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1st term – Lecture: 4- Parallel Circuits and the Application of
Ohm's Law



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Lecture: (4)
Parallel Circuits and the Application of Ohm's Law

Introduction

In this introduction to parallel resistance circuits, we will explain the three key principles you should know:

- **Voltage:** The voltage is equal across all components in a parallel circuit.
- **Current:** The total circuit current equals the sum of the individual branch currents.
- **Resistance:** The total resistance of a parallel circuit is *less* than any of the individual brand resistances.

We'll study these three principles using the parallel circuit of Figure 1, which contains three resistors connected in a parallel and a single battery.

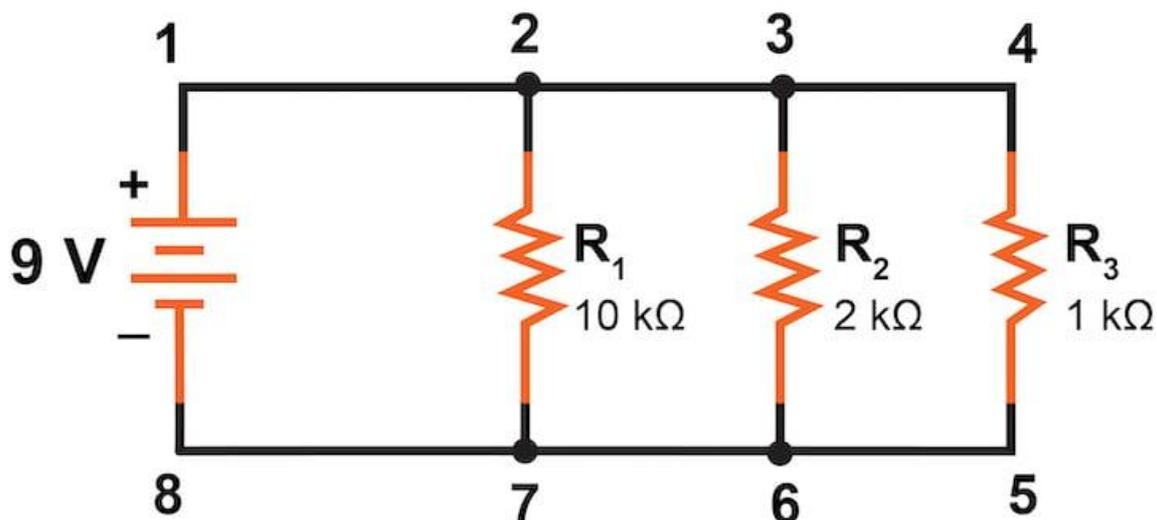


Figure 1. Parallel circuit with a battery and three resistors.

Voltage in a Parallel Circuit

The first principle to understand about parallel circuits is that the voltage is equal across each parallel component. This is because there are only two sets of electrically common points in a parallel circuit, and the voltage measured between sets of common points must always be the same at any given time.

With that concept in mind, in the circuit of Figure 1, nodes 1, 2, 3, and 4 are the same electrical node. Likewise, nodes 5, 6, 7, and 8 are the same electrical node. Therefore, the voltage across R₁ is equal to the voltage across R₂, which is equal to the voltage across R₃, and is then equal to the voltage across the battery (9 V).



Using Ohm's Law for Parallel Circuits to Determine Current

Similarly to series circuits, the same caveat for Ohm's law applies, where: values for voltage, current, and resistance must be in the same context for the calculations to work correctly.

$$I_{R1} = \frac{V_{R1}}{R_1} = \frac{9 \text{ V}}{10 \text{ k}\Omega} = 0.9 \text{ mA}$$

$$I_{R2} = \frac{V_{R2}}{R_2} = \frac{9 \text{ V}}{2 \text{ k}\Omega} = 4.5 \text{ mA}$$

$$I_{R3} = \frac{V_{R3}}{R_3} = \frac{9 \text{ V}}{1 \text{ k}\Omega} = 9.0 \text{ mA}$$

In the circuit of Figure 1, we can immediately apply Ohm's Law to each resistor to find its current because we know the voltage across each resistor (9 V) and its resistance.

