Lab 4 : Soldering and Thevenin Equivalents

GOALS:

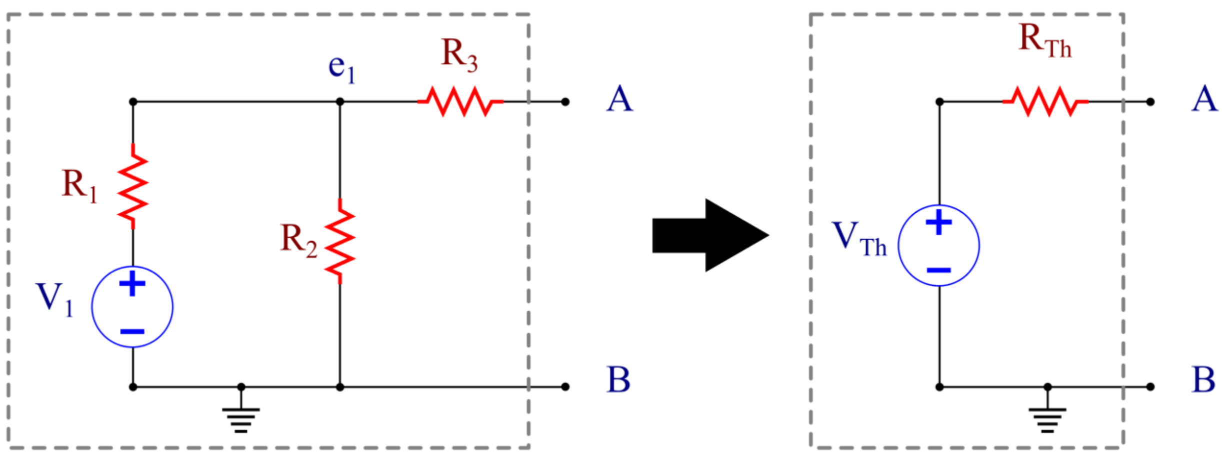
- Solder through-hole components into a printed circuit board (PCB)
- Thevenin equivalent circuit analysis

DATA required for Lab report (get instructor check off before leaving):

TABLE - Thevenin equivalent voltage and resistance		
PICTURE – Soldered circuit with closeups of joints		
SPICE SIMULATION – Diagram and DATA		

<u>Introduction</u>: Soldering through-hole components into a PCB

Soldering is an essential skill for electrical engineers. You will solder through-hole components (resistors and header pins) into a printed circuit board (PCB) with a soldering iron and then measure various voltages and currents in the circuit. You will verify Thevenin's theorem by measuring the equivalent voltage and resistance of your circuit and compare them to your theoretical calculations.



PART 1 – SOLDERING

SAFETY:

1. **Always wear safety glasses!** (Solder can splatter into your eyes easily!)
2. The iron will heat **any** metal it touches hot enough to burn you. Be careful!

General Soldering Tips:

1. Keep your workstation neat and organized
2. Solder will STICK to the tip of the iron if it is clean and ready for soldering
   (Clean with tip tinner for 10 seconds if solder does not stick)
3. Check resistor values with Multimeter BEFORE soldering
4. Watch: [Basic Soldering Lesson 6 - "Component Soldering"]
5. Watch: [SDG #066 Solder Through-hole Components - Soldering Techniques #02]

Solder Station Setup:

