Resistive Circuits

Motivation:

In this lab, we will explore voltage dividers, calculate equivalent resistances and analyze resistive circuits.

Related Lecture Content:

- Equivalent Resistances and Resistive Circuit Analysis

Before you start:

Potentiometer

A potentiometer is a three-terminal resistor with a rotating contact called the wiper that forms a variable resistor. While the resistance between the two end terminals is always constant, the resistance between one end and the middle wiper can be varied with a rotating knob, so make sure to identify the contacts when connecting the potentiometer to the circuit.

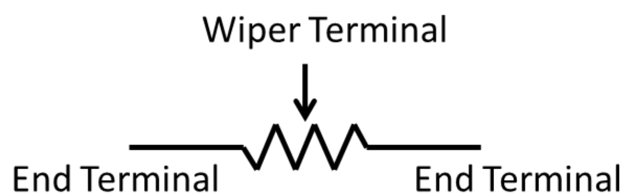

Figure 1: Potentiometer Schematic Drawing

Experiment:

Please fill out the experimental report while going through the lab and submit it to the TA by the end of the lab for grading.

Part 1

1.1 Connect the 10 kΩ potentiometer to the breadboard and to the power supply, as shown in Figure 2, with V_p = 10 V. Using the multimeter, record the voltage (up to three significant digits) of the power supply V_p, the voltage between the potentiometer's top terminal and the wiper, V_1, as well as the voltage between the wiper and the other end terminal V_2. What is the voltage difference between the power supply and the two measured voltages, $V_p - (V_1 + V_2)$? To think about: Is KVL satisfied? Is the voltmeter ideal?

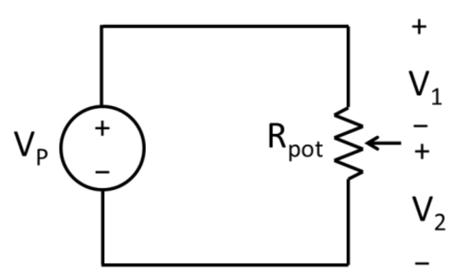

Figure 2: Potentiometer Circuit as a Voltage Divider

Part 2

In the next part of this lab, you will design a resistor cube as shown in Figure 3. The cube is a popular puzzle since it is a daunting task to calculate the equivalent resistance between the nodes using normal circuit analysis. Depending on the two nodes you are considering, you will observe a different resistance. You can measure the resistance between the nodes by applying a test voltage and measuring the current. Challenge yourself to build the circuit without referring to the hint of the layout given at the end of the report.

2.1 Design the circuit using twelve 22 kΩ resistors and calculate the equivalent resistance between an edge R_{AB}, a face diagonal R_{AC}, and a body diagonal R_{AD} by applying a voltage across the nodes and measuring the current with the ammeter. You can design the cube on the breadboard without having any overlapping wires. Note that there are 8 nodes with 3 branches attached to each.

