Overview

In this lab, series and parallel combinations of resistances are examined. We will begin by combining specified resistors in series and parallel, measuring the resulting equivalent resistance, and comparing the result to analytical expectations. DMMs will be used to measure the voltage and current across individual resistors within series and parallel combinations of resistors; the experimental measurements will be compared to analytical expectations based on the governing equations for voltage and current dividers.

We will also get additional exposure to design-type problems in this lab assignment. The first problem of this type will consist of designing resistive networks, composed of the available fixed resistors, to provide specified resistances.

In the second design-type problem of this lab assignment, students must design a temperature-measuring circuit. Unlike our previous temperature measuring circuit, the output voltage of this circuit is to be relative to the output voltage at room temperature. The output voltage is to be positive if the temperature is above room temperature, and negative if the temperature is below room temperature. Like our previous temperature measuring circuit, this circuit will use a thermistor to sense temperature changes.

Before beginning this lab, you should be able to:

- State Ohm’s law (Chapter 1.3)
- State the equations providing the equivalent resistance of series and parallel resistive networks (Chapter 1.4)
- State the voltage divider relationship for series resistor combinations (Chapter 1.5)
- State the current divider relationship for parallel resistor combinations (Chapter 1.5)
- Use a digital multimeter to measure resistance, voltage, and current (Lab 0)
- Use color codes on resistors to determine the resistor’s nominal resistance (Chapter 1.3)

After completing this lab, you should be able to:

- Design a resistive network to provide a specified equivalent resistance
- Design a thermistor-based circuit to measure temperature
- Use a potentiometer to provide a desired resistance value
- Use multiple power supplies in an electrical circuit.

This lab exercise requires:

- Digilent Analog Parts Kit
- Digilent EE board
- Digital multimeter
I. Series and Parallel Resistors and Equivalent Resistance

General Discussion:

This portion of the lab assignment concerns the circuit shown in Figure 1 below. A power supply is used to apply the 5V voltage difference. We wish to determine the power dissipated by the 1KΩ resistor.

![Circuit schematic](image)

**Pre-lab:**

Analyze the circuit of Figure 1 to estimate the power dissipated by the 1KΩ resistor.

**Lab Procedures:**

Construct the circuit of Figure 1; measure and record all actual resistance values. Measure the parameters necessary to determine the power dissipated by the 1KΩ resistor. Determine the power dissipated by the 1KΩ resistor. Compare the measured power with your estimate from the pre-lab. Comment on any differences between the estimated and measured values. Demonstrate operation of your circuit to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.
II. Equivalent Resistance – continued

General Discussion:

We need resistors with the following resistance values and tolerances:

1. $9\,\text{K}\Omega \pm 5\%$
2. $800\,\Omega \pm 5\%$
3. $35\,\text{K}\Omega \pm 5\%$

Resistors with these resistances are not included in the analog parts kit; we will use available fixed resistors to construct circuits with the required equivalent resistance.

Pre-lab:

Using only fixed-value resistors available in your analog parts kit, design circuits which have the equivalent resistances listed above.

Lab Procedures:

Construct the three circuits you designed in the pre-lab. Use an ohmmeter to measure the equivalent resistance of each of the circuits. Comment on your results – specifically, whether the design requirements were met. Demonstrate operation of your circuits to the Teaching Assistant. Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.

Note: As always, measure and record the resistance of the individual resistors used in your circuits.

III. Temperature Measurement System

General Discussion:

In this portion of the lab assignment, we will refine the temperature measurement system we designed in Lab 2. The system will still use a thermistor to detect temperature changes. (Recall that a thermistor is a device whose electrical resistance changes as a function of the temperature of the thermistor. The thermistor we will use has a temperature-resistance curve approximately as shown in Figure 2. Thermistor operation is discussed in more detail in the companion document to Lab 2.)

Our design requirements for this assignment are as follows:

1. $\pm 5\,\text{V}$ input voltage to the system
2. Output voltage is $0\,\text{V} \pm 10\,\text{mV}$ at room temperature (approximately $25\,\text{C}$)
3. Output voltage is positive for temperatures above room temperature, negative for temperatures below room temperature
4. Output voltage increases by a minimum of $1\,\text{V}$ over a temperature range of $25\,\text{C}$ to $37\,\text{C}$.
   (These temperatures correspond approximately to room temperature and body temperature, respectively.)
**Pre-lab:**

In the circuit of Figure 3, the resistance $R_{TH}$ is the variable resistance of the thermistor. The voltage $V_{out}$ is the voltage that we will use to indicate temperature. Two 5V voltage supplies are used to apply power to the circuit as shown – note that $V_{ba} = +5V$ and $V_{ca} = -5V$. $V_{out}$ is measured between nodes d and a with the polarity shown. The design problem is to choose a value for R so that $V_{out}$ satisfies the given design requirements. It is recommended that you choose R based on requirement 2, and then check to see that this resistance satisfies the remaining design requirements.

Be sure to document your analyses (preferably in a lab notebook), including the equation(s) governing the system, your desired value for R, your expected output voltage change over the specified temperature range, and your expected output voltage at room temperature.
Lab Procedures:

Implement and test the design you created in the pre-lab. It is suggested that you perform at least the following steps when doing this:

1. Measure the room-temperature resistance of your particular thermistor. Compare this value to the assumed value used in your pre-lab and modify your desired value of R accordingly.

2. Implement your design. Be sure to record actual resistance values for any fixed resistors used in your design. In order to meet requirement 2, it may be necessary for you to implement a very specific resistance. A potentiometer (variable resistor) can be used to provide an arbitrary resistance value. You can monitor the output voltage while adjusting the potentiometer to ensure that requirement 2 is met. If desired, the potentiometer can be placed in parallel or series with a fixed resistor.

3. Measure and record the voltage response at room temperature. Measure and record the output voltage at the high temperature condition by firmly holding the thermistor between two fingers. Verify that the output voltage becomes negative when the thermistor is below room temperature by holding a cold can (or bottle) of your favorite beverage against the thermistor. Discuss your circuit’s performance relative to the design specifications. (e.g. Were requirements met? If not, why?)

4. *Demonstrate operation of your circuit to the Teaching Assistant* Have the TA initial the appropriate page(s) of your lab notebook and the lab checklist.