Thevenin and Norton Equivalents

This tutorial is intended to show how Thevenin and Norton Equivalent Circuits can be calculated. In your lecture class, you will cover these topics in more detail, but the information here is enough to perform the ECE 2100 Lab III Exercise.

Before doing Thevenin and Norton Equivalents, we discuss one other important topic: Source Transformations.

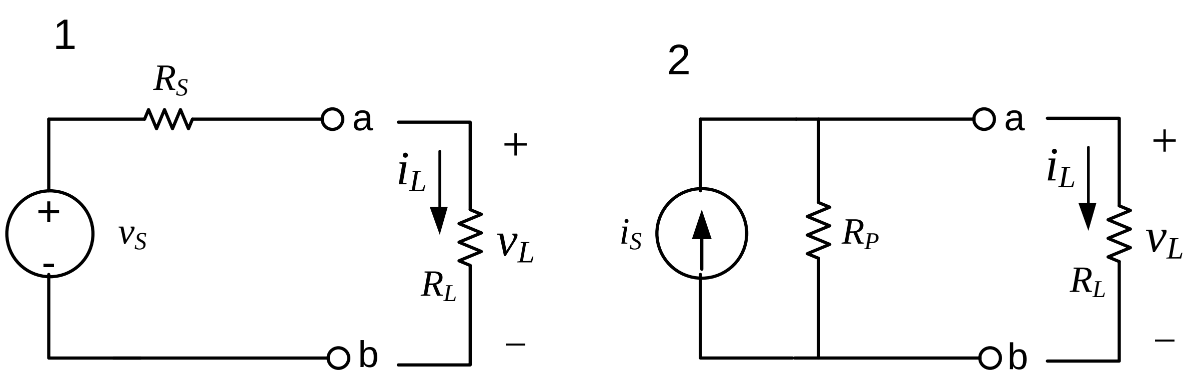
Source Transformations

Idea

With respect to two particular terminals, called "a" and "b" in the circuits below, a voltage source in series with a resistance is equivalent to a current source in parallel with a resistance.

Discussion

The circuits "1" and "2" below are ***equivalent with respect to terminals a and b***, provided that v_s, R_s, i_s, and R_p are related to one another in a particular way. If they are, then a resistor R_L connected to terminals a and b will have the same voltage across it (and the same current through it) whether it is connected to circuit 1 or to circuit 2.



Note that it is very important to include the qualifier *with respect to terminals a and b,* because two circuits are not necessarily equivalent at just any two terminals.

Calculation

If the parameters are related correctly, a voltage source in series with a resistor can be replaced with a current source in parallel with a resistor. The relationships that must exist between the parameters v_S, i_S, R_S, and R_P are as follows.

A voltage source v_S in series with a resistor R_S will be equivalent to a current source i_S in parallel with a resistor R_P if

$$v_S = i_S R_P \text{ and } R_S = R_P .$$

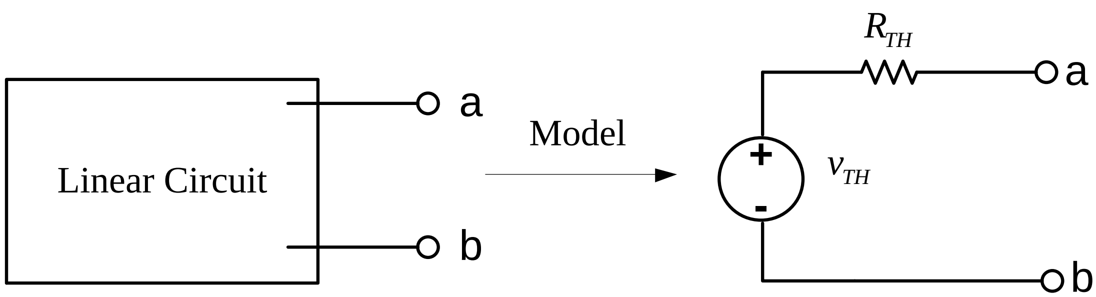
This is the ***source transformation theorem***.

Thevenin and Norton Equivalents

Idea

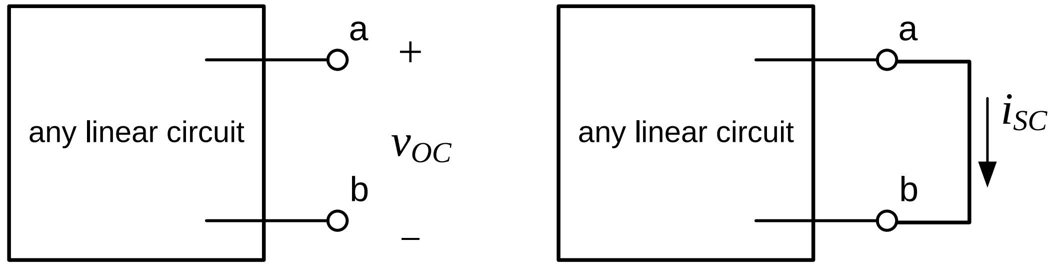
The behavior of any linear circuit at a specific pair of terminals in a circuit may be modeled by a voltage source v_{TH} in series with a resistor R_{TH}

What we are saying is this:



Calculation

The box in the figure below contains an arbitrary linear circuit. We have labeled terminals a) and b). On the right, we have an open circuit at a), b), resulting in an open-circuit voltage v_{OC}. (We can think of this as an infinite load resistance.) On the left, we have connected a short to the terminals, resulting in a short-circuit current i_{sc}.



By comparing the drawing on the left with the Thevenin Equivalent drawing above, it should be clear that

$$v_{OC} = v_{TH} \ .$$

By comparing the drawing on the left with the Thevenin Equivalent, we can see also that

$$i_{SC} = \frac{v_{TH}}{R_{TH}} \ .$$

So if we know the open-circuit voltage and the short-circuit current at the terminals a), b), we can find the Thevenin Equivalent:

$$v_{TH} = v_{OC} \quad \text{and} \quad R_{TH} = \frac{v_{TH}}{i_{SC}} \ .$$

If this were an experiment, we could measure v_{OC} and i_{SC}. If it is an analytical problem, we can calculate them using our knowledge of circuit theory.

In Lab III, we will measure and calculate the Thevenin Equivalents for two circuits. We will connect resistors to the terminals of those circuits and measure the current through them, and then we will compare those measurements with calculations predicted by the Thevenin Equivalent. This is illustrated below.