Thevenin equivalent circuits

In this lab, we will examine Thevenin equivalent circuits by measuring and calculating the Thevenin equivalents of four different circuits. For each of the circuits shown Fig. 1 – 4, follow the procedures described below to measure and calculate the Thevenin equivalents.

As always, use good lab procedures as you work. Be sure to measure the values of the resistors used and the voltages of the sources as you set up in each circuit. Lay out the circuits carefully and be sure to double-check in order to eliminate simple wiring errors.

1. **Build** the circuit as shown.
2. **Measure** the Thevenin voltage. Use the DC voltmeter to measure the open-circuit voltage between nodes *a* and *b* that define the output node. As we saw in class, the open-circuit voltage is equal to the Thevenin equivalent voltage, $V_{TH} = v_{oc}$.
3. **Measure** the Thevenin resistance. There are several ways to measure the Thevenin resistance. We will use three different approaches.
    a. Short-circuit current method. Attach the DC ammeter across the output terminals and measure the current. (The ammeter serves as a short circuit at the output.) Then $R_{TH} = V_{TH}/i_{sc} = v_{oc}/i_{sc}$, where v_{oc} is the open-circuit voltage measured in step 2. Use this method to determine R_{TH} for the circuit in Fig. 1. (As always, if you are having trouble obtaining readings with the ammeter, have the instructors check the ammeter fuse.)
    b. Ohm-meter method. When there are only independent sources and resistors in the circuit, we can measure equivalent resistance using an ohm-meter directly. (In class, we called this the "short-cut" method.) De-activate the independent sources (remove the voltage sources and replace with short circuits) and then simply measure the resistance at the output terminals using the ohm-meter. Use this method to determine R_{TH} for the circuit in Fig. 2. This method has limited applications, since it may not always be possible to de-activate the sources.
    c. Voltage-divider method. Attach a potentiometer across the output terminals. While measuring the voltage across the output terminals, adjust the potentiometer until the output voltage is exactly *half* of the open-circuit voltage. $v_o = v_{oc}/2 = V_{TH}/2$. As we know from our study of voltage dividers, if the two resistors making up a divider have the same resistance, the voltage across either one will be exactly half of the source voltage. In this case, the two resistors are the Thevenin resistance of the circuit and the potentiometer. When the output voltage is exactly half the open-circuit voltage, the potentiometer resistance must be equal to the Thevenin resistance. Remove the potentiometer from the circuit (without changing the setting) and measure the resistance. Use this method to determine R_{TH} for the circuit in Fig. 3. A 10-kΩ potentiometer is probably the correct value to use for any of these circuits.
    d. For the circuit of Fig. 4, measure the Thevenin resistance using all three methods. Confirm that they give the same result for R_{TH}.

4. **Calculate** the Thevenin equivalent analytically. Use whatever technique you think is appropriate for each circuit. You can do calculations before or after lab — do not use valuable lab time for calculations. Your report should include comparisons between the measurements and calculations. Note: You cannot use SPICE to do the calculations. You can use it to check your calculations if you want, but the report must include your hand calculations. (Bad news: The Thevenin resistance of the circuit in Fig. 4 cannot be determined using the short-cut method — you will have to find the short-circuit current.

