EE292: Fundamentals of ECE

Fall 2012
TTh 10:00-11:15 SEB 1242

Lecture 6
120913

http://www.ee.unlv.edu/~b1morris/ee292/

ENGINEERING TUTORING

Courses tutored include:

CEE – CPE – CS –EE –ME courses + much more

MATH: 181, 182, 283, 431

PHYS: 151, 152, 180, 181

General information:

- Free drop-in lab * no appt needed
- TBE – A 207L * Next door to the advising center
- Mon-Fri 12 - 5:00pm
- Sept. 4 – Dec 7, 2012
- (702) 774-4623
- UNLV student ID required

Staff

UNLV graduate & undergraduate engineering majors

*Accepting applications for new tutors this semester *

http://academicsuccess.unlv.edu/learningsupport/Tutoring/

Outline

- Review Mesh-Current Analysis
- Thevenin Equivalent Circuits
- Norton Equivalent Circuits
- Capacitance
- Inductance

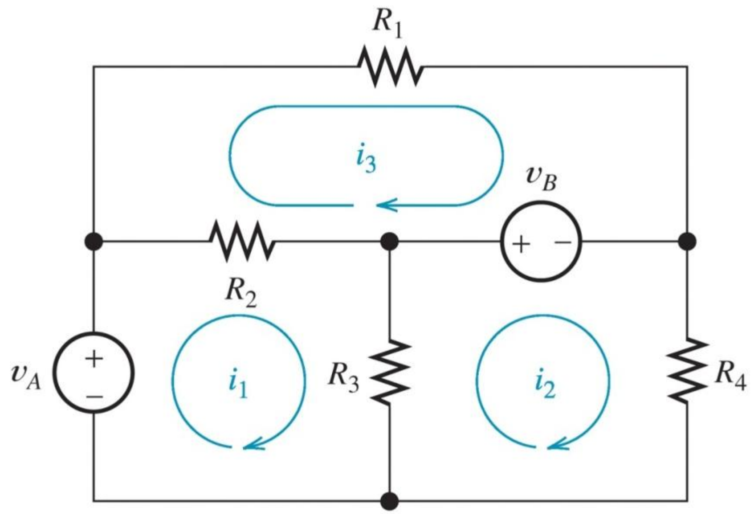
Mesh-Current Analysis

- Currents around a “mesh” are unknown
  - Requires planar (non-overlapping) circuits
- Use KVL equations around a mesh

- Steps:

1. Define mesh currents clockwise around “minimum” loops
2. Write network KVL equations for each mesh current
   - Define current sources in terms of mesh currents
   - Shared current sources require a supermesh
   - Dependent source equations should be re-written in terms of mesh currents
3. Put the equations into standard form and solve for the node voltages

