Chapter 2 Objectives

• Understand symbols and behavior of the following circuit elements:
  – Independent voltage and current sources;
  – Dependent voltage and current sources;
  – Resistors.

• Be able to use Ohm’s and Kirchhoff’s laws to analyze circuits.

• Know how to calculate the power for each element in a circuit and determine whether or not the power balances.
Various Circuit Elements

- Electric sources
  - Independent Sources – voltage, current;
  - Dependent Sources – voltage, current.
- Resistors, inductors, capacitors
- Measurement devices
  - Ammeters (current);
  - Voltmeters (volts);
  - Ohmmeters (resistance).
- Electric wire
Independent Voltage Sources

- An ideal voltage source is a circuit element that will maintain the specified voltage $v_s$ across its terminals.
A Battery as an Independent Voltage Source

- An “ideal” battery is an example of an independent voltage source.
  - A “real-world” battery has a maximum power that it can deliver.
Independent Current Sources

- An ideal current source is a circuit element that maintains the specified current flow $i_s$ through its terminals.
Dependent Voltage and Current Sources

- A *dependent* voltage or current source establishes a voltage or current whose value depends on a voltage or current elsewhere in the circuit.
Current

- Current is the same in all elements connected in **Series**.
Voltage

- Voltage is the same for all elements connected in *Parallel*.
Interconnection of Ideal Sources

- Which of the following are valid connections?

a)  Valid
b)  Valid
c)  Not Valid
d)  Not Valid
e)  Valid
The Concept of Ground

• *Ground* is commonly referred to as a *reference point*.
• *Ground* is said to be at a potential of 0.00 volts. In other words, *Ground* has zero voltage because it is referenced to itself.
• Ground symbols:
Ground

1 Volt

1 Volt

1Ω

0 Volts
Open Circuit

- An *open circuit* means no current can flow \((i = 0)\).
- *Voltage across* an open circuit can be any value.
- An open circuit is equivalent to a resistance of \(\infty \ \Omega\).
- *Open circuit summary:*  
  - Infinite resistance;  
  - Zero current;  
  - Voltage can be any value.
• A short circuit means the voltage is zero ($v = 0$).
• Current through a short circuit can be any value.
• A short circuit is equivalent to a resistance of $0 \, \Omega$.
• Short circuit summary:
  – Zero resistance;
  – Zero voltage drop;
  – Current can be any value.
Resistance (R) and Conductance (G)

- **Resistance** (R) is the capacity of a material to impede the flow of current.
- More current will flow if there is less resistance.
- **Conductance** (G) is the inverse of resistance.
- The *unit* of resistance is the **ohm (R)**, has the symbol Ω, and has units of (volts/amp).
- The circuit symbol used for a resistor of R ohms is:
Ohm’s Law

• The relationship between voltage, current, and resistance is defined by *Ohm’s law* which states that

\[ V = IR \]

where

- \( V \) = the voltage in volts;
- \( I \) = the current in amps;
- \( R \) = the resistance in ohms.
Other Forms of Ohm’s Law

- Ohm’s law can be expressed in any one of three forms, depending on which quantities are known:

\[ V = IR \quad \text{(I and R known)} \]
\[ I = \frac{V}{R} \quad \text{(V and R known)} \]
\[ R = \frac{V}{I} \quad \text{(V and I known)} \]
Ohm’s Law Illustrated
Ohm’s Law Examples

Using Ohm’s law, calculate the values of $v$ and $i$ in the examples below and determine the power dissipated in each resistor.

\[ a) \quad v_a = 8V \quad p = 8W \]
\[ b) \quad i_b = 10A \quad p = 500W \]
\[ c) \quad v_c = -20V \quad p = 20W \text{ (positive)} \]
\[ d) \quad i_d = -2A \quad p = 100W \]
The resistance of a wire is determined by the resistivity of the conductor as well as the geometry:

\[ R = \frac{\rho l}{A} \]

In most cases, the resistance of wires can be assumed to be 0 Ω.
Resistors
# Resistor Color Code Chart

<table>
<thead>
<tr>
<th>COLOR</th>
<th>1st BAND</th>
<th>2nd BAND</th>
<th>3rd BAND</th>
<th>MULTIPLIER</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1Ω</td>
<td>± 1% (F)</td>
</tr>
<tr>
<td>Brown</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10Ω</td>
<td>± 1% (F)</td>
</tr>
<tr>
<td>Red</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100Ω</td>
<td>± 2% (G)</td>
</tr>
<tr>
<td>Orange</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1KΩ</td>
<td>± 1% (F)</td>
</tr>
<tr>
<td>Yellow</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>10KΩ</td>
<td>± 1% (F)</td>
</tr>
<tr>
<td>Green</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>100KΩ</td>
<td>± 0.5% (D)</td>
</tr>
<tr>
<td>Blue</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>1MΩ</td>
<td>± 0.25% (C)</td>
</tr>
<tr>
<td>Violet</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>10MΩ</td>
<td>± 0.10% (B)</td>
</tr>
<tr>
<td>Grey</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>100MΩ</td>
<td>± 0.05%</td>
</tr>
<tr>
<td>White</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>1GΩ</td>
<td>± 1% (F)</td>
</tr>
<tr>
<td>Gold</td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>± 5% (J)</td>
</tr>
<tr>
<td>Silver</td>
<td></td>
<td></td>
<td></td>
<td>0.01</td>
<td>± 10% (K)</td>
</tr>
</tbody>
</table>

