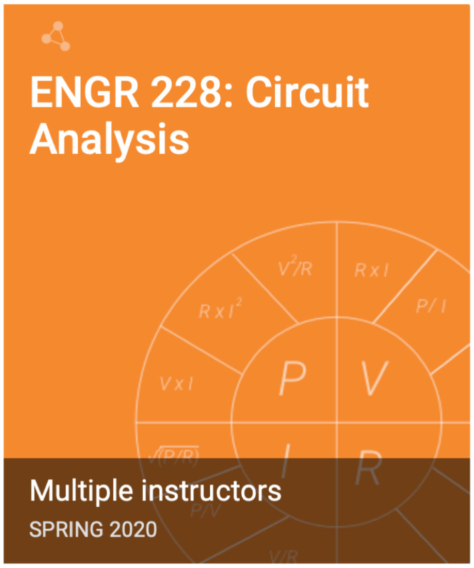


Chapter 3.8

Analysis Techniques

Thevenin and Norton Equivalent Circuits

Engr228 - Circuit Analysis

Spring 2020

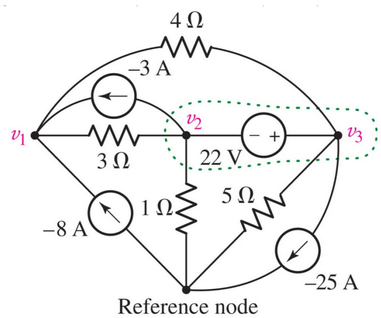
Dr Curtis Nelson

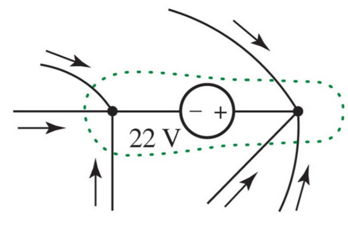
Section 3.8 Objective

- Learn to determine the Thévenin and Norton equivalent circuits of any input circuit and use them to evaluate the response of an external load (or an output circuit) to the input circuit.

Voltage Sources and the Supernode

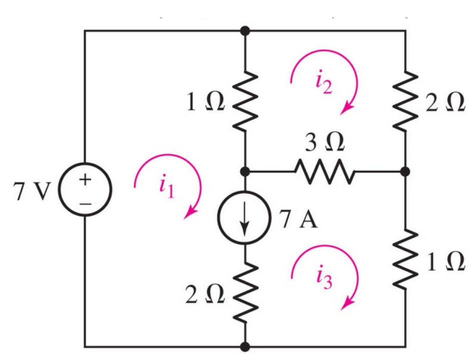
If there is a DC voltage source between two non-reference nodes the current through the voltage source may not be known and an equation cannot be written for it. Therefore, we create a ***supernode***.





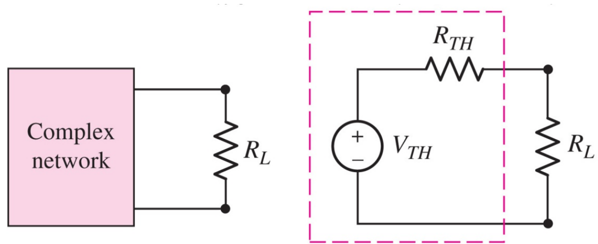
Current Sources and the Supermesh

If a current source is present in the network and shared between two meshes you must use a ***supermesh*** formed from the two meshes that have the shared current source.