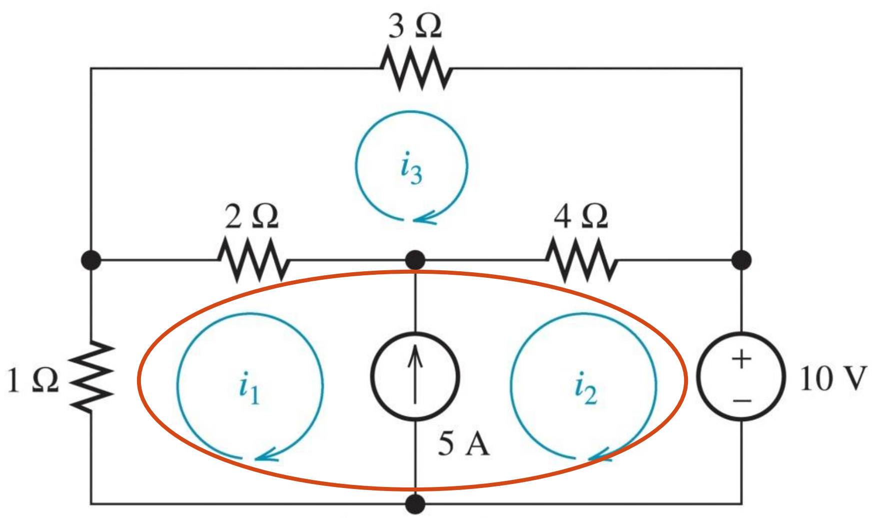
Write KVL Equations



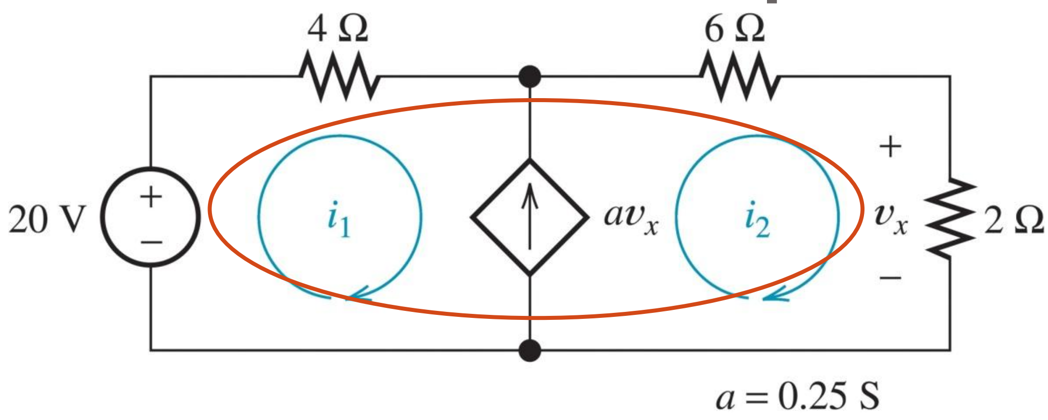
- KVL clockwise around mesh i_1
  - $v_A - (i_1 - i_3)R_2 - (i_1 - i_2)R_3 = 0$
- KVL clockwise around mesh i_2
  - $-(i_2 - i_1)R_3 - v_B - i_2R_4 = 0$
- KVL clockwise mesh i_3
  - $-i_3R_1 + v_B - (i_3 - i_1)R_2 = 0$

Supermeshes

- A combination of meshes useful for mesh-current analysis with shared current sources
  - Adjust KVL to get an equation around the supermesh
- Same idea as the supernode in node-voltage analysis



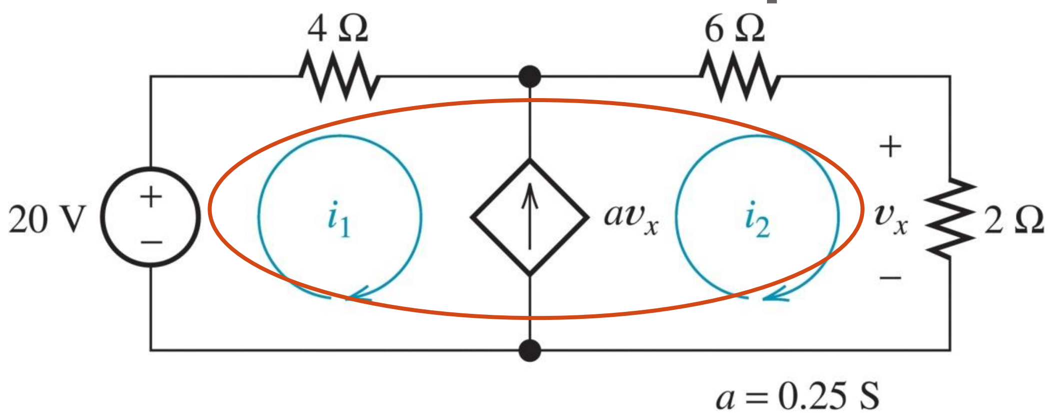
Example Controlled Supermesh



- 2 unknown mesh currents → need 2 equations

1. Replace controlling variable v_x with mesh currents
   - $v_x = 2i_2$
2. Create supermesh because of shared current source
3. KVL around supermesh
   - $20 - 4i_1 - 6i_2 - 2i_2 = 0$

Example Controlled Supermesh



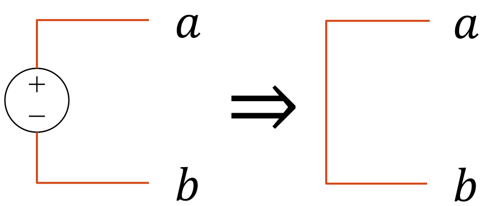
- 2 unknown mesh currents → need 2 equations

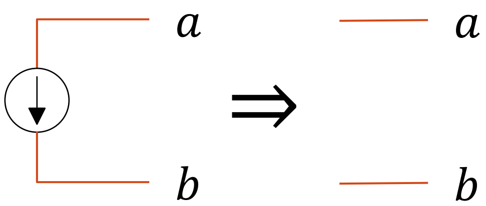
4. Write (mesh) expression for the current source
   - $av_x = a(2i_2) = i_2 - i_1$
   - $(2a - 1)i_2 = -i_1$
   - $i_1 = 0.5i_2$
5. Plug back into KVL equation
   - $20 - 4i_1 - 6i_2 - 2i_2 = 0$
   - $20 - 4i_2/2 - 6i_2 - 2i_2 = 0$
   - $10i_2 = 20$
   - $i_2 = 2\text{ A and } i_1 = 1\text{ A}$

