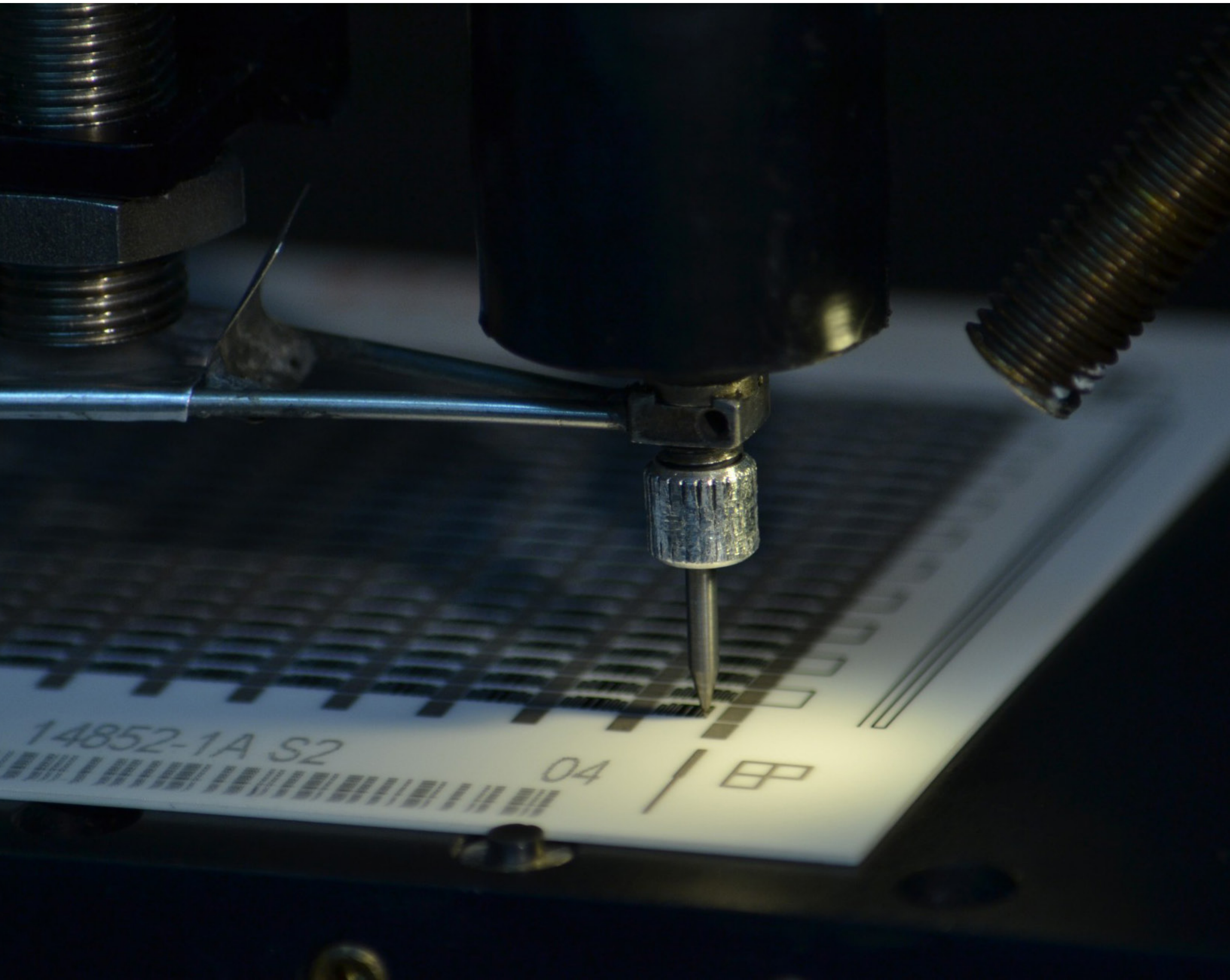
WHITEPAPER

You don’t have to choose between thick-film or thin-film resistors

Ohmcraft Micropenning gives you the best of both.



