

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 $q_e = -1.60 \times 10^{-19}$ 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 8×10^{-19} .
 - 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 (ampere). That is, one ampere is the current that flows when one coulomb of charge flows per second. Or, current (I) in amperes is:

$$I(t) = \frac{dq(t)}{dt}$$
 amperes, where $q(t)$ is the charge in coulombs, and t 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) currents which implies a time-reversal of direction of current such as in sinusoidal waves.
- VOLTAGE**: Voltage difference (also known as potential difference) between two points is defined as the work (per unit 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.

Note that: $V(t) = \frac{dq(t)}{dt}$ volts

- 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).

$p(t) = \frac{dq(t)}{dt}$ positive or watts

Note: $p(t) \cdot I(t) = \frac{dq(t)}{dt} \cdot \frac{dq(t)}{dt} = \frac{dq(t)}{dt} \cdot \frac{dq(t)}{dt} = p(t)$

- power ($p(t)$) 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 plus (+) sign. That is, the current must enter the positive terminal to use the above formula. Otherwise use minus (-). If $p(t) > 0$, then the element delivers power. If $p(t) < 0$, then the element absorbs power. See the following examples:

- In Fig. 1(a) the element is consuming/absorbing 10W of power, and in Fig. 1(b) the element is delivering 10W.
- 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. 4(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

In 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:
 $i = \alpha V_x$, where V_x is a voltage somewhere else in the circuit and α is a constant. See Fig. 7.



- current controlled current source:
 $i = \beta I_x$, where I_x is a current somewhere else in the circuit and β 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).

Fig. 9 shows the resistor symbol.

Resistor Symbols

Fig. 10 shows Ohm's Law.



Ohm's Law

OHM'S LAW: At a given temperature, is given by $v = IR$ volts, 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 $v = -IR$.

Ohm's Law

Open & Short Circuit

OPEN CIRCUIT: The graphical representation of an "open circuit" ($IR = 0$) is shown in Fig. 11. Note that the current can't flow due to infinite resistance. The terminals maintain an open circuit voltage.

Fig. 11
 $I = 0$ $R = \infty$
 Open Circuit

SHORT CIRCUIT: The graphical representation of a "short circuit" ($IR = 0$) 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.

Fig. 12
 $V = 0$ $R = 0$
 Short Circuit

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 Conventions**

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 fit the negative sign of the voltage source and the positive sign of v_2 . Thus $-v_1 + v_2 = 0$.

Fig. 13
 I V v_1 v_2
 Kirchhoff's Voltage Law

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 Conventions**

Currents entering will be positive. Currents leaving will be negative. (Opposite method is also permitted if you are consistent.) Example: In Fig. 14, KCL for the node is $-12.4 + 18.4 = 0$.

Fig. 14
 12.4 18.4
 Kirchhoff's Current Law

More Info!

Basic Circuit Study Guide

Milton Gussow

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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Thomas,2014-04-08 This book is intended to be a follow on to a basic circuit analysis text that can be offered in an upper level 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 The book covers advanced circuit analysis using the Laplace transform system analysis in the frequency domain using Bode plots and the design of passive and active filter circuits Visit author Facebook Page at facebook com HMichaelThomas Books *Physics, Study Guide* John D. Cutnell,Kenneth W. Johnson,1992-02-26 This Second Edition designed for a one year course in college physics includes the following new features Integration of Concepts explores the common ground between fundamental ideas in the current chapter and previous ones Problem Solving Insight provides reinforcement and emphasizes issues that students need to recognize as important and a reasoning step which appears before numerical solutions in each example Enhanced by hundreds of applications to biology medicine architecture and technology Worked out examples and homework problems have been substantially increased and full color reproductions added to facilitate students learning ability **Physics, , Student Study Guide** John D. Cutnell,Kenneth W.

Johnson,1997-09-04 Describes applications in medicine automobile features transportation home entertainment athletics household applications information processing detection devices camera technology and many more Contains numerous discussions and examples that focus on human physiology including muscle forces blood pressure the refraction of light by the eye and many others **The National Guide to Educational Credit for Training Programs 2002** (Ace) American

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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

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Electromagnetic Field Analysis Guide, 1998

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Table of Contents Basic Circuit Study Guide

1. Understanding the eBook Basic Circuit Study Guide
 - The Rise of Digital Reading Basic Circuit Study Guide
 - Advantages of eBooks Over Traditional Books
2. Identifying Basic Circuit Study Guide
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Basic Circuit Study Guide
 - User-Friendly Interface
4. Exploring eBook Recommendations from Basic Circuit Study Guide
 - Personalized Recommendations
 - Basic Circuit Study Guide User Reviews and Ratings
 - Basic Circuit Study Guide and Bestseller Lists
5. Accessing Basic Circuit Study Guide Free and Paid eBooks

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- Interactive Elements Basic Circuit Study Guide

8. Staying Engaged with Basic Circuit Study Guide

- Joining Online Reading Communities
- Participating in Virtual Book Clubs
- Following Authors and Publishers Basic Circuit Study Guide

9. Balancing eBooks and Physical Books Basic Circuit Study Guide

- Benefits of a Digital Library
- Creating a Diverse Reading Collection Basic Circuit Study Guide

10. Overcoming Reading Challenges

- Dealing with Digital Eye Strain
- Minimizing Distractions
- Managing Screen Time

11. Cultivating a Reading Routine Basic Circuit Study Guide

- Setting Reading Goals Basic Circuit Study Guide
- Carving Out Dedicated Reading Time

12. Sourcing Reliable Information of Basic Circuit Study Guide

- Fact-Checking eBook Content of Basic Circuit Study Guide
- Distinguishing Credible Sources

13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development

- Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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