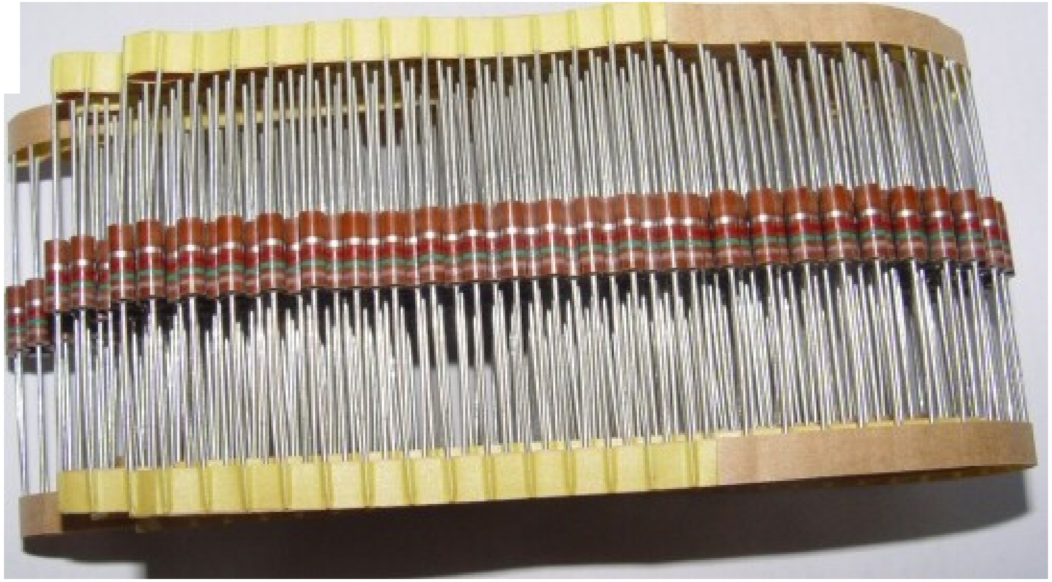
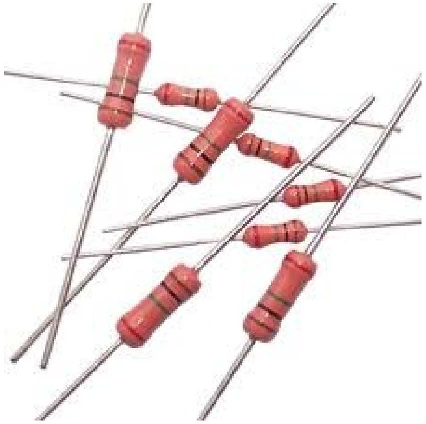
RESISTORS





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INTRODUCTION

- **A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.**

- **Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment.**

- **Practical resistors can be made of various compounds and films, as well as resistance wire.**

- **Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits.**

- **common commercial resistors are manufactured over a range of more than nine orders of magnitude.**

ELECTRONIC SYMBOL

The symbol used for a resistor in a circuit diagram varies from standard to standard and country to country.

American-style symbols: (a) resistor, (b) rheostat (variable resistor), and (c) potentiometer

IEC-style resistor symbol

THEORY

Ohm's law:

The behavior of an ideal resistor is dictated by the relationship specified by Ohm's law:

$$V = I \cdot R.$$

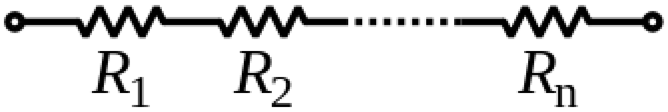
The ratio of the voltage applied across a resistor's terminals to the intensity of current in the circuit is called its resistance, and this can be assumed to be a constant (independent of the voltage) for ordinary resistors working within their ratings.

The ohm (symbol: Ω) is the SI unit of electrical resistance, named after Georg Simon Ohm. An ohm is equivalent to a volt per ampere.

The reciprocal of resistance R is called conductance G = 1/R and is measured in siemens, sometimes referred to as a mho.

eries and parallel resistors:

In a series configuration, the current through all of the resistors is the same, but the voltage across each resistor will be in proportion to its resistance.

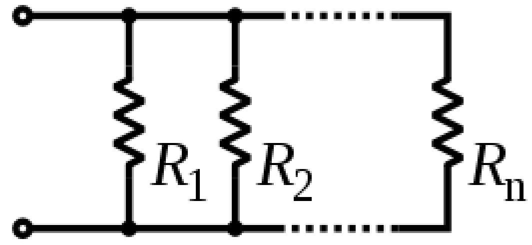


The potential difference (voltage) seen across the network is the sum of those voltages, thus the total resistance can be found as the sum of those resistances.

$$R_{\mathrm{eq}} = R_1 + R_2 + \cdots + R_n.$$

As a special case, the resistance of *N* resistors connected in series, each of the same resistance *R*, is given by *NR*.

