ohmcraft APPLICATION NOTE

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Glossary of Resistor Terminology

Absolute Tolerance

The tolerance of a resistor or a specific resistor in a network is also called the absolute tolerance. Refer to Resistor tolerance in this glossary.

Absolute TCR

The Temperature Coefficient of Resistance (TCR) of a resistor or a specific resistor in a network is also called the absolute TCR. Refer to TCR in this glossary.

Absolute VCR

The Voltage Coefficient of Resistance (VCR) of a resistor or a specific resistor in a resistor network is also called the absolute VCR. Refer to VCR in this glossary.

Cermet

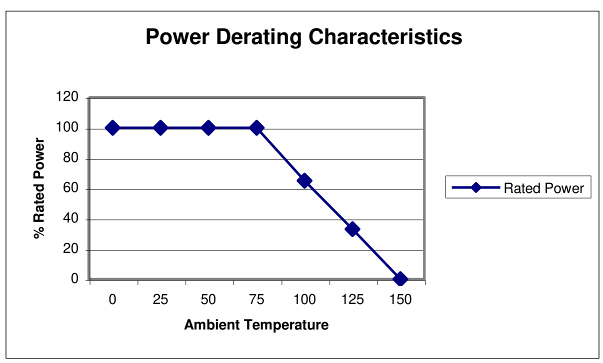
A cermet resistive element is made from a mixture of glass and metal oxides. The metal oxide is typically RuO_2 or an AgPt alloy. Applying cermet materials to a flat or cylindrical substrate, and then firing them at 850°C produce thick Film resistors. In the electronic industry cermet material is typically called Thick Film paste or ink.

Critical Resistance Value

The maximum nominal resistance value at which the rated power can be applied continuously without exceeding the maximum working voltage is the critical resistance value. The rated voltage is equal to the maximum working voltage in the critical resistance value. If the circuit designs permits, the choice of a high ohmic value resistor or divider network will eliminate this consideration.

Derating Curve

The curve that describes the relationship between the resistors's operating temperature and the maximum value of continuous power permitted at that temperature. If the circuit designs permits, the choice of a high ohmic value resistor or divider network will minimize this consideration and improve the resistor's performance because it will operate at lower power.



Dielectric Withstanding Voltage

For a leaded resistor, the Dielectric Withstanding Voltage is the voltage that can be applied between an electrode and the protective outer coating for one minute.

Maximum Working Voltage

The maximum voltage applied continuously to a resistor or a resistor element. The maximum value of the applicable voltage is the rated voltage at the critical resistance value or lower. If the circuit designs permits, the choice of a high ohmic value resistor or divider network will improve the resistor's performance because it will operate at lower power.

Noise

Resistor noise levels are typically measured with a Quantek, Inc. resistive noise meter. Resistive noise can have a devastating effect on low-level signals, charge amplifiers, high gain amplifiers, and other applications sensitive to noise. The best approach is to use resistor types with low or minimal noise in applications that are sensitive to noise. Because of their construction and manufacturing processes, Ohmcraft resistors feature low noise characteristics.

Power Rating

Power ratings are based on physical size, allowable change in resistance over life, thermal conductivity of materials, insulating and resistive materials, and ambient operating conditions. For best results, employ the largest physical size resistors at the less than their maximum rated temperature and power. Never use them continuously at their maximum rating unless you are prepared to accept the maximum allowed life cycle changes. If the circuit designs permits, the choice of a high ohmic value resistor or divider network will minimize the power level and improve the resistor's performance as it is operating at a lower power level. See the Derating curve entry in this glossary.

Ratio Tolerance

For a resistor divider or network, this is the tolerance of the ratio Is the relationship of each resistor to the others. It is often practical to specify tight ratio tolerances and loose absolute tolerances.

Rated Ambient Temperature

The maximum ambient temperature at which a resistor is capable of being used is called the rated ambient temperature. Typically the power dissipated by the resistor will raise the ambient and thus affect this parameter. The rated ambient temperature refers to the temperature around the resistor inside the equipment, not to the air temperature outside the equipment.