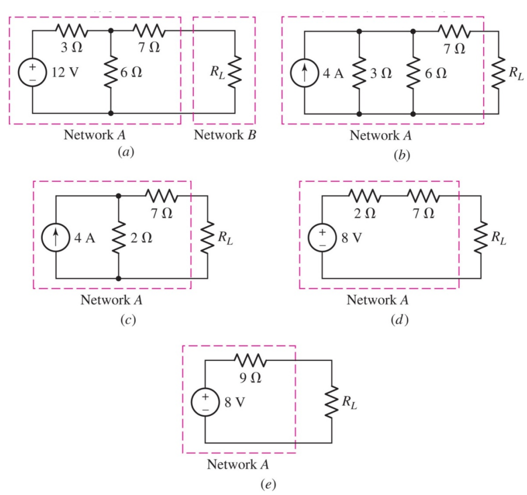
Thévenin Equivalent Circuits

Thévenin's theorem: a linear network can be replaced by its Thévenin equivalent circuit, as shown below:



Thévenin Equivalent using Source Transformations

- We can repeatedly apply source transformations on network A to find its Thévenin equivalent circuit;
- This method has limitations – due to circuit topology, not all circuits can be source transformed.



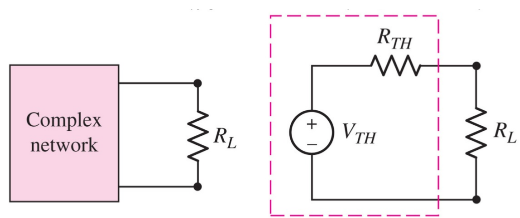
Finding the Thévenin Equivalent

- Disconnect the load;
- Find the open circuit voltage v_{oc};
- Find the equivalent resistance R_{eq} of the network with all independent sources turned off.
  - Set voltage sources to zero volts → short circuit
  - Set current sources to zero amps → open circuit

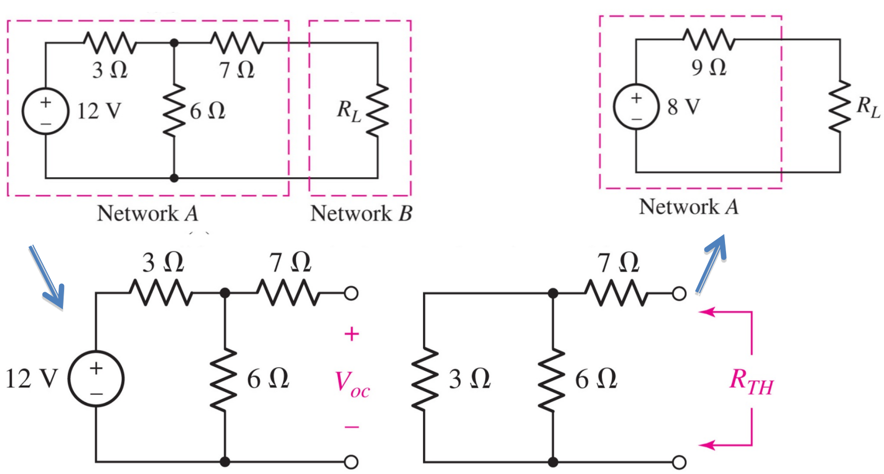
Then:

$V_{TH} = v_{oc}$ and

$R_{TH} = R_{eq}$

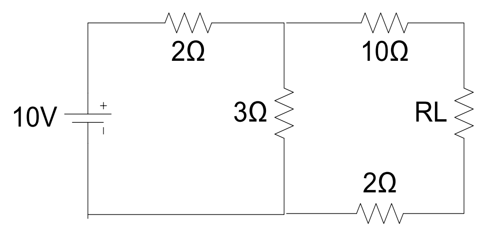


Thévenin Example #1



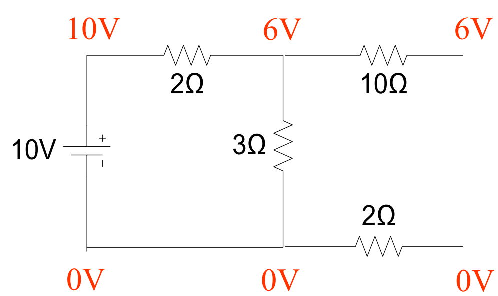
Thévenin Example #2

Find Thévenin's equivalent circuit and the current passing thru RL given that RL = 1Ω



