Using a Resistor with an LED

Purpose of a Resistor:

- **Protecting the LED**: When connecting an LED to a power source, a resistor is used to limit the current flowing through the LED to prevent it from burning out.
- **Controlling Current**: The resistor ensures that the LED receives the right amount of current, protecting it from damage.

What is a Resistor?:

- **Definition**: A resistor is a fundamental electronic component that provides resistance to the flow of electric current.
- **Passive Component**: It does not require an external power supply to work and does not amplify signals. It only limits current based on its resistance value.

In IoT Devices:

- **Function**: Resistors are crucial for managing current flow, protecting components, and ensuring that voltage levels are appropriate within circuits.

Passive vs. Active Components

Passive Electrical Components

- **Examples**:
    1. **Resistor**: Limits current flow and controls voltage levels.
    2. **Capacitor**: Stores and releases electrical energy.
    3. **Inductor**: Stores energy in a magnetic field.
    4. **Diode**: Allows current to flow in only one direction. *(Note: Diodes are typically classified as active components, but they are often included in discussions about passive components due to their simple one-way conduction property.)*
- **Characteristics**:
    - **No External Power Source**: Do not need an external power supply to function.

  - **Do Not Amplify**: Cannot increase the power of an electrical signal.
  - **Energy Absorption**: Can absorb and sometimes store energy.

Active Components

- **Definition**: Require an external power source to operate and can amplify electrical signals or perform switching and signal generation.
- **Examples**:
  - **Transistor**: Acts as a switch or amplifier. It has three terminals: base, collector, and emitter. It amplifies a small input signal into a larger output signal. A transistor is a semiconductor device used to switch or amplify electronic signals.
  - **Diode**: Allows current to flow in one direction; used for rectification (converts AC to DC by allowing current to pass only in one direction).
  - **Integrated Circuit (IC)**: A chip containing multiple electronic components (e.g., transistors, resistors) to perform complex functions. It performs complex functions and is used in devices like computers and smartphones to simplify and compact electronic designs.
  - **Light Emitting Diode (LED)**: Emits light when current flows through it. Though it is a type of diode, LEDs are often categorized as active components due to their light-emitting capability.
- **Why Use Active Components**:
  - **Amplification**: To increase signal strength (e.g., in audio amplifiers).
  - **Signal Generation**: To create electrical signals (e.g., in oscillators).
  - **Switching**: To control electrical signals (e.g., transistors in digital circuits).
- **How They Work**:
  - **Transistor**: Amplifies a small input signal into a larger output signal using its three terminals: base, collector, and emitter.
  - **Diode**: Allows current to flow in one direction only, with two terminals: anode and cathode.
  - **IC**: Contains many components like transistors and capacitors integrated into a single chip to perform specific tasks. Requires an external power source to operate.

Summary

Passive Components:

- No external power needed.
- Do not amplify signals.

Active Components:

- Require external power.
- Can amplify, generate, or switch signals.

Active vs. Passive Components

Active Components:

- **Definition**: Require external power to operate, can amplify signals, and perform switching and signal generation.
- **Examples**: Transistors, diodes, integrated circuits (ICs), LEDs, and operational amplifiers (op-amps).

Passive Components:

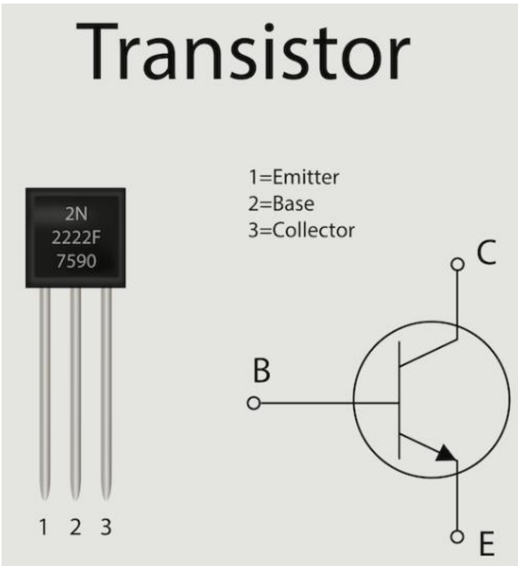
- **Definition**: Do not require external power, cannot amplify signals, and are used to absorb, store, or dissipate energy.
- **Examples**: Resistors, capacitors, inductors, transformers, and crystal oscillators.

Common Types of Active Components

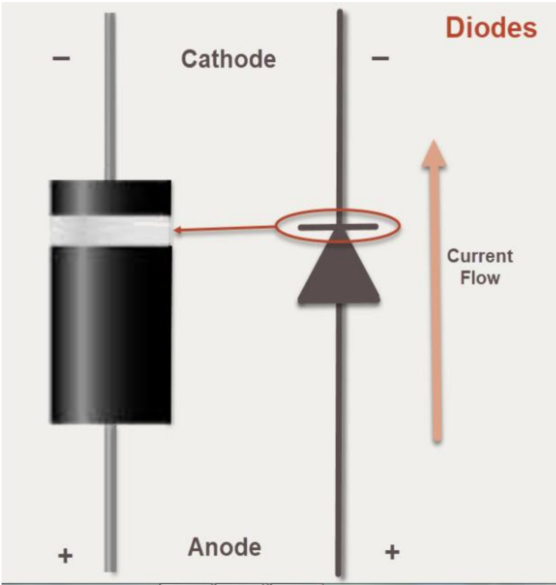
1. **Transistor**:
    - **Function**: Acts as a switch or amplifier.
    - **Types**:
        - **Bipolar Junction Transistor (BJT)**: Uses both electron and hole charge carriers.

