

University of California at Santa Cruz
Baskin School of Engineering
EE-70L: Introduction to Circuits Lab
Laboratory 2

Introduction:

Building on what you have learned in lab 1, this experiment deals with resistive circuits as well. This time, the emphasis is on how circuits, which may potentially be large and complicated, can be described by simple equivalent circuit models. You will investigate how a real voltage source such as a battery deviates from its ideal circuit model. In addition, you will use the load line method to analyze a linear circuit.

In the design part, you will see that you don't need to know the internal structure of a circuit in order to draw the maximum power from it. Thevenin's and Norton's theorems will allow you to determine the right load with two quick measurements. At the end of this lab, you should be able to:

- Understand real voltage sources
- Replace an unknown circuit with a simple equivalent circuit
- Match a resistive load to an unknown circuit for maximum power transfer
- Understand graphical methods for linear circuits

Topics from the lecture you need to be familiar with:

- Thevenin's and Norton's theorems
- Load line technique
- Power transfer to a load resistor

Pre-lab questions (hand in before lab starts):

1. What are the two simplest realizations of an equivalent circuit for a linear network?
2. What distinguishes an ideal voltage source from a realistic one?
3. How can you model a realistic voltage source with a current source? (i.e. what is the Norton equivalent of a real voltage source?)
4. Why does a car battery deliver less current in cold weather?
5. Explain why there is a maximum in dissipated power in a load resistor that is connected to a linear network.

Part 1: Basics of equivalent circuits

1. Equivalent circuit for a resistive network

- Rebuild your voltage divider circuit from lab 1 ($V_0=10V$, $V_1=2.5V$, $V_2=7.5V$). Designate your output terminals as the ones which have a voltage drop of $V_1=2.5V$ across them. Draw the circuit diagram and indicate your output terminals.
- Measure the open circuit voltage (V_{OC}) and the short circuit current (I_{SC}) at the output terminals and determine the Thevenin and Norton equivalent for your circuit.
- Take a 10k potentiometer and set it to $1k\Omega$. Connect it across the output terminals. Measure the power dissipated in the pot. Verify your result graphically by drawing the load line for the voltage divider circuit and the I-V curve of the $1k\Omega$ pot. Do the measured and graphical results for the dissipated power agree? How large is the discrepancy (absolute in mW and relative in percent) and what could be the reasons for the discrepancy?
- Vary your load resistance by setting the pot to different values. Determine the dissipated power for each value. Plot the power versus load (pot) resistance. At what resistance does the load power have a maximum? (Make sure you have enough data points around the maximum.)

2. Realistic voltage source

- Obtain a 9V battery from the TA and determine its Thevenin equivalent. **NOTE: DO NOT** short the battery terminals to measure I_{SC} ! This may damage the battery. Instead you will have to measure the open circuit voltage and a second point on the load line to determine R_T . Do this by connecting a resistor across the battery terminals and measure the voltage and current across it.

Part 2: Matching a load to an unknown circuit

- Obtain one of the numbered 'black' boxes from the TA.
- Find its Thevenin equivalent and draw the I-V diagram with the load line. You can connect circuit elements to the black box by clamping a wire under the output terminals screws and tightening the screws. Then turn on the power by flipping the switch on the box.
- Determine the matching load resistance for maximum power transfer.
- Connect the matching load across the output terminals of the box and measure the actual dissipated power in the load. Compare with your expectations.
- Connect a light bulb to the output terminals. Is it matched to the black box? Could you increase the bulb brightness by adding another resistance to the output in order to match the Thevenin resistance of the black box? Try this and record your (qualitative) findings on the brightness. Can you explain your result intuitively and/or mathematically?