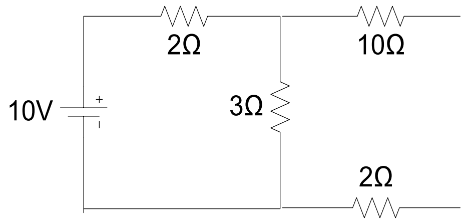
Thévenin Example #2 - continued

Find V_{TH}



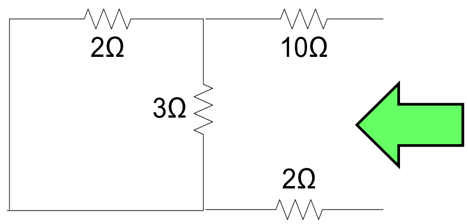
$$V_{TH} = \frac{3}{2+3} \times 10 = 6V$$

Thévenin Example #2 - continued



Find R_{TH}

Short voltage source

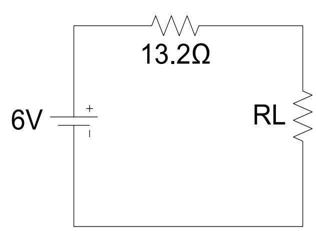


R_{TH}

$$R_{TH} = 10 + 2 \parallel 3 + 2$$
$$= 10 + \frac{2 \times 3}{2+3} + 2$$
$$= 13.2\Omega$$

Thévenin Example #2 - continued

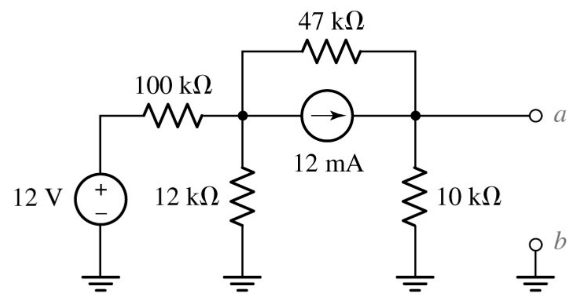
Thévenin's equivalent circuit



The current thru RL = 1Ω is $\frac{6}{13.2+1} = 0.423A$

Example Problem

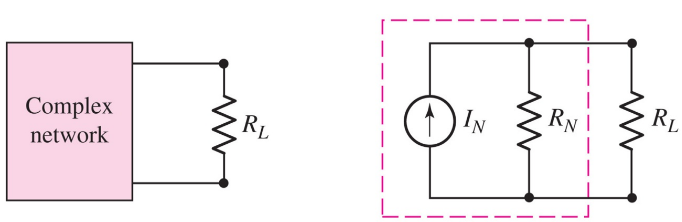
Find the Thévenin equivalent of the circuit below.



$R_{TH} = 8.523\ k\Omega$
$V_{TH} = 83.5\ V$

Norton Equivalent Circuits

Norton's theorem: a linear network can be replaced by its Norton equivalent circuit, as shown below:

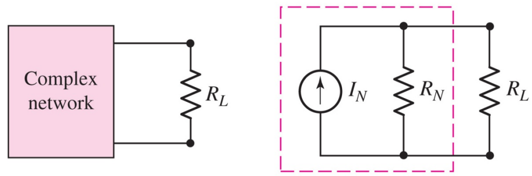


Finding the Norton Equivalent

- Replace the load with a short circuit;
- Find the short circuit current i_{sc};
- Find the equivalent resistance R_{eq} of the network with all independent sources turned off (same as Thévenin)
  - Set voltage sources to zero volts → short circuit;
  - Set current sources to zero amps → open circuit.