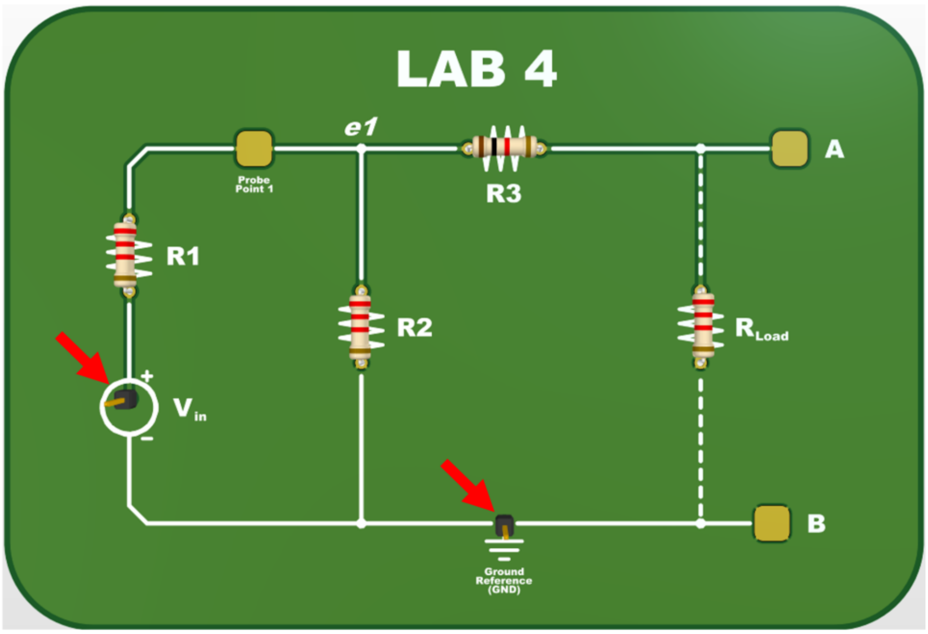
1. Plug in your iron fully and turn on your soldering station
2. Set the temperature to 750° F (we'll be using lead-free solder)
3. Increase the standby time so it stays on longer than a few minutes.
4. Wet the sponge and turn the cuts in the sponge front/back
   (If the cuts are sideways, the sponge will FLING MOLTEN solder)
5. Clean your safety glasses with alcohol spray at the front of lab (WEAR THEM!)

Solder the header pins into the PCB for applying voltage to the circuit:

1. Break pins into single pins, then insert them in the board for V1 and GND.
   Cut with a snips and be careful as the pins can go flying if not held.
   (Another reason to wear your safety glasses!)

2. To hold the pins in place while you solder them, use a breadboard (or black sponge) to hold the header pins while they're inserted into the PCB, with the PCB **upside down**. Otherwise, the pin could slide down and make it hard to connect to.

3. Apply the solder iron tip to the PCB pad and to the component lead (wire) simultaneously to heat them up before adding any solder. It should heat up in just a few seconds if your solder iron tip is already 'tinned' with a little solder.