However, at this point, we still don't know the total current or total resistance for this parallel circuit. Despite that, if we think carefully about what is happening, it should become apparent that the total current must equal the sum of all individual resistor ("branch") currents (shown in Figure 2):

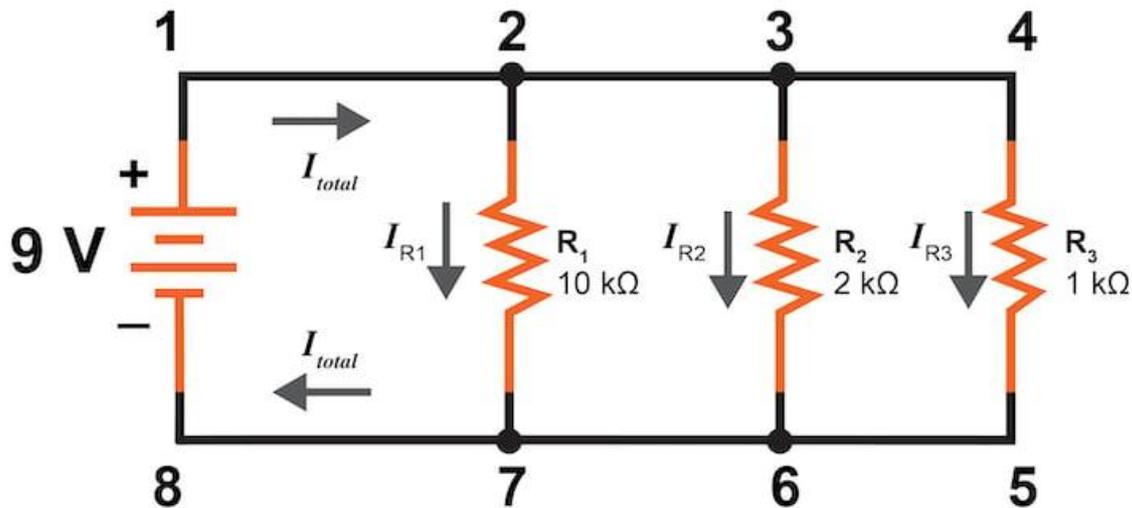


Figure 2. Currents in a parallel circuit.

As the total current exits the positive (+) battery terminal at point 1 and travels through the circuit, some of the flow splits off at point 2 to go through R₁, some more splits off at point 3 to go through R₂, and the remainder goes through R₃. Like a river branching into several smaller streams, the combined flow rates of all streams must equal the flow rate of the whole river.

The same thing is encountered where the currents through R₁, R₂, and R₃ rejoin to flow back to the battery's negative terminal (-) toward point 8. The current flow from point 7 to point 8 must equal the sum of the branch currents through R₁, R₂, and R₃.

$$I_{total} = I_{R1} + I_{R2} + I_{R3} = 0.9 + 4.5 + 9.0 = 14.4 \text{ mA}$$

This is the second principle of parallel circuits: the total parallel circuit current equals the sum of the individual branch currents.

How to Calculate Total Resistance in a Parallel Circuit

By applying Ohm's law to the total circuit with voltage (9 V) and current (14.4 mA), we can calculate the total effective resistance of the parallel circuit.



$$R_{total} = \frac{V_{total}}{I_{total}} = \frac{9 \text{ V}}{14.4 \text{ mA}} = 625 \Omega$$

Please note something very important here. The total circuit resistance is only 625 Ω . This is *less* than any one of the individual resistors.

In a series circuit, the total resistance is the sum of the individual resistances and is, therefore, always *greater* than any of the resistors individually.

However, here in the parallel circuit, the opposite is true. Each parallel resistor added to a circuit reduces the total equivalent resistance. Mathematically, the relationship between total resistance and individual resistance in a parallel circuit looks like this:

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

If we think of our parallel circuit in terms of conductance rather than resistance, this often makes more sense. The conductance of a parallel circuit is the sum of the individual branch conductances as the circuit gets more conductive as we add more paths for currents to flow:

$$G_{total} = G_1 + G_2 + G_3$$