Electronics Tutorial about the Types of Resistors

The Different Types of Resistors

Resistors (R), are the most fundamental and commonly used of all the electronic components, to the point where they are almost taken for granted. There are many different **Types of Resistors** available to the electronics constructor, from very small surface mount chip resistors up to large wirewound power resistors. The principal job of a resistor within an electrical or electronic circuit is to "resist" (hence the name resistor) or to impede the flow of electrons through them by using the type of material that they are composed from. Resistors can also act as voltage droppers or voltage dividers within a circuit.

A Typical Resistor

Resistors are "Passive Devices", that is they contain no source of power or amplification but only attenuate or reduce the voltage signal passing through them. This attenuation results in electrical energy being lost in the form of heat as the resistor resists the flow of electrons through it.

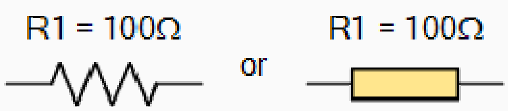
Then a potential difference is required between the two terminals of a resistor for current to flow. This potential difference balances out the energy lost. When used in DC circuits the potential difference, also known as a resistors voltage drop, is measured across the terminals as the circuit current flows through the resistor.

Most resistors are linear devices that produce a voltage drop across themselves when an electrical current flows through them because they obey Ohm's Law, and different values of resistance produces different values of current or voltage. This can be very useful in Electronic circuits by controlling or reducing either the current flow or voltage produced across them.

There are many thousands of different **Types of Resistors** and are produced in a variety of forms because their particular characteristics and accuracy suit certain areas of application, such as High Stability, High Voltage, High Current etc, or are used as general purpose resistors where their characteristics are less of a problem. Some of the common characteristics associated with the humble resistor are; **Temperature Coefficient, Voltage Coefficient, Noise, Frequency Response, Power** as well as **Temperature Rating, Physical Size** and **Reliability**.

In all Electrical and Electronic circuit diagrams and schematics, the most commonly used symbol for a fixed value resistor is that of a "zig-zag" type line with the value of its resistance given in Ohms, Ω. Resistors have fixed resistance values from less than one ohm, (<1Ω) to well over tens of millions of ohms, (>10MΩ) in value. Fixed resistors have only one single value of resistance, for example 100Ω's but variable resistors (potentiometers) can provide an infinite number of resistance values between zero and their maximum value.

Standard Resistor Symbols



The symbol used in schematic and electrical drawings for a Resistor can either be a "zig-zag" type line or a rectangular box.

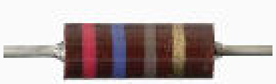
All modern fixed value resistors can be classified into four broad groups;

- Carbon Composition Resistor - Made of carbon dust or graphite paste, low wattage values
- Film or Cermet Resistor - Made from conductive metal oxide paste, very low wattage values
- Wire-wound Resistor - Metallic bodies for heatsink mounting, very high wattage ratings
- Semiconductor Resistor - High frequency/precision surface mount thin film technology

There are a large variety of fixed and variable resistor types with different construction styles available for each group, with each one having its own particular characteristics, advantages and disadvantages compared to the others. To include all types would make this section very large so I shall limit it to the most commonly used, and readily available general purpose types of resistors.

Composition Type Resistors

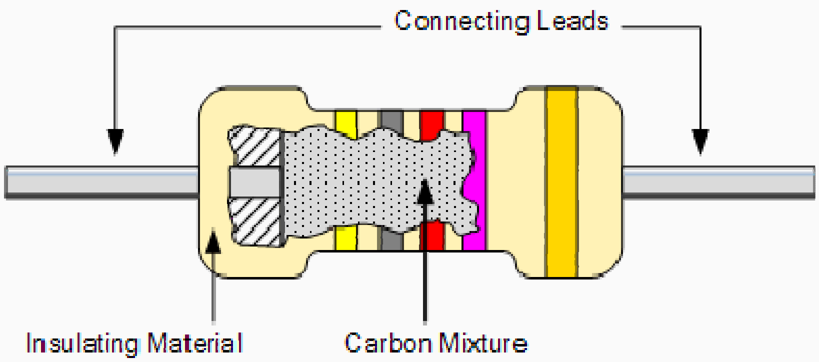
Carbon Resistors are the most common type of **Composition Resistors**. Carbon resistors are a cheap general purpose resistor used in electrical and electronic circuits. Their resistive element is manufactured from a mixture of finely ground carbon dust or graphite (similar to pencil lead) and a non-conducting ceramic (clay) powder to bind it all together.



