deviation from the nominal value) and their Temperature Coefficient of Resistance (TCR). The TCR is a measure of the maximum change in resistance over a given change in temperature and is measured in parts-per-million per degree Centigrade. The specified resistance tolerance is sometimes referred to as the "nominal tolerance" or "purchase tolerance" and is meant to indicate the expected tolerance on the resistance value as the product is delivered to the customer. But as we all know, many factors influence the resistance value of the components as they are assembled into circuits such as type of board attach process, profile, materials; the influence of the amount of power applied; where the components are in the circuit (influence of nearby components); environmental factors (temperature, humidity, etc.) and simply the influence of this combination of factors over time. Component values continue to change over time to varying degrees, depending on technology and other factors previously mentioned. Therefore, there must be a mutual understanding between the component supplier and the user (customer) that the resistance value of the product will shift and an expectation of the maximum shift. The resistors' performance characteristics (reliability test results) help guide the customer expectations given these various influences.



There are several ways to determine the maximum expected shift, sometimes referred to as "drift tolerance," over the service life of the component given the reliability test data. One of the most accepted and common is to calculate the RSS (root sum of squares) of the maximum specification ΔRs of all the specified tests. Below is an example of the use of RSS to calculate the expected change in resistance due to the combination of reliability tests for a hypothetical resistor type based on their maximum allowed deviations for each test.*

Test	% allowed *Tj*	$(Tj)^2$
Power conditioning	0.5	0.25
Temperature cycling	0.25	0.0625
Low-temp. storage	0.25	0.0625
Low-temp. operation	0.25	0.0625
Short-time overload	0.5	0.25
Terminal strength	0.25	0.0625
Resistance to soldering	0.25	0.0625
Moisture resistance	1	1
Shock and vibration	0.5	0.25
Life, 2000 hours	2	4
High-temperature exposure*	2	4
TOTALS *Tj*	7.75%	$(Tj)^2 = 10.0625(\%)^2$
Total tolerance		$\sqrt{10.0625}(\%)^2 = \pm 3.16\%$

* 2000 hours at 150ºC, not powered. Probably a good accelerated shelf-aging test.

Pic 2 - Charles A. Haper, Ed, Passive Electronic Component Handbood, 2nd Ed. (New York, McGraw-Hill, 1977), Pg. 47.

For this example, the root sum of the squares is ±3.16%. The "purchase" tolerance (for our purposes let us use a ±1% resistor) must be added to this, giving a total maximum expected shift of ±4.16%. Typically, some of the reliability tests will shift the samples in the positive resistance direction, some in the negative direction. If *actual* test data are used for a particular manufacturing lot, the RSS is likely to fall well within the hypothetical limits and provide an accurate estimation of expected drift for the service life of that lot. But the point is that the design engineer must take these potential shifts into account.

Tolerance analysis is an important technique in the designer's toolbox for estimating expected resistor performance. Manufacturers' product datasheets, as well as MIL and EIA specifications provide the test limits to be used for this analysis. This is much more realistic than expecting a resistor to maintain its purchase tolerance for the life of the product.