

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

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 rev,9/13/12

Objectives

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

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 k Ω , and 10 k Ω resistors
- Breadboard and wires
- 500 Ω trim potentiometer

Check out from stockroom:

- Portable digital multimeter
- Servo

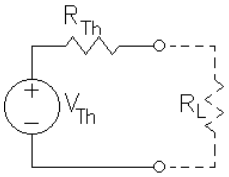
Thévenin equivalent

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} .

Thévenin equivalent

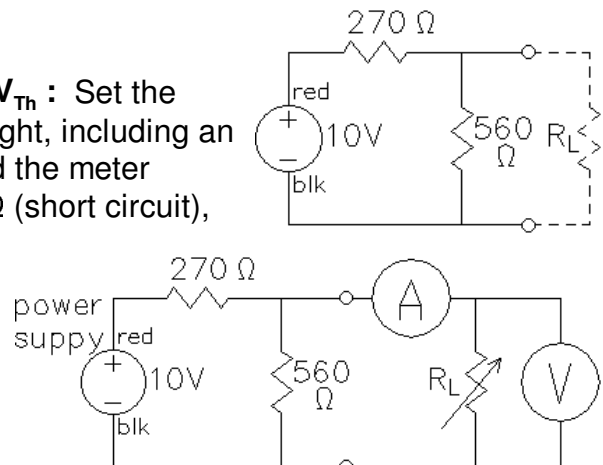
To calculate the Thévenin equivalent on paper:

- 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.



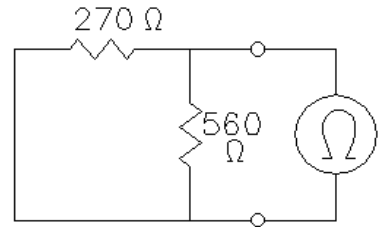
I want you to make the Thévenin equivalent circuit of the circuit shown below, but first I want you to make an I vs V plot for this circuit. That way when you have the Thévenin circuit you can actually see if they're equivalent.

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; $R_L = 0 \Omega$ (short circuit), $R_L = 100 \Omega$, $R_L = 390 \Omega$, and finally, $R_L = \infty \Omega$ (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.)



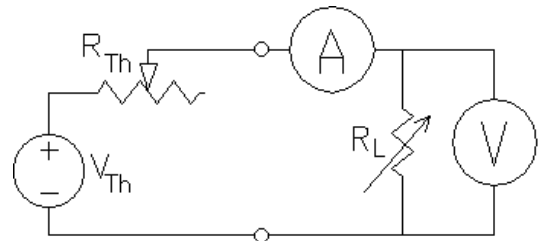
Part 2, Zero the source: Disconnect the power supply and replace it with a short. This is the best way to zero the voltage source. You could turn the output down to 0 V, but that method is not as good and not as easy. Incidentally, don't short the supply, place the short in the circuit where the supply *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 [$\sim 180 \Omega$]. (Place the ohmmeter across the open terminals where R_L would be connected.) This is the Thévenin source resistance (R_{Th}).



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.)

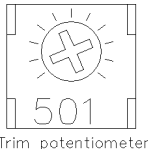


Confirm that this new circuit behaves just like the one it supposedly replaces, that is, take another set of readings with each of the following loads; $R_L = 0 \Omega$ (short circuit), $R_L = 100 \Omega$, $R_L = 390 \Omega$, and $R_L = \infty \Omega$ (open circuit). Graph these on your I vs V plot and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

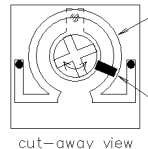
Calculate and compare: Finally, just in case you thought this was easier than the calculations, I want you to find the Thévenin equivalent circuit by calculations as well and compare your measured and calculated R_{Th} and V_{Th} values. (You may do this later)

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.



Trim potentiometer



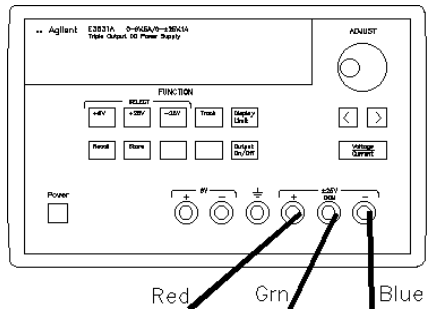
carbon film resistor
Rotating Wiper



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 $\pm 6V$ 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.