Superposition Principle

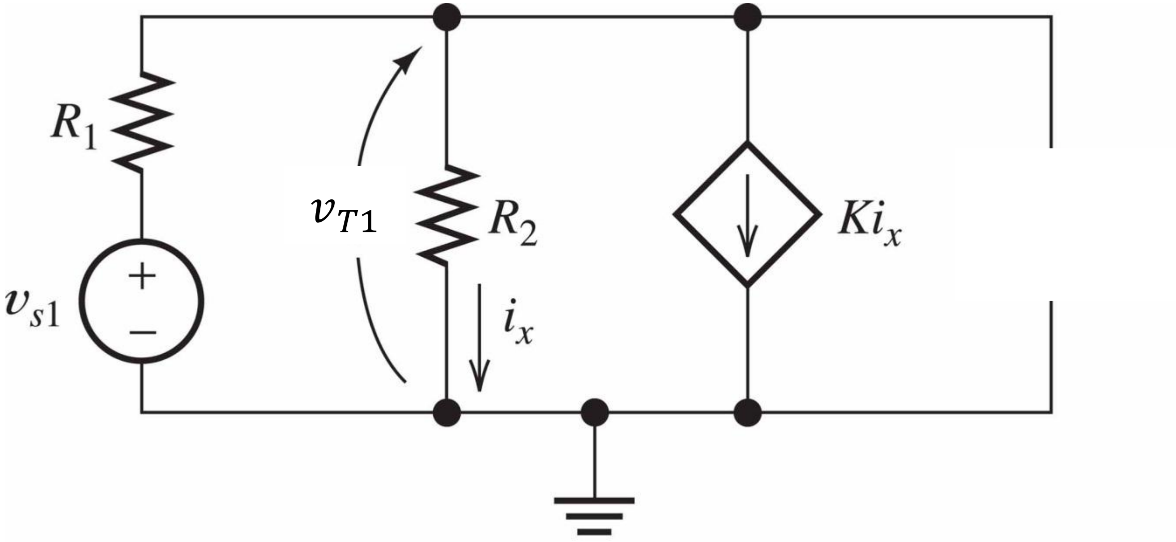
- Given a circuit with multiple independent sources, the total response is the sum of the responses to each individual source
  - Requires linear dependent sources

- Analyze each independent source individually
  - Must zero out independent sources, but keep dependent sources
    - A voltage source becomes a short circuit
    - A current source becomes an open circuit



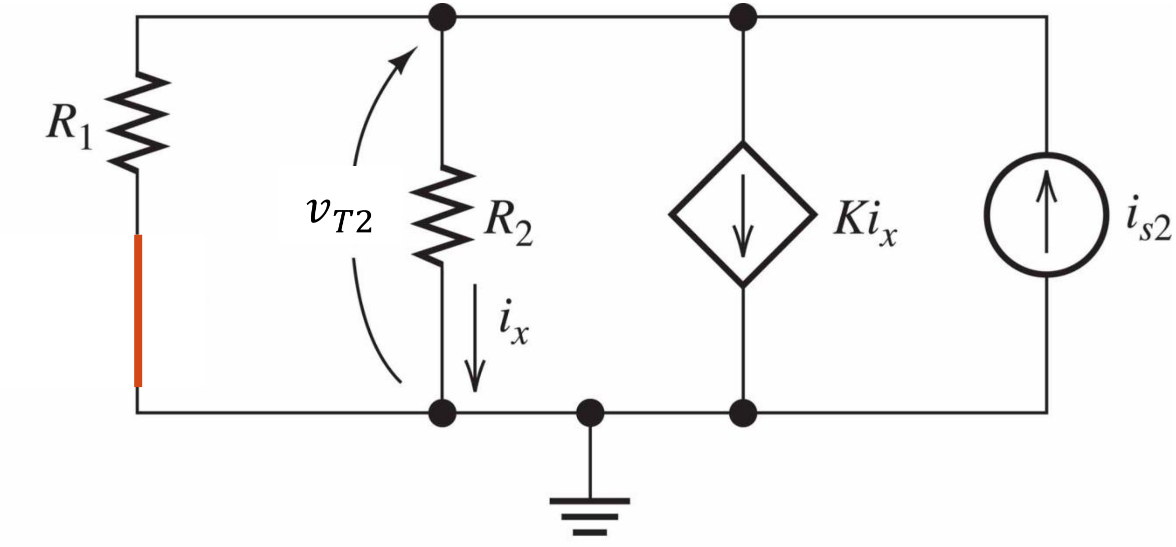


Superposition Example



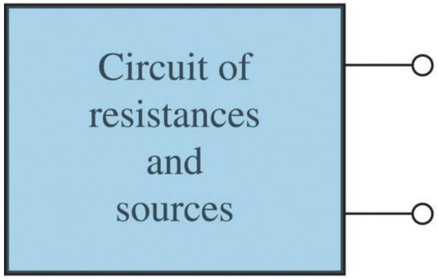
- 2 independent sources
  - Response is sum of each source response
  - $v_T = v_{T1} + v_{T2}$

