Dependent Sources

Key component in Operational Amplifiers and Transistors
Objective of Lecture

- Describe how dependent voltage and current sources function.
- Explain how they are treated when analyzing a circuit and provide examples.

- Chapter 2.8
  Basic Engineering Circuit Analysis by J.D. Irwin and R.M. Nelms
Dependent Sources

The output voltage or current of a dependent source is determined by one of the parameters associated with another component in the circuit.

- In this course, the parameter is the voltage across or current flowing through of the other component.
- Other parameters may be the component’s resistance, amount of light shining on the component, the ambient temperature, and mechanical stress applied to the component including changes in atmospheric pressure.
Practical Dependent Sources

- Operational amplifiers
- Transistors
  - Bipolar Junction Transistors (BJTs)
  - Metal-Oxide-Semiconductor Field Effect Transistors (MOSFETs)
- Voltage and current regulators
- Other devices include:
  - Photodetectors, LEDs, and lasers
  - Piezoelectric devices
  - Thermocouples, thermovoltaic sources
Dependent Power Sources

- Voltage controlled voltage source
  - (VCVS)
- Current controlled voltage source
  - (CCVS)
- Voltage controlled current source
  - (VCCS)
- Current controlled current source
  - (CCCS)
Power Generators

- Dependent voltage and current sources generate power and supply it to a circuit **only** when there are other voltage or current sources in the circuit.
  - These other sources produce a current to flow through or a voltage across the component that controls the magnitude of the voltage or current output from the dependent source.
Circuit Analysis

- Treat similar to the independent voltage and current sources when performing nodal and mesh analysis.
- Do not treat like an independent source when using superposition.
  - Independent voltage and current sources are turned on and off as we apply superposition. Dependent sources remain on.
Example #1: Nodal Analysis

Voltage controlled current source

The value of the current is $-2 \times 10^{-3}$ times the voltage across $R_1$. 
Example #1 (con’t)

Note that there are no units on the coefficient for the dependent source. It is assumed that you know that the units should be A/V for a VCCS.
Example #1 (con’t)

Node A: \( I_V = I_1 + I_4 \)
Node B: \( I_1 + 1mA = I_2 + I_3 \)
Node C: \( I_3 + -2 \times 10^{-3} V_{R1} = 0 \)
Node D: \( I_4 = 1mA \)
Example #1 (con’t)

\[ V_A = 4V \]
\[ I_1 = \frac{(V_A - V_B)}{R_1} \]
\[ I_2 = \frac{V_B}{R_2} \]
\[ I_3 = \frac{(V_B - V_C)}{R_3} \]
\[ I_4 = \frac{(V_A - V_D)}{R_4} \]
\[ V_{R_1} = V_A - V_B \]
Example #1 (con’t)

Node A: \( I_V = \left(4V - V_B\right)/R_1 + \left(4V - V_D\right)/R_4 \)

Node B: \( \left(4V - V_B\right)/R_1 + 1mA = V_B/R_2 + \left(V_B - V_C\right)/R_3 \)

Node C: \( \left(V_B - V_C\right)/R_3 + -2 \times 10^{-3}\left(4V - V_B\right) = 0 \)

Node D: \( I_4 = 1mA \)
Example #1 (con’t)

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Voltages (V)</th>
<th>Currents (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4V</td>
<td>$I_v$</td>
</tr>
<tr>
<td>B</td>
<td>6V</td>
<td>$I_1$</td>
</tr>
<tr>
<td>C</td>
<td>22V</td>
<td>$I_2$</td>
</tr>
<tr>
<td>D</td>
<td>1V</td>
<td>$I_3$, $I_4$</td>
</tr>
</tbody>
</table>

$I_v = -1$ mA

$I_1 = -2$ mA

$I_2 = 3$ mA

$I_3 = -4$ mA

$I_4 = 1$ mA
Example #2: Superposition

V2 is a current controlled voltage source (CCVS).

The value of the voltage of the CCVS is 3000 times the current $i_2$, which is the current flowing out of V1.
Example #2 (con’t)

- The two circuits that will be analyzed are
  1. When V1 is on and I1 is turned off.
  2. When I1 is on and V1 is turned off.
     - In both circuits, V2 is left on.
Example #2 (con’t)

When I1 is turned off, one terminal of R4 is not connected to the rest of the circuit and it can be eliminated.
Example #2 (con’t)

You can select any analysis to solve for $i_2$. 
Example #2 (con’t)

\[-V_1 + V_{R1} + V_{R2} = 0\]
\[-V_{R2} + V_{R3} + V_2 = 0\]

\[V_1 = 4V\]
\[V_{R1} = i_2 R_1\]
\[V_{R2} = (i_2 - i_3)R_2\]
\[V_{R3} = i_3 R_3\]
\[V_2 = 3000 \Omega i_2\]
Example #2 (con’t)

\[-4V + i_2 (1k\Omega) + (i_2 - i_3)(2k\Omega) = 0\]
\[-(i_2 - i_3)(2k\Omega) + i_3 (4k\Omega) + 3000i_2 = 0\]
Example #2 (con’t)

<table>
<thead>
<tr>
<th>Currents</th>
<th>Dependent Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_2$</td>
<td>1.2mA</td>
</tr>
<tr>
<td>$i_3$</td>
<td>-0.2mA</td>
</tr>
</tbody>
</table>
Example #2 (con’t)

Again, you can select which ever analysis technique that you would like in order to solve for $i_2$. 
Example #2 (con’t)

\[ V_{R1} + V_{R2} = 0 \]
\[ -V_{R2} + V_{R3} + V_2 = 0 \]
\[ V_4 + V_{I1} - V_{R1} = 0 \]

\[ I_1 = i_1 = 1mA \]
\[ V_{R1} = (i_2 - i_1)R_1 \]
\[ V_{R2} = (i_2 - i_3)R_2 \]
\[ V_{R3} = i_3R_3 \]
\[ V_{R4} = i_1R_4 \]
\[ V_2 = 3000\Omega i_2 \]
Example #2 (con’t)

\[
(i_2 - 1 mA)(1 k\Omega) + (i_2 - i_3)(2 k\Omega) = 0
\]
\[
-(i_2 - i_3)(2 k\Omega) + i_3 R_3 + 3000 i_2 = 0
\]
\[
i_1 (3 k\Omega) + V_{I1} - (i_2 - 1 mA)(1 k\Omega) = 0
\]
Example #2 (con’t)

<table>
<thead>
<tr>
<th>Currents</th>
<th>Dependent Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_2$</td>
<td>0.3mA</td>
</tr>
<tr>
<td>$i_3$</td>
<td>-50μA</td>
</tr>
<tr>
<td>$V_2$</td>
<td>0.9V</td>
</tr>
</tbody>
</table>
Example #2 (con’t)

Currents

| i2   | (1.2+0.3) mA = 1.5 mA |

Dependent Source

| V2   | (3.6+0.9) V = 4.5 V |
Summary

- Dependent sources are voltage or current sources whose output is a function of another parameter in the circuit.
  - Voltage controlled voltage source (VCVS)
  - Current controlled current source (CCCS)
  - Voltage controlled current source (VCCS)
  - Current controlled voltage source (CCVS)
- Dependent sources only produce a voltage or current when an independent voltage or current source is in the circuit.
- Dependent sources are treated like independent sources when using nodal or loop analysis, but not with superposition.