Electronic Basics #16: Resistors

Introduction to Resistors

A **resistor** is a fundamental passive electronic component that opposes the flow of electric current. It is widely used in circuits for **voltage division, current limiting, signal conditioning, and power dissipation**. Resistors come in various types, materials, and values, making them essential in almost all electronic and electrical applications. The resistance of a resistor is measured in **ohms (Ω)** and follows **Ohm's Law**, which states:

V=IR

where:

- V = voltage across the resistor (volts)
- I = current flowing through the resistor (amperes)
- R = resistance (ohms)

Fig16.1: Resistor

Resistor Color Code Chart

Resistor color coding is a standard method to indicate **resistance values** using **colored bands** printed on the resistor body. This system follows the **Electronic Industries Association (EIA) standard** and is commonly used for through-hole resistors.

Understanding the Color Code

A standard **4-band resistor** has:
First Band – First significant digit
Second Band – Second significant digit
Multiplier – Power of ten (10n10^n10n)
Tolerance – Accuracy of the resistor

A **5-band resistor** includes an extra **third significant digit**, improving precision.

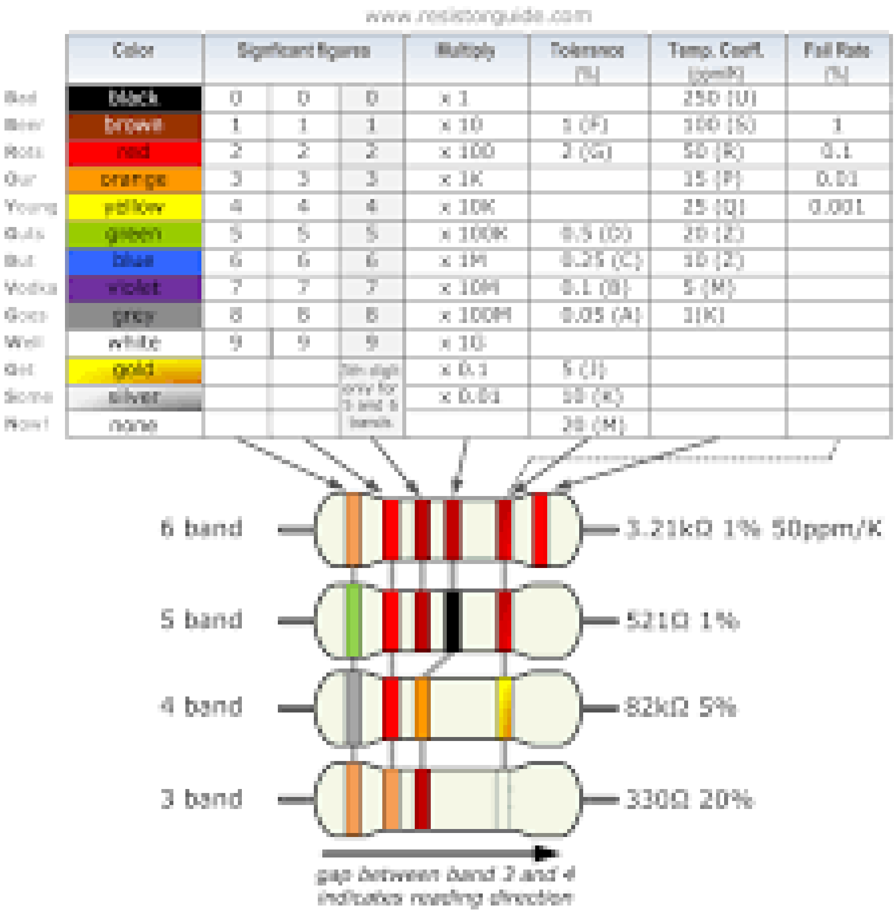

Fig16.2: Resistor Color Code Chart

Types of Resistors

Fixed Resistors

Fixed resistors have a **constant resistance value** that does not change under normal conditions. Common types include:

- **Carbon Composition Resistors** – Cheap but less precise.
- **Metal Film Resistors** – More accurate and stable.
- **Wirewound Resistors** – High power handling capability.

Variable Resistors (Potentiometers & Rheostats)

These resistors allow for **adjustable resistance** by sliding or rotating a contact.

- **Potentiometers** – Used for **volume control** in audio circuits.
- **Rheostats** – Used for **current control** in motors and lighting.

