Bulk Metal® Foil Resistor Demonstration Background

This document provides engineers with guidelines for choosing resistors that will best suit their application needs.

INTRODUCTION

There is more to resistor precision than meets the eye. Resistors from different technologies may seem alike on the surface, and may often have similar published specifications; however, beneath the surface each is made differently. Inherent design and processing variations strongly influence electrical performances, leading to different behaviors after mounting.

Vishay Foil Resistors has established a new demonstration kit that illustrates the differences between foil, thin film, and thick film resistor technologies in real time. The purpose of the presentation is to give a perceptible explanation of the primary factors that influence resistor stability.

1. Temperature Coefficient of Resistance (TCR)
2. Power Coefficient of Resistance (PCR)or "ΔR due to self-heating"
3. Electrostatic Discharge (ESD)
4. Short Time Overload
5. Thermal EMF
6. Humidity Resistance

Temperature Coefficient of Resistance (TCR) is the best-known parameter used to specify a resistor's stability, and is used to depict the resistive element's sensitivity to temperature change due to ambient temperature variations.

Power Coefficient of Resistance (PCR) is a lesser-known, but still extremely important parameter. This parameter quantifies the resistance change due to self-heating when power is applied.

Electrostatic Discharge (ESD) damage to electronic devices can occur at any point in the component's life cycle, from manufacturing to field service. Generally, ESD damage is classified as either a catastrophic failure or latent defect. A catastrophic failure can be detected when the resistor is tested prior to shipment; but in the case of a latent defect, the damage will go undetected until the device fails in operation. A latent defect is more difficult to identify because a resistor that is exposed to an ESD event may be partially degraded, yet continue to perform its intended function. Premature failure can occur after the resistor is already functioning in the finished product for a period of time.

Short Time Overload (STO) occurs when a circuit is subjected at one point in time to a temporary, unexpected high pulse (or overload) that can result in device failure.

Thermal EMF, which is negligible in ordinary resistors, may become a significant noise source of drift or instability in high-precision resistors, and is considered a parasitic effect interfering with pure resistance. It is often caused by the dissimilarity of the materials used in the resistor construction, especially at the junction of the element and the lead materials. The thermal EMF performance of a resistor can be degraded by external temperature difference between the two junctions, dissymmetry of power distribution within the element, and the dissimilarity of the molecular activity of the metals involved.

Humidity from the environment can penetrate all resin coatings to varying degrees over time, and eventually reaches the resistive surface. When this occurs, damage can result when voltage applied to the resistor causes an electrolytic conversion of the resistive alloy into compounds at the inter-granular boundaries, causing the resistance to increase until failure.

Vishay Foil Resistors' demonstrations show the importance of taking TCR, PCR, ESD, STO, thermal EMF, and humidity resistance into consideration when striving to achieve high stability.

TEMPERATURE COEFFICIENT OF RESISTANCE (TCR)

The TCR test consists of two electrically isolated circuits (see Figure 1). The test resistor (Rx) is connected to a precision ohmmeter on one circuit. The second circuit has a 100-Ω power resistor physically mounted to a substrate. A current is passed through the power resistor for a predetermined period of time. The temperature rise of the power resistor, and to Rx as a result, are predetermined time functions. After the heat rise of the resistor, the current flow through the power resistor is stopped, and Rx is monitored periodically as it cools down. The temperature coefficient is then calculated according to the resistance change of Rx relative to the temperature drop.

