

TEMPERATURE SENSORS

Goals: The goals of this laboratory are to introduce different kinds of thermal sensors and investigate their behavior and applications.

Learning Objectives: After completing this laboratory, you should be able to:

1. Explain the operating principles, advantages, and disadvantages of thermistors, thermocouples, and RTDs.
2. Design and implement interface circuitry between the sensors and LabVIEW.
3. Determine the critical issues for sensor choice, placement, and circuit implementation through laboratory investigation of a particular temperature-sensing application.

Laboratory Preparation: In preparation for this laboratory, you should:

1. Attend the lecture session on Temperature Sensors and read over this laboratory activity. Read the data sheets available for the sensors used in this laboratory (included as Lab 4 Appendix A on the course website).
2. Download and read the Watlow Temperature Sensor manual. You can find it on the web at: http://www.watlow.com/literature/prodtechinfo/files/sensors/we4e_16.pdf

PQ1: Solve for the “ β ” value for the NTC thermistors used in the lab. Calculate the curve over a temperature range of 10°C to 30°C as well as the range 40°C to 60°C. You can use the thermistor R vs T data provided in one of the references in Appendix A. Assume a thermistor of type Z.

PQ2: Write out the Steinhart-Hart equation for the NTC thermistors we will use in the lab. You can find the coefficients from the data sheets in Appendix A (assume a 10 k Ω thermistor of type Z).

3. Design a DC bridge that can be used to collect data from a negative temperature coefficient thermistor with a room temperature impedance of 10 k Ω . Appendix B gives details on this if you’re not familiar with DC bridge circuit design.
4. Design another DC bridge that can be used to collect data from a RTD with a room temperature impedance of roughly 110 Ω .
5. List several applications that call for temperature sensing.
6. Anticipate the practical issues that may arise in these applications by answering these questions:

PQ3: What kind of accuracy is necessary?

PQ4: How repeatable do the measurements have to be?

PQ5: What is the result of an incorrect or inaccurate sensor reading?

Here are some other useful references on the web that you should read.

- 1) Thermocouples: <http://www.picotech.com/applications/thermocouple.html>
- 2) NTC thermistors: <http://www.thermometrics.com/assets/images/ntcnotes.pdf>
- 3) RTDs: <http://www.omega.com/pdf/temperature/Z/pdf/z033-035.pdf>

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Laboratory Tasks and Questions: During the laboratory, you should do the following:

1. Using the provided data sheets and parts, examine the thermistors, thermocouples, and RTDs provided in the lab.

Q1: How are they different and how are they the same? Discuss shape, size, and operation.

Temperature Measurements Using Thermocouples

2. Configure an analog input channel to make measurements based on a Type J thermocouple curve using the DAQ Assistant Express VI. Connect the thermocouple to a protoboard and use LabVIEW to measure the room temperature. Save your VI.
3. Use the battery compensated thermocouple to read the room temperature. To do so, power on the multimeter and set it to read DC voltage. Then plug in the thermocouple to the terminals and turn the switch to °F or °C. Compare your Type J thermocouple measurements to the readings from the battery compensated thermocouple.

Q2: How far off are the readings?

Q3: What are some possible reasons for any differences?

Temperature Measurements Using Thermistors

4. Measure the impedance of the thermistor with the multimeter.
5. Connect the thermistor into its appropriate bridge circuit that you designed for the prelab. Based on voltage readings from the bridge circuit and formula conversions from coefficients obtained from the data sheet, use LabVIEW to make temperature measurements. Save your VI. Document your observations.
6. If the measured temperature is not clean and stable, determine a course of action to rectify this.

Temperature Measurements Using RTDs

7. Repeat steps 4 and 5 from the previous section using a RTD. Don't forget that you now have new conversion coefficients.

Q4: How do temperature measurements from the RTD compare to the ones obtained by using a thermistor?

Q5: What are some possible reasons for the differences you observe?

TEMPERATURE SENSORS***Sensor Placement***

8. **MINI-EXPERIMENT:** Now we will investigate the effects of sensor placement. Consider the following application: A product placed on the top of a heated metal block needs to achieve a certain temperature in order to heat a glue strip to around 30°C . We have versions of the metal block in the laboratory.
- Select two of the sensors and attach them to two positions on the metal block.
 - Modify one of your VIs so that you can obtain readings from 2 of the sensors simultaneously using 2 separate input channels. Save your VI.
 - Adjust the heating mechanism so that it heats the block slowly. Record the data with the modified VI.

Mini-Experiment Purpose

Mini-Experiment Equipment and Setup

Mini-Experiment Hypotheses

Mini-Experiment Results

Mini-Experiment Conclusions

To help lead your Mini-Experiment write-up, consider the following questions...

- Of the two sensors and placement choices, which are more appropriate for this application? Why? Are these the two that you ultimately used?
- Is there a difference in the outputs of your graphs? Do you suppose it is related to position on the block, or sensor type? Why?

9. Return all materials, sensors, and equipment to their original positions.

Student Post-Lab Questions and Conclusions

1. Explain the operation of thermocouples and include their advantages and disadvantages.
2. Explain the operation of thermistors and include their advantages and disadvantages.
3. Explain the operation of RTDs as well as their advantages and disadvantages.
4. Two of the sensors in this laboratory required DC bridges to make the measurement. Calculate the *worst-case* uncertainty in these voltage measurements if the rest of the resistors in the bridge circuits have:
 - i. $\pm 1\%$ tolerance
 - ii. $\pm 10\%$ toleranceFor each case, assume that you initially designed the bridge such that it was in total balance (e.g., $R_1 = R_2 = R_3 = R_4 = R$).
5. In your view, what are the three most important issues to consider when selecting a temperature-sensing device for a particular application? Justify your answers.
6. What are two important lessons that you learned from this lab that deal with temperature sensing and sensors?

Plots and Figures:

TEMPERATURE SENSORS

- Thermocouple VI Front Panel
- Thermocouple VI Block Diagram
- Thermistor VI Front Panel
- Thermistor VI Block Diagram
- RTD VI Front Panel
- RTD VI Block Diagram
- Mini Experiment VI Front Panel
- Mini Experiment VI Block Diagram
- Wheatstone Bridge Circuits