Traditional resistor technology falls short.

When it comes to making resistors, traditional hybrid technologies have their limitations. Screen-formed thick-film resistors can be made in a wide range of values, but the short current path and material constraints severely compromise performance characteristics.

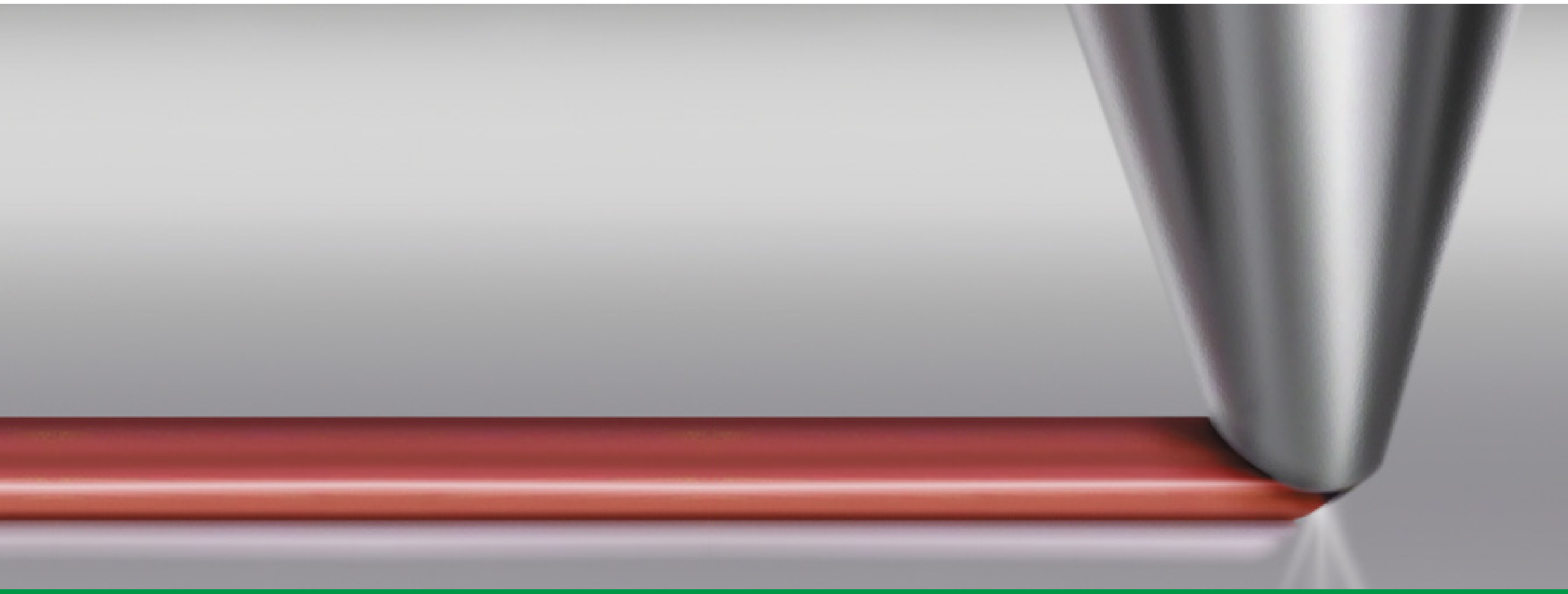
Thin-film resistors, while capable of high precision, are expensive to design and manufacture and severely limited in attainable value.

Older technologies are burdened by extensive tooling requirements, so prototyping and pilot runs incur high per-part costs.

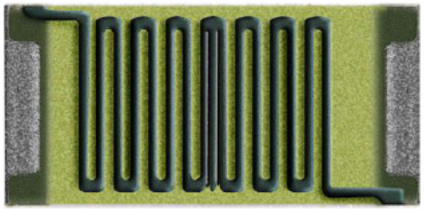
Meet Ohmcraft resistors with Micropenning technology that deliver high resistance values in a small footprint.

