University of Utah
Electrical & Computer Engineering Department
ECE 2210/2200
Experiment No. 3

Thévenin & Superposition

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rev,9/9/08

Objectives

1.) Learn about Thévenin equivalent circuits.
2.) Find the Thévenin equivalent of the servo's "Input Position" potentiometer.
3.) Learn about Superposition

Check out from stockroom:

- Portable digital multimeter
- ECE 2210 kit, optional, if available.
- Servo

Parts to be supplied by the student:

These items may be bought from stockroom or may be in the ECE 2210 kit.

- 100 Ω, 220 Ω, 270 Ω, Two 390 Ω, 560 Ω, 1 kΩ, and 10 kΩ resistors
- Breadboard and wires
- 500 Ω trim potentiometer

Thévenin equivalent

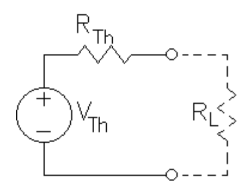
In the box at right you'll find a review of the steps you use to find a Thévenin equivalent circuit on paper. In this lab you'll do practically the same procedure on the lab bench, but with real-life parts. Instead of calculating and computing V_{Th} and R_{Th}, you'll measure V_{Th} and R_{Th}.

I want you to make the Thévenin equivalent circuit of the circuit shown below, but first I want you to make an I vs V plot for this circuit. That way when you have the Thévenin circuit you can actually see if they're equivalent.

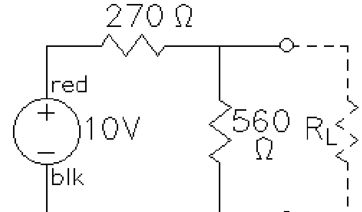
Thévenin equivalent

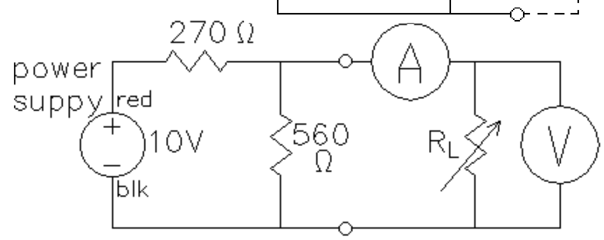
To calculate the Thévenin equivalent on paper:

1) Disregard the load and calculate the open-circuit voltage. This is the Thévenin voltage (V_{Th}).
2) Zero all the sources. (To zero a voltage source, replace it with a short. To zero a current source, replace it with an open.)
3) Compute the total resistance between the load terminals. (DO NOT include the load in this resistance.) This is the Thévenin source resistance (R_{Th}).
4) Draw the Thévenin equivalent circuit and add your values.



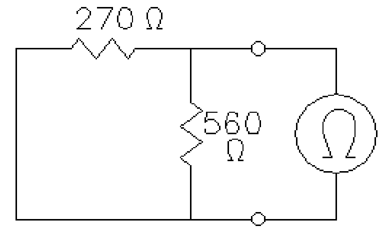
Part 1, I vs V Plot of original circuit & Measure V_{Th} : Set the power supply to 10 V and construct the circuit at right, including an ammeter and voltmeter as shown below it. Record the meter readings with each of the following loads; R_L = 0 Ω (short circuit), R_L = 100 Ω, R_L = 390 Ω, and finally, $R_L = \infty$ Ω (open circuit). The last voltage measurement (with R_L completely removed) is called the open-circuit voltage and will be your Thévenin voltage (V_{th}) (should be ~6.7 V). Draw an I vs V plot in





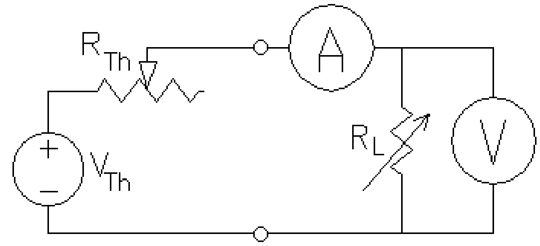
your notebook. (Plot your four sets of measurements, I on vertical axis, V on horizontal.)

