Lecture 4

9/18/18

O'RECAP

(2) DEPENDENT SOURCES

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\[ V_A e = \frac{V_A - e}{R_1 + R_2 + ki_1} = 0 \]

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

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

Thevenin / Norton

- Only if dependent source is linear.
- Only if both ports are inside circuit being modeled.

Dependent source increases effective source by \( (k+1) \).

- Use supernodes for floating dependent voltage sources.

ii) Find \( R_{TH} \)

- Turn off independent sources.
- Do not turn off dependent sources!

i) \( V_{TH} = V_{oc} \)

\[ V_{oc} \rightarrow i_1 = 0 \Rightarrow ki_1 = 0 \]

\[ \Rightarrow V_{TH} = 0 \]
Lecture 4

A V_{\text{test}} + R_T = \frac{V_{\text{test}}}{R_T} = \frac{R_1 + R_2(k+1)}{R_1 + R_2(k+1)}

\begin{align*}
e & = R_2 i_{\text{test}}(k+1) \\
V_{\text{test}} & = e + i_{\text{test}} R_1 \\
V_{\text{test}} & = i_{\text{test}} [R_1 + R_2(k+1)]
\end{align*}

\begin{enumerate}
  \item \textbf{Superposition}
  \begin{itemize}
    \item Turn off independent sources
    \item Only apply superposition to independent sources
  \end{itemize}

\begin{align*}
  V & = 1V \Rightarrow i = 10mA \\
  \Rightarrow V_0 & = 10V
\end{align*}

\item Turn OFF 2V source

\begin{align*}
  V & = \frac{1}{2}V \Rightarrow i = 5mA \\
  \Rightarrow V_0 & = 5V
\end{align*}

V_o = V_s - GV_v R_L = V_s - R_L G V_i

V_o = 5V + 10V = 15V

If R_L G > 1 \rightarrow \text{amplification}
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

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

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

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, memory, logic, etc.

Amplification brings signal to required level and enhances noise tolerance:

- Without amplification:
  - Hard to see signal
  - Useful signal: 1 mV

- With amplification:
  - Better!
  - Noise: 10 mV
  - Useful signal: 10 mV

https://www.researchgate.net/profile/Kevin_Otto/publication/283011881/figure/fig1/AS:321734516461568@1453718894/Placement-of-the-Utah-electrode-arrays-in-one-NHP-The.png
Amplifiers

- Amplifier is a 3-port system:

  ![Amplifier Diagram](image)

  ...but often power port not explicitly shown.

- Ports are typically referenced to a common “ground” node:

  ![Ground Node Diagram](image)

Amplifiers

Our first amplifier will be an op-amp, and we’ll model it with dependent sources
Dependent sources

Recall independent sources:

\[ v = V \]

\[ i = I \]

Two-terminal one-port devices

-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)
- \( i_o = f(v_i) \)

Current-controlled current source (CCCS)
- \( i_o = f(i_i) \)

Voltage-controlled voltage source (VCVS)
- \( v_o = f(v_i) \)

Current-controlled voltage source (CCVS)
- \( v_o = f(i_i) \)

Linear dependent source
- \( f(x) = kx \)
Dependent sources also model transducers

A nonlinear current-controlled current source

Dependent sources for amplifiers

\[ v_O = V_S - R_L G v_I \]

\[ R_L G > 1 \]

\[ v_I \]

\[ v_O \]
Dependent sources for amplifiers

Output signal has $180^\circ$ phase shift
Offset varies, but often doesn’t matter