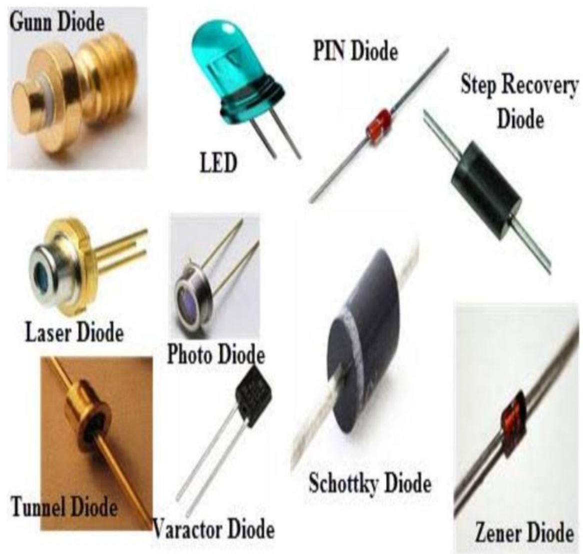
- **Field-Effect Transistor (FET)**: Uses electric fields to control the flow of current.

- **Applications**: Used in amplifiers, switches, and signal modulation.

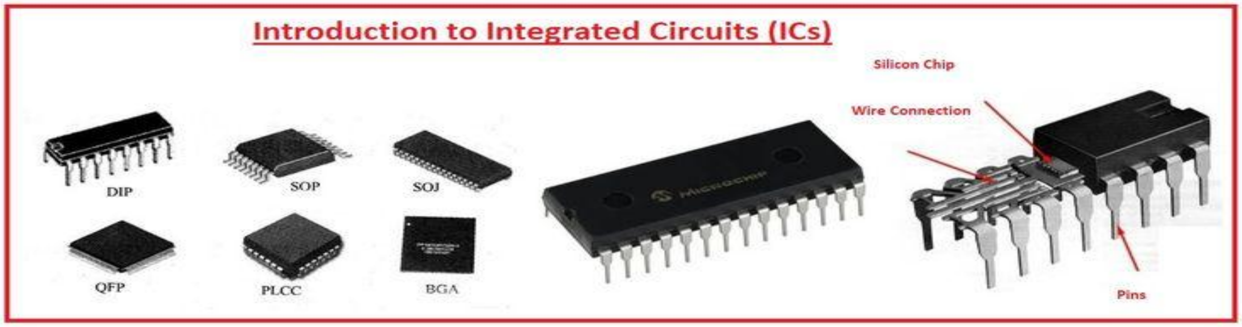


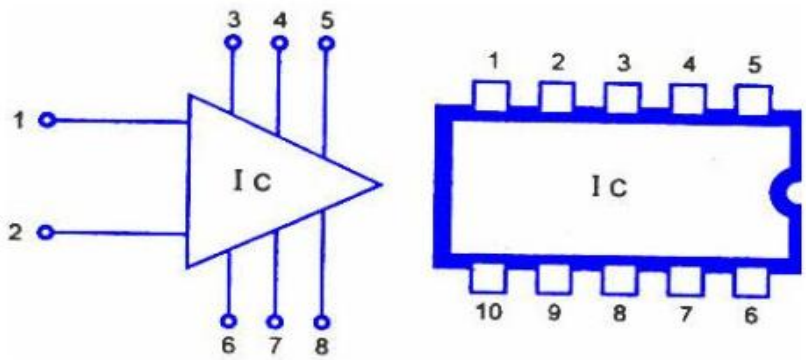
2. **Diode**:
   - **Function**: Allows current to flow in only one direction, acting as a one-way valve.
   - **Types**:
     - **Standard Diode**: Used for general rectification and signal blocking.
     - **Zener Diode**: Designed to operate in the reverse breakdown region for voltage regulation.
     - **Light Emitting Diode (LED)**: Emits light when current flows through it.
   - **Applications**:
     - **Rectification**: Converts alternating current (AC) to direct current (DC).
     - **Voltage Regulation**: Maintains a constant voltage level (e.g., Zener diodes).
     - **Signal Demodulation**: Extracts information from modulated signals.





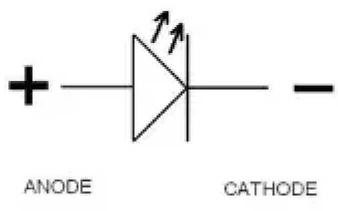
3. **Integrated Circuit (IC)**:
   - **Function**: A complete electronic circuit embedded in a small chip. It combines multiple components, such as transistors, resistors, and capacitors, to perform specific tasks or functions within a single package.
   - **Types**:
     - **Analog ICs**: Handle continuous signals and include components like operational amplifiers (op-amps) and voltage regulators.
     - **Digital ICs**: Process discrete signals and include components like microprocessors, memory chips, and logic gates.
   - **Applications**:
     - **Computers**: For processing, memory, and interfacing tasks.
     - **Mobile Phones**: For signal processing, power management, and communication functions.
     - **Audio and Video Equipment**: For sound amplification, video processing, and signal conversion.

