Overview

In this lab assignment, we will use KVL and KCL to analyze some simple circuits. The circuits will be constructed and tested and the actual circuit response compared to the expected response from the analysis.

An extremely important circuit characteristic – the circuit’s input resistance – will be determined using Kirchoff’s laws. The input resistance of a circuit can be a significant design parameter; if the circuit is later incorporated in part of a larger overall system, the circuit’s input resistance can have a significant effect on the behavior of the overall system.

This lab assignment also includes our first design-related task: we will design a circuit whose output voltage provides a crude temperature measurement. A thermistor – a device whose resistance changes with temperature – is used to sense the temperature. We will create an electrical circuit which uses this resistance change to output a voltage which indicates the temperature of the thermistor.

Before beginning this lab, you should be able to:

- State Ohm’s law from memory (Chapter 1.3)
- 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)
- Use KVL and KCL for circuit analysis (Chapter 1.4)

This lab exercise requires:

- Digilent Analog Parts Kit
- Digilent EE board
- Digital multimeter

After completing this lab, you should be able to:

- Measure power dissipation of a resistor in a resistive network
- Estimate the input resistance of a resistor network from measured voltage-current characteristics
- Design a thermistor-based circuit to measure temperature
Symbol Key:

- Demonstrate circuit operation to teaching assistant; teaching assistant should initial lab notebook and grade sheet, indicating that circuit operation is acceptable.
- Analysis; include principle results of analysis in laboratory report.
- Numerical simulation (using PSPICE or MATLAB as indicated); include results of MATLAB numerical analysis and/or simulation in laboratory report.
- Record data in your lab notebook.

I. Resistive Network Power Dissipation

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 4.7KΩ resistor.

![Circuit Schematic](image)

Figure 1. Circuit schematic.

Pre-lab:

Analyze the circuit of Figure 1 to estimate the power dissipated by the 4.7KΩ resistor.

Lab Procedures:

Construct the circuit of Figure 1. Measure and record the actual resistance values used in your circuit. Measure the parameters (voltages and/or currents) necessary to determine the power dissipated by the 4.7KΩ resistor. Determine the power dissipated by the 4.7KΩ 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. Circuit Input Resistance

General Discussion:

The input resistance of a circuit is the effective resistance that a source (or another stage of an overall system) will see when it is connected to the circuit. This value can be an extremely important design parameter for a circuit. In this part of the lab assignment, we will determine the input resistance of the circuit shown in Figure 2.

![Figure 2. Circuit schematic for part II.]

Pre-lab:

Determine the relationship between $V_{in}$ and $i_{in}$ for the circuit shown in Figure 2. Defining the input resistance according to Ohm’s law as $R_{in} = \frac{V_{in}}{i_{in}}$, determine the input resistance of the circuit of Figure 2.

Lab Procedures:

1. Construct the circuit of Figure 2. Measure and record the actual resistance of all resistors used in your circuit. Use a variable voltage supply to apply $V_{in}$ and $i_{in}$ to the circuit. For at least five different values of $V_{in}$ between 0V and 5V, measure $V_{in}$ and $i_{in}$.
2. Plot the voltage-current characteristic for the five points determined in part 1. Estimate the input resistance of the circuit from the slope of the voltage-current characteristic. (Feel free to draw your own best-fit line to the data points, without performing a least-squares best fit.)
3. Calculate the input resistance for each combination of $V_{in}$ and $i_{in}$ measured in part 1. Determine the average input resistance over the five measurements and the standard deviation of the measurements. Compare this value of input resistance to the one determined in part 2.
4. 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.
III. Temperature Measurement System

General Discussion:

In this portion of the lab assignment, we will design and construct a temperature measurement system. The system will use a thermistor to detect temperature changes. A thermistor is a device whose electrical resistance changes as a function of the temperature of the thermistor. The thermistor we will use, for example, has a temperature-resistance curve approximately as shown in Figure 3. It is worthwhile noting that the relationship between temperature and resistance is not linear. However, during the design process it is common to approximate the data as a straight line – at least over some range of temperatures.