Part 2, Zero the source: Disconnect the power supply and replace it with a short. This is the best way to zero the voltage source. You could turn the output down to 0 V, but that method is not as good and not as easy. Incidentally, don't short the supply, place the short in the circuit where the supply *used* to be. (Pull out the wire plugged into the + terminal and push it into the plug already plugged into the - terminal. This effectively disconnects the power supply and replaces it with a short.)



Part 3 Measure R_{Th} : Use an ohmmeter to measure the resistance between the load terminals [~180 Ω]. (Place the ohmmeter across the open terminals where R_L would be connected.) This is the Thévenin source resistance ($_{Rth}$).

Part 4 Build Thévenin circuit:
Build the circuit as shown below. Adjust the power supply to the V_{Th} value. Adjust the 500 Ω potentiometer (pot) to the R_{Th} value with the aid of an ohmmeter. (It's best to put the pot in the bread board, connect the ohmmeter to the center and one of the other terminals, adjust the pot to the right value, and then build the rest of the circuit around it without touching it again.

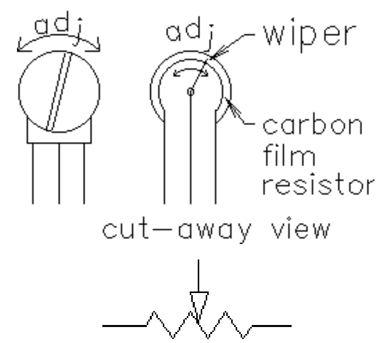


Confirm that this new circuit behaves just like the one it supposedly replaces, that is, take another set of readings with each of the following loads; R_L = 0 Ω (short circuit), R_L = 100 Ω, R_L = 390 Ω, and $R_L = \infty$ Ω (open circuit). Graph these on your I vs V plot and comment on circuit equivalence.

Calculate and compare: Finally, just in case you thought this was easier than the calculations, I want you to find the Thévenin equivalent circuit by calculations as well and compare your measured and calculated R_{Th} and V_{Th} values. (You may do this later)

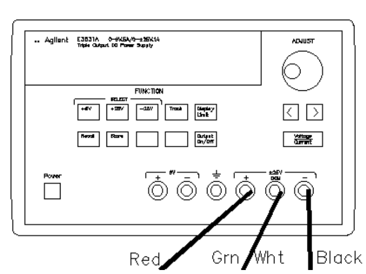
Trim Potentiometers

To get just the right R_{th}, you'll use an adjustable resistor called a *trim* potentiometer. It's just a smaller version of the potentiometers on the servo that you are already familiar with.



Thévenin equivalent of the servo's "Input Position" potentiometer

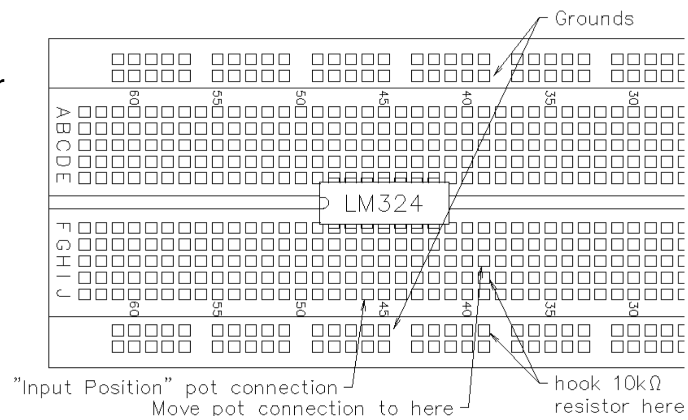
Turn off the power switch on the servo and hook it up to the power supply. Adjust the power supply to provide ± 6V as you did in the first lab. If you've forgotten how to do this, refer back to the lab handout for lab 1. Turn on the power switch on the servo and make sure that it is functioning properly. When you do something like this you should note it in your lab notebook, sort-of like this: "We hooked power to the servo and made sure it was still working."