Rated Power

Rated power is the maximum value of power (watts), which can be continuously applied to a resistor at a rated ambient temperature. The basic mathematical relationship is:

$$\text{Power (watts)} = [\text{Current (amps)}]^2 \text{ X Resistance (ohms)}.$$

If the circuit designs permits, the choice of a high ohmic value resistor or divider network will minimize the power level and improve the resistor's performance because it is operating at a lower power and temperature level.

Rated Voltage

The maximum voltage applied continuously to a resistor at the rated ambient temperature. Rated voltage is calculated from the following formula, but it must not exceed the maximum working voltage.

$$\text{Rated Voltage (V)} = \sqrt{\text{Rated Power (W) X Nominal Resistance Value } (\Omega)}.$$

High voltage resistors often are potted or operated in oil as the arc over voltage, in air, is approximately 10,000 volts per inch. Ohmcraft's resistors feature higher voltage ratings due to their high square count and associated design characteristics.

Reliability

Reliability is the probability that a resistor (or any other device) will perform its desired function. There are two ways of defining reliability. One is Mean Time Between Failures (MTBF) and the other is Failure Rate per 1,000 hours of operation. Both of these means of evaluating reliability must be determined with a specific group of tests and a definition of what is the end of life for a device, such as a maximum change in resistance or a catastrophic failure (short or open). Various statistical studies are used at arriving at these failure rates and large samples are tested at the maximum rated temperature with rated load for up to 10,000 hours (24 hrs per day for approximately 13 months). Reliability is generally higher at lower power levels. If the circuit designs permits, the choice of a high ohmic value resistor or divider network will minimize the power level and improve the resistor's performance and reliability because it is operating at a lower power and electrical stress levels.

Resistance

The opposition to the flow of electrical current is resistance. The unit of measure is ohms (Ω). Ohms law:

$$\text{Voltage (volts)} = \text{Current (amps) X Resistance (ohms)}$$

Ohms law defines the basic electrical relationships between voltage, current and resistance. OhmCraft's resistors are unique as they are available in very high ohmic values, high voltage ratings and are very stable and have excellent low noise performance. OhmCraft's technology enables excellent stability and low noise performance also.

Resistor

The resistor is the most common and well-known passive electrical component. A resistor resists or limits the flow of electric current in a circuit, Their uses are many: they are used to drop voltage, limit current, attenuate signals, act as heaters, act as fuses, furnish electrical loads and divide voltages.

A resistor's uses are basic. For example, a voltage divider is used to divide voltages in specified increments of the applied voltage such as for analog to digital converters and digital to analog converters. Resistors are also used as matched pairs with relative accuracy much greater than their absolute accuracy. For example, matching is used in building voltage dividers and Wheatstone & Kelvin Bridges with extremely precise accuracy over a wide range of temperatures and voltages. Accurately defining the absolute value, TCR tracking, and VCR tracking and stability characteristics is critical for these applications.

There are numerous varieties of resistor technologies. To name a few: thick film, thin film, wire wound, Carbon composition, metal film, and foil. Each of these resistor technologies fill a particular application niche.

Resistors have numerous characteristics that determine their accuracy when used. The performance indices affect the accuracy to a greater or lesser extent depending on the application. Some of these are indices are: Tolerance using DC voltage, Temperature Coefficient of Resistance (TCR), Voltage Coefficient of Resistance (VCR), Noise, Stability with Time and Load, Power Rating, Physical Size, and Mounting Characteristics. Additionally, resistor networks typically require temperature and voltage tracking performance specifications.

If the circuit designs permits, the choice of a high ohmic value resistor or divider network will minimize the electrical stress on the resistor and improve its long-term performance.

Resistor Tolerance

Resistor Tolerance is expressed as the deviation from nominal value in percent and is measured at 25°C only with no appreciable load applied. A resistors value will also change with applied voltage (VCR) and temperature (TCR). For networks, **absolute resistor tolerance** refers to the overall tolerance of the network. **Ratio tolerance** refers to the relationship of each resistor to the others. It is often practical to specify tight ratio tolerances and loose absolute tolerances.