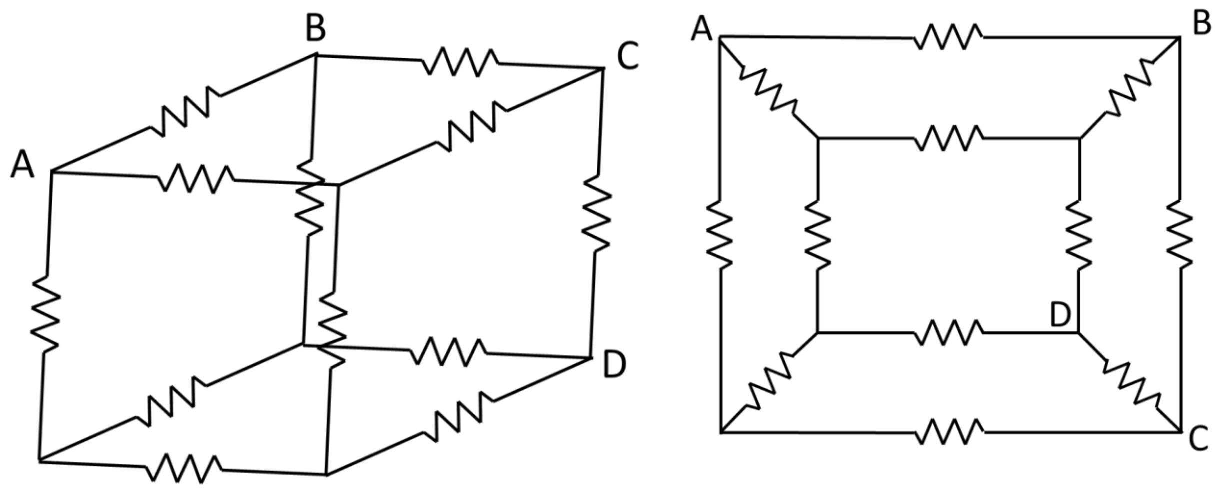

Figure 3: Resistor Cube Schematic

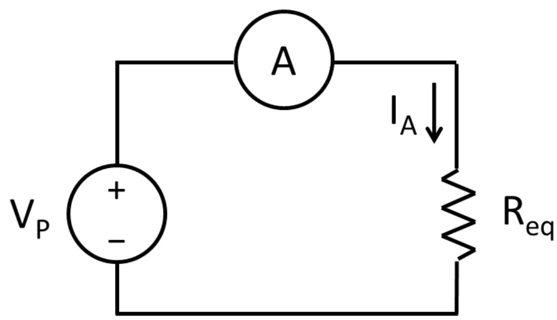

Figure 4: Test Voltage Circuit

2.2 Measure the equivalent resistance between an edge R_{AB}, a face diagonal $R_{AC,}$ and a body diagonal R_{AD} using the multimeter.

Usually though, this problem is given in compromising situations like a job interview, or a final exam, and you cannot just build the circuit and measure the equivalent resistances. To solve this circuit, it is better to make use of symmetry and basic voltage and current laws. In your free time, try and solve for the three resistances you measured during the lab and see if they are the same.

Part 3

In the final part of this lab, we will explore the Wheatstone Bridge. It is a simple circuit used to accurately measure unknown resistor values, by balancing two legs of a bridge circuit. While digital multimeters provide the simplest way to measure resistances, the Wheatstone Bridge remains an extremely useful circuit for measuring resistance down to milli-ohms and is used for many sensor applications.

The circuit is nothing more than two simple series-parallel arrangements of resistors connected to a power supply and produces a zero voltage difference (V_{out}) between the two parallel branches when balanced. $V_{\text{out}} = \left(\frac{R_2}{R_1+R_2} - \frac{R_4}{R_3+R_4}\right) V_{\text{p}}$. The circuit is balanced only when $R_1R_4 = R_2R_3$.

3.1 Implement the Wheatstone Bridge, shown in Figure 5, with four 10 kΩ resistors with a 0.1% tolerance and $V_p = 10$ V. Measure V_{out} with the multimeter. You will notice the circuit is not perfectly balanced.

3.2 Replace R_4 with a resistor of your choice, and observe the output voltage. Calculate the exact resistance of the resistor you have chosen using the value of V_{out}, and the other three 10 kΩ resistors. Measure your resistor with the multimeter and compare the two values.

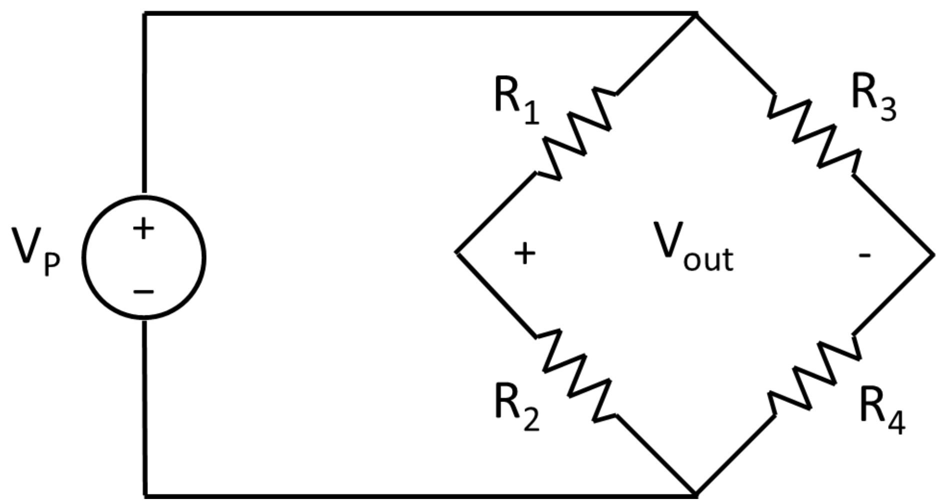

Figure 5: Wheatstone Bridge Circuit

Hint: The circuit layout of Part 2

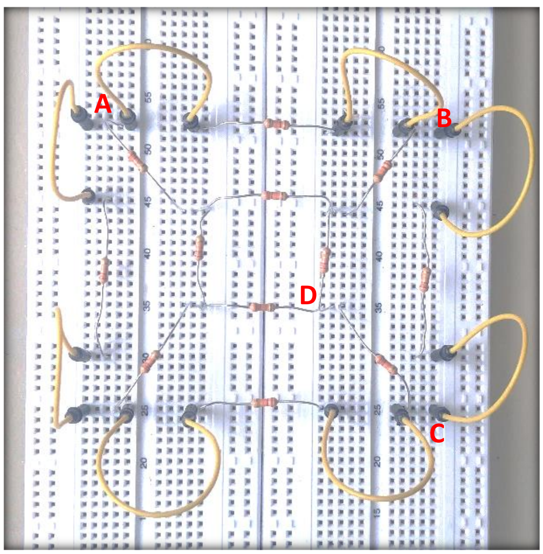

Figure 6: Resistor Cube Circuit