Lab 6
Thévenin's Theorem

Objectives

- *concepts*

  1. equivalent circuits
  2. maximum power transfer

- *skills*

  1. reducing a circuit to its Thevenin equivalent

Key Prerequisites

- Chapter 4: Circuit Theorems

Required Resources

- Circuit Kits
- MATLAB or FreeMat

Many modern electrical systems are composed of numerous components, making it difficult to predict system behavior under varying circumstances. We might, for example, wish to choose a load resistor for a circuit in order to obtain the maximum power delivered to the load. How can we easily do this without simulating the circuit over and over again with different load resistors?

Thevenin's theorem can help us. It states that a circuit composed exclusively of dependent or independent voltage and current sources, as well as resistors, can be reduced to a single voltage source in series with a single resistor. This can greatly simplify our analysis of complex circuits.

Furthermore, knowing the Thevenin equivalent for a circuit allows us to easily select a load resistor that will absorb the most power from the circuit. In this lab we are going to build a circuit on our breadboard, then use Thevenin's theorem to create a simplified model of the circuit so that we can select an RL that will draw the most power from the circuit.

Discussion and Procedure

Part 1 – Deriving the Thevenin Equivalent Circuit

Figure 1 shows the circuit we are going to construct and analyze in today's lab. The circuit has two 12V sources and three resistors (220, 470 and 1000 Ω).

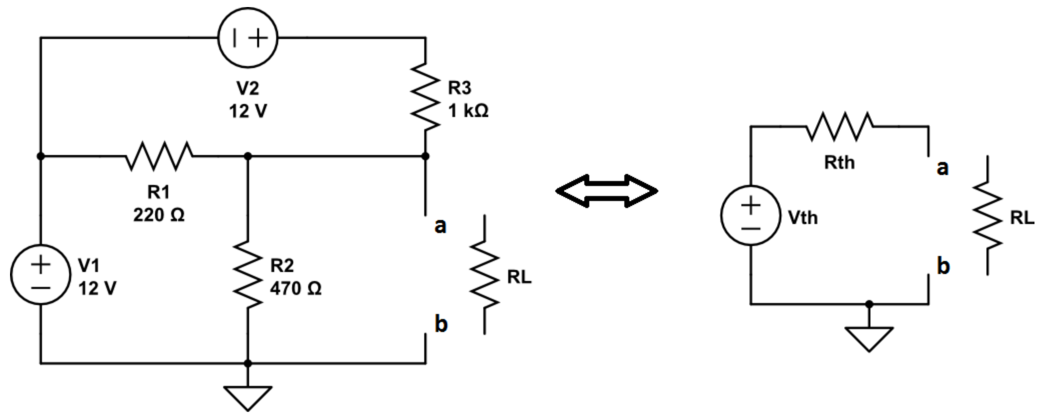


Fig 1. (Left) The circuit we will model using Thevenin's theorem. (Right) the Thevenin equivalent circuit. What value of RL will absorb the most power?

Before breadboarding a circuit, it's always helpful to construct a model of it so that we can tell as soon as we turn on the power whether we've wired it correctly. Although you could use a circuit simulator, in this case the model we are going to construct is the Thevenin equivalent circuit. We can use this model to verify our breadboard circuit at power-up since the open circuit voltage at terminals a-b will be easy to measure.

However, in order to develop the most accurate circuit model, we should first select the components we will use so that we can incorporate those into our analysis.

