Resistor Energy Ratings, Technology and Construction Types

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The power rating and voltage rating of a resistor is a common source of misunderstanding. When current passes through a resistor power is dissipated and this manifests itself in the form of heat. In turn this causes the temperature of the resistor to rise, and if too much current passes through the resistor, the temperature rise can cause the resistance to change, or in extreme cases cause damage to the resistor. So simply put, the power rating is the amount of heat a resistor can dissipate in a given time at the designated ambient temperature without overheating and sustaining damage.

The power rating of resistors can vary from one tenth of a watt or less to many hundreds of watts depending upon its size, construction and ambient operating temperature. Generally speaking the larger the physical size the higher the wattage rating as more power can be dissipated safely into the ambient air or into a heatsink. When a resistor has a power rating of 1W, a maximum of 1W power can be fed to it for all combinations of voltage and current.

One should keep in mind, however, that in terms of general guidelines, the importance of noting the conditions at which power dissipation ratings are quoted in a spec sheet cannot be understated and use at full rated power usually is not recommended without careful consideration, as reliability and parametric stability are likely to become issues by that point.

Even engineers are sometimes surprised to learn that a resistor with a relatively high power rating might have a very poor energy handling capability. The energy rating of a resistor is dependent on the mass of the resistive element employed. In the case of a wirewound resistor, for instance, the resistance wire itself can vary greatly in mass. Of all resistor construction types Composition (Carbon or Ceramic) offers the highest energy ratings for a given size because the mass of the resistor element is far greater than any other technology. The entire body of the resistor comprises the element, unlike wire or film, and it is unmatched in its ability to withstand high energy pulses.

On the other hand thick film resistors have not been a good candidate for high energy applications because the mass of the resistor element is quite low, and trimming is almost always required to bring the resistor to its desired value.
PULSE LOADS
The continuous-power rating is the primary parameter that you do not want to exceed for a resistor. Resistors can withstand single pulse loads higher than their rated dissipation over a short duration without degrading, changing value, or failing.

Exceeding the rated power for a limited period is generally acceptable but prolonged overload can result in excessive temperatures. A surge condition for a resistor is the application of a power level that exceeds the continuous-power rating of the part for a defined length of time or pulse width. The pulse width is normally 25% or less of the thermal time constant of the resistor.

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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 cylindrical shape. 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. The inherent low inductance of composition technology resistors makes them ideally suited for high pulse energy requirements and high switch speed power supply applications.

Carbon resistors are the most common type of Composition Resistors. Their resistive element is manufactured from a mixture of finely ground carbon dust or graphite and a non-conducting ceramic (clay) powder to bind it all together.

Ceramic-based resistors can range from 1/2 watt to a 1000 watts in a single component, and are compatible with a wide array of end products, including rail charging stations, switchgear, motor controls, defibrillators, circuit breakers, high voltage power supplies, etc.

Thin and thick film resistors are characterized by a resistive layer on a ceramic base. 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. Thick film technology is useful in applications requiring resistors in smaller, lower power, and surface mountable packages that have high surge handling capability compared to thin film resistors, which has made thick film pulse withstanding resistors popular. Thin Film resistors have relatively limited surge capabilities such as ESD and short time overload due to the low mass of resistive material. 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 1: The AS series is a small size and lightweight anti-surge resistor. According to IEC 61000-4-5, the AS Series Anti-surge Thick Film Chip Resistor can withstand voltages of 5KV.

Resistors that tolerate pulse or surge are required for pre-charge resistors, ESD protection, and lightning protection.

There are many other possible causes for pulse loads to occur in electronic circuits: The switching of capacitors or inductors may introduce pulses at other passive components in a circuit. The voltage on an automotive supply system is distorted (e.g., a “load dump” pulse, caused by disconnecting the battery with the engine with the generator still running).

COMMON RESISTOR CONSTRUCTION TYPES
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 film. Wirewound construction resistors can be chosen based on mounting, application, and resistance range.

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Carbon resistors are the most common type of Composition Resistors. Their resistive element is manufactured from a mixture of finely ground carbon dust or graphite and a non-conducting ceramic (clay) powder to bind it all together.

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Thin and thick film resistors are characterized by a resistive layer on a ceramic base. 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. Thick film technology is useful in applications requiring resistors in smaller, lower power, and surface mountable packages that have high surge handling capability compared to thin film resistors, which has made thick film pulse withstanding resistors popular. Thin Film resistors have relatively limited surge capabilities such as ESD and short time overload due to the low mass of resistive material. 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.
IMPACT OF RESISTOR TRIMMING ON THICK FILM RESISTORS

There are many different trimming methods which can be used to adjust the value of the resistor such as, heat trimming, electrical trimming, mechanical trimming, chemical trimming and laser trimming, with laser trimming is by far the most effective and popular method for thick film resistors. The laser uses a light beam of a few μm in diameter to remove the resistive film from the ceramic substrate in a very short time period (less than 1 msec).

Among common geometries are plunge, ‘L’ and serpentine cuts. The plunge cut is a simple cut consisting of a single Kerf --the width of material that is removed by a cutting process orthogonal to the current flow through the resistive element. On the other hand its overall tolerance accuracy can be less than other methods. The ‘L’ cut is the most frequently employed method due to its stability and tolerance accuracy. With this type of cut the resistance increases rapidly as the cut is perpendicular to the current flow. A shadow cut consists of an additional plunge to the side of an ‘L’ cut or plunge cut. As a result, tighter resistance tolerances can be achieved as the kerf is cut in an area of low current density in the shadow of the first cut. The additional trimming time needed can make this type of cut expensive. A serpentine cut consists of multiple cuts made in areas of high current density which effectively increase the geometric length of the resistor and thus its resistance value. It has the ability to give a large resistance gain. As a result, the tolerance accuracy of the resistor is improved.

Figure 2 Ohmite’s TP Series high-energy resistors offer users the benefits of non-inductive performance and high power density. Double-sided screen printing of pulse-tolerant, thick film ink, coupled with a scan-cut laser trimming process, maximizes the energy withstanding capabilities of the series.

WHY OHMITE?
Ohmite has been the leading provider of resistive products for high current, high voltage, and high energy applications for over 90 years. The company’s full complement of resistor construction includes wirewound, wire element, thick film, and ceramic composition. Ohmite also leads the way in thermal management for resistive and other technologies offering a vast array of heatsinks. Through partnerships with distributors Ohmite will continue to expand choices for customers, in packaging, construction, power ratings, and resistance values.