

CIRCUIT ANALYSIS

INTRODUCTION TO AC AND DC CIRCUIT ANALYSIS

Definitions

- ELECTRICAL CHARGE** has four characteristics:
 - Its magnitude is measured in **coulombs (C)**. The charge carried by an **electron** is $q_e = -1.60 \cdot 10^{-19} \text{ C}$. A **proton** has the same amount of charge, but with positive polarity.
 - Charges are, therefore, of two types: positive and negative.
 - Charges exist in discrete, integral multiples of $\pm q_e$.
 - Charges are conserved: They can be neither created nor destroyed.
- CURRENT**. In an electric circuit, the charges move along specified, closed paths. The motion of charges constitutes an electric conduction current. Current is measured in **amperes (amperes/second)**. That is, one ampere is the current that flows when one coulomb of charge flows per second. Or, current $I(t)$ in amperes is:

$$I(t) = \frac{dq(t)}{dt} \text{ amperes, where } q(t) \text{ is the charge in coulombs, and } t \text{ is the time in seconds.}$$

- Conventions:** A negative quantity of charge traveling from B to A along a conductor is equivalent to a positive quantity of charge going from A to B. Hence, current is a vector.
- Unidirectional transfer of electric charge through a conductor constitutes the direct electric current, or **dc**. This is in contrast to ac (alternating current) which implies a time-reversal of direction of current such as a sinusoidal wave.

- VOLTAGE.** Voltage difference (also known as potential difference) between two points is defined as the work $[w(t)]$ in joules required to move a unit charge from one point to the other. The unit of potential difference is the volt (V). Voltage (v) can be positive or negative.

$$\text{Note that: } v(t) = \frac{dw(t)}{dq} \text{ volt}$$

- POWER.** Power $p(t)$ is the rate of doing work or the rate of change of energy. The electrical unit of power is the watt (W).

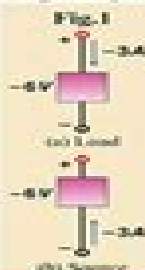
$$p(t) = \frac{dw(t)}{dt} \text{ joules/sec or watts}$$

$$\text{Note: } v(t)I(t) = \frac{dw(t)}{dq} \frac{dq}{dt} = \frac{dw(t)}{dt} = p(t)$$

Thus, $p(t) = v(t)I(t)$ is subject to the following sign convention: *Whenever the reference direction for the current in an element is in the direction of the voltage drop across the element, use the formula $p = vI$. That is, the current must enter the positive terminal to use the above formula. Otherwise use $p = -vI$. If $p(t) > 0$, then the element absorbs power. If $p(t) < 0$, then the element delivers power. See the following examples:*

- In Fig. 1(a) the element is consuming/absorbing 18W of power, and in Fig. 1(b) the element is delivering 18W.
- FACT:** The total power delivered must equal the total power absorbed in any circuit.

- BRANCH.** A branch is an element (for example, resistor, sources, etc.).
- NODE.** A node is a junction where two or more elements come together.
- GROUND.** A ground is the voltage reference point which has zero potential.



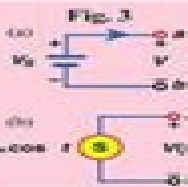
Ideal Independent Sources

IDEAL INDEPENDENT VOLTAGE SOURCE

This element maintains a specified voltage between its terminals regardless of the rest of the circuit where it is inserted. The voltage is completely independent of the current through the element. The symbol for the element is shown in Fig. 2.



- Fig. 3 shows other variations of Fig. 2:



- Fig. 3(a) shows an ideal battery which has a constant voltage with respect to time and (b) shows a sinusoidal voltage source which swings up and down between the peak values $+v_m$ and $-v_m$ producing an alternating current.

IDEAL INDEPENDENT CURRENT SOURCE. This element maintains a specified current through it independent of the voltage across it. See Fig. 4.



Ideal Dependent Sources

IDEAL DEPENDENT VOLTAGE SOURCE. Is a dependent (or controlled) voltage source, the voltage across the source depends upon the voltage or current across some other element in the network. There are two types of controlled voltage sources:

- **voltage controlled voltage source**

$v = \alpha v_x$, where v_x is a voltage somewhere else in the circuit and α is a constant. See Fig. 5.



- **current controlled voltage source**

$v = \beta i_x$, where i_x is a current somewhere else in the circuit and β is a constant. See Fig. 6.



IDEAL DEPENDENT CURRENT SOURCE. In a dependent (or controlled) current source, the current through the source depends upon the voltage or current through another element in the network. There are two types of controlled current sources:

- **voltage controlled current source**

$i = \gamma v_x$, where v_x is a voltage somewhere else in the circuit and γ is a constant. See Fig. 7.



- **current controlled current source**

$i = \alpha i_x$, where i_x is a current somewhere else in the circuit and α is a constant. See Fig. 8.



