Lecture 4

1. **DEPENDENT SOURCES**

   - **Node analysis:** no change

   ![Circuit Diagram]

   \[ V_A = \frac{-e}{R_1 + R_2 + kI_1} \]

   ![Additional Circuit Diagram]

   \[ + e \left( \frac{1}{R_1} + \frac{1}{R_2} + \frac{k}{R_1} \right) = V_A \left( \frac{1}{R_1} + \frac{k}{R_1} \right) \]

   - **Thévenin / Norton**
     - Only use if dependent source is linear
     - Only use if both parts of dependent source are inside circuit being modeled

   \[ e = \frac{R_1}{V_A} \left( \frac{1}{R_1} + \frac{k}{R_1} \right) \]

   - Dependent sources increase "effective" $R_2$ by factor $k+1$

   - Floating dependent voltage sources $\rightarrow$ use supernode

2. **$R_{TH}$**

   - Turn off independent sources
   - Do not turn off dependent sources
   - Can use $V_{th}$ (test) $I_{test}$ method

   ![Additional Circuit Diagram]

   \[ V_{th} = \frac{D_{oc}}{R_1} \]

   At $D_{oc}$ \[ i_1 = 0 \rightarrow kI_1 = 0 \]

   \[ \Rightarrow V_{th} = 0 \]
9/17/19

Lecture 9

\[ v_{\text{test}} = i_{\text{test}} \left[ R_1 + R_2(1+k) \right] \]

At \( e^* \):

\[ \frac{e}{i_{\text{test}} + R_2 + k i_1} = 0 \]

\[ v_{\text{test}} = R_1 \cdot i_{\text{test}} \]

\[ v_{\text{test}} = i_{\text{test}} R_1 + e \]

\[ e = R_2(1+k) i_{\text{test}} \]

\[ \text{device: } v_{\text{test}} - e = i_{\text{test}} \]

\[ \frac{v_{\text{test}}}{R} = i_{\text{test}} \]

\[ v_{\text{test}} = i_{\text{test}} R_1 + e \]

\[ v_{\text{test}} = i_{\text{test}} R_1 \]

**2. Superposition**

- Turn off all but one independent source
- Only apply superposition to independent sources

\[ i = \frac{1}{1000} = 10mA \]

\[ v = 1V \Rightarrow i = 10mA \]

\[ \Rightarrow v_0 = 10V \]

**3. Turn off 2V source**

\[ v = \frac{1}{2} V \Rightarrow i = 5mA \Rightarrow v_0 = 5V \]

Total \( v_0 = 15V \)
Recap

1. Superposition
   Analyze a linear circuit with multiple sources by analyzing response to each source, then summing responses

   \[ e_1 = e_{1A} + e_{1B} + e_{1C} \]

   Adapted from Lang and Agarwal

2. Thévenin and Norton
   Any linear circuit can be modeled at a port by a voltage source and series resistor, or current source and parallel resistor

   \[ V_{TH} \quad \text{and} \quad R_{TH} \]

   where:
   \[ V_{TH} = \text{open-circuit voltage at the port} \]
   \[ R_{TH} = \text{the resistance looking into the port with all independent sources turned OFF} \]

   \[ I_N \]

   where:
   \[ I_N = \text{short-circuit current out of the port} \]
   \[ I_N = \frac{V_{TH}}{R_{TH}} \]
   \[ R_N = R_{TH} \]

This week

- Starting on printed-circuit board for Doppler ultrasound project
- US system will be introduced next week
- Soldering training this Tue and Wed
- We’ll be implementing our first stage of the US system in Lab 4
Amplification

DAC from Lab 2

- Resistive networks can only attenuate signals
- How can we amplify signals?

Amplification

- Amplifiers increase the voltage, current or power of signals
- Essential components in communications, signal processing, sensors, memory, logic, etc.
Amplification

- Amplification brings signal to required level and enhances noise tolerance:
  - Without amplification:
    - Hard to see signal
    - 1 mV
    - 10 mV
  - With amplification:
    - Better!
    - Noise reduced

Amplifiers

- Amplifier is a 3-port system:
  - Input port
  - Power port
  - Output port

…but often power port not explicitly shown.

- Ports are typically referenced to a common “ground” node:
Our first amplifier will be an op-amp, and we'll model it with dependent sources.

Dependent sources

Modeling an amplifier

Introduce a new symbol to denote that the voltage depends on some other quantity.
Dependent sources

**Two-port devices**
- Control port: sets the value of the source
- Output port: source terminals

**4 types of dependent current sources**

- **Voltage-controlled current source (VCCS)**
  - Control port: \( i_i \)
  - Output port: \( i_o \)
  - Relationship: \( i_o = f(v_i) \)

- **Current-controlled current source (CCCS)**
  - Control port: \( v_i \)
  - Output port: \( i_o \)
  - Relationship: \( i_o = f(i_i) \)

- **Voltage-controlled voltage source (VCVS)**
  - Control port: \( v_i \)
  - Output port: \( v_o \)
  - Relationship: \( v_o = f(v_i) \)

- **Current-controlled voltage source (CCVS)**
  - Control port: \( i_i \)
  - Output port: \( v_o \)
  - Relationship: \( v_o = f(i_i) \)

Dependent sources also model transducers

**A nonlinear current-controlled current source**

A non-linear current-controlled current source
Dependent sources for amplifiers

Not just voltage-controlled voltage source...

Example using voltage-controlled current source:

\[ v_O = V_S - R_L G v_I \]

\[ R_L G > 1 \]

Output signal has 180° phase shift
Offset varies, but often doesn’t matter