STUDY ON RESISTORS

A typical axial-lead resistor

Three carbon composition resistors in a 1960s valve (vacuum tube) radio

Axial-lead resistors on tape.

Components used to resist current.

1. See the Transducer section below for resistors used to sense environmental conditions (Thermistor, Photo resistor, RTD...)
2. See the Protection section below for resistors used for current or voltage limiting (MOV, Inrush Limiters...)

* Resistor - fixed value
* Resistor network - array of resistors in one package
* Trimmer - Small variable resistor
* Potentiometer, Rheostat - variable resistor
* Heater - heating element
* Resistance wire - wire of high-resistance material, similar to heating element
* Thermistor - temperature-varied resistor
* Varistor - voltage-varied resistor

A resistor is a two-terminal electronic component that produces a voltage across its terminals that is proportional to the electric current through it in accordance with Ohm's law:

$$V = IR$$

Resistors are elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome).

The primary characteristics of a resistor are the resistance, the tolerance, the maximum working voltage and the power rating. Other characteristics include temperature coefficient, noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current, and above which the limit is applied voltage. Critical resistance is determined by the design, materials and dimensions of the resistor.

Resistors can be integrated into hybrid and printed circuits, as well as integrated circuits. Size, and position of leads (or terminals), are relevant to equipment designers; resistors must be physically large enough not to overheat when dissipating their power.

Units

The ohm (symbol: Ω) is the SI unit of electrical resistance, named after Georg Simon Ohm. Commonly used multiples and submultiples in electrical and electronic usage are the milliohm (1x10−3), kilohm (1x103), and megohm (1x106).

Lead arrangements

Through-hole components typically have leads leaving the body axially. Others have leads coming off their body radially instead of parallel to the resistor axis

Other components may be SMT (surface mount technology) while high power resistors may have one of their leads designed into the heat sink.

Carbon composition

Carbon composition resistors consist of a solid cylindrical resistive element with embedded wire leads or metal end caps to which the lead wires are attached. The body of the resistor is protected with paint or plastic. Early 20th-century carbon composition resistors had uninsulated bodies; the lead wires were wrapped around the ends of the resistance element rod and soldered. The completed resistor was painted for color coding of its value.

The resistive element is made from a mixture of finely ground (powdered) carbon and an insulating material (usually ceramic). A resin holds the mixture together. The resistance is determined by the ratio of the fill material (the powdered ceramic) to the carbon. Higher concentrations of carbon, a weak conductor, result in lower resistance. Carbon composition resistors were commonly used in the 1960s and earlier, but are not so popular for general use now as other types have better specifications, such as tolerance, voltage dependence, and stress (carbon composition resistors will change value when stressed with over-voltages). Moreover, if internal moisture content (from exposure for some length of time to a humid environment) is significant, soldering heat will create a non-reversible change in resistance value. These resistors, however, if never subjected to overvoltage nor overheating were remarkably reliable considering the component's size [1]

They are still available, but comparatively quite costly. Values ranged from fractions of an ohm to 22 megohms. Because of the high price, these resistors are no longer used in most applications. However, carbon resistors are used in power supplies and welding controls[1].

[edit] Carbon film

A carbon film is deposited on an insulating substrate, and a helix cut in it to create a long, narrow resistive path. Varying shapes, coupled with the resistivity of carbon, (ranging from 90 to 400 nΩm) can provide a variety of resistances.[2] Carbon film resistors feature a power rating range of 0.125 W to 5 W at 70 °C. Resistances available range from 1 ohm to 10 megohm. The carbon film resistor has an operating temperature range of -55 °C to 155 °C. It has 200 to 600 volts maximum working voltage range.[3]. Special carbon film resistors are used in applications requiring high pulse stability[1].

Metal film

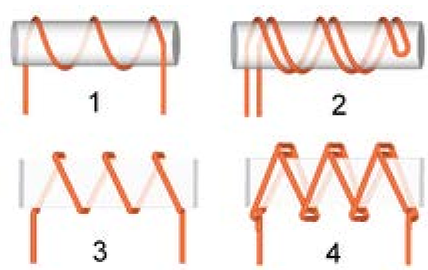
A common type of axial resistor today is referred to as a metal-film resistor. Metal electrode leadless face (MELF) resistors often use the same technology, but are a cylindrically shaped resistor designed for surface mounting. Note that other types of resistors (e.g., carbon composition) are also available in MELF packages.

Metal film resistors are usually coated with nickel chromium (NiCr), but might be coated with any of the cermet materials listed above for thin film resistors. Unlike thin film resistors, the material may be applied using different techniques than sputtering (though that is one such technique). Also, unlike thin-film resistors, the resistance value is determined by cutting a helix through the coating rather than by etching. (This is similar to the way carbon resistors are made.) The result is a reasonable tolerance (0.5, 1, or 2%) and a temperature coefficient that is generally between 50 and 100 ppm/K.[4]. Metal film resistors possess good noise characteristics and low non-linearity due to a low voltage coefficient. Also beneficial are the components efficient tolerance, temperature coefficient and stability[1].

Metal Oxide film

Metal-Oxide film resistors resemble Metal film types, but are made of metal oxides such as tin oxide. This results in a higher operating temperature and greater stability/reliability than Metal film. They are used in applications with high endurance demands.

Wirewound



Types of windings in wire resistors:

1 - common

2 - bifilar

3 - common on a thin former

4 - Ayrton-Perry

Wirewound resistors are commonly made by winding a metal wire, usually nichrome, around a ceramic, plastic, or fiberglass core. The ends of the wire are soldered or welded to two caps or rings, attached to the ends of the core. The assembly is protected with a layer of paint, molded plastic, or an enamel coating baked at high temperature. Because of the very high surface temperature these resistors can withstand temperatures of up to +450 °C[1]. Wire leads in low power wirewound resistors are usually between 0.6 and 0.8 mm in diameter and tinned for ease of soldering. For higher power wirewound resistors, either a ceramic outer case or an aluminum outer case on top of an insulating layer is used. The aluminum-cased types are designed to be attached to a heat sink to dissipate the heat; the rated power is dependent on being used with a suitable heat sink, e.g., a 50 W power rated resistor will overheat at a fraction of the power dissipation if not used with a heat sink. Large wirewound resistors may be rated for 1,000 watts or more.

Because wirewound resistors are coils they have more undesirable inductance than other types of resistor, although winding the wire in sections with alternately reversed direction can minimize inductance. Other techniques employ bifilar winding, or a flat thin former (to reduce cross-section area of the coil). For most demanding circuits resistors with Ayrton-Perry winding are used.

Applications of wirewound resistors are similar to those of composition resistors with the exception of the high frequency. The high frequency of wirewound resistors is substantially worse than that of a composition resistor

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