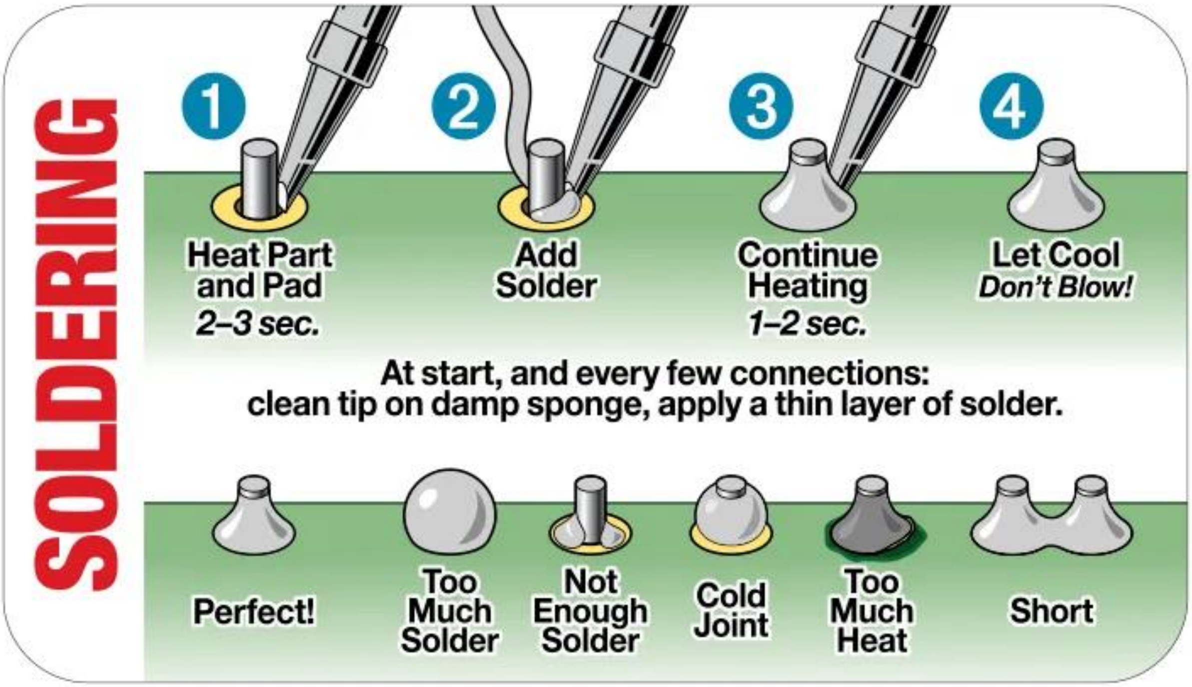


4. Once the PCB and component lead are hot, apply a small amount of solder to the PCB pad and the component lead. You should not need to touch the solder directly to the iron tip. The solder should melt just by touching the PCB pad and flow freely, 'wetting' the surface of the PCB and creating a concave meniscus with good adhesion.

   Take turns with your lab partner soldering components.

   Keep your iron tip clean as you solder by brushing it off with the brass sponge or sponge with water to remove excess flux. Excess flux will burn on to your tip and prevent it from tinning properly. Brass cleans the tip without damaging it.
   Any burnt areas on the solder tip will not conduct heat and the solder will not melt.

Tin your tip often! Turn off your solder iron when not in use!
Keep your soldering station in good condition for the next group!



Inspect your joints and repair if you see:

1. Excess Solder or shorting between pads:
   Remove with a solder wick. Laying the wick on the solder and heating the wick will cause the solder to be drawn up the wick and remove it from the pad. You can use extra flux to help wick the solder up. (ASK a TA for assistance).
2. Not enough solder: Reheat joint and add a little more solder
3. Cold joint: Reheat the joint after re-tinning your iron tip
4. Too much heat: Ask TA for help. You may need a new board.
5. Shorting: Same solution as excess solder above.
   Use solder wick to remove solder.(Ask TA for help)

The smoke: You'll notice your iron smokes when you melt new solder, but then stops. Why?
The smoke stops because the FLUX inside the solder burns away, leaving just the metal. Without flux the solder doesn't flow as well. You can add just flux with a flux pen, but it is often convenient to just add more solder (which has more flux inside).

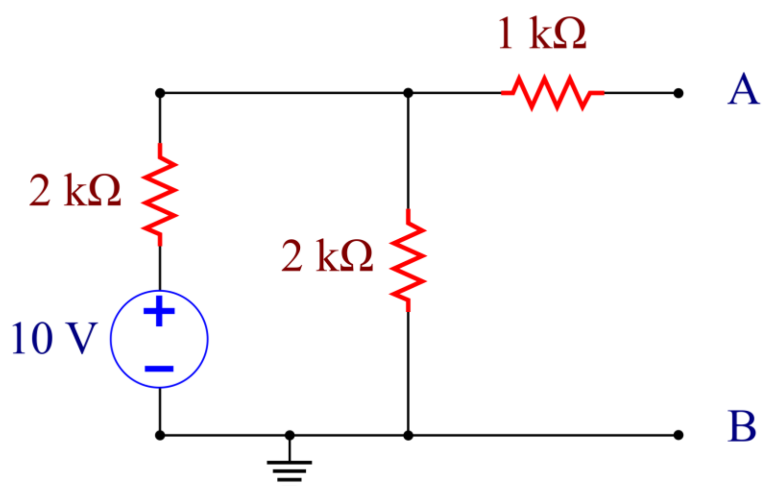
Solder the resistors into the PCB:

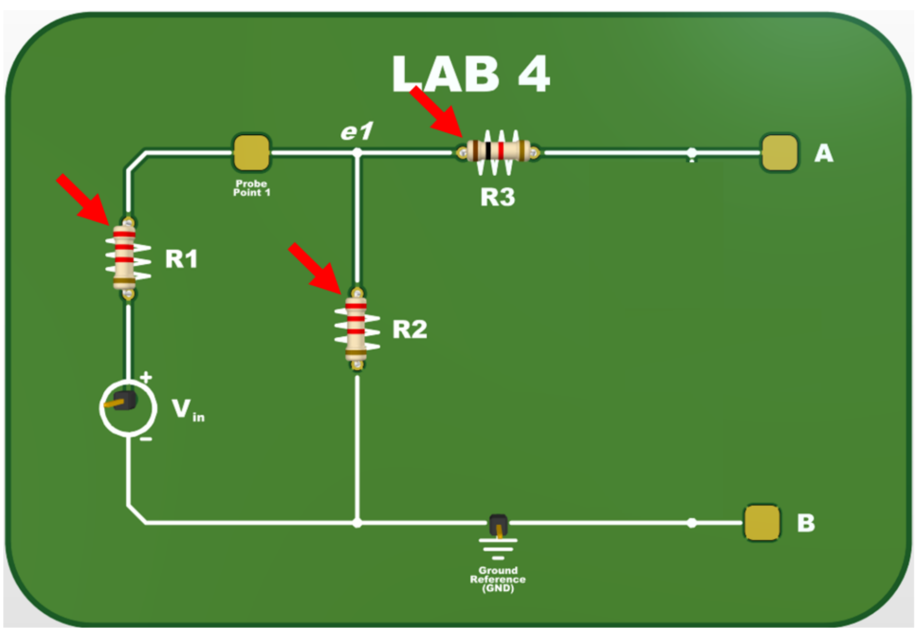
Solder in the resistors R1, R2 and R3 similarly but trim the leads on the back side of the PCB as you go. Be careful to avoid having the clippings fly off by holding them as you clip them. (One more reason to always wear safety glasses.)

Do not solder in anything to R_{Load} yet.

Test all resistors with the multimeter to verify they're soldered in correctly as you go.

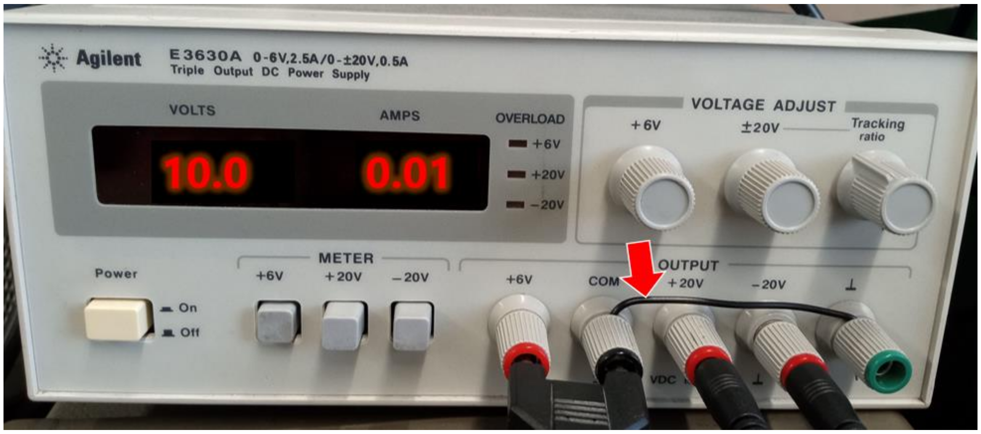
Remember that both lab partners should be taking turns soldering. Call a TA over if you have any questions about the soldering procedure or the quality of your connections (but check your connections with your multimeter first).





PART 2 – Thevenin Measurements

Now that the circuit is soldered together, we will make measurements to verify the Thevenin equivalent voltage and resistance. First, we will supply power to the circuit.



Apply 10 Volts to the voltage source pin on the PCB:

1. Turn on the power supply

2. Press the button under "METER" for "+20V"

3. Adjust the "VOLTAGE ADJUST" knob to set the voltage output to 10 Volts
   Verify the value on the display.

4. Connect the 'COM' output and the Ground output (green) with a wire
   You may need to unscrew the output knob a bit to expose the metal underneath, which has a hole that the wire can be inserted through. Screw the output knob back in to secure the wire. This ensures that all outputs are referenced to the same ground.

5. Use the multimeter to verify the voltage between the OUTPUT +20 and COM/GND

6. Connect ground to the PCB using one of the linked ground outputs.

7. Connect the voltage supply outputs to their corresponding pins using alligator clips.

Measuring the Thevenin equivalents of the PCB:

Voltage:

1. Measure the Thevenin equivalent voltage $V_{Th} =$ _____________
   (Probe the voltage between probe pads 'A' and 'B')

2. Calculate the Thevenin equivalent voltage V_{Th} of the circuit.
   (Voltage divider from V_{in} to e_1 & 'A')

3. Compare your measured V_{Th} and your calculated V_{Th}.
   They should match exactly. Record your findings for your lab report.