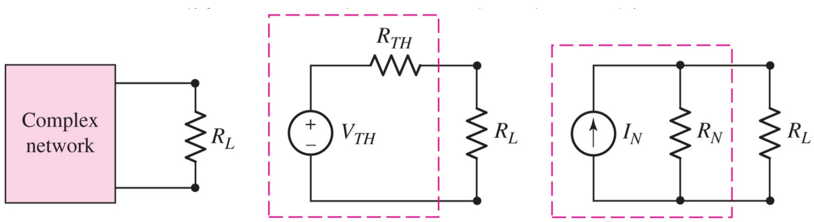
Then:

$I_N = i_{sc}$ and $R_N = R_{eq}$



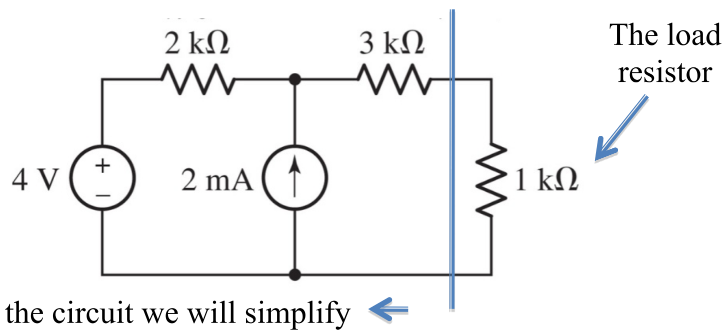
Source Transformation: Norton and Thévenin

The Thévenin and Norton equivalents are source transformations of each other.

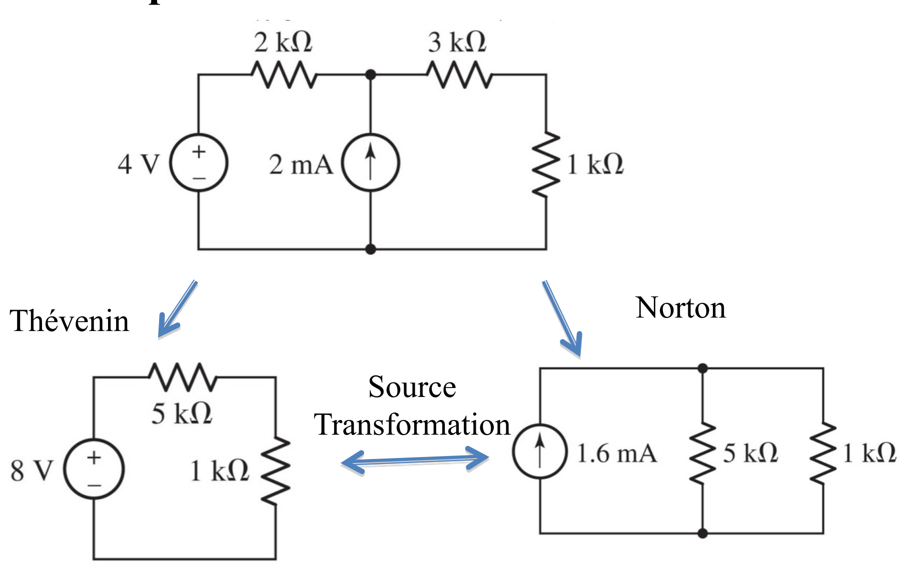


Example - Norton and Thévenin

Find the Thévenin and Norton equivalents for the network faced by the 1-kΩ resistor.

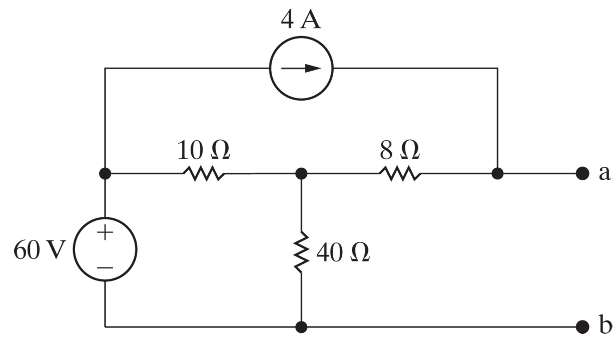


Example - Norton and Thévenin - continued



Textbook Problem 4.66 (Nilsson 10th)

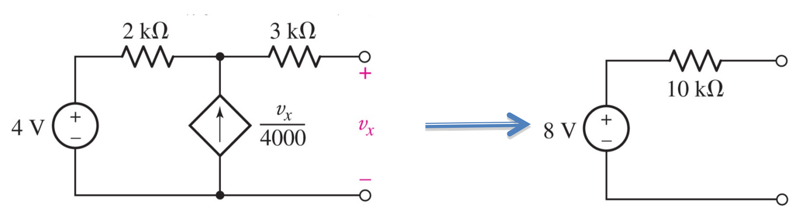
Find the Norton Equivalent with respect to terminals a,b.