In the last lab you saw how the “Input Position” potentiometer translates shaft position into voltage. Sensors are often modeled as variable sources with a source resistance, just like a Thévenin equivalent. In this case that’s not a perfect model, since the Thévenin resistance (R_{th}) also changes a little as you turn the pot. Nevertheless, we’ll find a Thévenin equivalent for most clockwise position of the pot and call it good.

There is a switch on an aluminum heat-sink near the motor. This is the motor disconnect switch. Switch it down so the motor will not run.

Find a green wire about 1.5 inches to the left of the switch. This wire is a ground wire. It connects the top ground row to the bottom ground row of the breadboard. Connect the black lead of a voltmeter to one of these rows. (You’ll probably find it easiest to push a wire into one of these rows and clip to that wire. The metal to which the “Input Position” potentiometer power switch etc. is mounted is also ground. You can clip directly to that metal, if you want.)



Find the yellow wire that connects the center of the “Input Position” pot to breadboard. Pull it out of the board and move it to a free location, see the suggested location at right. Connect the red lead of the voltmeter to this point. Measure and record the range of voltages here as you turn the pot through its range of motion.

Turn the pot to the fully clockwise position and leave it there. Measure the open-circuit voltage. This is the Thévenin voltage (V_{th}). Connect a 10kΩ resistor between the yellow lead and ground (R_L). The voltage should decrease somewhat. Record this as the loaded voltage (V_L). Draw the Thévenin circuit including the load and show the values that you know (V_{th}, V_L, and R_L). Calculate the value of Thévenin resistance (R_{th}).

This kind of Thévenin or source resistance is often called the “output resistance” or “output impedance” of the sensor. A power source has a “source resistance”, a Thévenin equivalent circuit has a “Thévenin resistance”, and a signal source has a “output resistance”. These all refer to the same basic idea and are used somewhat interchangeably.

Adding a load and observing the change in the voltage is the most common way to find the output resistance, and is the method you should try to remember. In contrast, don’t remember the next method, it will rarely work well. I only ask you to use it because it is a quick-and-dirty way to see that the Thévenin resistance (R_{th}) also changes a little as you turn the pot.

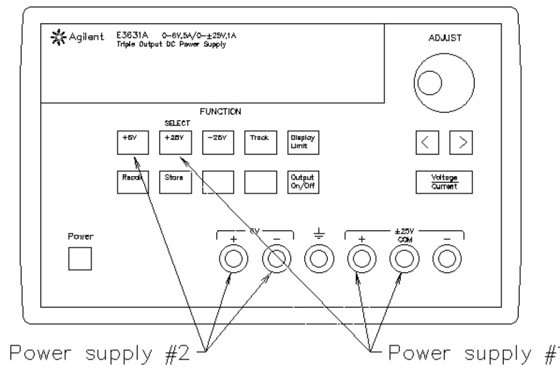
Turn off the output of the power supply by hitting the “Output On/Off” button. Replace R_L (the 10kΩ resistor between the yellow lead and ground) with and ohmmeter. Record the as another measurement of R_{Th}. Compare this to what you got before.

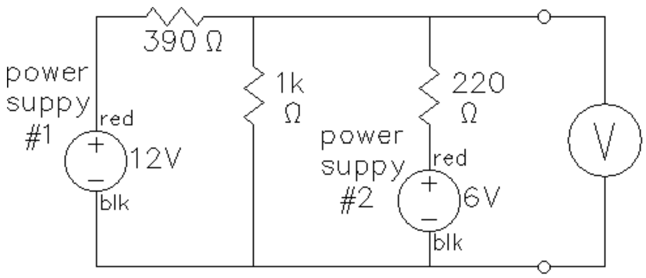
Turn the pot to the center of its range of motion. What does the ohmmeter read now? Comment in you notebook. Remove the ohmmeter and replace the yellow wire where it came from. See the drawing above or find the other yellow wire, they both go to the same place.

Turn on the output of the power supply. Switch up the motor disconnect switch and make sure that the servo is again functioning properly before you return it to the counter. If it doesn't work, turn it off, check the connections you messed with and/or ask the TA for help.