Carbon Resistor

The ratio of carbon dust to ceramic (conductor to insulator) determines the overall resistive value of the mixture and the higher the ratio of carbon, the lower the overall resistance. The mixture is moulded into a cylindrical shape with metal wires or leads are attached to each end to provide the electrical connection as shown, before being coated with an outer insulating material and colour coded markings to denote its resistive value.

Carbon Resistor

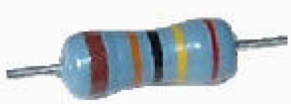


The **Carbon Composite Resistor** is a low to medium type power resistor which has a low inductance making them ideal for high frequency applications but they can also suffer from noise and stability when hot. Carbon composite resistors are generally prefixed with a "CR" notation (eg, CR10kΩ) and are available in E6 (± 20% tolerance (accuracy)), E12 (± 10% tolerance) and E24 (± 5% tolerance) packages with power ratings from 0.125 or 1/4 of a Watt up to 5 Watts.

Carbon composite resistors are very cheap to make and are therefore commonly used in electrical circuits. However, due to their manufacturing process carbon type resistors have very large tolerances so for more precision and high value resistances, **film type resistors** are used instead.

Film Type Resistors

The generic term "**Film Resistor**" consist of *Metal Film*, *Carbon Film* and *Metal Oxide Film* resistor types, which are generally made by depositing pure metals, such as nickel, or an oxide film, such as tin-oxide, onto an insulating ceramic rod or substrate.

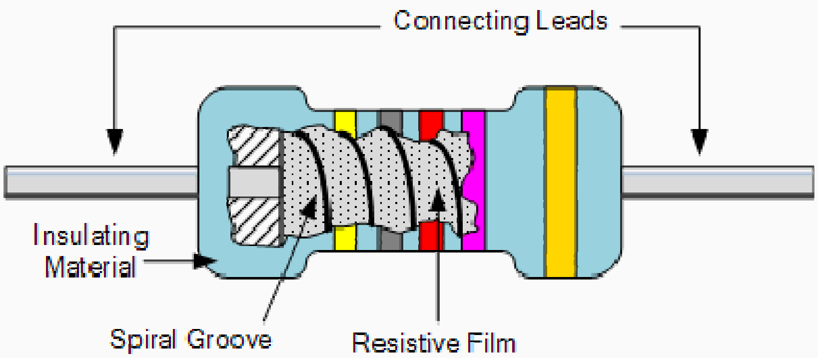


Film Resistor

The resistive value of the resistor is controlled by increasing the desired thickness of the deposited film giving them the names of either "thick-film resistors" or "thin-film resistors". Once deposited, a laser is used to cut a high precision spiral helix groove type pattern into this film. The cutting of the film has the effect of increasing the conductive or resistive path, a bit like taking a long length of straight wire and forming it into a coil.

This method of manufacture allows for much closer tolerance resistors (1% or less) as compared to the simpler carbon composition types. The tolerance of a resistor is the difference between the preferred value (i.e, 100 ohms) and its actual manufactured value i.e, 103.6 ohms, and is expressed as a percentage, for example 5%, 10% etc, and in our example the actual tolerance is 3.6%. Film type resistors also achieve a much higher maximum ohmic value compared to other types and values in excess of 10MΩ (10 Million Ω´s) are available.

Film Resistor



Metal Film Resistors have much better temperature stability than their carbon equivalents, lower noise and are generally better for high frequency or radio frequency applications. **Metal Oxide Resistors** have better high surge current capability with a much higher temperature rating than the equivalent metal film resistors.

Another type of film resistor commonly known as a **Thick Film Resistor** is manufactured by depositing a much thicker conductive paste of **CER**amic and **MET**al, called **Cermet**, onto an alumina ceramic substrate. Cermet resistors have similar properties to metal film resistors and are generally used for making small surface mount chip type resistors, multi-resistor networks in one package for pcb's and high frequency resistors. They have good temperature stability, low noise, and good voltage ratings but low surge current properties.

Metal Film Resistors are prefixed with a "MFR" notation (eg MFR100kΩ) and a CF for Carbon Film types. Metal film resistors are available in E24 (±5% & ±2% tolerances), E96 (±1% tolerance) and E192 (±0.5%, ±0.25% & ±0.1% tolerances) packages with power ratings of 0.05 (1/20th) of a Watt up to 1/2 Watt. Generally speaking Film resistors are precision low power components.