Superposition Example



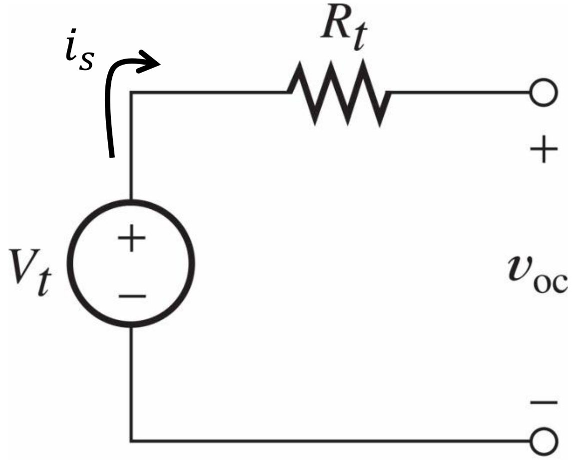
- 2 independent sources
  - Response is sum of each source response
  - $v_T = v_{T1} + v_{T2}$

Thevenin Equivalent Circuit



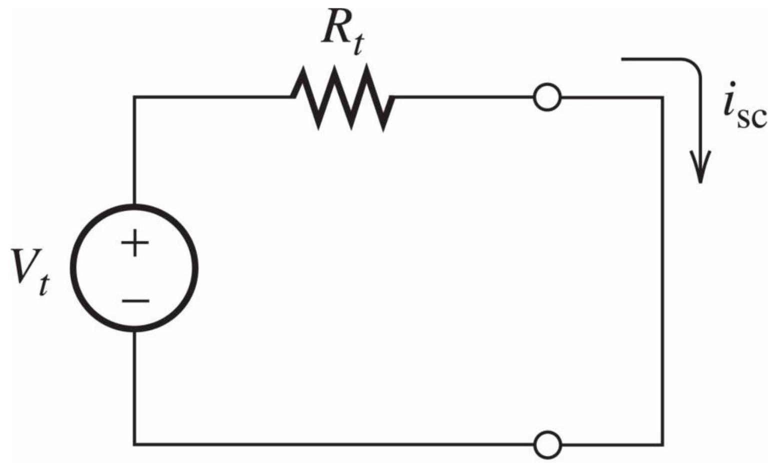
- Equivalent circuit consisting of a voltage source in series with a resistance
  - View the circuit from two terminals
- We care about three things
  - Open circuit voltage
  - Short circuit current
  - Equivalent resistance

Open Circuit Voltage



- Open circuit means terminal unconnected
  - No current flows through R_t
- Using KVL
  - $V_t - i_s R_t - v_{oc} = 0$
    - $i_s = 0$
  - $V_t = v_{oc}$

Short Circuit Current



- Short circuit uses a wire to connect the terminals
  - Current flows through series resistor
- Current is a function of Thevenin source voltage and resistance
  - $i_{sc} = \frac{V_t}{R_t}$

Thevenin Equivalent Resistance

- Equivalent resistance is computed using Ohm's Law
  - Use the open source voltage and short circuit voltage
  - $R_t = \frac{v_{oc}}{i_{sc}} = \frac{V_t}{i_{sc}}$

- Find two of v_{oc}, i_{sc}, or R_t to define the Thevenin equivalent circuit

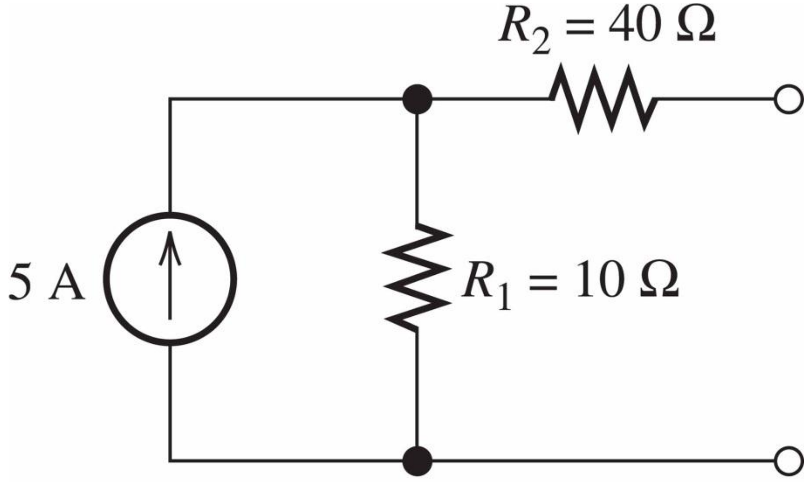
Compute R_t Directly

- Possible only when there are no dependent sources present in network

- Steps:

1. Zero out independent sources
   - Short voltage sources
   - Open current sources
2. Compute R_t by series/parallel equivalent steps

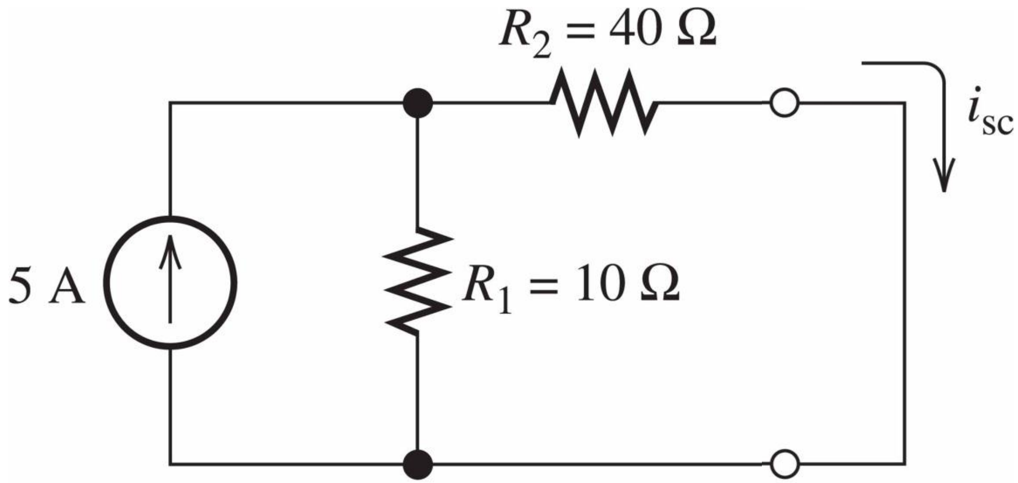
Example



- Find Thevenin equivalent

1. Find short circuit current
2. Find open circuit voltage
3. Solve for equivalent resistance

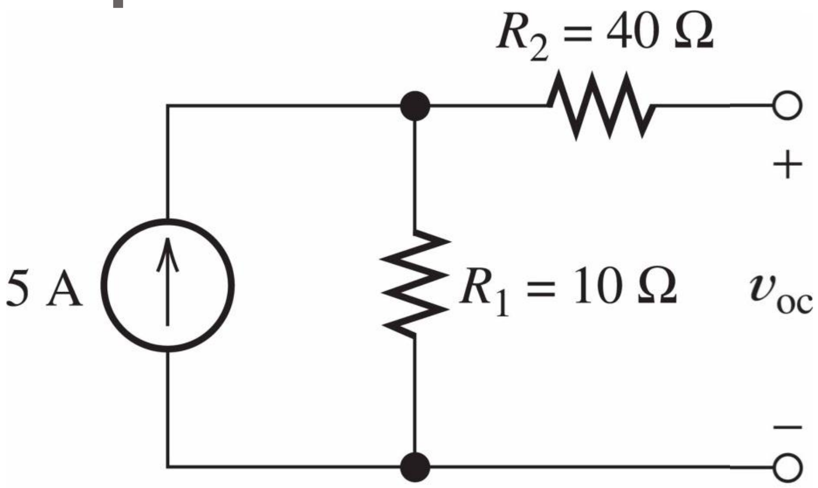
Example: Short Circuit Current



1. Find short circuit current i_{sc}

- Notice this is a parallel current divider
  - Opposite resistor over sum of resistances
  - $i_{sc} = i_s\left(\frac{R_1}{R_1+R_2}\right)$
  - $i_{sc} = 5\left(\frac{10}{10+40}\right) = 1\text{ A}$

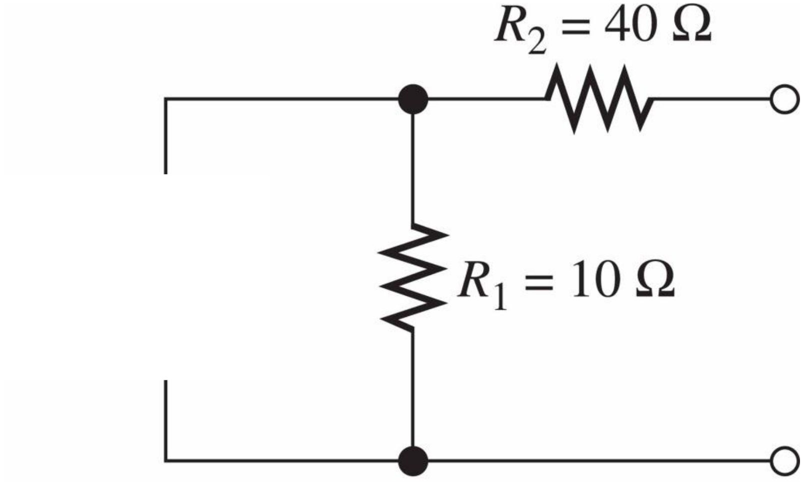
Example: Open Circuit Voltage



2. Find open circuit voltage v_{oc}

- Notice there is no current through R_2
  - $v_{oc} = i_s R_1$
  - $v_{oc} = 5 \cdot 10 = 50\ \text{V}$