Resistors in a parallel configuration are each subject to the same potential difference (voltage), however the currents through them add.



The conductances of the resistors then add to determine the conductance of the network. Thus the equivalent resistance (*Req*) of the network can be computed:

$$\frac{1}{R_{\mathrm{eq}}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}.$$

$$R_{\mathrm{eq}} = R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}.$$

The greater the number of resistors in parallel, the less overall resistance they will collectively generate, and the resistance will never be higher than that of the resistor with the lowest resistance in the group.

Power dissipation:

At any instant of time, the **power P** consumed by a resistor of resistance *R* (ohms) is calculated as:

$$P = I^2R = IV = \frac{V^2}{R}$$

The total amount of **heat energy released** over a period of time can be determined from the integral of the power over that period of time:

$$W = \int_{t_1}^{t_2} v(t)i(t)\,dt.$$

Therefore one could write the **average power dissipated** over that particular time period as:

$$\bar{P} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} v(t)i(t)\,dt.$$

Resistors required to dissipate substantial amounts of power, particularly used in power supplies, power conversion circuits, and power amplifiers, are generally referred to as **power resistors.** This designation is loosely applied to resistors with power ratings of 1 watt or greater.

Power resistors are physically larger and may not use the preferred values, color codes, and external packages

An aluminium-housed power resistor rated for 50 W when heat-sinked.

TYPES OF RESISTORS

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. High power resistors may have one of their leads designed into the heat sink.

Resistors with wire leads for through-hole mounting.

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.

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 good conductor - result in lower resistance. They are used in [illegible] and welding controls.

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

Carbon pile:

A carbon pile resistor is made of a stack of carbon disks compressed between two metal contact plates. Adjusting the clamping pressure changes the resistance between the plates. These resistors are used when an adjustable load is required, for example in testing automotive batteries or radio transmitters. A carbon pile resistor can also be used as a speed control for small motors in household appliances, with ratings up to a few hundred watt. A carbon pile resistor can be incorporated in automatic voltage

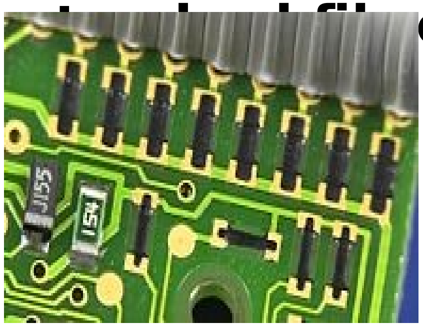
Carbon film:

A carbon film is deposited on an insulating substrate, and a helix is cut in it to create a long, narrow resistive path. Varying shapes, coupled with the resistivity of amorphous carbon (ranging from 500 to 800 μΩ), can provide a variety of resistances. 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 ... ature range of −55 °C to 155 °C. It has 200 ... num working voltage range.

Partially exposed Tesla TR-212 1 kΩ carbo film resistor.

rinted carbon resistor:

Carbon composition resistors can be printed directly onto printed circuit board (PCB) substrates as part of the PCB manufacturing process. Whilst this technique is more common on hybrid PCB modules, it can also be used on ... eglass PCBs.



A carbon resistor printed directly onto the SMD pads on a PCB, Inside a 1989 vintage Psion II Organiser.

Thick and thin film resistors:

Thin film resistors are made by sputtering the resistive material onto an insulating substrate. The film is then etched in a similar manner to the old (subtractive) process for making printed circuit boards; that is, the surface is coated with a photo-sensitive material, then covered by a pattern film, irradiated with ultraviolet light, and then the exposed photo-sensitive coating is developed, and underlying thin film is etched away.

Because the time during which the sputtering is performed can be controlled, the thickness of the thin film can be accurately controlled. The type of material is also usually different consisting of one or more ceramic (cermet) conductors such as tantalum nitride (TaN), ruthenium oxide (RuO2), lead oxide (PbO), bismuth ruthenate (Bi2Ru2O7), nickel chromium (NiCr), or bismuth iridate (Bi2Ir2O7).

Thin film resistors are usually far more expensive than thick film resistors.

The resistive element of thick films is 1000 times thicker than thin films. These are manufactured using screen and stencil printing processes.