Squares & Square Count

The resistive material used in Ohmcraft resistors is characterized by a specific 'sheet resistance'. The sheet resistance is specified as the resistance in ohms of a given square (Ω / (ῑof material. 1 square of material is an area where the X and Y dimensions are identical. For example, consider an area of resistive material 1 inch by 1 inch. This is one square. An area 10 mils by 10 mils is also 1 square, as is an area 1 mil by 1 mil. If one were to make each of these resistive elements with a 100Ω /□, all three of these areas would have a resistance of 100 ohms.

The typical Ohmcraft resistor is designed with tens to thousands of squares. For example, if a resistor is made with a 3-mil wide line, and the total serpentine line length is 300 mils, the resistor would contain 100 squares. The total resistance of these resistors will equal:

Resistance = Total number of squares X Ω/ □of the resistor material.

For Ohmcraft resistors the range of the Ω/ □is 1Ω/□ to 10,000,000,000Ω/ □.

Stability

Stability is the change in resistance with time at a specific load, humidity level, stress, and ambient temperature. When these stresses are minimized, the stability is improved. For example, humidity will cause the insulation or passivation on the resistor to swell, applying pressure (stress) to the resistive element and cause a change. Changes in temperature alternately apply and relieve stresses on the resistive element, thus causing changes in resistance. The wider the range of the temperature changes and the more rapid these changes are, the greater the change in resistance. If severe enough, it can literally destroy the resistor. Rapidly and continuously subjecting a device to it's lowest and highest operating temperatures (called a Thermo cycle Test) is considered a destructive test. It should be noted that the majority of resistance change will occur during the first 100 hours of resistor operation. In critical applications, a 48 or 96-hour power conditioning cycle is specified to move the resistor into a more stable operating region. If the circuit designs permits, the choice of a high ohmic value resistor or divider network will minimize the stress on the resistor and improve its long-term performance.
OhmCraft's resistors exhibit excellent stability and are the benchmark in stable high value and/or high voltage applications.

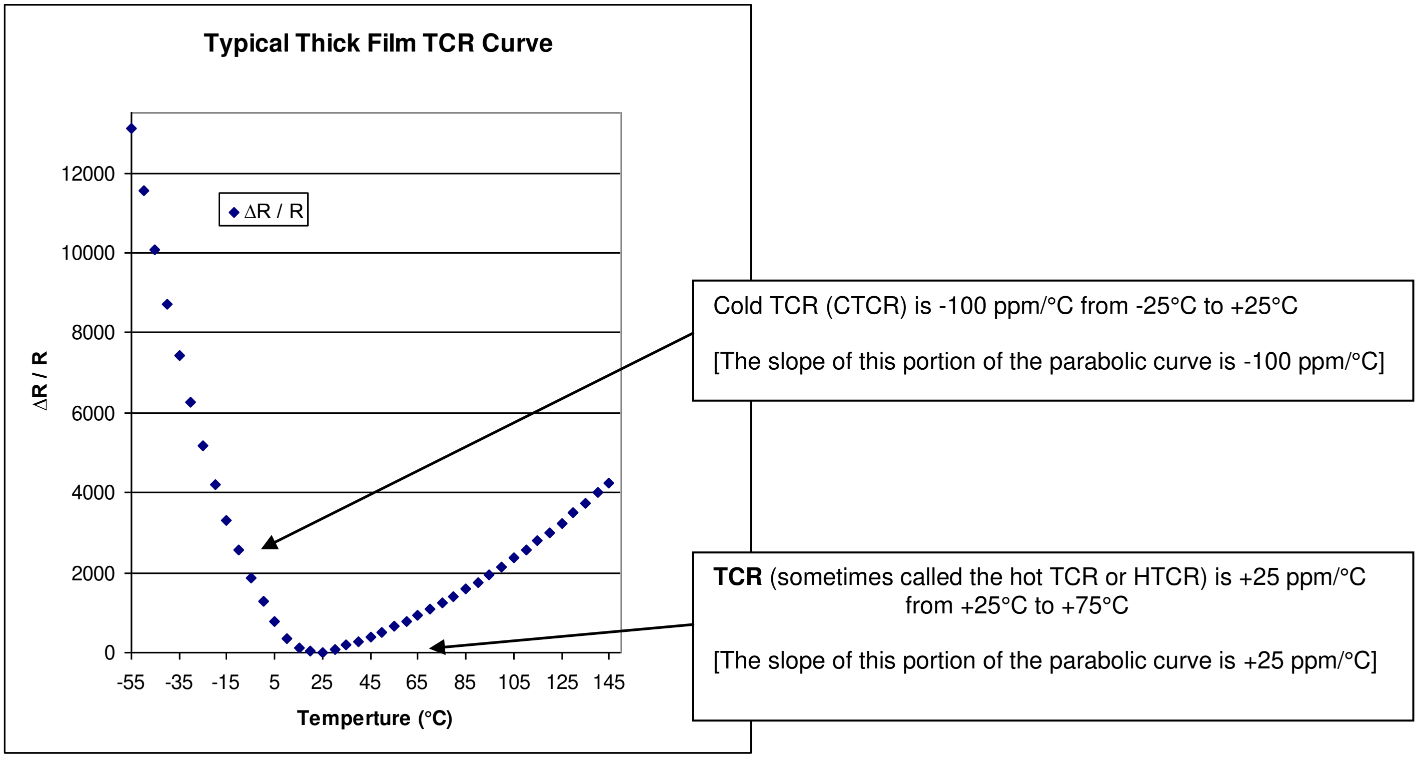
Temperature Coefficient of Resistance (TCR)

