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Design Guide for Precision Resistive Devices

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Design Guide

Design Guide for Precision Resistive Devices

Introduction

Even in this digital age, a number of measurement and instrumentation applications rely on the accuracy of the value of one or more resistors. To guarantee the performance of the system, the designer must understand what factors can affect the value of a precision device, and how the combined effect of these factors may be evaluated.

There are essentially three types of error source to be understood.

- The first is measurement errors, which limit the precision with which the actual resistance value can be known.
- Secondly, short-term change factors, reflecting uncertainty in the resistance value in a customer's recently assembled PCB.
- Thirdly, long-term change factors, reflecting value drift throughout the product's life.

The combination of all these factors is termed total excursion.

Measurement Errors

Care is often needed when measuring precision devices to keep the measurement uncertainty at a negligible level compared to the resistance error. In addition to controlling the measurement temperature and voltage, the connections may need to be four-terminal (Kelvin) and using screened cables. If very high values are encountered, the use of guarding techniques may be needed to eliminate surface leakage paths.

The instrument used must have sufficient resolution and traceable calibration to enable the measurement uncertainty to be quantified. If measurement uncertainty cannot be made negligible, it should be allowed for. For example, when checking the value of 0.01% tolerance resistor on a meter with 0.001% (10ppm) measurement uncertainty, acceptance limits of 0.009% should be used.

Long-Term Change Factors

Datasheets often quote a number of figures for the performance data to enable the designer to assess the maximum lifetime change in resistance value. In general, only one of these figures should be used – the one that most closely reflects operating conditions.

The shelf life figure applies where loading is negligible and the environment is benign. The load figure applies where power dissipation is the main factor, the long-term damp heat figure where humid environments may be encountered.

In all these tests the majority of the value change happens within the period of the test, as the value will tend to stabilize. For example, the 1,000-hour load figure is a good guide to the change predicted over a longer period of service. For greater precision, mathematical models exist to extrapolate from tested stability levels to long-term stability under application conditions.

Short-Term Change Factors

The most basic factors are tolerance and temperature coefficient of resistance (TCR). The tolerance is simply the maximum percentage deviation of actual resistance value from nominal for resistors as delivered, measured at a specified temperature (normally 25℃). In some cases the measurement voltage is also specified.

The TCR specifies a limit on the variation of resistance with temperature. It is defined as the maximum average change in resistance value per degree centigrade between two defined temperatures, and expressed in ppm/℃. Unless otherwise stated, the tolerance and TCR figures are positive or negative, ie, "0.1%" means "±0.1%".

When defining the temperature range for a resistor it is necessary to consider the internal ambient temperature, the effect of nearby heat-generating components and the temperature rise due to dissipation in the resistor itself.

There are other factors that can affect resistance value measurements in some cases. For high-value and high-voltage parts, the value obtained can depend on the measurement voltage used. The maximum error from this source may be calculated from the voltage coefficient of resistance (VCR), which expresses this change in ppm/V. VCR is always negative. Customers may specify measurement voltages which reflect actual operating conditions to eliminate this error.

At the other extreme, very low-value resistors for current-sensing applications may generate thermal EMFs at junctions of dissimilar metals when a temperature difference arises through self-heating, or some other cause. This can be significant compared to the resistive volt drop and therefore generate an error. Designing for thermal symmetry across the resistor can normally eliminate this error source.

TCR and VCR both produce reversible changes in resistance value; the resistance would recover to its original value if measured at room temperature and standard measurement voltage. Other changes are permanent, and the first of these to consider is value shifts due to processing by the PCB assembler. This can be assessed by looking at the performance figure for resistance to solder heat in the datasheet.

Clearly initial calibration can be used to eliminate tolerance and soldering process induced errors.