- 4-Band-Code
- 5-Band-Code
- 0.1%, 0.25%, 0.5%, 1%
- 237Ω ± 1%
- 560kΩ ± 5%
Ohm’s Law Example

Calculate the value of R from the information shown in the graph below:

R is the inverse of the slope of the line:

\[ R = \frac{V}{I} = \frac{8V}{4A} = 2\Omega \]
Power and its Alternate Forms

- Resistors *always* absorb power:

\[ p = vi = \frac{v^2}{R} = i^2R \]
Power Example

Calculate the power absorbed or generated by both elements in the circuit below:

- Resistor absorbs power: $10V \times 2.5mA = 25mW$
- DC source generates power: $10V \times -2.5mA = -25mW$
- Sum of all power in a circuit must = 0

Note: Resistors always absorb power but DC sources can either generate or absorb power.
Find the total power developed in the circuit if $v_o = 5 \text{ V}$.

\[
P_{9A} = -135 \text{W} \quad P_{20V} = 180 \text{W} \quad P_{10va} = -75 \text{W}
\]
\[
P_{vg} = 27 \text{W} \quad P_{6A} = 3 \text{W}
\]
\[
P_{total} = 210 \text{W} \quad \text{and generated power = absorbed power}
\]
Nodes, Paths, Loops, Branches

- These two circuits are equivalent.
- There are three *nodes* and five *branches*:
  - *Node*: a point at which two or more elements have a common connection;
  - *Path*: a sequence of nodes;
  - *Branch*: a single path in a circuit composed of one simple element and the node at each end of that element;
  - *Loop*: a closed path.
Kirchhoff’s Current Law

- Kirchhoff’s Current Law (KCL) states that the algebraic sum of all currents entering a node is zero.

\[ i_A + i_B + (-i_C) + (-i_D) = 0 \]
KCL: Alternative Forms

• Current IN is positive:
  \[ i_A + i_B + (-i_C) + (-i_D) = 0 \]

• Current OUT is positive:
  \[ (-i_A) + (-i_B) + i_C + i_D = 0 \]

• Current IN = Current OUT:
  \[ i_A + i_B = i_C + i_D \]
Find the current through resistor $R_3$ if it is known that the voltage source supplies a current of 3 A.

Answer: $i = 6$ A
Kirchhoff’s Voltage Law

- Kirchhoff’s Voltage Law (KVL) states that the algebraic sum of the voltages around any closed path is zero.

\[-v_1 + v_2 + -v_3 = 0\]
KVL: Alternative Forms

- Sum of *RISES* is zero (clockwise from B):
  \[ v_1 + ( - v_2 ) + v_3 = 0 \]
- Sum of *DROPS* is zero (clockwise from B):
  \[ ( - v_1 ) + v_2 + ( - v_3 ) = 0 \]
- Sum of *RISES* is equal to sum of *DROPS* (clockwise from B):
  \[ v_1 + v_2 = v_3 \]
KVL Application

Find the current $i_x$ and the voltage $v_x$

$Answer: v_x = 12 \text{ V and } i_x = 120 \text{ mA}$
Textbook Problem 2.18 (Nilsson 10E)

Find the values of $i_a$, $i_b$, $v_o$, and the power absorbed or generated by all circuit elements.

\[ i_a = 2A \quad i_b = 0.5A \]
\[ v_o = 40V \]
\[ P_{40} = 25W \]
\[ P_{20} = 80W \]
\[ P_{80} = 20W \]
\[ P_{50v} = -125W \text{ (delivered)} \]
Circuit Analysis with Dependent Sources

- Circuits that contain dependent sources can be analyzed using Ohm’s and Kirchhoff’s laws.
- A dependent source generally adds another equation to the solution process.
Textbook Example - Figure 2.22 (Nilsson 9E)

A) Use Kirchhoff’s and Ohm’s laws to find the voltage $v_o$.
B) Show that the total power developed equals the total power dissipated.

\[ A) \quad v_o = 480 \text{ V} \]
\[ B) \quad \text{Power developed} = -21.7 \text{ W} \]
Testbook Problem 2.22 (Nilsson 10E)

The current $i_0$ is 1 A.

A) Find $i_1$.

B) Find the power dissipated in each resistor.

C) Verify that the power developed = power absorbed.

\[ A) \ i_1 = 2A \]

\[ B) \ P_4 = 100W \quad P_{50} = 50W \quad P_{10} = 90W \quad P_{65} = 260W \quad P_{25} = 400W \]

\[ C) \ P_{150V} = 900W = \text{sum of powers dissipated in the 5 resistors.} \]
Chapter 2 Summary

• Understand symbols and behavior of the following circuit elements:
  – Independent voltage and current sources;
  – Dependent voltage and current sources;
  – Resistors.

• Defined and used Ohm’s and Kirchhoff’s laws to analyze circuits.

• Illustrated how to calculate power for each element in a circuit and determine whether or not power balances.