Current:

4. Calculate the expected current between 'A' and 'B' when it is shorted by the multimeter.
   (Should be the same as the current through R_3 if A and B are connected by a wire)

5. Measure the current between 'A' and 'B' $I_{AB} =$ __________

6. Compare your measurements and calculations. Record your findings for your lab report.

Aside - Norton Equivalent:
*-How is the current you measured related to the **'Norton equivalent'** current?*

Resistance:

7. Calculate the Thevenin equivalent resistance using Ohm's Law:
   $R_{Th} = \frac{V_{Thevenin}}{I_{Norton}} =$ _________
8. Measure the Thevenin equivalent resistance R_{Th}:
   a. Turn off the power supply and disconnect the wires to the PCB.
   b. Short the pin for V_{in} to ground to complete the path for R_1 to ground.
   c. Measure the resistance between the probe pads 'A' and 'B'

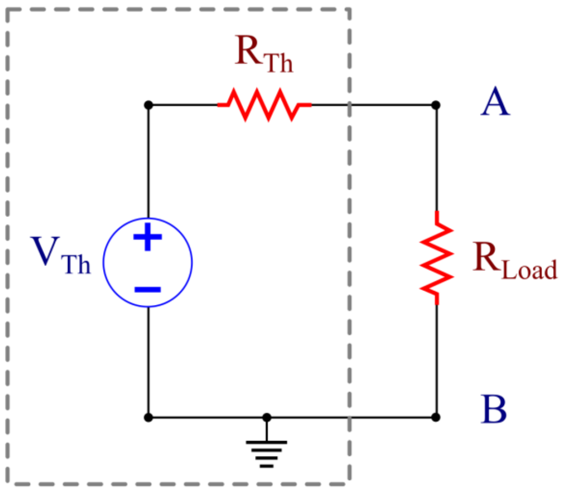
9. Calculate the Thevenin equivalent resistance by analyzing the circuit.
   (Calculate the equivalent resistance of the circuit you created above)

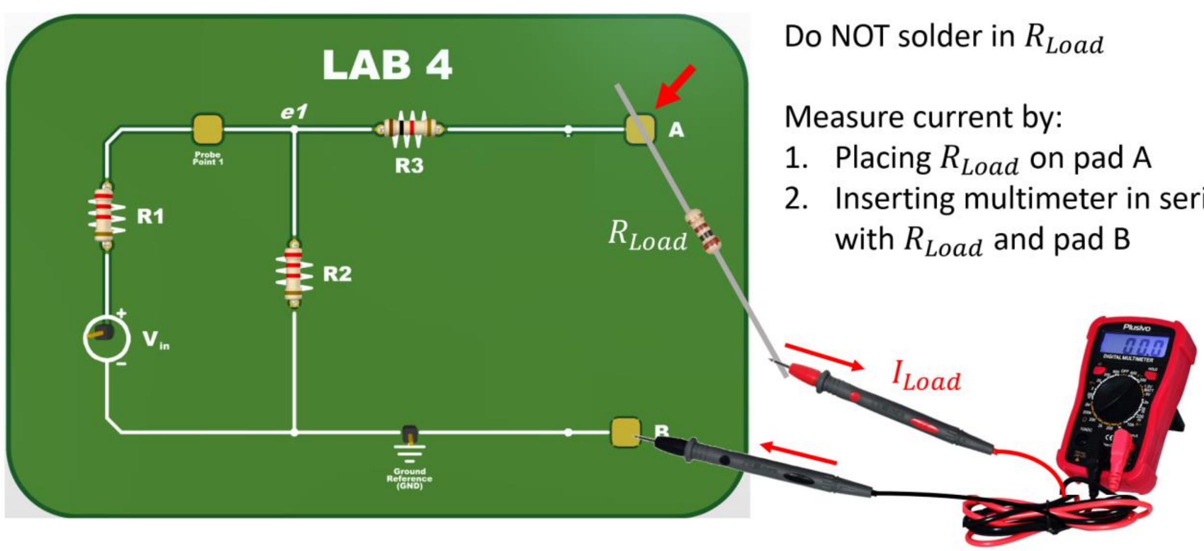
10. Compare your measured R_{Th} and both of your calculated R_{Th} values.
    They should all match exactly. Record your findings for your lab report.