These Ohmcraft resistors get their performance characteristics from our proprietary electronic printing technology, which deposits thick film resistor inks in line/spacing widths that are effectively a full order of magnitude smaller than otherwise possible. This results in significantly enhanced characteristics—we can use corresponding lower-value inks to reach a given resistance value in a given area.

Micropenning also offers linearity and much higher voltage ratings in both the steady state and pulsed mode because of the greater length of the conducting trace. These advantages are most significant in higher values.

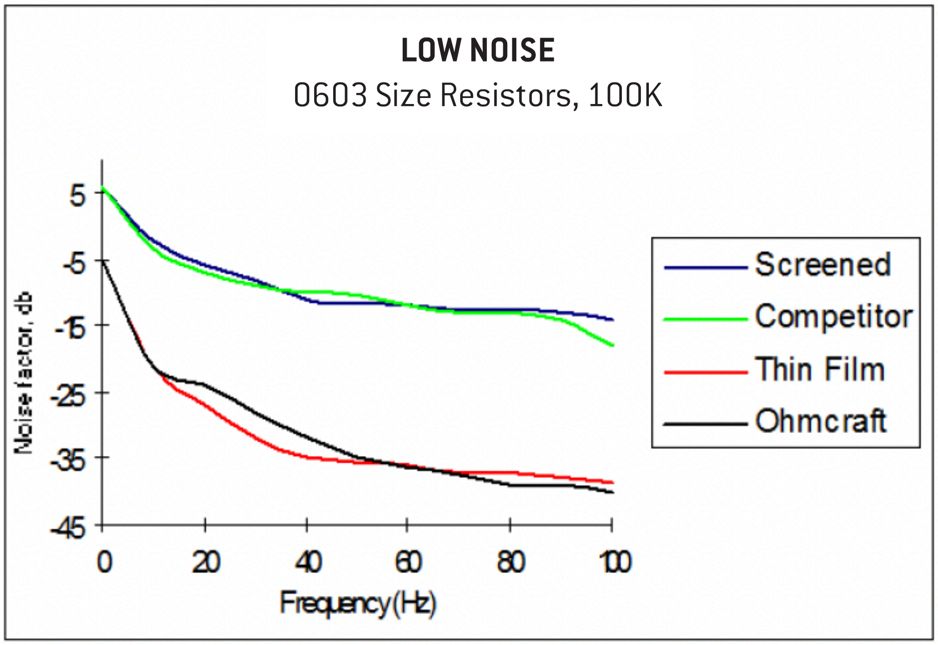


Long, high-aspect ratio trace
+
Lower conductivity film
=
Design flexibility with higher performance.