Resistance & Conductance

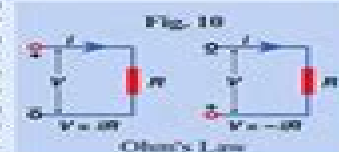
RESISTANCE. A resistor is a circuit element used to model the resistance to the flow of electrical charge. The unit of resistance is the ohm denoted by (Ω).



CONDUCTANCE. Conductance (G) is defined as the reciprocal of resistance; that is, $G = 1/R$. Conductance is measured in siemens (S).

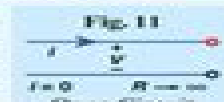
Ohm's Law

OHM'S LAW (at a given temperature) is given by $v = iR$ volt, and is based on the following convention: $v = iR$ applies whenever the reference direction for the current in the resistor is in the direction of the voltage drop across the resistor. Otherwise use $v = -iR$.

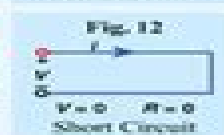


Open & Short Circuit

OPEN CIRCUIT. The graphical representation of an "open circuit" ($R = \infty$) is shown in Fig. 11. Note that the current can't flow due to infinite resistance. The terminals maintain an open circuit voltage.



SHORT CIRCUIT. The graphical representation of a "short circuit" ($R = 0$) is shown in Fig. 12. Note that a short circuit can be considered as a piece of wire assumed as a perfect conductor (voltage = 0, resistance = 0). Short circuit current flows in the loop.



Kirchhoff's Laws

KIRCHHOFF'S VOLTAGE LAW (KVL): The algebraic sum of all the voltages around any closed path in a circuit equals zero for every instant of time.

- **Common Convention:** To avoid sign errors regarding KVL, use the voltage polarity sign of the element which you first encounter in passing by that element. Example: If in Fig. 13 we choose to take the loop clockwise, we hit the negative sign of the voltage source and the positive sign of v_x . Thus $-v + v_x = 0$.



KIRCHHOFF'S CURRENT LAW (KCL): The algebraic sum of all the currents at any node in a circuit equals zero for every instant of time.



- **Common Convention:** Currents entering will be negative. Currents leaving will be positive. (Opposite method is also permitted if you are consistent.) Example: In Fig. 14, KCL for the node is $-12A + 10A + i_x = 0$.

More Inside!

Basic Circuit Study Guide

John D. Cutnell, Kenneth W. Johnson



Basic Circuit Study Guide:

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DC Electrical Circuit Analysis Mehdi

Rahmani-Andebili, 2020-10-09 This study guide is designed for students taking courses in electrical circuit analysis The book includes examples questions and exercises that will help electrical engineering students to review and sharpen their knowledge of the subject and enhance their performance in the classroom Offering detailed solutions multiple methods for solving problems and clear explanations of concepts this hands on guide will improve student s problem solving skills and basic understanding of the topics covered in electric circuit analysis courses

Basic Circuit Analysis H Michael

Thomas, 2012-12-19 This is a non calculus based circuit analysis text that can be offered in the first term It could also be used by students as supplementary material for self study and as an additional source of information Problem solutions are provided for all the problems in the book in order to provide the student with an extensive source of worked examples Both DC and AC steady state circuit analysis are covered by introducing circuit analysis concepts with DC circuits containing sources and resistors using simpler math and then expanding the analysis to AC circuits containing sinusoidal sources resistors capacitors and inductors using more complex math Topics such as series parallel and series parallel circuits Ohm s law Kirchhoff s voltage and current laws voltage and current divider rules superposition Thevenin and Norton equivalent

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Engineering Circuit Analysis, Study Guide J. David Irwin, Chwan-Hwa Wu, 1999-12-22 This popular introductory circuits text known for its learn by doing format has been further improved with the additions of new problem solving techniques and other learning enhancements The presentations of the fundamental principles are replete with examples drill problems extension exercises and design problems **Study Guide and Exercises for Welding Processes and Power Sources** Edward R. Pierre, 1985 *Schaum's Outline of Theory and Problems of Basic Circuit Analysis* John O'Malley, 1982 Confusing Textbooks Missed Lectures Not Enough Time Fortunately for you there's Schaum's Outlines More than 40 million students have trusted Schaum's to help them succeed in the classroom and on exams Schaum's is the key to faster learning and higher grades in every subject Each Outline presents all the essential course information in an easy to follow topic by topic format You also get hundreds of examples solved problems and practice exercises to test your skills This Schaum's Outline gives you Practice problems with full explanations that reinforce knowledge Coverage of the most up to date developments in your course field In depth review of practices and applications Fully compatible with your classroom text Schaum's highlights all the important facts you need to know Use Schaum's to shorten your study time and get your best test scores Schaum's Outlines Problem Solved **Electromagnetic Field Analysis Guide**, 1998

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