

1.4.4: Temperature Measurement System

Overview:

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
- Use a digital multimeter to measure resistance, voltage, and current (Lab 1.1, 1.2.1)
- Use the Analog Discovery's arbitrary waveform generator (AWG) to apply constant voltages to a circuit (Lab 1.2.2)
- Use the Analog Discovery voltmeter to measure a constant voltage (Lab 1.2.1)
- Use color codes on resistors to determine the resistor's nominal resistance
- Use KVL and KCL for circuit analysis

After completing this lab, you should be able to:

- Design a thermistor-based circuit to measure temperature

This lab exercise requires:

- Analog Discovery module
- Digilent Analog Parts Kit
- Digital multimeter (optional)

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.

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 1. 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.

Related Material:

Thermistors are classified as NTC (Negative Temperature Coefficient) or PTC (Positive Temperature Coefficient) depending on whether their resistance decreases or increases with temperature. Thermistor specifications also include their nominal resistance at some temperature. The thermocouple with the temperature-resistance curve shown in Figure 2 is specified as an “NTC 10K Ω @ 25°C” thermistor. Additional information about thermistors can be found in the backup information provided as a companion document on to this lab.

It can be seen from Figure 1 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 2, 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.

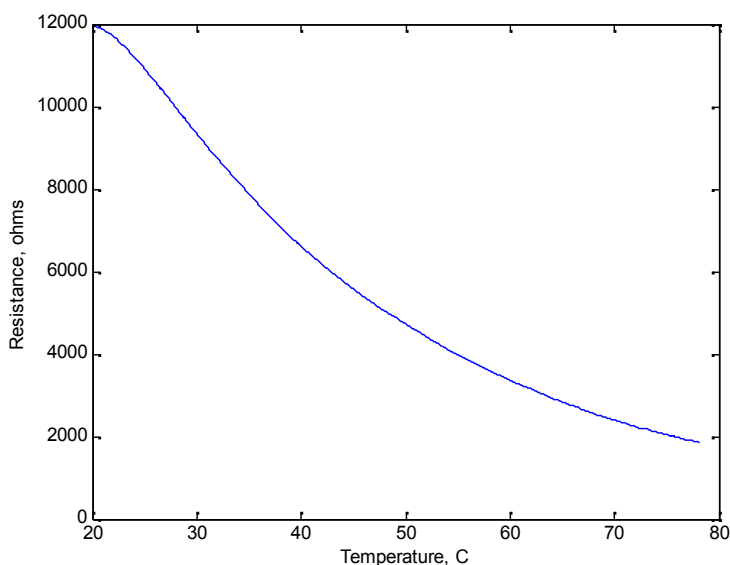


Figure 1. Thermistor temperature-resistance characteristic.

Pre-lab:

In the circuit of Figure 2, 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,

ANALYSIS

1. Analyze the circuit of Figure 2 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 1, 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.

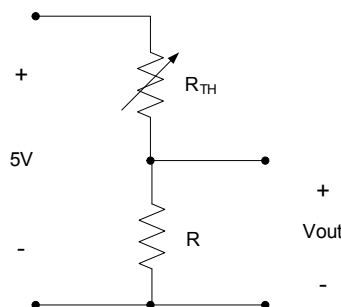


Figure 2. Temperature measurement circuit schematic.

Lab Procedures:

Note on the design process:

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 the preliminary design from the pre-lab. Our pre-lab analysis, 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 1 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!

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

DATA

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.

DATA

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

DATA

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?)

ANALYSIS

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

DEMO

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.

Post-Lab Exercises:

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 $0.1 \text{ V}/^{\circ}\text{C}$ (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.