Figure 1

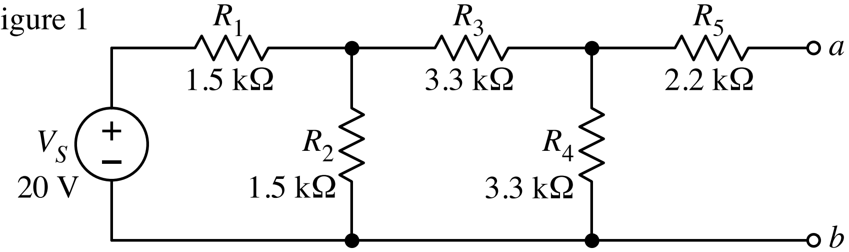


Figure 2

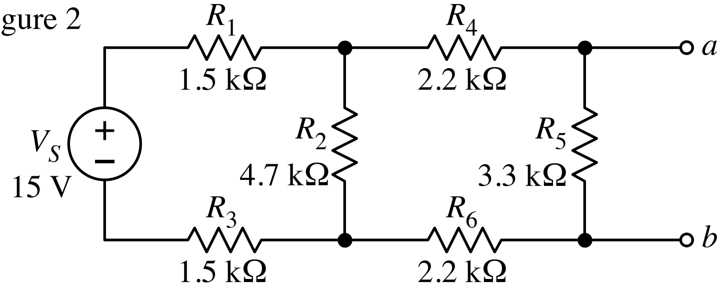


Figure 3

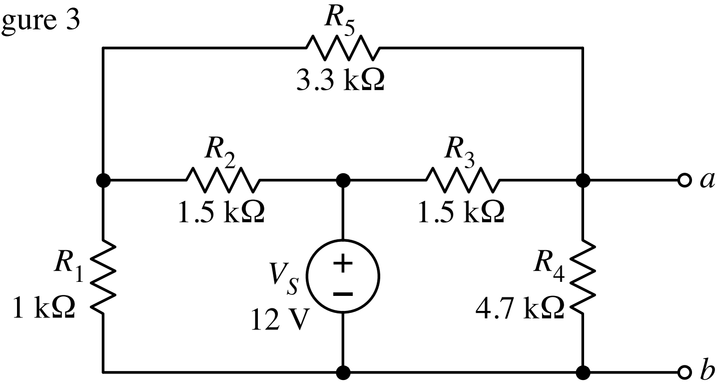
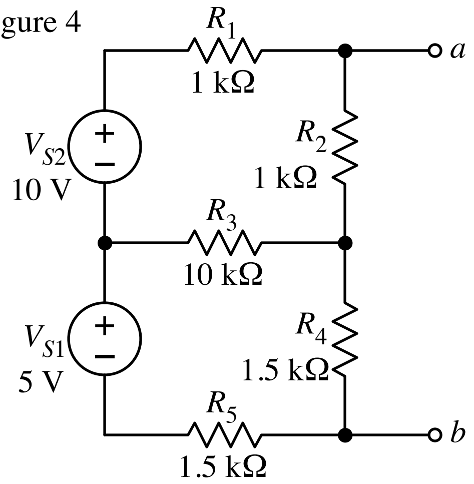


Figure 4



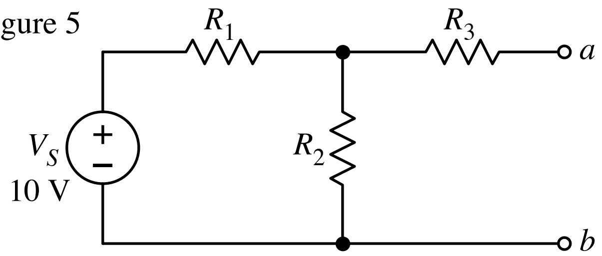
Maximum power transfer

Before disassembling the circuit in Fig. 4, let's take a quick look at maximum power transfer. Make a sequence of measurements with the following resistors attached at the output port, *i.e.* between nodes *a* and *b*. R_L = 150 Ω, 470 Ω, 1 kΩ, 1.25 kΩ (≈ 1 kΩ + 220 Ω + 33 Ω), 2.2 kΩ, 10 kΩ, and 22 kΩ. For each value, measure the resistor voltage and then calculate the power dissipated in the resistor. Make a table of your results. Which value of resistance has the maximum power dissipation?

Design it.

Finally, let's do a bit of design. Choose values for the resistors in the circuit of Fig. 5 so that the Thevenin equivalent voltage is 6 V and the Thevenin equivalent resistance is 6 kΩ. Build the circuit and do measurements to confirm that the Thevenin voltage and resistance are correct to within ±5%. Demonstrate your design to your lab supervisor. (Hint: There is a nice set of 3 resistors that give the desired result — there is no need to cobble together intricate combinations to obtain unusual resistor values.)

Figure 5



Reporting

Prepare a report for the work done in this lab. Be sure to include all of the measured and calculated values. When finished, upload the report to Canvas. Check the schedule page for due dates.