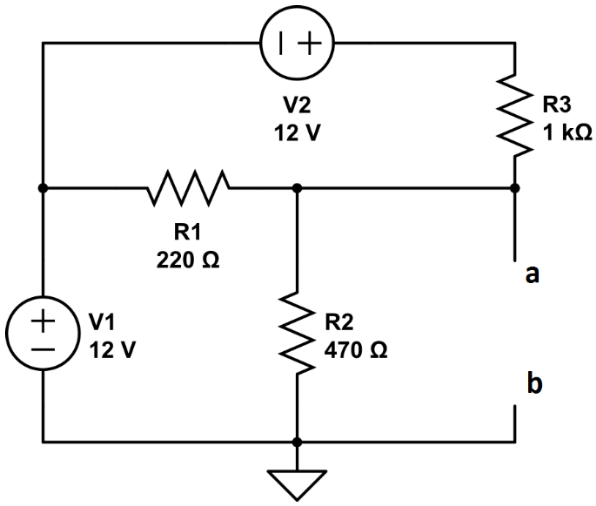
1. Select the components necessary to build the circuit in Figure 1. Record the values of V1, V2 and R1 – R3 using your multimeter in Table 1.
2. Using the component values you measured in step 1, derive the Thevenin equivalent circuit by finding the open circuit voltage (Vth) and the equivalent resistance (Rth) seen from the terminals a-b.

   To find Vth, you might consider which of the following methods would be the easiest to apply – Superposition, Source Transforms, or Nodal or Mesh analysis.

   To find Rth, turn off the sources by replacing them with short circuits, and find the equivalent resistance between terminals a and b.

   You may work the solution in the space provided below, but when you finish, summarize your work where indicated in the datasheet, including any equations you used to reach your final result.

Derive Vth and Rth here, *using the measured values of your components from Table 1 in your analysis*.



Part 2 – Build the Circuit

3. Now build the circuit on your breadboard. You may wish to refer to the Layout Tips section from the Lab 5 FAQ if you need guidance on how to layout your circuit in an orderly fashion.
4. Apply power and measure the open circuit voltage at a-b, which should agree closely with the Vth you derived above. Record both of these in Table 2, along with an error calculation.
5. Now DISCONNECT the power supplies and replace with a short circuit (jumper wire) connected across the terminals. With NO POWER going to your circuit, measure the equivalent resistance between terminals a-b using your ohmmeter and record in Table 2, along with an error calculation.
6. If your % Error calculation is more than 3% for Vth and Rth, spend some time investigating whether you made an error, either in your analysis or your breadboard wiring. Is your 470 Ω resistor really 4.7 kΩ? Did you make a mistake in assessing the series / parallel resistors for Rth?

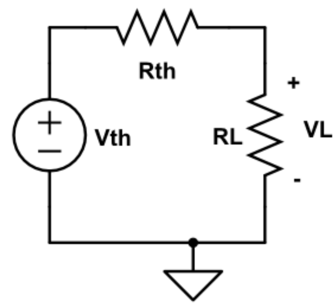
Part 3 – Find RL for Max Power

Now that we have a Thevenin equivalent model of our circuit, we can verify the accuracy of this model for predicting the load voltage when different resistors are connected to terminals a-b. We can also assess whether the predicted value of RL to achieve maximum power seems correct.

After all, the Thevenin model of our circuit is so simple, we can use the voltage divider formula to determine the load voltage when we attach various load resistors to the circuit.

7. Select the resistors called for in Table 3 (all but the last 2), then measure and record these in the Table.

8. Then use your Thevenin circuit with the voltage divider formula to predict the voltage VL for each load resistor when it is inserted into your breadboard between the a-b terminals.



Thevenin Model of the original circuit, with load RL attached.

9. Remove the jumper wires you added in step 5 and re-connect the voltage sources to the breadboard. Now insert the different load resistors into your breadboard circuit and measure VL for each using your voltmeter, recording the values in Table 3. Also compute the % error between Calculated VL and measured VL.
10. For each resistor RL inserted into the breadboard, also calculate PL, the power absorbed by the load resistor, using $PL = (VL)^2/RL$ with the measured values.
11. According to the maximum power transfer formula, the load resistance that will absorb the most power from the circuit is the same as the Thevenin resistance. You can construct a load resistor "network" that is equivalent to Rth by assembling the same resistor values used in your circuit, in a manner that provides the same net resistance. For instance, if Rth is the parallel combination of R1, R2, and R3, you can select new resistors with these values and insert them in parallel across terminals a-b. Do this now and measure VL when your load resistor RL is the same as Rth.
12. Finally, complete the table by forming an RL across a-b from two 100 Ω resistors in parallel (50 Ω).

Part 4 – Postlab Questions

In datasheet