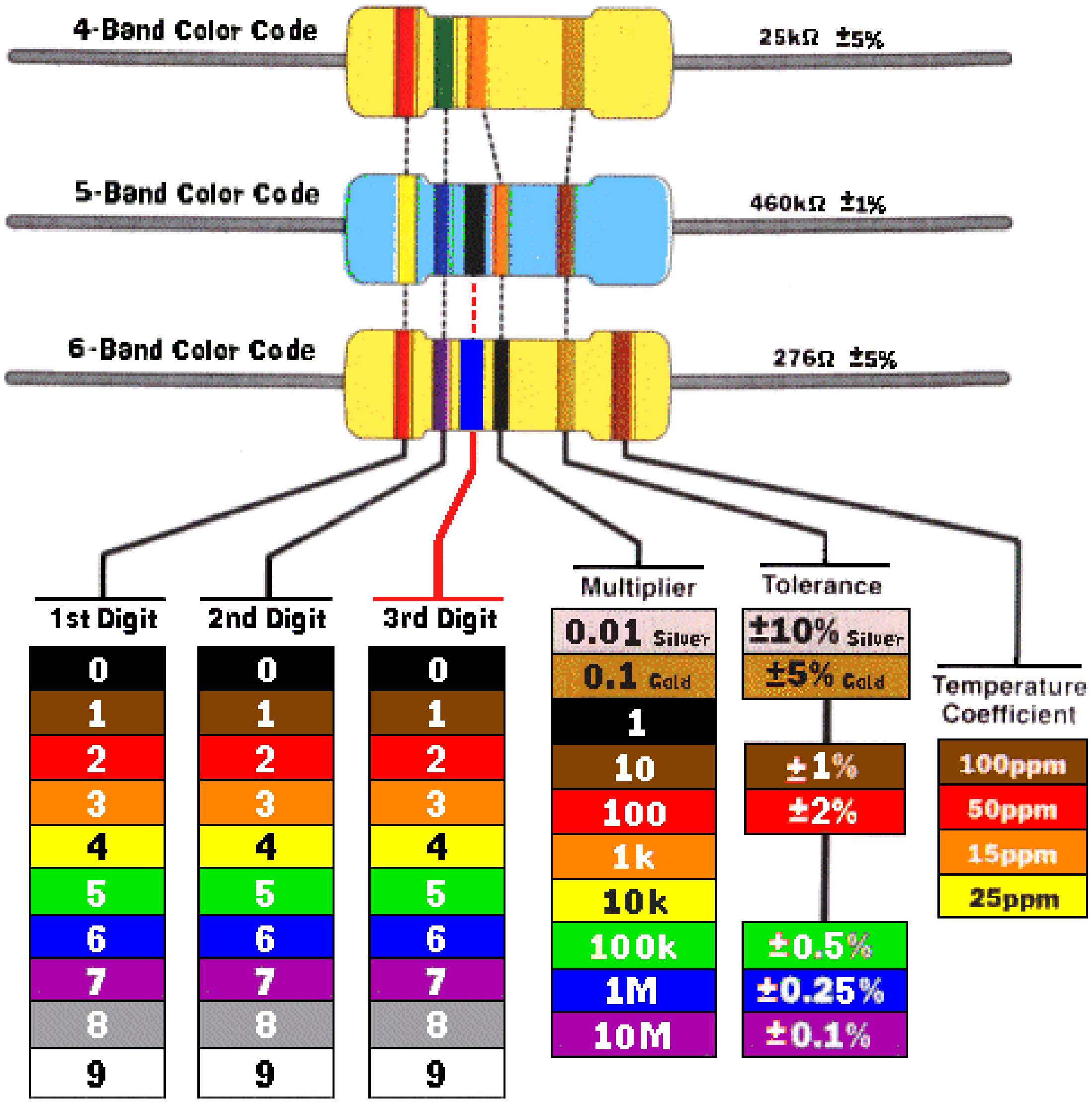
They may use the same conductive ceramics, but they are mixed with sintered (powdered) glass and a carrier liquid so that the composite can be screen-printed. This composite of glass and conductive ceramic (cermet) material is then fused (baked) in an oven at about 850 °C.

The resistance of both thin and thick film resistors after manufacture is not highly accurate; they are usually trimmed to an accurate value by abrasive or laser trimming.

Wire-wound resistors:

Wire-wound 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.

COLOR CODE



4-Band Color Code
25kΩ ±5%
5-Band Color Code
460kΩ ±1%
6-Band Color Code
276Ω ±5%
1st Digit
2nd Digit
3rd Digit
0
1
2
3
4
5
6
7
8
9
Multiplier
0.01 Silver
0.1 Gold
1
10
100
1k
10k
100k
1M
10M
Tolerance
±10% Silver
±5% Gold
±1%
±2%
±0.5%
±0.25%
±0.1%
Temperature Coefficient
100ppm
50ppm
15ppm
25ppm

COLOR	DIGIT	MULTIPLIER	TOLERANCE	TC
Silver		x 0.01 Ω	±10%	
Gold		x 0.1 Ω	±5%	
	0	x 1 Ω		
Brown	1	x 10 Ω	±1%	±100*10-6/K
Red	2	x 100 Ω	±2%	±50*10-6/K
Orange	3	x 1 kΩ		±15*10-6/K
Yellow	4	x 10 kΩ		±25*10-6/K
Green	5	x 100 kΩ	±0.5%	
Blue	6	x 1 MΩ	±0.25%	±10*10-6/K
Violet	7	x 10 MΩ	±0.1%	±5*10-6/K
Grey	8	x 100 MΩ		
White	9	x 1 GΩ		±1*10-6/K


THANK
YOU