Power Resistor Materials and Construction

WHITEPAPER

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contents

3 Wirewound Resistors
4 Composition Resistors
5 Thin and Thick Film Resistors
5 In Summary
6 Ohmite Contact
Resistors are a fundamental and common two-terminal electronic component used to control current flow. Various types of resistors are employed in circuits, used in conjunction with other parts such as inductors and capacitors to process signals and control circuit voltages and currents so that ICs and transistors that produce or amplify signals are supplied with the correct voltages and currents.

In order to meet the demands of multiple applications, resistors are produced with a wide variety of materials and manufacturing processes. This white paper describes common types of resistor construction including wirewound, composition, thick film and thin film. Each resistor construction uses different materials. These materials have specific properties and areas of use.

Let’s look at these construction types one at a time.

**WIREWOUND RESISTORS**

Wirewound resistors are constructed using a conductive wire. The conductive wire is then wound around a non-conductive core. Resistive elements are commonly lengths of wire, usually an alloy such as Nichrome (Nickel-Chromium) or Manganin (Copper/Nickel/Manganese) wrapped around a ceramic or glass fiber rod or tube and coated in an insulating flameproof coating. With all types of wirewound resistor, fire protection is important and flame proof cases or coatings are vital. To that end wirewound resistors can be designed using element wire that has a thin coating on it to prevent arcing between windings.

The conductive wire can be made of varying thickness (gauge) to control the resistance value. General properties of wirewound resistors are good stability, high-temperature performance, and a wide resistance range.

Wirewounds also have good surge handling characteristics and can be built to withstand very high power pulses for short durations with extremely little resistance shift; it is to be noted that the lower the resistance value the greater the surge that can be handled due to the lower gauge wire used in lower values. In some cases, wirewound resistors can also withstand relatively high voltage in upper resistance ranges.

Wirewound resistors can be designed using a wire alloy with a specific resistance per foot without reducing overall wire mass, yielding a resistor with excellent voltage...
handling capabilities without sacrificing its pulse power handling. When built in this way fewer turns are required to achieve the needed resistance, thereby widening the gap between consecutive windings and increasing the voltage capability.

Typically used in high power and industrial applications such as welding equipment and motor control. Wire-wound construction resistors can be chosen based on mounting, application, and resistance range. Different types of wirewound resistors include Precision, Axial, Tubular, Surface mount and Adjustable, which all have good stability and resistance range and are produced in many wattage sizes. Higher wattage wirewound resistors are used in High Current/Braking applications in the transportation market.

A wirewound resistor can have a smaller physical size for a given power rating than carbon composition or film resistors. Standard wirewound resistors however, do not have the close tolerance of film types. The resistance tolerance of a power resistor is the extent to which its resistance may be permitted to deviate above or below the specified resistance.

Generally speaking their inductance, however, is much higher than that of a carbon composition device; even those which are non-inductively wound will still have inductance that is too high for high speed switching power supplies.

### COMPOSITION RESISTORS

Composition resistors for high energy and pulse handling are produced using a mixture of a finely ground insulator and conductor. This mixture is then compressed into a shape (cylinder is the most popular). Terminals are attached and the insulation coating is applied to the outside. The resistance is based on the ratio of the insulator and conductor mixture. Composition resistors are chosen based on energy handling and resistance value and typically have a high tolerance.

Composition resistors perform best in high energy/surge applications as the large amount of mass contained in the resistor enables high levels of energy absorption. The high levels can be repeated without permanent effects to the manufactured resistance value. Composition resistors have proven to be a robust choice in handling surge applications.

The inherent low inductance of composition construction resistors makes them ideally suited for high pulse energy requirements and high switch speed power supply applications. Even non-inductively wound wire-wounds have higher inductance than a similar size carbon composition part. The material mass provides pulse handling far superior to film resistor technology.

Figure 2: Ohmite offers over 20 different series in wirewound construction, which can be chosen based on mounting, application, and resistance range. Different types of wirewound resistors include Precision, Axial, Tubular, Surface mount, and Adjustable, which all have good stability and resistance range and are produced in many wattage sizes. The higher wattage wirewound resistors are used in High Current/Braking applications.

Figure 3: Ohmite’s non-inductive, high voltage, high power tubular resistors are available in a wide range of standard sizes, ceramic materials, terminations and mounting hardware. The ceramic resistors provide excellent performance for high peak power or high-energy pulses. Bulk construction allows energy and power to be uniformly distributed through the entire ceramic resistor body; there is no film or wire to fail. These ceramic-based resistors are compatible with a wide array of end products, including rail charging stations, switchgear, motor controls, defibrillators, accelerators, circuit breakers, high voltage power supplies, etc.
THIN AND THICK FILM RESISTORS

Thin and thick film resistors are characterized by a resistive layer on a non-conductive substrate. Although their appearance might be very similar, their properties and manufacturing process are very different. The naming originates from the different layer thicknesses. However, the main difference is the method in which the resistive film is applied onto the substrate. While thick film resistors are formed by screen printing metal particle resin composite, thin film resistors are formed by a deposited vacuum process such as Sputtering and Chemical Vapor Deposition. Thin film is more accurate, has a better temperature coefficient and in general is more stable. It therefore competes with other technologies that feature high precision, such as wirewound.

Figure 4: Ohmite offers over 20 different series in Thick Film construction. Thick Film parts can be chosen based on mounting, application, and voltage range. They are easily integrated into a heat-sinkable package for high wattage application. High values can be obtained and High Voltage can be applied to thick film products with little change in resistance value.

Thick film technology is useful in applications requiring higher resistance values and voltage handling. Process and design improvements have made high surge handling capability possible, which has made thick film pulse withstandng resistors popular.

High voltage thick film resistors fall under two broad categories: coated or printed. Printed versions have a serpentine pattern applied by screen printing onto a flat or cylindrical substrate. Coated versions have the substrate coated in ink and then trimmed using a diamond cutting wheel. Serpentine patterns are trimmed by using a laser beam. Tiny “ladders” are removed, thereby changing the current flow in a direction which adds resistance in “steps,” allowing the operator to “tune in” to the proper value and tolerance. This allows for much tighter resistance tolerances and better performance specifications.

Thin Film resistors are known for stability and tight tolerances. The resistive layer is sputtered (vacuum deposition) onto a non-conductive substrate. This creates a uniform metallic film of around 0.1 micrometer thick. This process allows the same high values of a Thick Film product but yields better specifications with regard to stability. Thin Film resistors have relatively limited surge capabilities such as ESD and short time overload due to the low mass of resistive material. Precision test equipment and constant current source circuits benefit from Thin Film resistor construction technology.

Thin film resistors are very precise and boast very tight resistance tolerances, and excellent Temperature Coefficient of Resistance (TCR) characteristics. TCR is the measure of change in electrical resistance of any substance per degree of temperature change. Thin film resistors also have much less current noise and have better performance characteristics in high frequency applications.

Thick film parts can be chosen based on mounting, application, and voltage range. They are easily integrated into a heat sinkable package for high wattage applications. High voltage can be applied to thick film products with little change in resistance value.

Ohmite has multiple part series for high voltage applications. With custom specifications offered and multiple mountings, Ohmite high voltage resistors fill the need for multiple applications including power supplies, avionics, medical instruments, and industrial controls.

IN SUMMARY

In summary, Ohmite strives to offer customers the widest variety of product options in all resistor product categories. The company has been the leading provider of resistive products for high current, high voltage, and high energy applications for over 90 years. Through partnerships with distributors Ohmite will continue to expand the choices for customers, in packaging, construction, power ratings, and resistance values.