Bulk Metal® Foil Resistor Demonstration Background

Figure 1

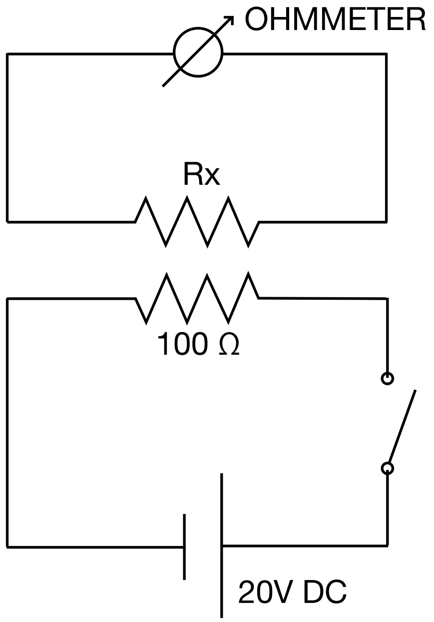
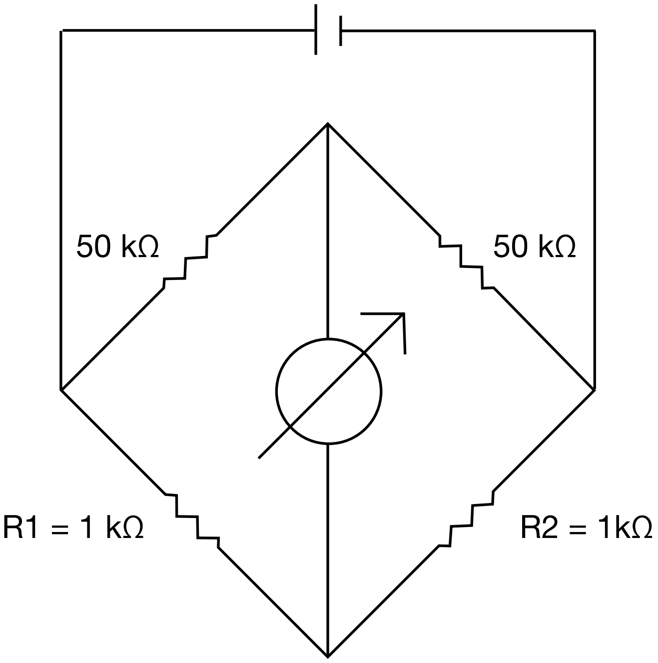


Figure 2



The temperature coefficient of Vishay Bulk Metal® foil resistors is the result of matching the variation in resistance of the alloy with temperature, and the variation of the resistance of the alloy with stress. These two effects occur simultaneously with changes in temperature. The result is an unusually low and predictable TCR.

Owing to the Bulk Metal foil resistor design, this TCR characteristic is accomplished automatically, without selection, and regardless of the resistance value or the date of manufacture — even if years apart!

POWER COEFFICIENT OF RESISTANCE AND PCR TRACKING DEMONSTRATIONS

The power coefficient of resistance (PCR) demonstration operates as a basic bridge circuit (see Figure 2). The resistor under test is R_1. The other three legs of the bridge consist of high-Watt, low-TCR foil resistors designed and selected to ensure zero drift when voltage is applied across the bridge. For the PCR tracking demonstration, R_1 and R_2 represent the two resistors being tested. The other two legs of the bridge are high-value resistors, and therefore undergo an insignificant load.

The PCR test measures and graphs the stability of R_1 relative to the other three legs of the bridge as it is subjected to continuous and increasing power. The graphic display shows the change in resistance of R_1 from the nominal reading, measured in PPM. The nominal reading is taken at 0.1 W. Readings are then taken in 1/10-W increments up to 1 W for leaded parts, and 0.5 W for surface-mount units. The demonstration measures the PCR (ΔR due to self-heating). The test results can indirectly indicate the TCR of the part.

The PCR tracking test measures and graphs the stability of R_1 compared to R_2 as they are subjected to continuous and increasing power. The graphic display shows the tracking stability between R_1 and R_2, measured in PPM, under increasing loads. At 25 mW, the value of the target voltage divider, R_1 and R_2, is read. The difference between R_1 and R_2 is set to zero, as shown graphically on the display. As subsequent readings are taken, the graph shows the change from the original R_1/R_2 reading, measured in parts per million (ppm). The readings are taken in 25 mW increments up to 250 mW.

This demonstration measures the stability of the R_1/R_2 ratio under increasing load within a voltage divider ($\Delta R1\text{-}R2/\Delta P$, measured as ppm/W). The change in ratio occurs as a result of the absolute TCR of the target resistors. Both resistors are simultaneously loaded with the same amount of power, but they don't heat up at the same rate, due to small differences in their thermal resistance. Therefore, the resistance of each resistor changes differently as a result of the TCR. If the two

Bulk Metal® Foil Resistor Demonstration Background

resistors have nearly identical low TCR, they will exhibit very good tracking stability under applied power. However, if the resistors do not have a similarly low TCR, they will exhibit poor tracking under applied power.