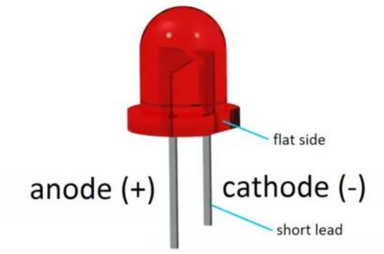


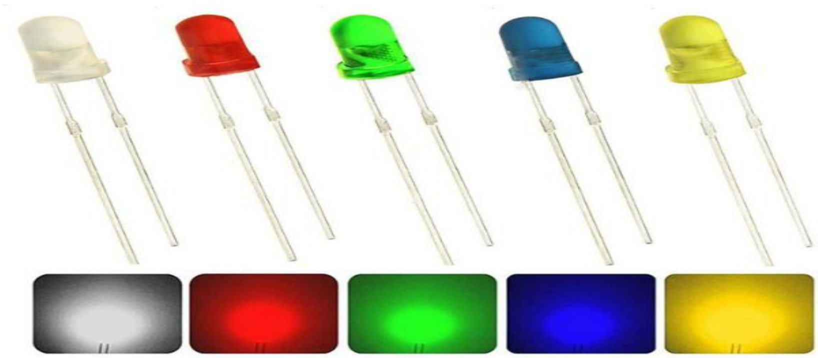


Integrated Circuit Symbol

4. **Light Emitting Diode (LED)**:
    - **Function**: Emits light when electrical current passes through it.
    - **Types**:
        - **Standard LED**: Commonly used for general-purpose indicators and small displays.
        - **Organic LED (OLED)**: Uses organic compounds to emit light, providing high-quality displays with vibrant colors and flexibility.
    - **Applications**:
        - **Indicators**: Lights up to show the status of devices (e.g., power indicators).
        - **Displays**: Used in screens and panels for visual output (e.g., digital clocks, TV screens).
        - **Lighting**: Provides illumination in various settings (e.g., room lighting, automotive lighting).







5. **Operational Amplifier (Op-Amp)**:
   - **Function**: Amplifies voltage, providing a high gain for signal processing.
   - **Types**:
     - **General-Purpose Op-Amps**: Versatile and used for a wide range of applications, such as in simple amplification circuits.
     - **Precision Op-Amps**: Designed for high accuracy and stability in measurements and signal processing, with low offset voltage and drift.
   - **Applications**:
     - **Signal Conditioning**: Enhances or modifies signals for further processing (e.g., amplifying weak signals).
     - **Filtering**: Removes unwanted frequencies from signals (e.g., in audio and communication systems).
     - **Analog Computing**: Performs mathematical operations like addition, subtraction, integration, and differentiation in analog circuits.

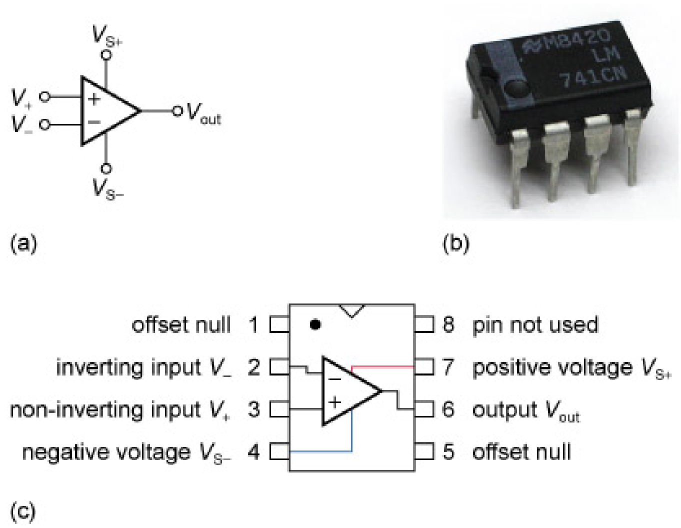


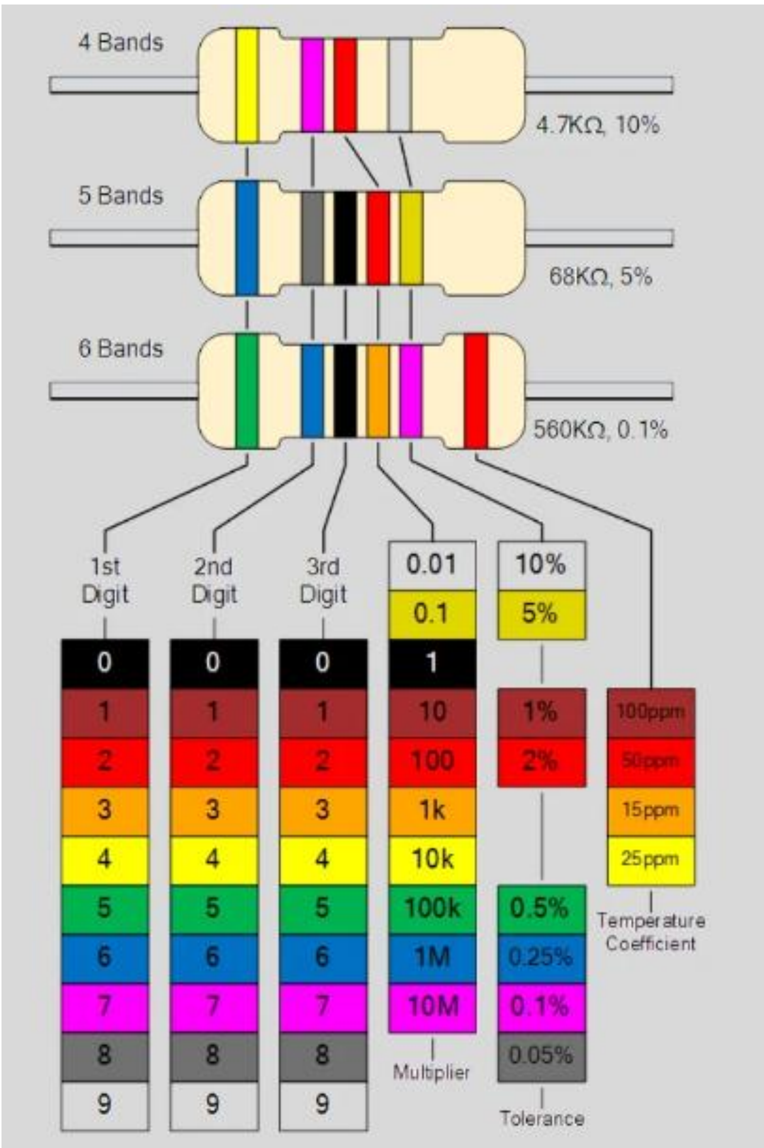
Figure 15 (a) Symbol for an op-amp; (b) the 741 op-amp package; (c) top view of an LM741 dual inline package (DIL), showing internal configuration and pin connections