Applying a load to the circuit for maximum power transfer

The maximum power transfer theorem states that the maximum power is transferred from the circuit to the load when the source impedance is matched to the load impedance.
Note: This is not the same as maximum efficiency!
The max efficiency is when the source resistance is low (batteries etc.)

1. Find a resistor that is as close as possible to R_{Th} to match the impedances.
2. Place the resistor on pads 'A' and 'B' to load the circuit
   (DO NOT SOLDER IN YET!)
3. Measure the current through the resistor using the multimeter.
4. Calculate the power dissipated through the resistor



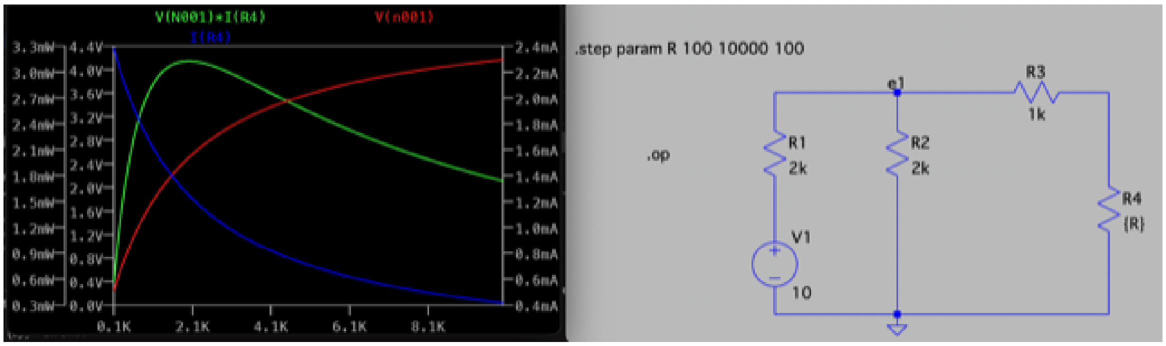


Do NOT solder in R_{Load}

Measure current by:
1. Placing R_{Load} on pad A
2. Inserting multimeter in series with R_{Load} and pad B

<u>SPICE Simulation:</u>

For your lab report verify that R_{Load} transfers the maximum power by sweeping the resistance and measuring the power ($P = I \cdot V$).



<u>LAB REPORT DUE NEXT WEEK</u>

Start outlining report.

Do you have all the data you need?

Do you need to take pictures of your setup?

DETAILED RUBRIC ON NEXT PAGE

<u>Lab Report 4 – Rubric</u>

To practice your technical writing skills, you will write a concise (short) lab report which is a self-contained document. Start by DEFINING important concepts with citations to a few sources, motivating your experiment. Then present your experimental setup and your experimental results (PLOTS, TABLES etc.) and analyze your results to verify your calculations are confirmed by your measurements. In the conclusion summarize all results and quantitatively compare results with predictions from calculations, then discuss possible sources of error and uncertainty. *(Human error is just wrong and will be marked zero).*

Lab reports should prove that you made the measurements accurately and precisely. So you will need to take pictures of your circuit and setup and present data in well labeled figures that are easy to interpret towards your conclusions.

MAX 2,000-words   1 report/group

Focus on presenting your data clearly with well labeled plots. You can use any plotting software.

		Points	
	Introduce and define all concepts (*What did you measure?)*	5	
	Motivation for experiment *(Why did you measure?)*	5	
1	Experimental Diagram (drawing + PICTURE with labels) *(How did you measure?)*	5	
	TABLE – Thevenin measurements **(*What did you measure?)***	10	
	Analysis (show your work for calculations) (How well did you measure?)	10	
2	Experimental Diagram (drawing + PICTURE with labels)	5	
	TABLE – Load resistance for maximum power transfer	5	
	Analysis (show your work for calculations)	5	
3	SPICE Simulation diagram	5	
	PLOT - SPICE Simulation	5	
	Analysis	5	
	Conclusion – Summarize ALL main results. Quantitatively compare results and calculations and discuss sources of error and uncertainty.	5	
		70	