The Temperature Coefficient of Resistance (TCR) is expressed as the change in resistance in ppm (0.0001%) with each degree of change in temperature Celsius (°C). For example, a resistor with a TCR of +100 ppm/°C will change +0.1% total over a 10-degree change and +1% total over a 100-degree change. The TCR value quoted on specification sheets is typically quoted as being referenced at +25°C and is the +25°C to +75°C slope of the TCR curve. TCR is typically not linear, but parabolic with temperature, as illustrated by the accompanying figure. Often the circuit designer treats the TCR as being linear unless very accurate measurements are needed. MIL STD 202 Method 304 is often referenced as a standard for measuring TCR. The following formula expresses the rate of change in resistance value per 1 °C in a prescribed temperature range:

$$\text{TCR (ppm/°C)} = (R-R_o)/R_o \times 1/(T-T_o) \times 10^6$$

R: Measured resistance (Ω) at T °C
R_o: Measured resistance (Ω) at T_o °C
T: Measured test temperature (°C)
T_o: Measured test temperature (°C)

In the context of a resistor network, this TCR value is called the **absolute TCR** in that it defines the TRC of a specific resistor element.



TCR tracking

This term defines the difference in TCR between each specific resistor in a network. TCR Tracking is expressed in ppm/ºC. It specifies how R_1 tracks to R_2 with changes in temperature.

Temperature Rating

Temperature rating is the maximum allowable temperature at which the resistor may be used. It is generally defined with two temperatures. For example, a resistor may be rated at full load up to +70°C derated to no load at +125°C. This means that with certain allowable changes in resistance over the life of the resistor, it may be operated at +70°C at it's rated power. It also may be operated with temperatures in excess of +70°C if the load is reduced, but in no case should the temperature exceed the design temperature of +125°C with a combination of ambient temperature and self-heating due to the applied load. Also, see the 'Derating curve' entry in this glossary.

Tracking

Most precision divider or network applications depend upon achieving and maintaining close relative resistance values. Relative changes within the network are called tracking. The designer uses the terms TCR tracking and VCR tracking to define tracking performance.

Voltage Coefficient of Resistance

The Voltage Coefficient is the change in resistance with applied voltage. This is entirely different and in addition to the effects of self-heating when power is applied. A resistor with a VCR of 100 ppm/V will change 0.1% over a 10 Volt change and 1% over a 100 Volt change. The rate of change in resistance value per 1 volt in the prescribed voltage range is expressed by the following formula:

$$VCR\ (ppm/V) = (R_o - R)/R_o \times 1/(V_o - V) \times 10^6$$

R: Measured resistance (Ω) at base voltage
R_o: Measured resistance (Ω) at upper voltage
V: Base voltage
V_o: Upper voltage

In the context of a resistor network, this VCR value is called the **absolute VCR** in that it defines the VRC of a specific resistor element.

VCR tracking

This term defines the difference in VCR between each specific resistor in a network. VCR Tracking is expressed in ppm/V. It specifies how R_1 tracks to R_2 with changes in applied voltage.