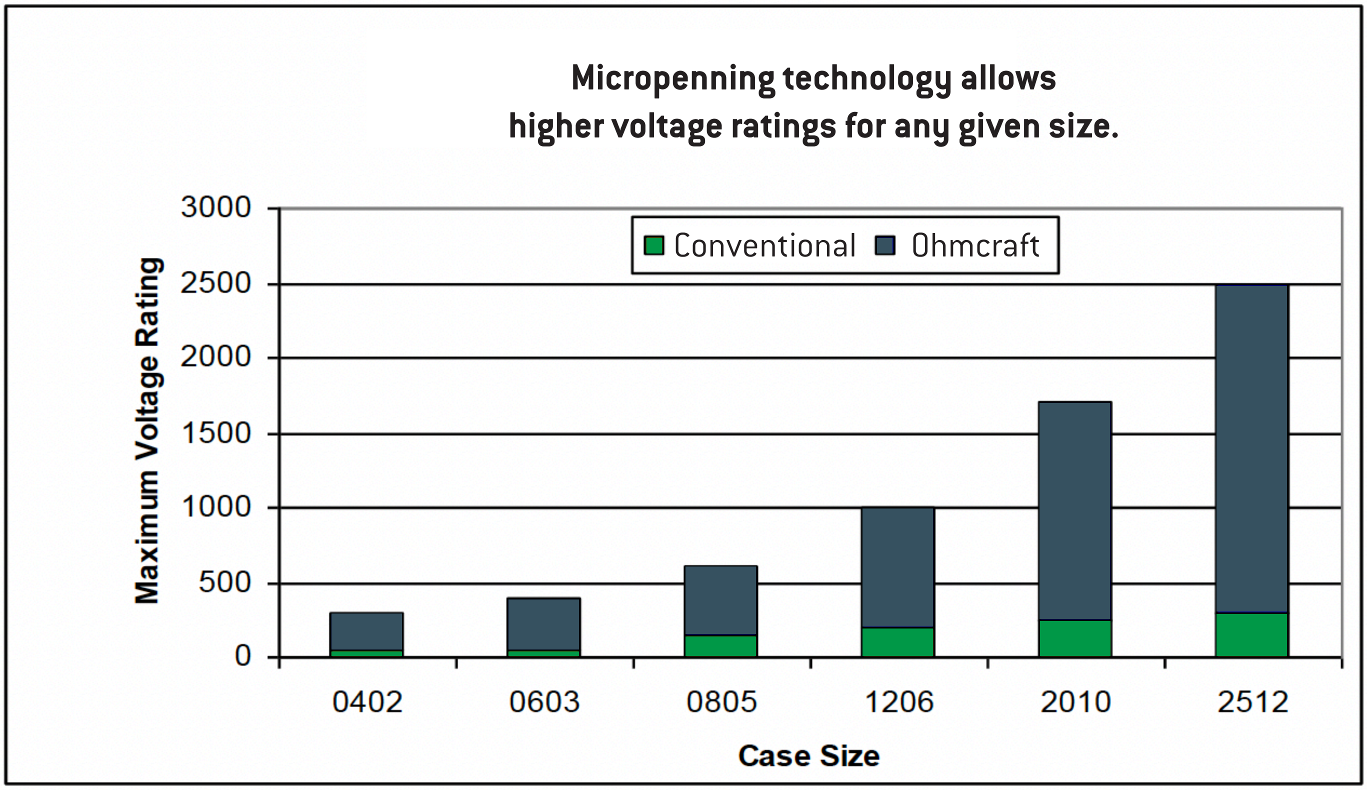

1206 Chip Size

Durability, range and low cost of thick film; high performance of thin film.

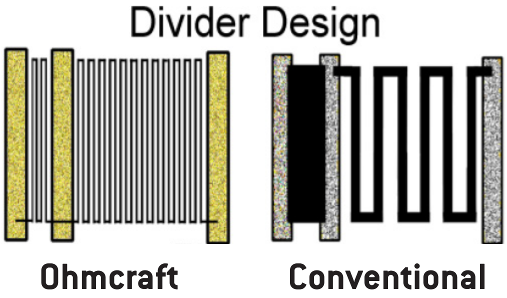
Ohmcraft Micropen resistors combine the close tracking, low current noise, current-voltage linearity, low TCR, and close resistance tolerance of thin film with the high durability, wide resistance range, and low cost of thick film.



Micropenning allows us to make high-ohmic resistors in a smaller footprint.