Superposition

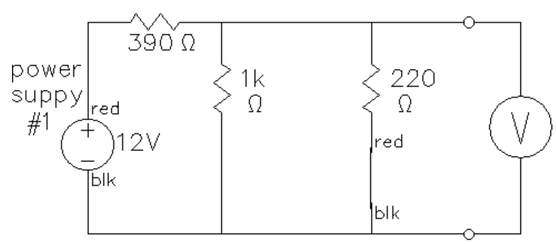
The E3631A on your bench contains two separate power supplies. Set them to 12V and 6V using the appropriate buttons. Use these to make the circuit shown below.





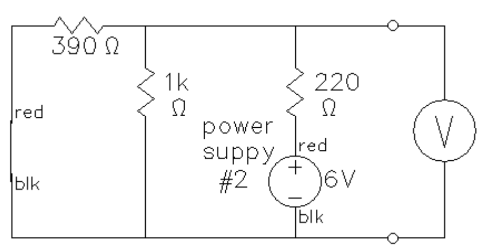
With both power supplies on, the voltmeter should read about 7.2V. Record this voltmeter reading as Vo.

Part 1, Measure $Vo_{(1)}$: "Zero" power supply #2. (Pull out the wire plugged into the + terminal and push it into the plug already plugged into the - terminal. This effectively disconnects the second power supply and replaces it with a short.) See below left. Record the new voltmeter reading as $Vo_{(1)}$ [~3.8V], the voltage due to source number 1.



Part 2, Measure $Vo_{(2)}$: Reconnect power supply #2. Now "Zero" power supply #1. See above right. Record the new voltmeter reading as $Vo_{(2)}$ [~3.4V], the voltage due to source number 2.

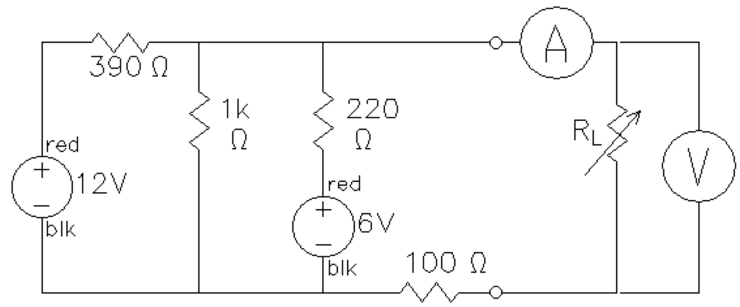
Compare $Vo_{(1)} + Vo_{(2)}$ to the Vo that you originally measured with both power supplies connected. This is superposition. The effects of several sources can be considered separately and added later. Isn't linearity nice? Reconnect both power supplies again for the next section.



Conclude

As always, get your lab instructor to check you off. Write a conclusion in your notebook. Make sure that you touch on each of the subjects in your objectives. Say something about the usefulness of Thévenin and superposition. Discuss the agreement of measurements and calculations. Mention any problems that you encountered in this lab and how you overcame them.

Big Thévenin



Add an ammeter to your existing circuit as shown. Record the meter readings with each of the following loads; R_L = 0 Ω (short circuit), R_L = 100 Ω, R_L = 390 Ω, and $R_L = \infty$ Ω (open circuit), which is also V_{th} [~7.2 V]. Plot the data. (May be done later.)

"Zero" both sources, and measure the terminal resistance (R_{th}). Make the Thévenin equivalent and confirm the I vs V plot, just exactly like you did before in Experiment 1.

Compare to calculations: In the interest of time, I've done the calculations in the appendix. First, I found the theoretical Thévenin equivalent circuit. Compare your measured R_{Th} and V_{Th} values to those I calculated. Next, I found the load voltages for R_L = 100 Ω and R_L = 390 Ω using my Thévenin equivalent. I Also calculated the short-circuit current (I_{SC}). Again, compare your measured values to those I calculated. Contemplate calculating all these load voltages and the short-circuit current from the original circuit and comment on the value of the Thevenin equivalent.

Conclude

As always, get your lab instructor to check you off.

Write a conclusion in your notebook. Make sure that you touch on each of the subjects in your objectives. Say something about the usefulness of Thévenin and superposition. Discuss the agreement of measurements and calculations. Mention any problems that you encountered in this lab and how you overcame them.