I_{Norton} = *7A*
R_{Norton} = *16Ω*

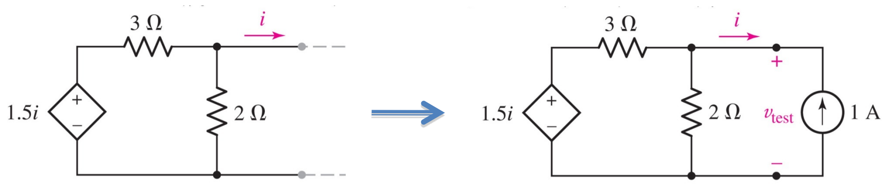
Thévenin Example: Handling Dependent Sources

The normal technique for finding Thévenin or Norton equivalent circuits can not *usually* be used if a dependent source is present. In this case, we can find both V_{TH} and I_N and solve for $R_{TH}=V_{TH}/I_N$



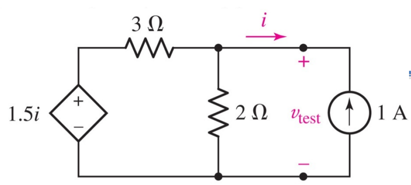
Thévenin Example: Handling Dependent Sources

Another situation that *rarely* arises, is if both V_{TH} *and* I_N are zero, or just I_N is zero. In this situation, we can apply a test source to the output of the network and measure the resulting short-circuit (I_N) current, or open-circuit voltage (V_{TH}). R_{TH} is then calculated as V_{TH}/I_N



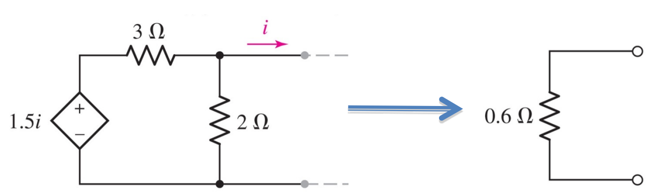
Thévenin Example: Handling Dependent Sources

Solve: $v_{test} = 0.6$ V, so $R_{TH} = 0.6\ \Omega$



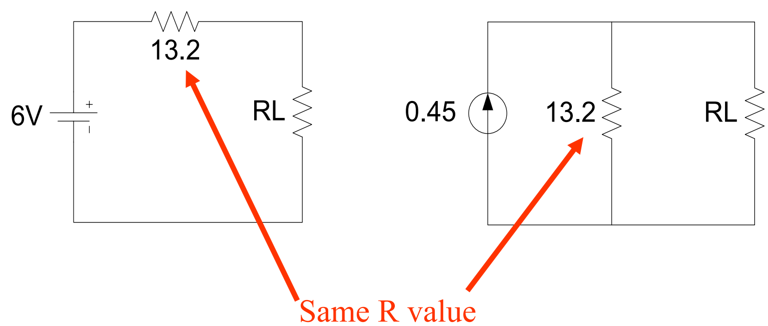
$$\frac{v_{test}}{2} + \frac{v_{test} - (1.5i)}{3} = 1$$

$$i = -1$$



Recap: Thévenin and Norton

Thévenin's equivalent circuit | Norton's equivalent circuit



$$R_{TH} = R_N$$

$$V_{TH} = I_N \times R_{TH}$$

$$6 = 0.45 \times 13.2$$

Section 3.8 Summary

- You learned to determine the Thévenin and Norton equivalent circuits of any input circuit and use them to evaluate the response of an external load (or an output circuit) to the input circuit.