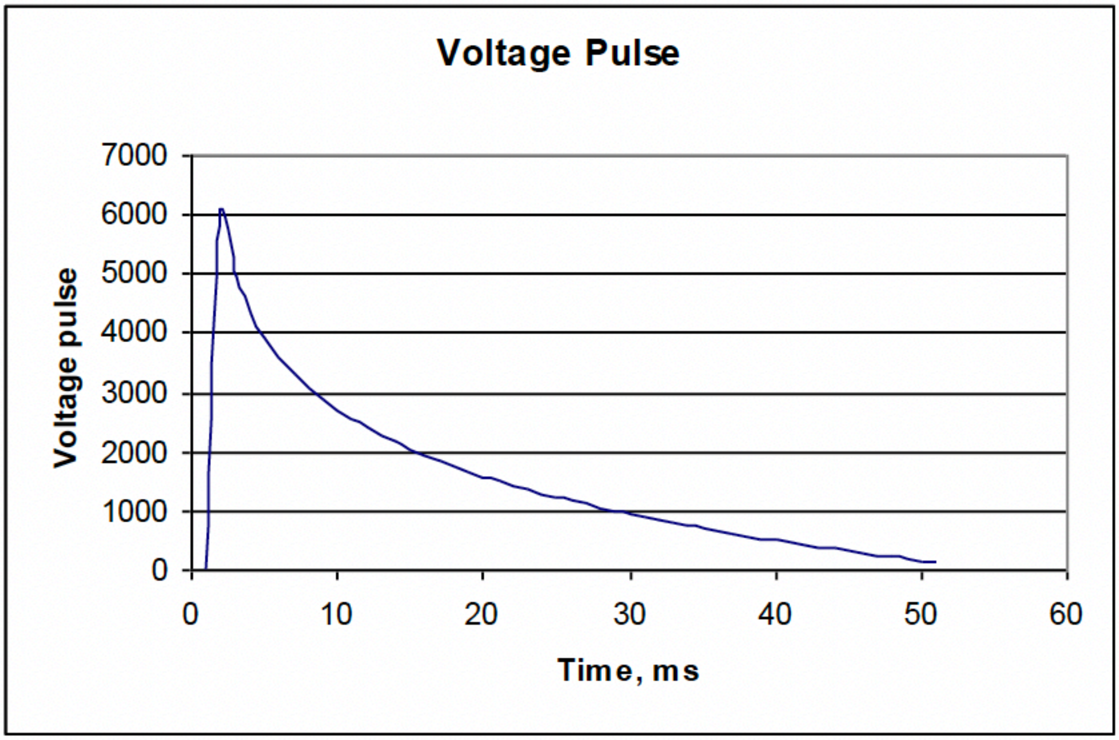
Micropenning enables Ohmcraft to design longer resistor patterns, allowing for much higher ohmic values for any given case size. The technology also results in greater dimensional stability, which leads to manufactured tolerances that competitive products are unable to achieve.

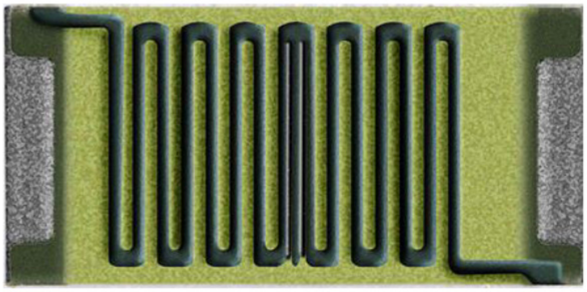


Micropenning allows us to create virtually any divider ratio with outstanding tracking.

The long serpentine pattern used in manufacturing Ohmcraft High-Voltage Dividers (HVD's), coupled with the use of low ohms/square thick film inks, makes it possible to create virtually any divider ratio with exceptional tracking. For example, Ohmcraft has produced 800 Meg-Ohm dividers with a 20,000:1 ratio. Low noise, low TCR, low VCR, and many other features add up to the finest leaded divider in the industry today.

Unequaled Peak Pulse Tolerance





The longer trace in an Ohmcraft resistor leads to greatly reduced internal voltage gradients, which allow it to handle intermittent voltage spikes and ESD much more effectively than conventional designs.

Case Size	2512	1206	0805
Ohms	1 K – 1 M	1 K – 1 M	1 K – 1 M
Continuous Power	2 W	1 W	0.2 W
Continuous Voltage	2500 V	1000 V	600 V
Peak Power in Joules	2 J	0.5 J	0.3 J

Using Micropenning technology, these components have been designed and tested, especially to withstand and dissipate very high peak voltage energy pulses and transient overloads. They are especially effective by comparison with conventional designs in higher values. In order to maximize these advantages, they are usually designed without close tolerance features such as trim areas.

Close Resistance Tolerance

The long-path configuration of Ohmcraft micropenned resistors permits trimming of such features as ladders, loops, or top hats, which provide separate regions of high and low trim sensitivity. This is in contrast to conventional thick-film trimming, which is limited to destabilizing and damage-prone single notch or plunge cuts.

