

Introduction to Circuit Analysis

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Fundamentals, Methods, and Practical Tips

1. What Is Circuit Analysis?

Aspect	Description
Definition	The systematic study of electrical circuits to determine voltages, currents, and power distribution.
Goal	Predict how a circuit will behave before it is built (or diagnose an existing circuit).
Scope	Includes DC (steady-state) and AC (time-varying) circuits, linear and nonlinear elements, transient and steady-state responses.

2. Basic Electrical Quantities

Symbol	Quantity	Unit	Relationship
V	Voltage (electric potential difference)	Volt (V)	($V = IR$) (Ohm's Law)
I	Current (flow of charge)	Ampere (A)	($I = \frac{V}{R}$)
R	Resistance	Ohm (Ω)	($R = \frac{V}{I}$)
P	Power (rate of energy transfer)	Watt (W)	($P = VI = I^2R = \frac{V^2}{R}$)
C	Capacitance	Farad (F)	($I = C\frac{dV}{dt}$)
L	Inductance	Henry (H)	($V = L\frac{dI}{dt}$)

3. Fundamental Laws

Law	Statement	Typical Use
Kirchhoff's Current Law (KCL)	The algebraic sum of currents entering a node = 0.	Node analysis, current distribution.
Kirchhoff's Voltage Law (KVL)	The algebraic sum of voltages around any closed loop = 0.	Loop analysis, checking supply drops.

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Law	Statement	Typical Use
Ohm's Law	($V = IR$) for linear resistors.	Quick voltage/current calculations.
Thevenin & Norton Theorems	Any linear bilateral network can be replaced by an equivalent voltage source + series resistance (Thevenin) or current source + parallel resistance (Norton).	Simplifying complex networks, load analysis.
Superposition	In linear circuits, total response = sum of responses from each independent source acting alone (others set to zero).	Analyzing circuits with multiple sources.

4. Common Analysis Techniques

4.1. Node Voltage (Nodal) Analysis

1. **Identify nodes** and select a reference (ground).
2. **Assign node voltages** ($V_1, V_2, \dots$).
3. **Apply KCL** at each non-reference node: ($\sum I_{\text{leaving}} = 0$).
4. **Express currents** using Ohm's law (e.g., ($I = \frac{V_a - V_b}{R}$)).
5. **Solve the linear system** (matrix form ($\mathbf{G}\mathbf{V} = \mathbf{I}$) or using substitution).

4.2. Mesh Current (Loop) Analysis

1. **Define independent meshes** (loops that do not contain other loops).
2. **Assign mesh currents** ($I_1, I_2, \dots$).
3. **Apply KVL** around each mesh: ($\sum V_{\text{drops}} = 0$).
4. ****Include**