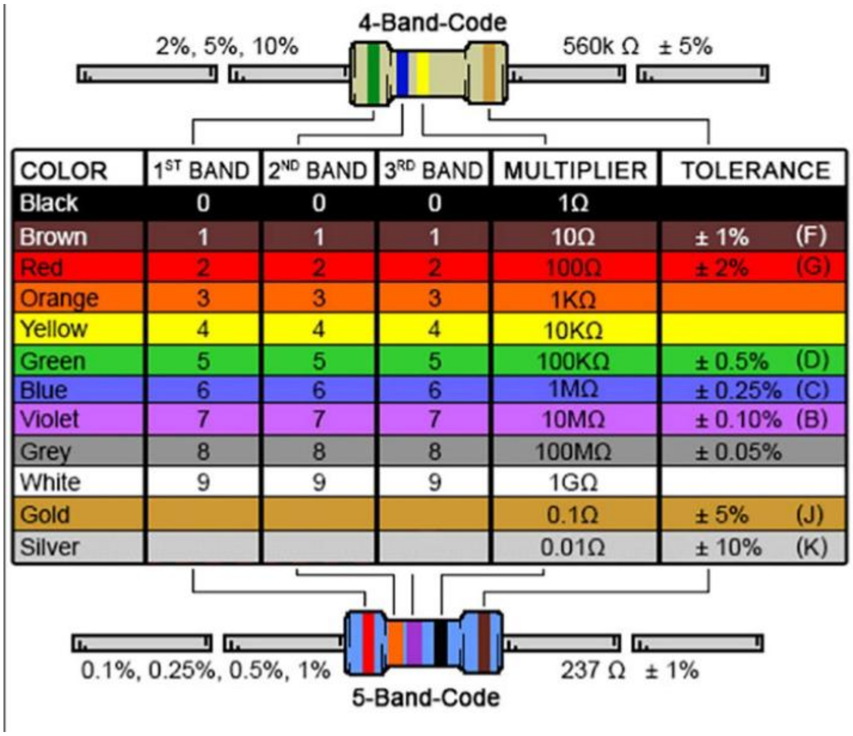
Common Types of Passive Components

1. Resistor

- **Function**: Limits the flow of electric current and controls voltage levels.
- **Types**:
  - **Fixed Resistor**: Has a constant resistance value, used in various circuits.
  - **Variable Resistor (Potentiometer)**: Allows adjustment of resistance, used for tuning and control.
  - **Thermistor**: Changes resistance with temperature, used in temperature sensing.
- **Applications**:
  - **Voltage Division**: Splits voltage across different components.
  - **Current Limiting**: Protects components by controlling the amount of current.
  - **Biasing**: Sets operating points for active components like transistors.


Symbol
Resistor


4 Bands
4.7KΩ, 10%
5 Bands
68KΩ, 5%
6 Bands
560KΩ, 0.1%
1st Digit
2nd Digit
3rd Digit
0.01
0.1
1
10
100
1k
10k
100k
1M
10M
Multiplier
10%
5%
1%
2%
0.5%
0.25%
0.1%
0.05%
Tolerance
100ppm
50ppm
15ppm
25ppm
Temperature Coefficient
0
1
2
3
4
5
6
7
8
9



COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8	100MΩ	± 0.05%
White	9	9	9	1GΩ	
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

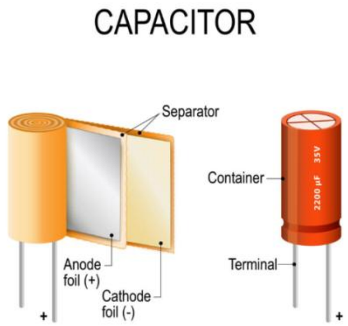
2. **Capacitor:**
   - **Function:** Stores electrical energy in an electric field for later use.

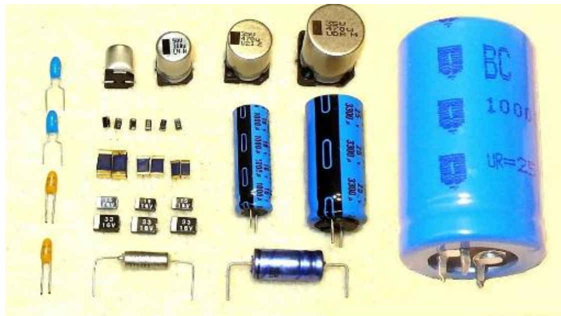
Types:

- **Ceramic Capacitor**: Known for stability and small size, used in general-purpose applications.
- **Electrolytic Capacitor**: Offers high capacitance values, used in power supply filtering and energy storage.
- **Tantalum Capacitor**: Provides stable capacitance and high reliability, used in compact and critical applications.