Wirewound Type Resistors

Another type of resistor, called a **Wirewound Resistor**, is made by winding a thin metal alloy wire (Nichrome) or similar wire onto an insulating ceramic former in the form of a spiral helix similar to the film resistor above. These types of resistors are generally only available in very low ohmic high precision values (from 0.01 to 100kΩ) due to the gauge of the wire and number of turns possible on the former making them ideal for use in measuring circuits and Whetstone bridge type applications.

They are also able to handle much higher electrical currents than other resistors of the same ohmic value with power ratings in excess of 300 Watts. These high power resistors are moulded or pressed into an aluminum heat sink body with fins attached to increase their overall surface area to promote heat loss and cooling. These types of resistors are called "Chassis Mounted Resistors". They are designed to be physically mounted onto heatsinks or metal plates to further dissipate the generated heat increasing their current carrying capabilities even further.

Wirewound Resistor

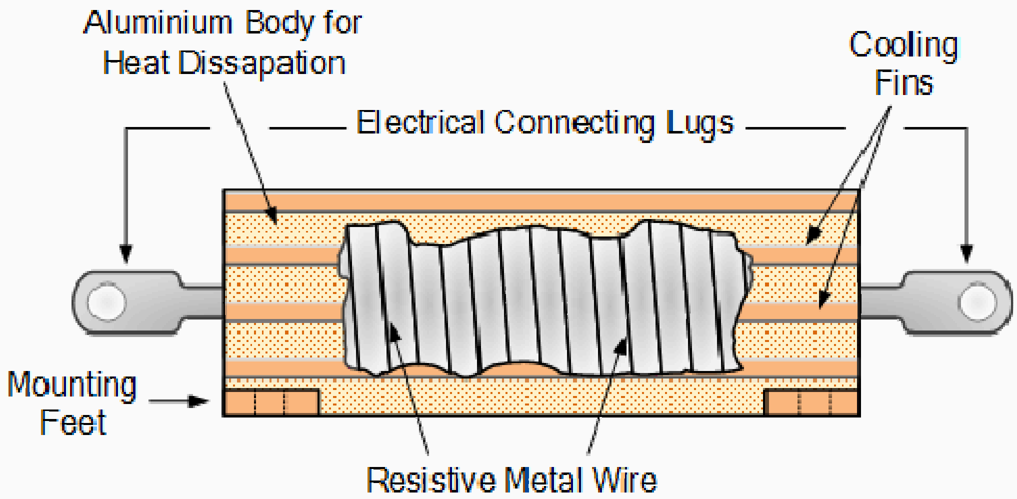
Another type of wirewound resistor is the **Power Wirewound Resistor**. These are high temperature, high power non-inductive resistor types generally coated with a vitreous or glass epoxy enamel for use in resistance banks or DC motor/servo control and dynamic braking applications. They can even be used as space or cabinet heaters.

The non-inductive resistance wire is wound around a ceramic or porcelain tube covered with mica to prevent the alloy wires from moving when hot. Wirewound resistors are available in a variety of resistance and power ratings with one main use of power wirewound resistor is in the electrical heating elements of an electric fire which converts the electrical current flowing through it into heat with each element dissipating up to 1000 Watts, (1kW) of energy.

Because the wire is wound into a coil, it acts like an inductor causing them to have inductance as well as resistance and this affects the way the resistor behaves in AC circuits by producing a phase shift at high frequencies especially in the larger size resistors. The length of the actual resistance path in the resistor and the leads contributes inductance in series with the "apparent" DC resistance resulting in an overall impedance path Z. impedance (Z) is the combined effect of resistance (R) and inductance (X), measured in ohms and for a series AC circuit is given as, $Z^2 = R^2 + X^2$.

When used in AC circuits this inductance value changes with frequency (inductive reactance, $XL = 2\pi f L$) and therefore, the overall value of the resistor changes. Inductive reactance increases with frequency but is zero at DC (zero frequency). Then, wirewound resistors must not be designed into AC or amplifier type circuits where the frequency across the resistor changes. However, special non-inductive wirewound resistors are also available.

Wirewound Resistor



Wirewound resistor types are prefixed with a "WH" or "W" notation (eg WH10Ω) and are available in the WH aluminium cladded package (±1%, ±2%, ±5% & ±10% tolerance) or the W vitreous enamelled package (±1%, ±2% & ±5% tolerance) with power ratings from 1W to 300W or more.

In the next tutorial about Resistors, we will look at the different ways of identifying the resistive value of the different types of fixed resistors with the most common method of identification being the use of **Colour Codes** and colour bands around the body of the resistor.