Find the wires that go to the motor and pull the plug out of the circuit board. This disconnects the motor so it won't run.

Connect the black lead of a voltmeter to the lead from the power-supply common (the green banana connector on the board). This is the ground of the servo board.

Find the center terminal of the "Input Position" pot, where the yellow is soldered. 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.

Find the jumpers on the circuit board labeled "Connect BNC", and "Connect Pot". Move the "Connect BNC" jumper to the "Connect Resistor" position. This connects a $10\text{k}\Omega$ resistor between the center connection of the pot (yellow lead) and ground making the load resistance $10\text{k}\Omega$ ($R_L = 10\text{k}\Omega$). The measured 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 a 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.~~

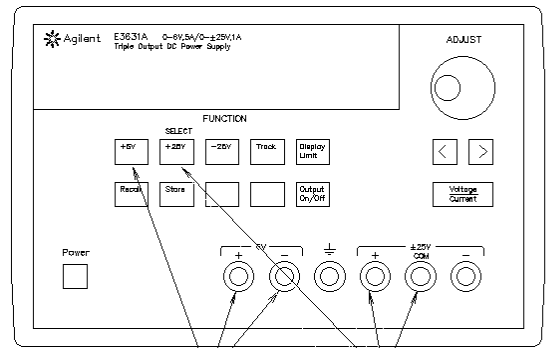
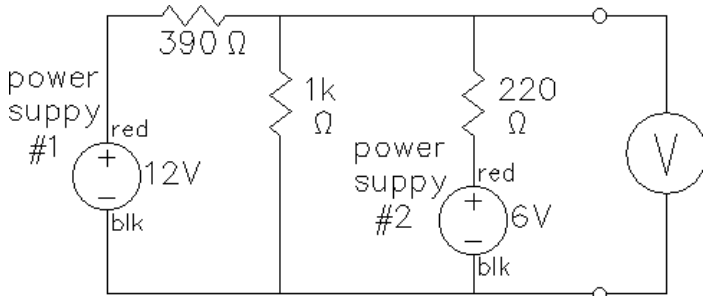
~~Turn off the output of the power supply by hitting the "Output On/Off" button. Pull the "Connect Resistor" jumper and replace your voltmeter with an ohmmeter (you probably just have to turn a switch or change the multimeter setting to read ohms (Ω)). Record the ohmmeter as another measurement of R_{th} . 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 your notebook. Remove the ohmmeter, replace the jumper to the "Connect BNC" position and reconnect the motor.~~

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

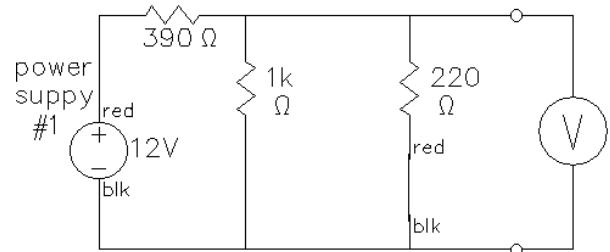
The E3631A on your bench contains two separate power supplies. Set them to 12V and 6V using the appropriate buttons. Use these to make the circuit shown below.



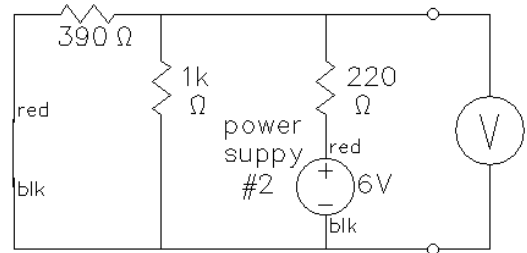
Power supply #2 Power supply #1

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

Part 1, Measure $V_{o(1)}$: “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.) Record the new voltmeter reading as $V_{o(1)}$ [$\sim 3.8V$], the voltage due to source number 1.



Part 2, Measure $V_{o(2)}$: Reconnect power supply #2. Now “Zero” power supply #1. Record the new voltmeter reading as $V_{o(2)}$ [$\sim 3.4V$], the voltage due to source number 2.



Compare $V_{o(1)} + V_{o(2)}$ to the V_o 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?

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.