Lecture 6: Finish chapter 4

Adminstrivia → Anonymous feedback [choose ee100]
http://inst.eecs.berkeley.edu/~inst/anon/
Midterm review session [next Friday (tentative)]

Today: Finish Thevenin
- Source transforms
- Superposition
- Maximum power transfer theorem.
- Chapter 6 start + lab lecture

Continuing from last lecture

(2) If a circuit has only dependent
sources & resistors:

\[ \begin{align*}
& V_x \quad \text{in} \\
& M - V_x + i \\
& 5V_x \\
& V_{oc} = ?
\end{align*} \]

\[ i > 0 \quad \text{[open-circuit]} \]
\[ \Rightarrow V_x = 0 \\
\Rightarrow V_{oc} = 0 \]
\( i_{sc} = 1 \)

\( V_x = 2i \)

\[
\begin{align*}
\text{kuv} : & \quad 5V_x = -V_x \\
\Rightarrow & \quad V_x = 0 \Rightarrow i = 0
\end{align*}
\]

\( i_{sc} = 0 \)

\[
R_m = \frac{V_{oc}}{i_{sc}} = \frac{0}{0} = \text{undefined!}
\]

\[\underline{\text{Let's try to understand what's going on}}\]

\[\text{by looking at the following circuit:}\]

\[
\text{Notice that in this circuit,} \quad V_{oc} = V_{th} = 0 \quad \text{and} \quad i_{sc} = 0 \quad \text{A}
\]

\[\therefore R_m \text{ cannot be computed using } V_{oc} \text{ & } i_{sc}\]
Therefore we need another way to compute $R_m$.

\[ R_m = \frac{V_{\text{test}}}{i_{\text{test}}} \]

In our case:

\[ R_m = \frac{V_{\text{test}}}{i_{\text{test}}} \quad i_{\text{test}} = i_1 + i_2 \]

\[ V_{\text{test}} = \frac{V_{\text{test}}}{R_m} + \frac{V_{\text{test}}}{10k} \]

\[ \Rightarrow \quad \frac{1}{R_m} = \frac{1}{10k} + \frac{1}{10k} \]

\[ \Rightarrow \quad R_m = 5k \]
Then, equivalent:

Let's apply this method to the circuit with purely dependent sources:

Apply test source:

Ohm's law: \( V_x = (i_{\text{Test}}) \times (2R) \)

KVL: \( V_{\text{Test}} = V_x + 5V_x \)

\[ = 6V_x \]

\[ = (6 \times 2) \times (i_{\text{Test}}) \]

\[ R_m = \frac{V_{\text{Test}}}{i_{\text{Test}}} = 12 \, \Omega \]
**Thevenin's Theorem [Summary]**

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Equivalent</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Contains only independent sources and resistors</td>
<td><img src="image" alt="Circuit Diagram" /></td>
<td>(1) Find $V_{oc}$, find $I_{sc}$, $R_m = \frac{V_{oc}}{I_{sc}}$</td>
</tr>
<tr>
<td>(2) Contains only dependent sources and resistors</td>
<td><img src="image" alt="Circuit Diagram" /></td>
<td>(2) Find $V_{oc}$, kill all sources, then find $R_m$</td>
</tr>
</tbody>
</table>

**Notes:**
- (3) **Nonlinear Elements**
- Can't Thevenize entire circuit!
(4.9) Source transforms

\[ i_{sc} = \frac{V_{oc}}{R_m} \]

Source transform

\[ V_{oc} = i_{sc} R_m \]

Norton equivalent

Example: Assessing Objective 4 [Eq. 139]

(a) Find \( V \)

\[ V = 98 \text{ V} \]

Solution: Many ways to approach problem, lets do source transforms [quickest method for this problem]
\[ j_1 = \frac{(2.4)}{(2.4 + 9.6)} \times 30 \quad \text{[Current divider from Chapter 3]} \]

\[ V = (j_1)(8 \, \text{m}) = \frac{2.4 \times 30.8}{12} \]

\[ = \frac{24 \times 30.8}{12} = 48 \, \text{V} \]

(4.13) Superposition

Ly is not really used as a circuit analysis technique because it makes the problem harder to do. Rather, you use it extensively in nonlinear circuit analysis (e.g., small-signal analysis).
(a) Find \( V \)

\[ V = 16 \text{ V} \]

**Source transform:**

\[ V = V_1 + V_2 \]

\[ V_1 = \frac{3}{3 + b} \times 120 \]

\[ V_2 = -I_2 \times 3 \]

\[ V_1 = 40 \text{ V} \]

\[ V = V_1 + V_2 = 16 \text{ V} \]

*Recommend: avoid superposition (for now, we will need it in small-signal analysis)*
(4.12) Maximum Power Transfer

\[ P_{\text{max}} = \frac{V_o^2}{R_m + R_L} \]

**Question:** What should be \( R_L \) (in terms of \( R_m \)) for maximum power dissipated in \( R_L \)?

**Answer:** \( R_L = R_m \) (?).

**Proof:**

\[
P_{R_L} = \frac{V_o^2}{R_L} = V_L \left( \frac{V_L}{R_L} \right) = \frac{V_L^2}{R_L}
\]

\[
P_{R_L} = \left( \frac{R_L + R_m}{R_L + R_m} \right)^2 \cdot \frac{1}{R_L}
\]

\[
= \frac{P_L(R_L)}{R_L} = \left( \frac{V_o}{R_L + R_m} \right)^2 \cdot R_L
\]

\[
= \text{Voc constant}
\]

Load eg: loudspeaker, you want maximum power delivered to it!
\[ \maxim:\quad \frac{dP_{RL}}{dR_L} = 0 \]

\[ \Rightarrow \quad R_L = R_m \]

**Chapter 6 & 7**

Skip 6.5 [No Mutual Inductance]

Skip 7.7 [We haven't covered op-amps yet!]

**Chapter 6:**

[Let's start Chapter 6, finish Monday]

(6.2) Capacitor

\[ \begin{align*}
\text{Charge:} & \quad \frac{q}{C} = CV \\
\text{Voltage:} & \quad V \quad \downarrow \\
[C]: & \quad \text{farad (capacitance)} \\
\text{"polarized"} & \quad \frac{1}{\frac{dt}{dt}} \\
\Rightarrow & \quad i = \frac{C}{dt} + \frac{V}{dt} \frac{dC}{dt} (C \text{ is constant})
\end{align*} \]
\[ i = \frac{cdv}{dt} \]

(a) is capacitor linear element?

\[ \frac{v_1 + v_2}{\frac{cd}{dt}} \rightarrow i = \frac{c}{dt} (v_1 + v_2) \]

\[ = \frac{cdv_1}{dt} + \frac{cdv_2}{dt} \]

(A:) Ye0! Capacitor is a linear element!

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Continue Chapter 6 & 7 on Monday, and lab lecture on Monday.

(1) lab for next week is only 3 hours, but I give you 6 hours to do it!

\[ \text{Try to understand lab!} \]