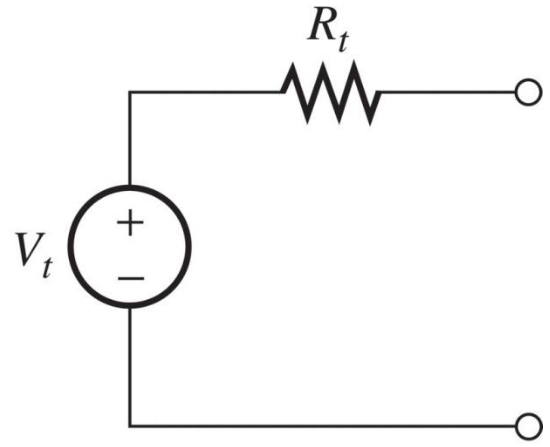
Example: Thevenin Resistance



3. Solve for equivalent resistance R_t
   - Ohm's Law
   - $R_t = \frac{v_{oc}}{i_{sc}} = \frac{50}{1} = 50\ \Omega$

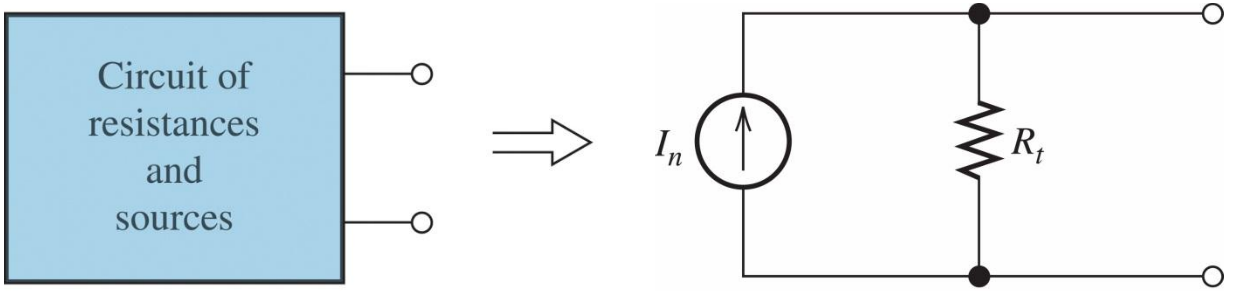
- Direct calculation of equivalent resistance
  - Zero sources → open current source
  - Notice series connection
  - $R_t = R_1 + R_2 = 50\ \Omega$

Example: Thevenin Equivalent

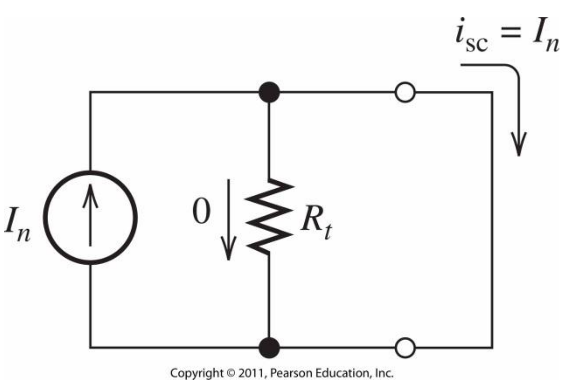


- Replace original circuit with equivalent
  - $v_{oc} = 50\text{ V}$
  - $R_t = 50\ \Omega$