It can be seen from Figure 3 that the temperature can be inferred from the resistance of the thermistor. However, resistance is not a common quantity to use to represent a physical parameter – it is much more usual to use voltage to represent the parameter. (Voltages are generally easier to use than resistance to represent information. For example, digital logic circuits generally operate based on voltages applied to them.) We will design a circuit which outputs a voltage, from which the temperature of the thermistor can be inferred.

Our design criteria are as follows: Design a circuit like that shown in Figure 4, containing a thermistor as one of the resistances, which satisfies the following specifications:

1. +5V input voltage to the system
2. Output voltage varies by a minimum of 0.5V over a temperature range of 25°C to 37°C.
3. Output voltage must increase as temperature increases

The selected temperature range provided in the design requirements corresponds (approximately) to the change between room temperature and human body temperature. We can thus check our temperature measurement system by measuring the output voltage when the thermistor is at room temperature and then changing the temperature by firmly holding the thermistor between two fingers. The voltage should increase by at least 0.5V as a result of this temperature change.
Lab 2: Kirchoff’s Laws

Pre-lab:

In the circuit of Figure 4, the resistance $R_{TH}$ is the variable resistance of the thermistor. (The arrow through the resistor symbol typically means that the resistance is not necessarily constant.) The voltage $v_{out}$ is the voltage that we will use to indicate temperature. The 5V input voltage is applied across the two resistors as shown. The design problem is to choose a value for $R$ so that $v_{out}$ increases by a minimum of 0.5V over a temperature range of 25°C to 37°C. To do this,

1. Analyze the circuit of Figure 4 to determine $v_{out}$ as a function of $R_{TH}$ and $R$.
2. Verify that $v_{out}$ increases as temperature increases (or, equivalently, as $R_{TH}$ decreases)
3. Using the temperature-resistance curve provided in Figure 2, choose a value for $R$ such that $v_{out}$ changes by at least 0.5V over the specified temperature difference.

In your lab notebook, be sure to include the results of your analyses, 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.

Figure 3. Thermistor temperature-resistance characteristic.

Figure 4. Temperature measurement circuit schematic.
Lab Procedures:

Implement and test your design from the pre-lab. It is suggested that you perform at least the following steps when implementing your design:

1. Check the resistance variation of your particular thermistor, over the specified temperature variation. To do this, measure and record the resistance of the thermistor at room temperature. Then hold the thermistor firmly between two fingers and record the resulting resistance value. This provides the resistance variation over the desired temperature range.

2. Check your preliminary design generated in the pre-lab with the measured resistance variation determined in step 1 above. It is entirely possible that this step may indicate that your design does not meet the design requirements, however, do not modify your design to meet the design requirements.

Note:
In general, design is an iterative process. As new information becomes available, the design is revised to ensure that the design requirements are met or the design requirements are revised to ensure that they are realistic. Since this is our first experience with design, we will not iterate on our preliminary design. This step, however, still provides valuable information which can be used to discuss our final design performance relative to system requirements. For example, we may claim that the design requirements were not met because our thermistor did not have the sensitivity provided in Figure 4 or that our fingertips did not apply the desired 37°C temperature. Either way, we have a reason why we did not meet the design requirements – this can be important when discussing your system performance relative to the design requirements with your customer!

3. Implement your design. Be sure to record actual resistance values for any fixed resistors used in your design.

4. Measure the voltage response to the specified temperature change. Record the output voltage at the high and low temperature conditions. Discuss your circuit’s performance relative to the design specifications. (e.g. Were requirements met? If not, why?)

5. Calculate the percent error between the expected performance (based on your pre-lab analysis) and the measured performance.

6. 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.

IV. Post-Lab Exercise

Using the thermistor provided in this lab assignment, design a temperature measurement system which meets the following requirements:

1. The output voltage must increase as temperature increases.
2. The output sensitivity of the device must be at least 0.1 V/°C (or 100 mV per degree Centigrade of temperature change).

Analyze the design to show that the requirements are met. You do not need to implement your design.