Resistor Combinations and Characteristics

Series Combination

In a series combination, resistors are connected end-to-end, and the current through each resistor is the same. The total resistance is the sum of the individual resistances:

$$R_{\text{total}} = R_1 + R_2 + R_3 + \cdots$$

- **Current:** The same current flows through each resistor.
- **Voltage:** The total voltage across the series combination is the sum of the voltages across each resistor.

Example

Given: Three resistors with resistances $R_1 = 2\,\Omega$, $R_2 = 3\,\Omega$, and $R_3 = 5\,\Omega$ are connected in series with a 12V battery.
Solution:

$$\begin{aligned}
R_{\text{total}} &= R_1 + R_2 + R_3 = 2\,\Omega + 3\,\Omega + 5\,\Omega = 10\,\Omega \\
I &= \frac{V}{R_{\text{total}}} = \frac{12\,\text{V}}{10\,\Omega} = 1.2\,\text{A} \\
V_1 &= I \times R_1 = 1.2\,\text{A} \times 2\,\Omega = 2.4\,\text{V} \\
V_2 &= I \times R_2 = 1.2\,\text{A} \times 3\,\Omega = 3.6\,\text{V} \\
V_3 &= I \times R_3 = 1.2\,\text{A} \times 5\,\Omega = 6.0\,\text{V} \\
V_{\text{total}} &= V_1 + V_2 + V_3 = 2.4\,\text{V} + 3.6\,\text{V} + 6.0\,\text{V} = 12\,\text{V}
\end{aligned}$$

Parallel Combination

In a parallel combination, resistors are connected across the same two points, and the voltage across each resistor is the same. The total resistance is given by:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

- **Current:** The total current is the sum of the currents through each resistor.
- **Voltage:** The voltage across each resistor is the same.

Example

Given: Three resistors with resistances $R_1 = 2\,\Omega$, $R_2 = 3\,\Omega$, and $R_3 = 6\,\Omega$ are connected in parallel with a 12V battery.
Solution:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2\,\Omega} + \frac{1}{3\,\Omega} + \frac{1}{6\,\Omega}$$
$$\frac{1}{R_{\text{total}}} = \frac{3+2+1}{6} = \frac{6}{6} = 1$$
$$R_{\text{total}} = 1\,\Omega$$
$$I_{\text{total}} = \frac{V}{R_{\text{total}}} = \frac{12\,\text{V}}{1\,\Omega} = 12\,\text{A}$$
$$I_1 = \frac{V}{R_1} = \frac{12\,\text{V}}{2\,\Omega} = 6\,\text{A}$$
$$I_2 = \frac{V}{R_2} = \frac{12\,\text{V}}{3\,\Omega} = 4\,\text{A}$$
$$I_3 = \frac{V}{R_3} = \frac{12\,\text{V}}{6\,\Omega} = 2\,\text{A}$$
$$I_{\text{total}} = I_1 + I_2 + I_3 = 6\,\text{A} + 4\,\text{A} + 2\,\text{A} = 12\,\text{A}$$

Understanding with an Analogy

Imagine a group of students walking through three bridges. In the series configuration, all students must walk through each bridge one after another. If any bridge collapses, all students are stopped.
In the parallel configuration, students have three bridges to choose from. If one bridge collapses, students can still pass through the other bridges. This is why parallel connections are more reliable.

Household Wiring

For household wiring, parallel connections are preferred. This ensures that each appliance receives the full voltage and operates independently. If one appliance fails, others continue to work.

Advantages and Disadvantages

Advantages and Disadvantages of Series and Parallel Circuits

Characteristic	Series Circuit	Parallel Circuit
Current (I)	Same through all components	Sum of currents through each component
Voltage (V)	Sum of voltages across each component	Same across all components
Total Resistance (R)	Sum of individual resistances	Reciprocal of the sum of reciprocals of individual resistances
Advantage	Simple design	Each component gets full voltage; reliable
Disadvantage	One component fails, all fail	More complex wiring
Best For	Simple circuits	Household wiring, reliable circuits