Special Purpose Resistors

- **Thermistors** – Temperature-dependent resistors (NTC/PTC).
- **LDR (Light Dependent Resistors)** – Changes resistance based on light intensity.

- **Shunt Resistors** – Low-value resistors used for **current measurement**.

How Resistors Work

Resistors work by **converting electrical energy into heat** as they oppose current flow. The amount of heat generated is given by **Joule's Law**:

P=I2RP = I^2 R

where:

- P= power dissipated (watts)
- I = current (amperes)
- R = resistance (ohms)

In a **series circuit**, resistors **add up**:

Rtotal=R1+R2+R3+…R

In a **parallel circuit**, resistances combine as:

1Rtotal=1R1+1R2+1R3+…

Creating a Voltage Divider

A voltage divider is a simple circuit that splits a voltage into a lower desired value using two resistors in series. It is widely used in sensor interfacing, reference voltage generation, and signal scaling. The output voltage is given by:

Vout=Vin×R2R1+R2V

where:

- **Vin is the input voltage,**
- **Vout is the reduced output voltage,**
- **R1R_1 and R2R_2 are the resistors in series.**

For example, to step down 5V to 3.3V, choosing R1 = 1kΩ and R2 = 2kΩ will give the desired output voltage. This method is commonly used in microcontroller ADC inputs, biasing circuits, and power supply adjustments.

Resistors in Current Limiting Applications

In circuits, resistors **protect components** by limiting excessive current. For example, in an LED circuit, a **series resistor** prevents the LED from burning out. The required resistance is calculated as:

R=(Vsource−VLED)/ILED

where VLEDV is the LED forward voltage and ILEDis the desired current.

Resistors in Signal Conditioning

Resistors are used in **pull-up and pull-down configurations** in digital circuits to maintain defined logic levels.

- **Pull-up resistor** – Connects a pin to **Vcc** to keep it HIGH.
- **Pull-down resistor** – Connects a pin to **GND** to keep it LOW.

These are crucial in **microcontroller inputs, communication protocols, and sensor interfaces**.

Using Resistors in Wheatstone Bridge Circuits

A **Wheatstone bridge** uses **four resistors** in a balanced configuration to **precisely measure unknown resistance**. The output voltage is given by:

Vout=Vin×(R2R1+R2−R4R3+R4)

This is commonly used in **strain gauges, temperature sensors, and precision measurement instruments**.

Power Rating of Resistors

Resistors have a **power rating** (in watts) that defines how much power they can safely dissipate without overheating. Common power ratings include **1/4W, 1/2W, 1W, and 5W**. Choosing a resistor with an appropriate power rating prevents **overheating and circuit failure**.

P=VI=I2R=V2RP = VI = I^2 R

Applications of Resistors

- **Voltage Regulation** – Used in **voltage dividers and regulators**.
- **Current Limiting** – Protects LEDs, transistors, and ICs.
- **Signal Processing** – Forms **RC filters in audio and communication circuits**.
- **Temperature Sensing** – Thermistors for environmental monitoring.
- **Precision Measurements** – Used in **Wheatstone bridge circuits**.

Resistors in AC Circuits

In **AC circuits**, resistors behave similarly to how they do in DC circuits, following **Ohm's Law (V=IRV = IR)**. However, unlike inductors and capacitors, resistors do **not introduce phase shift** between voltage and current. The current and voltage remain **in phase**, meaning their peaks and zero-crossings occur simultaneously.

The **power dissipation** in an AC resistor is given by:

P=VrmsIrmscosθ_P

Since the phase angle $\theta=0^\circ$ **is always 1**, meaning all power is converted into heat.

Why Does Current Increase When Frequency Increases?

For a **pure resistor**, the current does **not depend on frequency** because resistance is a fixed property. However, in **practical circuits**, resistors often have **small parasitic inductance and capacitance**, which affect the current at higher frequencies.

- **Parasitic Inductance**: At very high frequencies, even a straight resistor wire behaves like an inductor, slightly opposing the current.
- **Parasitic Capacitance**: Some resistors exhibit small **capacitive effects**, allowing **more current to pass at high frequencies**, reducing overall impedance.

In circuits where resistors are combined with **capacitors or inductors**, **reactance (XX)** plays a role, and the total impedance changes with frequency, affecting current flow.

Resistors are **fundamental** components in electronics, playing a crucial role in **controlling voltage, limiting current, signal processing, and power dissipation**. Their **versatility, reliability, and ease of use** make them indispensable in all types of electrical and electronic systems.