Applications:

- **Filtering**: Smooths out voltage fluctuations in power supplies.
- **Timing**: Works in timing circuits to create delays or oscillations.
- **Energy Storage**: Stores and releases energy in various electronic devices.

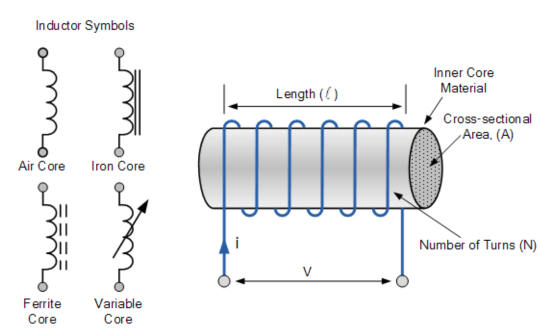




3. Inductor

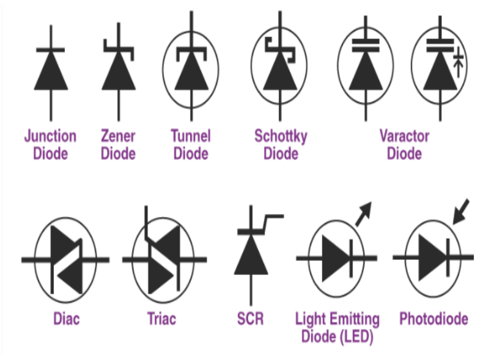
- **Function**: Stores energy in a magnetic field when current flows through it.
- **Types**:
  - **Air-Core Inductor**: Uses air as the core, suitable for high-frequency applications.
  - **Iron-Core Inductor**: Uses iron as the core, provides higher inductance and is used in low-frequency applications.
  - **Ferrite-Core Inductor**: Uses ferrite as the core, offers high inductance and reduces losses at high frequencies.
- **Applications**:
  - **Filtering**: Smooths out electrical signals and reduces noise.
  - **Energy Storage**: Stores energy in the magnetic field for later use.
  - **Inductive Coupling**: Transfers energy between circuits through magnetic fields.

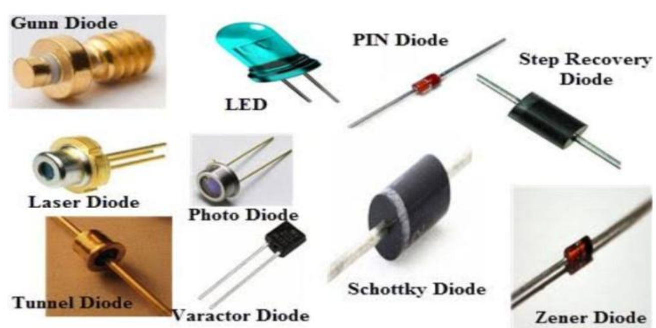
Inductor Symbol



4. Diode

- **Function**: Allows current to flow in one direction only.
- **Types**:
    - **Standard Diode**: Basic diode for general rectification.
    - **Schottky Diode**: Fast switching diode with low forward voltage drop.
    - **Zener Diode**: Allows current to flow in reverse direction when a specific voltage is reached, used for voltage regulation.
- **Applications**:
    - **Rectification**: Converts AC to DC.
    - **Voltage Regulation**: Maintains a constant voltage level.

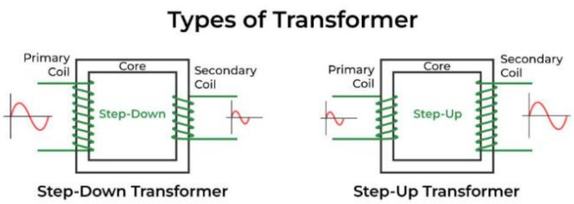




5. Transformer

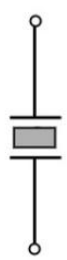
- **Function**: Transfers electrical energy between circuits through electromagnetic induction.
- **Types**:
    - **Step-Up Transformer**: Increases voltage from primary to secondary coil.
    - **Step-Down Transformer**: Decreases voltage from primary to secondary coil.
    - **Isolation Transformer**: Provides electrical isolation between circuits while maintaining the same voltage level.
- **Applications**:
    - **Voltage Conversion**: Changes voltage levels for different uses.
    - **Impedance Matching**: Matches impedance between different circuit stages.

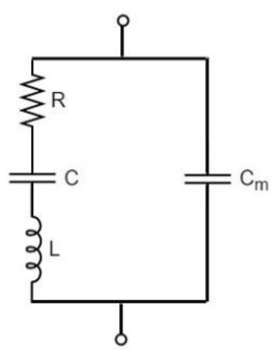
  - **Isolation**: Provides electrical separation to enhance safety and reduce noise.



6. **Crystal Oscillator**

- **Function**: Provides a precise frequency reference.
- **Types**:
  - **Quartz Crystal**: Uses a quartz crystal to maintain a stable frequency.
  - **Ceramic Resonator**: Uses a ceramic material for frequency stability, generally less precise than quartz.
- **Applications**:
  - **Clocks**: Keeps accurate time in electronic devices.
  - **Timers**: Provides consistent timing signals.
  - **Frequency Synthesizers**: Generates stable frequencies for communication systems.