Designed and produced with low-resistivity compositions, the stability of Ohmcraft resistors/dividers is significantly better than conventional designs, one measure of which is their virtually flat voltage coefficient of resistivity across a wide range of values. The technology also results in greater dimensional stability, which leads to manufactured tolerances that conventional products are unable to achieve.

Ohmcraft is your best source for high-performance chip and leaded resistor products.

Since our founding in 1982, Ohmcraft has realized steady growth as more and more companies have discovered the unique advantages of our micropenning resistor technology.

Our customers have discovered something else: Everyone at Ohmcraft is committed to matching the excellence of our products with equally excellent customer service. We emphasize and insist on this strong focus on quality in customer service—from the front office, to the factory floor, to our field sales offices.

How Can We Help?

To learn more about how our products can help provide high quality, cost-effective solutions for your products, contact us.

Contact Us:
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ohmcraftsales@exxelia.com

We have attached our Glossary of Resistor Terminology, which can be helpful in specifying Ohmcraft resistors with Micropenning technology.

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.

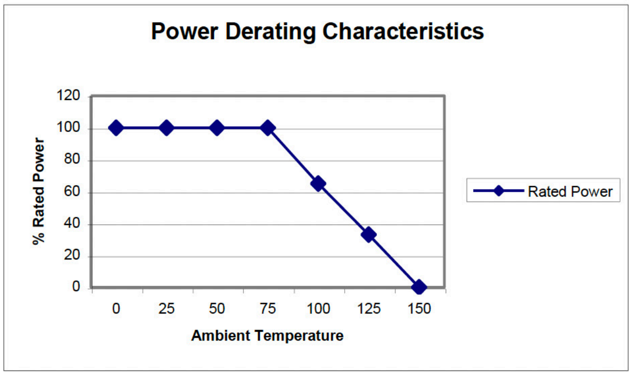
Absolute TCR
The Temperature Coefficient of Resistance (TCR) of a resistor or a specific resistor in a network is also called the absolute TCR. Refer to TCR in this glossary.

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. Cermet materials are applied to a flat or cylindrical substrate, and then fired at 850°C to produce thick-film resistors. In the electronic industry, cermet material is typically called Thick Film paste or ink.

Critical Resistance Value
The critical resistance value is the maximum nominal resistance value at which power can be continuously applied. The rated voltage is equal to the maximum working voltage in the critical resistance value. If the circuit design permits, the choice of a high ohmic value resistor or divider network will eliminate this consideration.

Derating Curve
This curve describes the relationship between the resistor's operating temperature and the maximum value of continuous power permitted at that temperature. If the circuit design 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 design 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 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 design 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 in 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 temperature 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:

Power (watts) = [Current (amps)]2 X Resistance (ohms).

If the circuit design 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.

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

High voltage resistors are often 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 the end of life is for a device, such as a maximum change in resistance or a catastrophic failure (short or open). Various statistical studies are used to arrive 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 design 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: Voltage (volts) = 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, are very stable, and have excellent low noise performance. Ohmcraft's micropenning technology enables this combination of excellent stability and low noise, along with high ohmic values and high voltage ratings.

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. Resistors 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 design 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 /) of material. 1 square of material is an area in which 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 and 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 its 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 design 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.