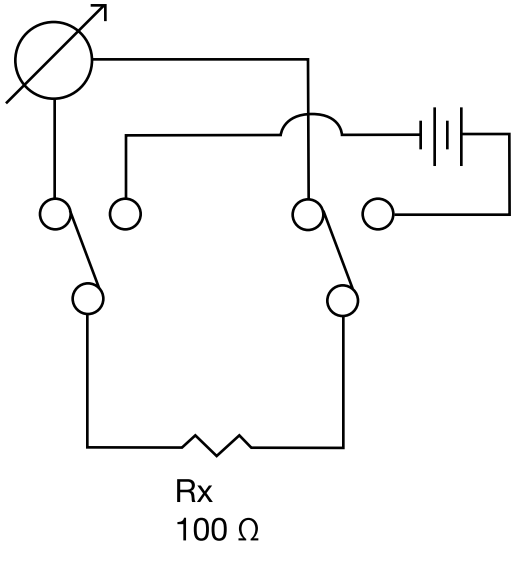
SHORT-TIME OVERLOAD DEMONSTRATION

The tested resistor (Rx) is connected to a 6.5 digit precision digital multi-meter (DMM), which takes the initial resistance reading (see Figure 3). After the reading is taken, the resistor is switched over to a power supply that applies an overload voltage for 5 seconds. After a sufficient cool-down time, the subject resistor is then switched back to the DMM, and the resistance is read again. The ΔR is displayed.

The test measures the change in resistance of the subject resistor due to the applied overload. The screen displays the ΔR, which is the difference in the resistance readings taken before and after the overload.

This demonstration measures the ΔR (measured in PPM) of a 100-R resistor subjected to an overload of 7 W for 5 seconds. This overload exceeds the power ratings of each device under test, specifically by a factor of 11 for the Vishay VFCP2512, a factor of 9 for the Vishay VSMP2512 resistor, and a factor of 7.5 for the thin film resistors.

Figure 3



Foil resistors are about 100 times thicker than thin film. The high heat capacity of the foil resistor results in a low temperature rise of the resistor element under a 5 second pulse. The thin film resistors lack the pure mass (heat capacity) to handle the heat generated, and will typically burn up and fail.

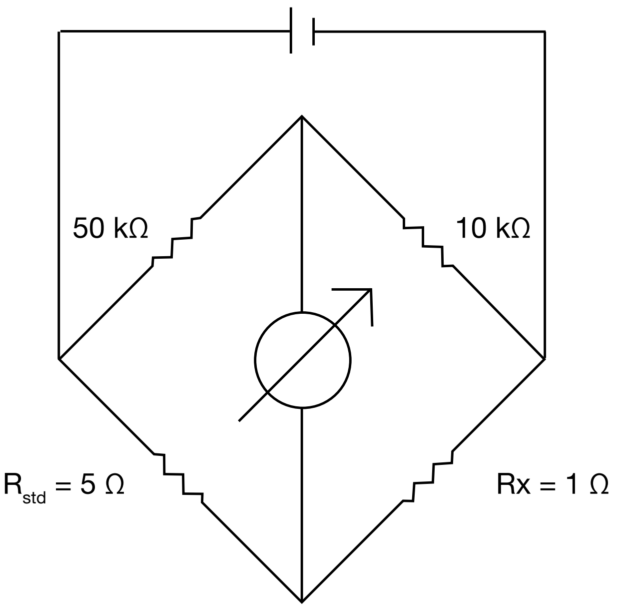
CURRENT SENSE DEMONSTRATION

The current sense demonstration is a simple bridge circuit (see Figure 4). The tested resistor is Rx. Rstd is a massive, high-power, low-TCR heat-sinked resistor capable of handling very high current while exhibiting zero drift. The other two legs of the bridge are comprised of high-Wattage, low-TCR foil resistors designed and selected to ensure zero drift when voltage is applied across the bridge.

The test measures and graphs the stability of Rx relative to Rstd as it is subjected to continuous and increasing current (and voltage). The graphic display shows the change in resistance of Rx from the nominal reading, measured in ppm. The nominal reading is taken at 0.1 A. Readings are taken in 0.1-A increments up to 1 A.

This demonstration indirectly measures the power coefficient of resistance (PCR). The graphic display shows the change in resistance with increasing current (ΔR/R)/ΔI, measured as ppm/A). The test results indirectly indicate the PCR as a

Figure 4



Bulk Metal® Foil Resistor Demonstration Background

function of Ohm's law. The subject resistor under test needs to have a resistance value of 1 ohm. The power can be calculated from Ohm's law using the ohmic value (1 ohm) and the current applied (in amps).