Symbol of a Crystal

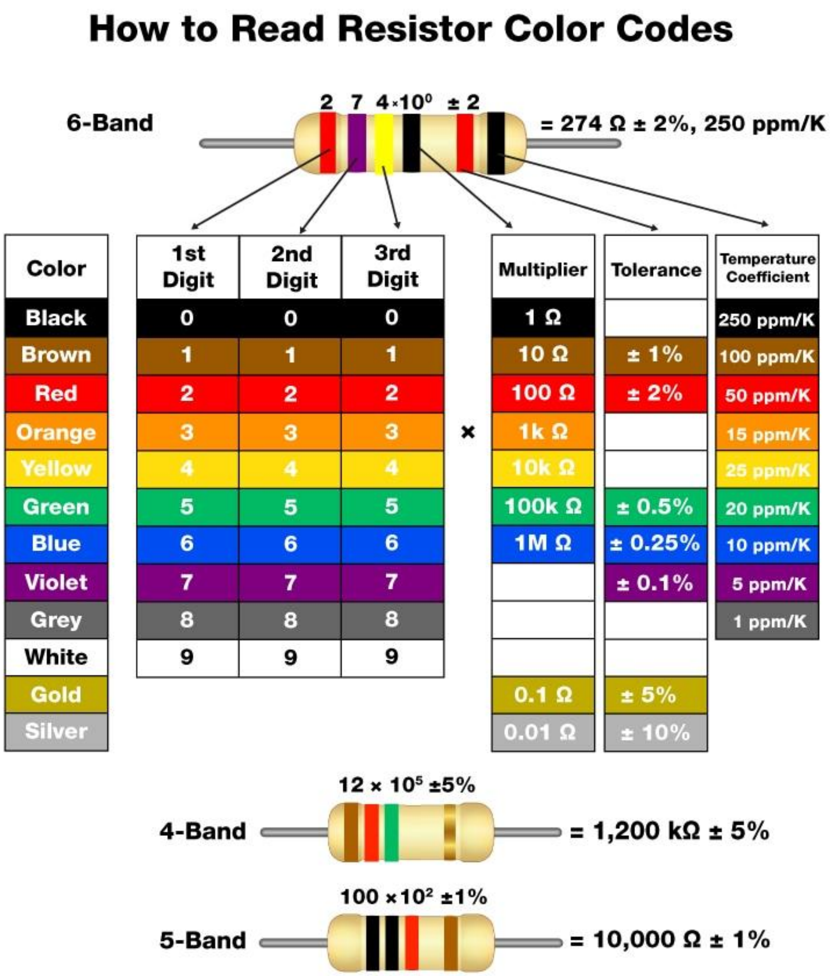


Equivalent circuit of a crystal

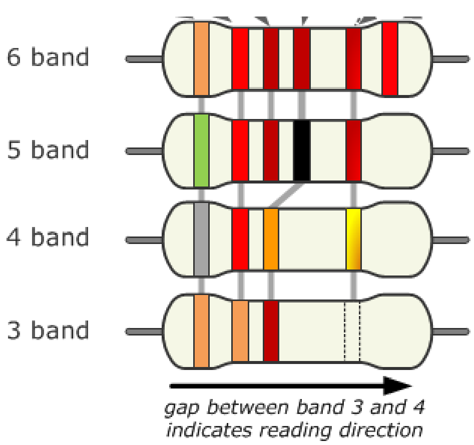
Crystal Oscillator

Resistor calculations

Remember: **B**etter **B**e **R**ight **O**r **Y**our **G**reat **B**ig **V**enture **G**oes **W**est



Color	1st Digit	2nd Digit	3rd Digit	Multiplier	Tolerance	Temperature Coefficient
Black	0	0	0	1 Ω		250 ppm/K
Brown	1	1	1	10 Ω	± 1%	100 ppm/K
Red	2	2	2	100 Ω	± 2%	50 ppm/K
Orange	3	3	3	1k Ω		15 ppm/K
Yellow	4	4	4	10k Ω		25 ppm/K
Green	5	5	5	100k Ω	± 0.5%	20 ppm/K
Blue	6	6	6	1M Ω	± 0.25%	10 ppm/K
Violet	7	7	7		± 0.1%	5 ppm/K
Grey	8	8	8			1 ppm/K
White	9	9	9			
Gold				0.1 Ω	± 5%	
Silver				0.01 Ω	± 10%	



Band Resistor

1-Band Resistor: *Color Band:* ***Brown***

Color Band: Brown

1. **Brown:** 1 (first digit)
2. **Assumed standard values:** 0 (second digit), multiplier $\times 10^0$

Calculation: $1 \times 10^0 = 1\,\Omega$

Diagram:

```
+ ----------[ Brown ]---------- -
|                               |
|                               |
---------------------------------
```

2-Band Resistor: *Color Bands:* ***Brown, Black***

2-Band Resistor: Color Bands: ***Brown, Black***

1. **Brown:** 1 (first digit)
2. **Black:** 0 (second digit)
3. **Assumed multiplier:** $\times 10^0$

Calculation: $10 \times 10^0 = 10\,\Omega$

Diagram:

```
+ ----------[ Brown ][ Black ]---------- -
|                                        |
|                                        |
------------------------------------------
```