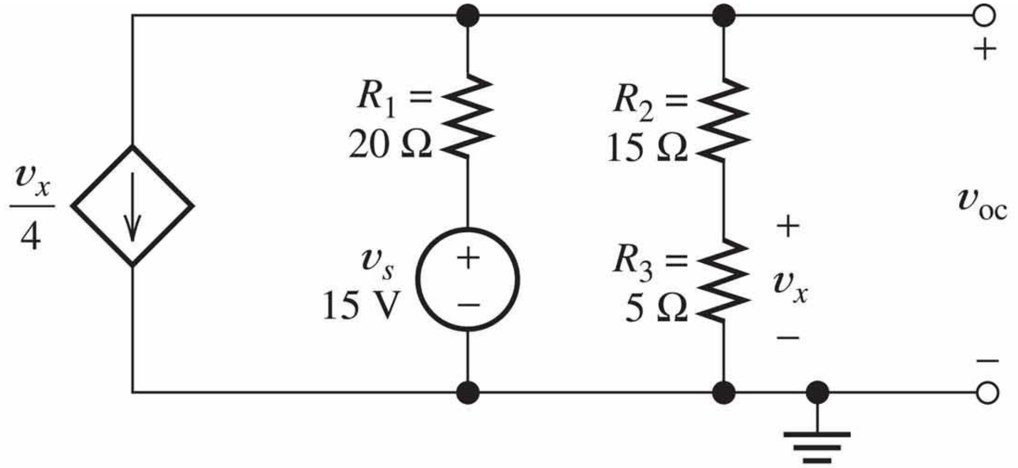
Norton Equivalent Circuit



- Equivalent circuit consisting of a current source in parallel with a resistance
- The same idea as Thevenin
  - Open circuit voltage $v_{oc} = I_n R_t$
  - Short circuit current $i_{sc} = I_n$
  - Equivalent resistance $R_t = \frac{v_{oc}}{i_{sc}}$

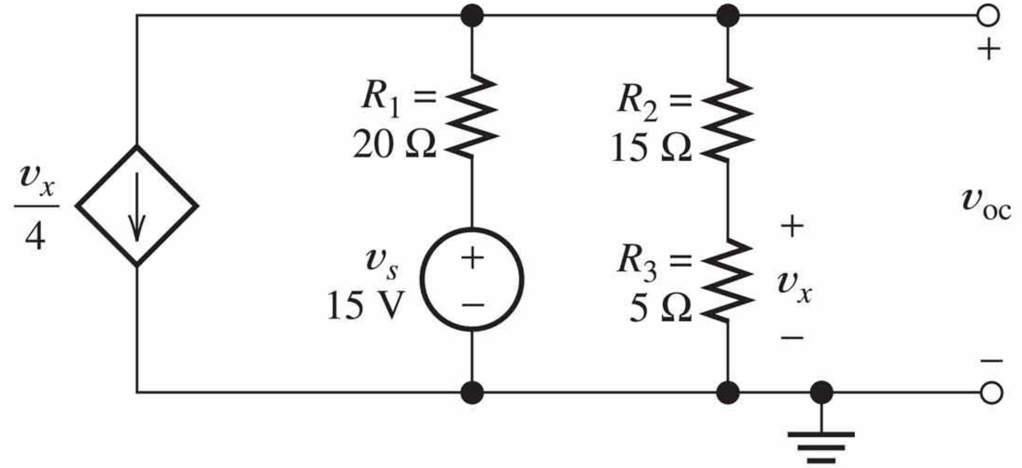


Example: Norton Equivalent



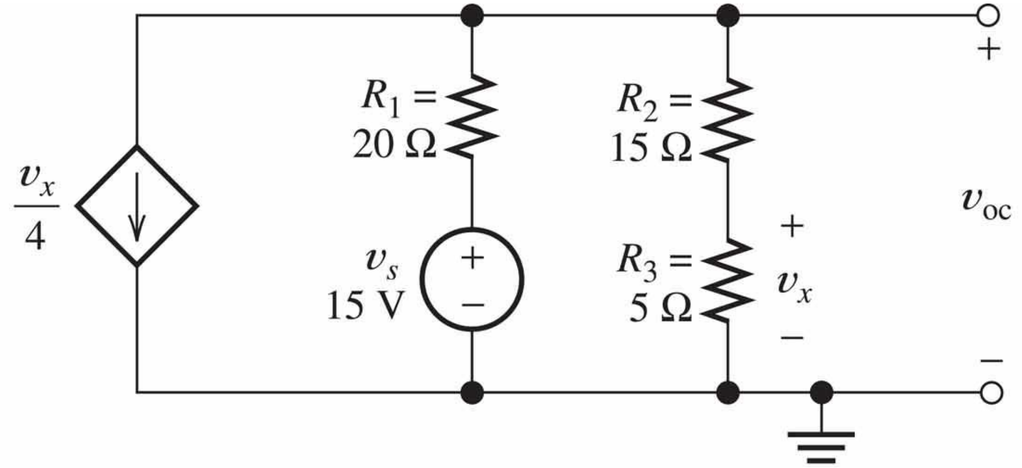
- Need to find v_{oc} and i_{sc}
  - Cannot get the equivalent Norton resistance directly because of the dependent source