ESD SENSITIVITY DEMONSTRATION

By using a 500-pF capacitor charged up to 4500 V, this demonstration shows that Vishay Bulk Metal foil resistors are not sensitive to electrostatic discharge (ESD) damage. The test, performed on a 10-kΩ resistor, begins with an initial 0.5-µs pulse at 2500 V. The unit is allowed time to cool down, after which the resistance measurement is taken and displayed in ppm deviation from the initial reading. Readings are then taken in 500-V increments up to 4500 V.*

(*) Tests up to 25 kV have been performed in Vishay-approved laboratories and have produced the same results.

THERMAL EMF DEMONSTRATION

The test resistor (Rx) is electrically isolated from the second circuit and connected to a precision DC voltmeter, which measures in microvolts (Figure 6). In the second circuit, two power resistors are physically mounted very close to the terminations of Rx. Power can be directed separately to each of the resistors, heating each of Rx's terminations differently, causing a thermal difference between them. The thermal EMF created by this temperature difference generates a voltage. This voltage is then measured with the precision voltmeter.

A key feature of Vishay Bulk Metal foil resistors is their low thermal EMF design. The flattened paddle leads make intimate contact with the chip, thereby maximizing heat transfer and minimizing temperature variations. The resistor element is designed to uniformly dissipate power without creating hot spots, and the lead material is compatible with the element material. These design factors result in a very low-thermal-EMF resistor.

Figure 5

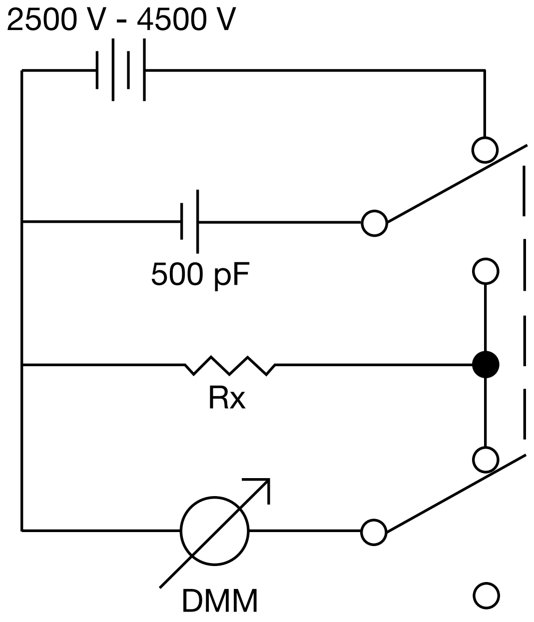
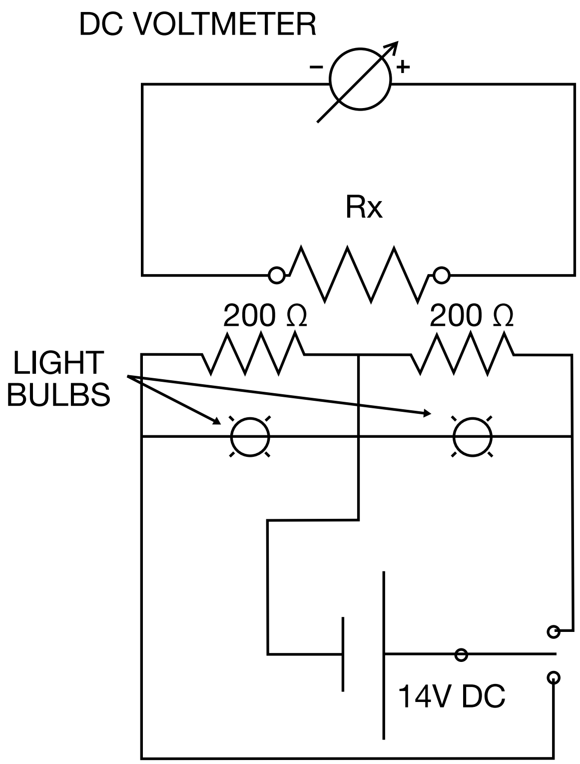


Figure 6



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