3-Band Resistor

- **Color Bands:** Brown, Black, Red
- **Value:** 1,000 ohms or 1 kΩ

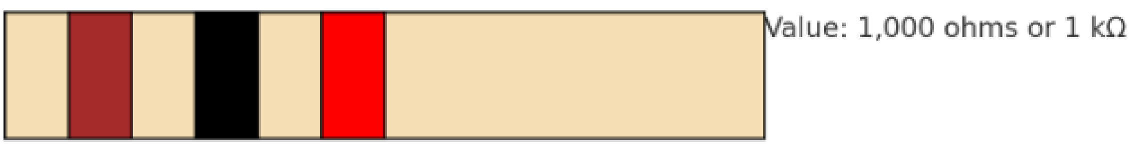
1. 3-Band Resistor

Color Bands: Brown, Black, Red

Value: 1,000 ohms or 1 kΩ

1. **Brown:** 1 (first digit)
2. **Black:** 0 (second digit)
3. **Red:** 2 zeros (multiplier)

Calculation: $10 \times 10^2 = 1,000\ \Omega$



4-Band Resistor

- **Color Bands:** Yellow, Violet, Red, Gold
- **Value:** 4,700 ohms or 4.7 kΩ
- **Tolerance:** ±5%

2. 4-Band Resistor

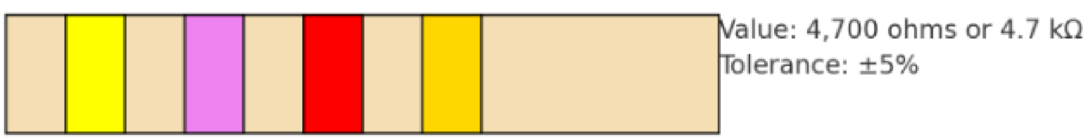
Color Bands: Yellow, Violet, Red, Gold

Value: 4,700 ohms or 4.7 kΩ

Tolerance: ±5%

1. **Yellow:** 4 (first digit)
2. **Violet:** 7 (second digit)
3. **Red:** 2 zeros (multiplier)
4. **Gold:** ±5% (tolerance)

Calculation: $47 \times 10^2 = 4,700\ \Omega$



5-Band Resistor

- **Color Bands:** Brown, Black, Black, Red, Brown
- **Value:** 10,000 ohms or 10 kΩ
- **Tolerance:** ±1%

3. 5-Band Resistor

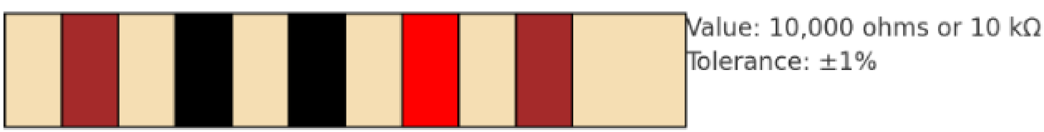
Color Bands: Brown, Black, Black, Red, Brown

Value: 10,000 ohms or 10 kΩ

Tolerance: ±1%

1. **Brown:** 1 (first digit)
2. **Black:** 0 (second digit)
3. **Black:** 0 (third digit)
4. **Red:** 2 zeros (multiplier)
5. **Brown:** ±1% (tolerance)

Calculation: $100 \times 10^2 = 10,000\,\Omega$



6-Band Resistor

- **Color Bands:** Blue, Gray, Black, Brown, Gold, Brown
- **Value:** 6,800 ohms or 6.8 kΩ
- **Tolerance:** ±5%
- **Temp Coeff:** 100 ppm/°C

4. 6-Band Resistor

Color Bands: Blue, Gray, Black, Brown, Gold, Brown

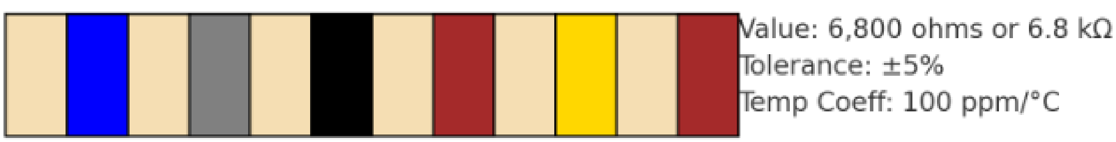
Value: 6,800 ohms or 6.8 kΩ

Tolerance: ±5%

Temp Coeff: 100 ppm/°C

1. **Blue:** 6 (first digit)
2. **Gray:** 8 (second digit)
3. **Black:** 0 (third digit)
4. **Brown:** 1 zero (multiplier)
5. **Gold:** ±5% (tolerance)
6. **Brown:** 100 ppm/°C (temperature coefficient)

Calculation: $680 \times 10^1 = 6,800\,\Omega$



Each color corresponds to a specific digit or multiplier:

Color	Digit	Multiplier	Tolerance	Temperature Coefficient
Black	0	1		
Brown	1	10	±1%	100 ppm/K
Red	2	100	±2%	50 ppm/K
Orange	3	1,000		15 ppm/K
Yellow	4	10,000		25 ppm/K
Green	5	100,000	±0.5%	
Blue	6	1,000,000	±0.25%	
Violet	7	10,000,000	±0.1%	
Gray	8	100,000,000	±0.05%	
White	9	1,000,000,000		
Gold		0.1	±5%	
Silver		0.01	±10%	
None			±20%	

The full form of ppm/K is **parts per million per kelvin**.

Explanation:

- **ppm (parts per million)**: This is a unit of measurement that describes the concentration or the ratio of one part of a substance to one million parts of the total mixture or solution.
- **K (kelvin)**: This is the unit of absolute temperature in the International System of Units (SI).