Example: Norton Open Circuit



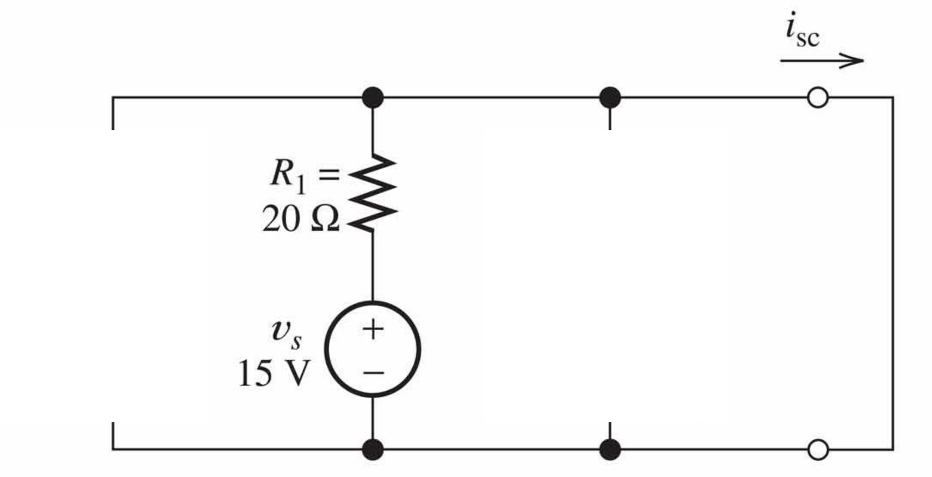
- Express dependent source in terms of voltages
  - Notice the voltage divider
  - $v_x = v_{oc}\left(\frac{R_3}{R_2+R_3}\right) = v_{oc}\left(\frac{5}{15+5}\right) = \frac{v_{oc}}{4}$
- Find v_{oc} with KCL @ top of circuit (node-voltage)
  - $\frac{v_x - 0}{4} + \frac{v_{oc} - v_s}{R_1} + \frac{v_{oc} - 0}{R_2 + R_3} = 0$

Example: Norton Open Circuit



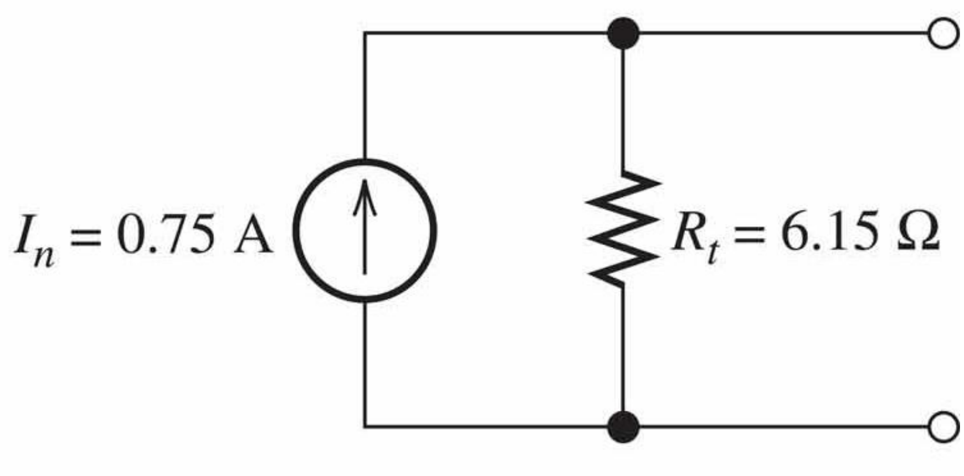
- Find v_{oc} with KCL @ top of circuit (node-voltage)
  - $\frac{v_x - 0}{4} + \frac{v_{oc} - v_s}{R_1} + \frac{v_{oc} - 0}{R_2 + R_3} = 0$
  - $\frac{v_{oc}/4}{4} + \frac{v_{oc} - 15}{20} + \frac{v_{oc}}{20} = 0$
- After rearranging
  - $v_{oc} = \frac{60}{13}\ V$

Example: Norton Short Circuit



- Find i_{sc} with KCL @ top of circuit (node-voltage)
  - No current through $R_2 + R_3$
    - v_x=0
    - Dependent source is zeros → open circuit
  - $i_{sc} = \frac{v_s}{R_1} = \frac{15}{20} = \frac{3}{4}\ A$

Example: Norton Equivalent Resistance



- Find Norton equivalent resistance R_t
  - Ohm's Law
  - $R_t = \frac{v_{oc}}{i_{sc}} = \frac{60}{13}\left(\frac{4}{3}\right) = \frac{240}{39} = 6.15\ \Omega$

Chapter 3: Inductance & Capacitance

- Inductors, capacitors are energy-storage devices.
- They are passive elements because they don't generate energy
    - Only energy put in can be later extracted.

- **Capacitance:** circuit property to deal with energy in electric fields
- **Inductance:** circuit property to deal with energy in magnetic fields