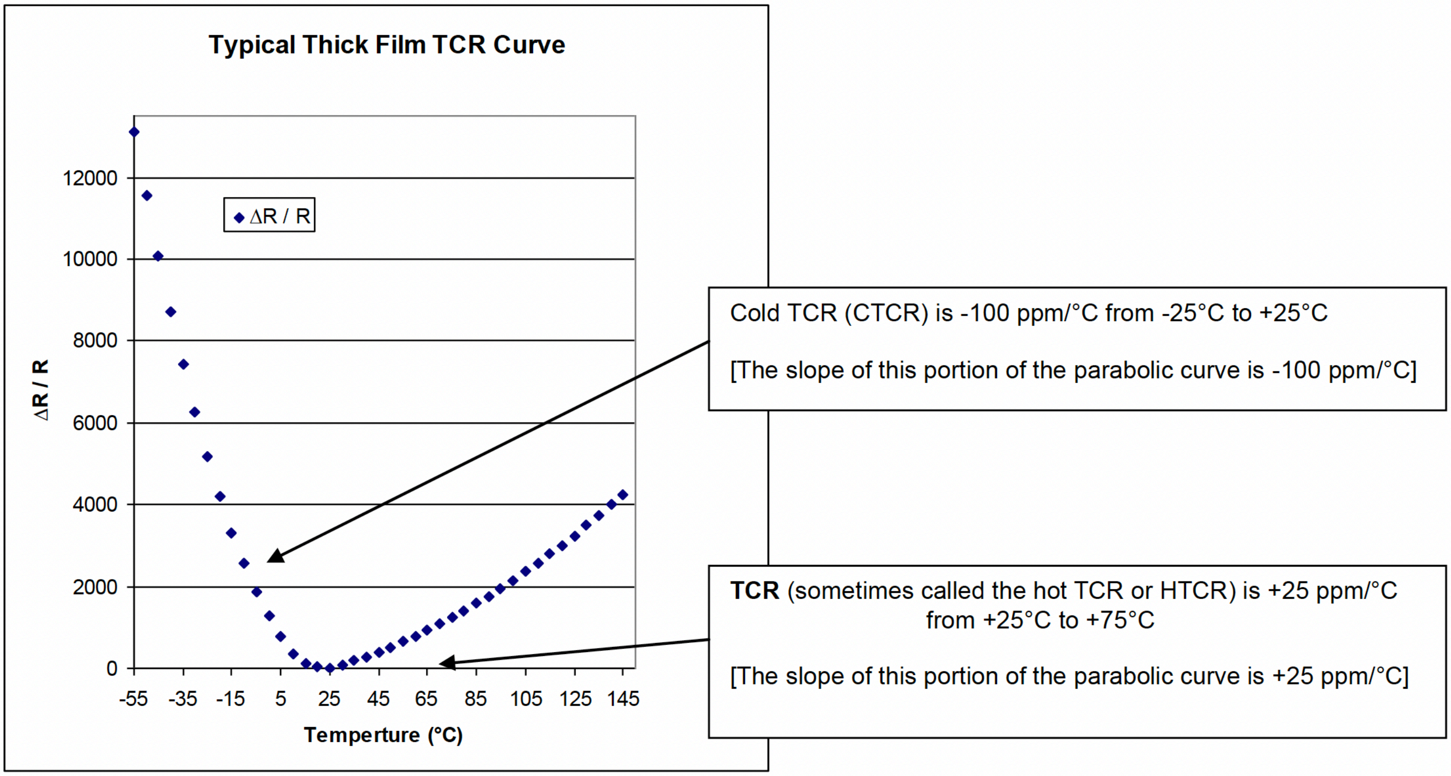
Temperature Coefficient of Resistance (TCR)

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. The circuit designer often 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:

TCR (ppm/°C) = (R-Ro)/Ro X 1/(T-To) X 10^6

- R: Measured resistance (Ω) at T °C
- Ro: Measured resistance (Ω) at To °C
- T: Measured test temperature (°C)
- To: Measured test temperature (°C)

Typical Thick Film TCR Curve



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

TCR tracking

This term defines the difference in TCR between specific resistors in a network. TCR Tracking is expressed in ppm/ºC. It specifies how R1 tracks to R2 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 its 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) = (Ro -R)/Ro X 1/(Vo -V) X 10^6

- R: Measured resistance (Ω) at base voltage
- Ro: Measured resistance (Ω) at upper voltage V: Base voltage Vo: 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 R1 tracks to R2 with changes in applied voltage.

How Can We Help?

To learn more about how our products can help provide high quality, cost-effective solutions for your products, contact us.

Contact Us:
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