Context in Resistors:

In the context of resistors, ppm/K indicates the temperature coefficient of resistance (TCR), which describes how much the resistance of the resistor changes with temperature. For example, a TCR of 50 ppm/K means that for every 1 kelvin (K) change in temperature, the resistance of the resistor changes by 50 parts per million of its value. This is crucial for precision app

ppm/°C (parts per million per degree Centigrade)

Temperature Coefficient (Temp Coeff) Explained in a Simple and Easy Way

- **50 ppm/°C and 50 ppm/K** indicate how much the resistance changes per degree Celsius or kelvin, respectively.
- For practical purposes, ppm/°C and ppm/K are numerically the same because a change of 1°C is the same as a change of 1K.
- The formula to calculate the change in resistance is the same for both units.
- For a 10°C (or 10K) change, a 50 ppm/°C (or ppm/K) temperature coefficient results in the same change in resistance.

In conclusion, 50 ppm/°C and 50 ppm/K represent the same rate of change in resistance, and you can use the same formula to calculate the change due to temperature variations.

Example 1: 50 ppm/°C

Suppose we have a 472 kΩ resistor and the temperature changes by 10°C.

$$\Delta R = 472,000\,\Omega \times \frac{50}{1,000,000} \times 10$$

$$\Delta R = 472,000\,\Omega \times 0.00005 \times 10$$

$$\Delta R = 472,000\,\Omega \times 0.0005$$

$$\Delta R = 236\,\Omega$$

So, the resistance changes by 236 Ω for a 10°C change.

Example 2: 50 ppm/K

Using the same 472 kΩ resistor and a temperature change of 10K:

Since 1°C change is the same as 1K change, the calculation is identical:

$$\Delta R = 472,000\,\Omega \times \frac{50}{1,000,000} \times 10$$

$$\Delta R = 472,000\,\Omega \times 0.00005 \times 10$$

$$\Delta R = 236\,\Omega$$

Again, the resistance changes by 236 Ω for a 10K change.

COMPONENT	SCHEMATIC DESIGNATOR
Diode	D
Light-emitting diode (LED)	D (or LED)
Inductor	L
Capacitor (nonpolarized)	C
Electrolytic capacitor	C
Basic switch	S (or SW)
Resistor	R
Variable resistor	VR
Transistor—BJT	Q
Transistor—MOSFET	Q
Battery (DC source)	BT (or B or V)
Mains power (AC source)	AC (or V)
Integrated circuit chip	IC

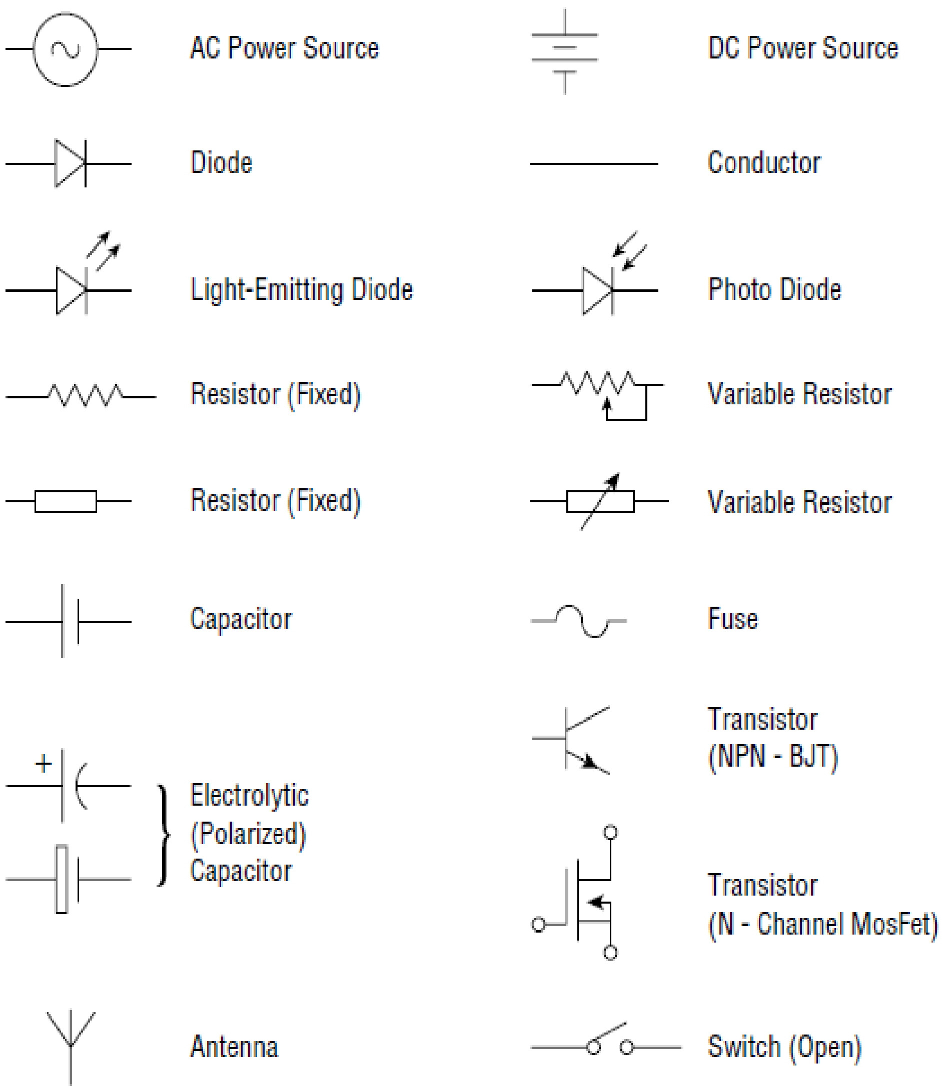


Figure 3.3: Common schematic symbols