Chapter 5

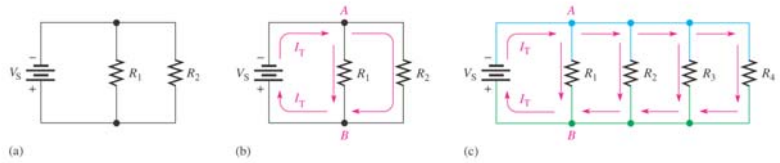
Parallel Circuits

Objectives

- Identify a parallel circuit
- Determine the voltage across each parallel branch
- Apply Kirchhoff's current law
- Determine total parallel resistance
- Apply Ohm's law in a parallel circuit
- Use a parallel circuit as a current divider
- Determine power in a parallel circuit

Resistors in Parallel

- Each current path is called a **branch**
- A parallel circuit is one that has more than one branch

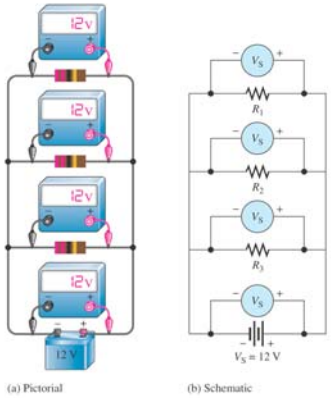


Identifying Parallel Circuits

- If there is more than one current path (branch) between two separate points, and if the voltage between those two points also appears across each of the branches, then there is a parallel circuit between those two points

Voltage in Parallel Circuits

- The voltage across any given branch of a parallel circuit is equal to the voltage across each of the other branches in parallel

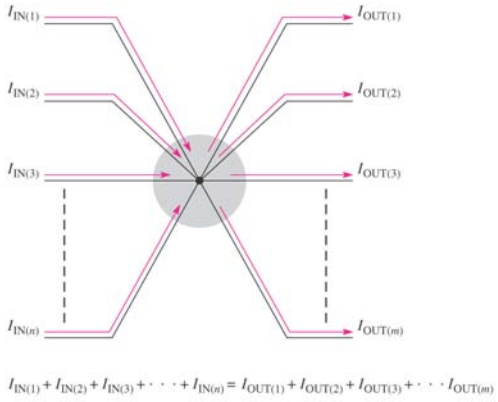


Kirchhoff's Current Law (KCL)

- **The sum of the currents into a node (total current in) is equal to the sum of the currents out of that node (total current out)**

$$I_{IN(1)} + I_{IN(2)} + \ldots + I_{IN(n)} = I_{OUT(1)} + I_{OUT(2)} + \ldots + I_{OUT(m)}$$

Generalized Circuit Node Illustrating KCL



Kirchhoff's Current Law

- Kirchhoff's current Law (KCL) can be stated another way:

The algebraic sum of all the currents entering and leaving a junction is equal to zero

Total Parallel Resistance

- When resistors are connected in parallel, the total resistance of the circuit decreases
- The total resistance of a parallel circuit is always less than the value of the smallest resistor

Formula for Total Parallel Resistance

$$\mathbf{1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \ldots + 1/R_n}$$

Two Resistors in Parallel

- The total resistance for two resistors in parallel is equal to the product of the two resistors divided by the sum of the two resistors

$$\mathbf{R_T = R_1R_2/(R_1 + R_2)}$$

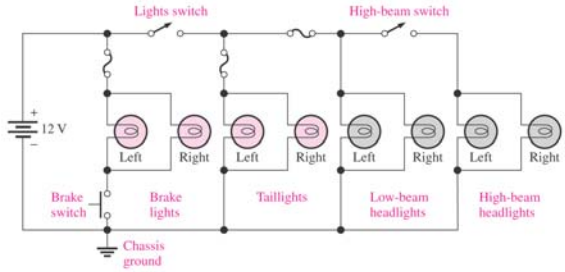
Notation for Parallel Resistors

- To indicate 5 resistors, all in parallel, we would write:

$$\mathbf{R_1||R_2||R_3||R_4||R_5}$$

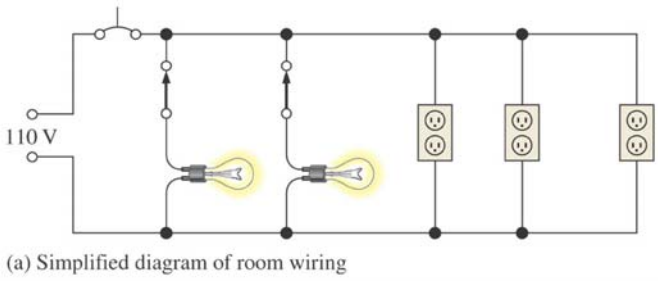
Application of a Parallel Circuit

- One advantage of a parallel circuit over a series circuit is that when one branch opens, the other branches are not affected



Application of a Parallel Circuit

- All lights and appliances in a home are wired in parallel
- The switches are located in series with the lights



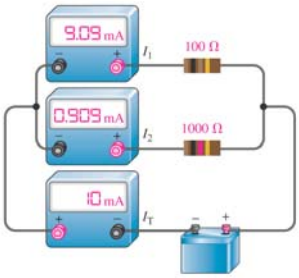
(a) Simplified diagram of room wiring

Current Dividers

- A parallel circuit acts as a current divider because the current entering the junction of parallel branches “divides” up into several individual branch currents

Current Dividers

- The total current divides among parallel resistors into currents with values inversely proportional to the resistance values



Current-divider Formulas for Two Branches

- When there are two parallel resistors, the current-divider formulas for the two branches are:

$$\mathbf{I_1 = (R_2/(R_1 + R_2))I_T}$$

$$\mathbf{I_2 = (R_1/(R_1 + R_2))I_T}$$

General Current-Divider Formula

- The current (I_x) through any branch equals the total parallel resistance (R_T) divided by the resistance (R_x) of that branch, and then multiplied by the total current (I_T) into the junction of the parallel branches

$$\mathbf{I_x = (R_T/R_x)I_T}$$

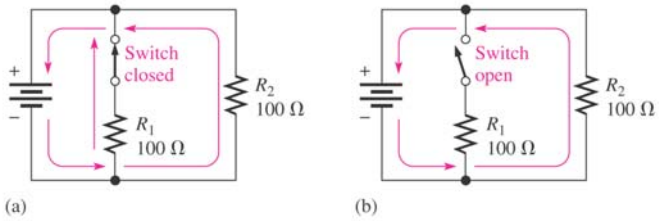
Power in Parallel Circuits

- Total power in a parallel circuit is found by adding up the powers of all the individual resistors, the same as for series circuits

$$P_T = P_1 + P_2 + P_3 + \ldots + P_n$$

Open Branches

- When an open circuit occurs in a parallel branch, the total resistance increases, the total current decreases, and the same current continues through each of the remaining parallel paths



Open Branches

- When a parallel resistor opens, I_T is always less than its normal value
- Once I_T and the voltage across the branches are known, a few calculations will determine the open resistor when all the resistors are of different values

Summary

- Resistors in parallel are connected across the same two nodes in a circuit
- A parallel circuit provides more than one path for current
- The number of current paths equals the number of resistors in parallel
- The total parallel resistance is less than the lowest-value parallel resistor

Summary

- The voltages across all branches of a parallel circuit are the same
- Kirchhoff's Current Law: The sum of the currents into a node equals the sum of the currents out of the node
- Kirchhoff's Current Law may also be stated as: The algebraic sum of all the currents entering and leaving a node is zero

Summary

- A parallel circuit is a current divider, so called because the total current entering a node divides up into each of the branches connected to the node
- If all of the branches of a parallel circuit have equal resistance, the current through all of the branches are equal
- The total power in a parallel-resistive circuit is the sum of all the individual powers of the resistors making up the parallel circuit

Summary

- The total power for a parallel circuit can be calculated with the power formulas using values of total current, total resistance or total voltage
- If one of the branches of a parallel circuit opens, the total resistance increases, and therefore the total current decreases
- If a branch of a parallel circuit opens, there is no change in current through the remaining branches