Equivalent Circuits: Thevenin Theorem

EGR 220, Chapter 4.5 - 4.11
(not section 4.9)
February 20, 2020

Overview

• Review concepts of
  • Voltage
  • \( R_{eq} \)
• Thevenin Equivalent Circuit
  • Equivalent \( V_t \)-with-series-\( R \)
  • “Equivalent” V-I-R behavior to an actual power supply or ‘driving’ circuit.

Equivalent Resistance

• Equivalent resistance and voltage are terminal-dependent
• Ohm’s Law tells us that \( V = I*R \) so...
  \( R = \frac{V}{I} \)
• Electrical resistance is the ratio of:
  • The (open circuit) voltage across a pair of nodes to
  • The (short circuit) through the pair of nodes

• Equivalent circuits concept
  a) Indistinguishable from each other,
  b) ...In terms of the \( V-I-R_{eq} \) characteristics,
  c) ...At the specified terminals (nodes)
Source Transformation & Equivalents

• Voltage \( V_{ab} \) and \( R_{eq} \) can be measured across any nodes of \textit{any} device or circuit.

• We are interested in this \textbf{measured or calculated} \( V - I - R \) behavior

![Linear two-terminal circuit diagram]

\( V_{oc} \) and \( I_{sc} \) ("sc" = short circuit; "oc" = open circuit)

---

Your Mission

• Find two circuits with equivalent behavior with
  1) 1 current source + 1 resistor
  2) 1 voltage source + 1 resistor

• If you design a power source with output of
  • \( I = \infty \, A \) \( \rightarrow \) Your computer will \textbf{melt}
  • \( V = 0 \, V \) \( \rightarrow \) Your computer will be a paper weight

---

Source Transformation

\[ V_s = i_s R \quad \Leftrightarrow \quad i_s = \frac{V_s}{R} \]

• Caution: maintain polarity of sources

---

Will your computer melt/do nothing?

Find \( V_{oc} \) and \( I_{sc} \)
Will your computer melt/do nothing?

Later: Can these be equivalent?
Source Transformation
• Find $i$ in the circuit below

Thevenin Equivalent

13

Thevenin Equivalent – Process
1) Find $R_{th}$:

2) Find $V_{th}$:

14

15

16
Thevenin Equivalent – Process

1) Find $R_{Th}$:
   a) Remove the load resistor (if there is one)
   b) Set all (independent) sources equal to zero.
      • $V$-source = 0V  $\Leftrightarrow$ < open / short >
      • $I$-source = 0A  $\Leftrightarrow$ < open / short >
   c) Find the equivalent resistance from the specified nodes

2) Find $V_{Th}$:
   a) Return to the original circuit, remove the load again, but keep all sources, and
   b) Find the open-circuit voltage across the specified nodes

Thevenin Equivalent

• A Thevenin equivalent circuit is
   • An equivalent version of a different circuit
   • ...In terms of the V-I characteristic, at the specified nodes
      • Defined in terms of specified terminals/nodes
   • Consists of a single resistor, $R_{Th}$, and a voltage source, $V_{Th}$
Thevenin: Find $V_{Th}$, $R_{Th}$

![Diagram 1](image1)

![Diagram 2](image2)

Thevenin: Find $V_{Th}$, $R_{Th}$

![Diagram 3](image3)

![Diagram 4](image4)
Thevenin: Find $V_{Th}$, $R_{Th}$

Try setting up a solution method for all our analysis techniques and think about pros and cons of the different approaches
Thevenin: Find $V_{Th}$, $R_{Th}$

* Maximum Power Transfer *
- **How** would we find the $P_{max}$ delivered to $R_L$?
- Do not solve – discuss strategy (chapter example)

Concept Question
- Are equivalent circuits all the same?
- Discuss $V_{Th}$, $R_{Th}$ at $a-b$ and $b-c$
- What is $R_L$ for maximum power transfer, and how do you find the amount of power transferred?
Concept Question
• Are equivalent circuits all the same?
• Discuss $V_{Th}$, $R_{Th}$ at $a-b$ and $b-c$
• What is $R_i$ for maximum power transfer, and how do you find the amount of power transferred?

Norton Equivalent Circuit

\[ V_{Th} = v_{oc} \]
\[ I_N = i_{sc} \]
\[ R_{Th} = R_N = R_{in} = \frac{v_{oc}}{i_{sc}} \]

Thevenin Self-Review
• What is a Thevenin Equivalent Circuit?
  • Draw a generic Thevenin equivalent circuit
  • Discuss and write down 3 good uses for a Thevenin equivalent circuit, or for the Thevenin theorem

• How might you find the maximum power that can be delivered to any load from any circuit?
  • Why is this an important question?

Summary
• Source transformation
• Equivalency
  • Equivalent resistance
  • Voltage – Current – $R_{eq}$ behavior
• Thevenin equivalent circuit
  • $V$-source & series resistor
  • Uses for Thevenin equivalent circuits
  • Only need to know the Norton equivalent exists. We will focus on Thevenin
Questions?