A13 - Lab Final
Procedure

Deliverables: checked notebook, checked circuit, plot of temperature (°C) vs. distance (in.) and corresponding Matlab script submitted to lab instructors and TA via email

Exam Rules

This is an in-lab final exam designed to test your *individual* laboratory skills. **You have 50 minutes to perform the procedure, make the deliverables, and email them to the TA and lab instructor.** You are to make an entry into your lab notebook as you have been doing through out the semester. Your lab notebook entry *must* follow the lab notebook guidelines posted on the resources page of the course website (https://www3.nd.edu/~prumbach/AME20216/resources/notebook_guidelines.pdf).

When you have the system working or the 50 minutes is up, you must email the deliverables to the TA and lab instructors, then have Prof. Ott check your setup and sign your lab notebook. (See Data Analysis and Deliverables section for details).

You may use a calculator, lap top computer, or the lab computer to make your deliverables.

Temperature Inside a Heated Pipe

For this in-lab exam, you will use a thermistor in a voltage divider circuit to measure the temperature inside a heated pipe, as shown in Figure 1. The thermistor has a "negative temperature coefficient" (NTC), which means that its resistance decreases as temperature increases. Similar to the A4 lab, the temperature T is related to the thermistor resistance R_s via the Steinhart interpolation formula

$$T(R_s) = \left[A + B \ln\left(\frac{R_S}{R_{ref}} \right) \right]^{-1}, \qquad (1)$$

where R_{ref} = 10kΩ, $A = 3.3527\times10^{-3}$ K^{-1}, and $B = 2.9064\times10^{-4}$ K^{-1}. The output voltage V_{out} of the circuit is given by the voltage divider equation

$$V_{out} = \left(\frac{R_2}{R_2 + R_S} \right) 12V, \qquad (2)$$

where R_2 = 4.7kΩ. The thermistor will be used the measure the temperature profile in a 12 inch long heated copper pipe. The copper pipes can be heated either from the top (Configuration A) or the bottom (Configuration B), as illustrated in Fig. 1b.

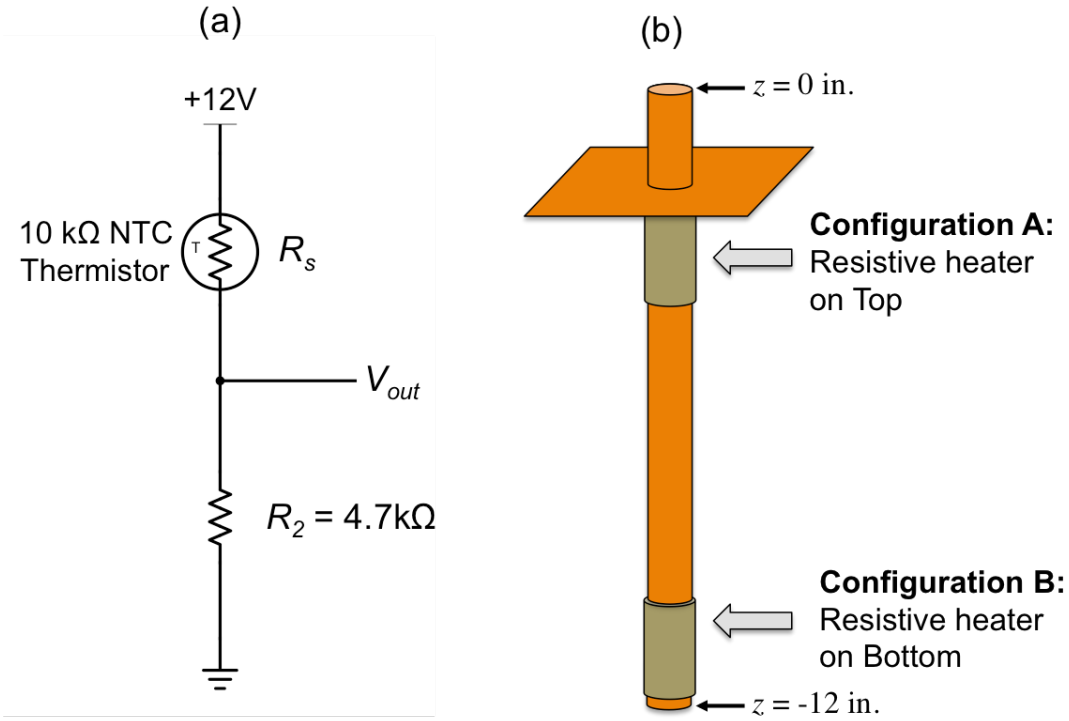

Figure 1 – (a) A thermistor is wired up in a voltage divider circuit. (b) An insulated copper pipe has a fin on top for cooling. It can be heated from either the top (Configuration A) or the bottom (Configuration B).

Procedure

1. Turn on the breadboard. Use the handheld DMM to verify that the +5V and variable +15V DC power supplies are all working.
2. Locate the thermistor. It looks like a long black wire with two pins on one end and a plastic probe tip on the other. The shiny plastic probe tip is where the sensor is located.
3. Use the handheld DMM to verify that the thermistor works. It should have a resistance around 10kΩ at room temperature, and the resistance should decrease when it is warmed up.
4. Sketch the schematic shown in Fig. 1 in your lab notebook. Note whether the red heater wires are coming out of the top or bottom of the insulation.
5. Write down the color of the tape on the insulation in your lab notebook.
6. Look at the DC power supply connected to the heater, and record the voltage and current displayed on its orange screen. It should be around 7 Volts and 0.3 Amps. Calculate the power and make sure it is a few Watts. If it is not, ask the lab instructor for help.
7. Using the breadboard, construct the voltage divider circuit shown in Fig. 1a.

Pro-tip: Measure any resistor before you place it in your circuit to make sure you have the correct value.

8. Use the Keysight Precision DMM to measure the output voltage V_{out} relative to ground.
9. Insert the thermistor into the heated copper pipe. You should see the voltage V_{out} change.
10. Use the output voltage V_{out} of the thermistor voltage divider circuit to determine the temperature T (units of degrees C) as a function of distance z (units of inches) inside the copper pipe. Use the convention that $z = 0$ inches at the top and $z = -12$ inches at the bottom. Start at $z = -1.5$ inches, and measure at least 8 different equally spaced data points.

Pro-tip: You don't have all day to wait for the sensor reach equilibrium, so record your voltages with a resolution of 0.1V.

11. Use Eqs. (1) and (2) to convert your measured voltages to temperatures. Importantly, use the values for the calibration constants A and B listed beneath Eq. (1).
12. Using Matlab, make a plot of the temperature T (units of degrees C) as a function of distance z (units of inches) down the copper pipe. Use the convention that $z = 0$ inches at the top and $z = -12$ inches at the bottom, as shown in Fig. 1b.
13. Remove the thermistor from the copper tube when you have finished collecting the data.
14. Email your results to your lab TA, Prof. Rumbach, and Prof. Ott for grading. See the "**Data Analysis and Deliverables**" section for details.
15. **IMPORTANT:** Ask Prof. Ott to grade your circuit and lab notebook.
16. Return the lab bench to its initial state:
    a. Turn off the digital multimeter and disconnect the cables.
    b. Disassemble the circuit on the breadboard.
    c. Return all resistors to the appropriate bins.
    d. Leave the heater ON. (Don't mess with the DC power supply and heater wires!)

Data Analysis and Deliverables

Please **email** the following deliverables to your lab section TA, Prof. Ott, and Prof. Rumbach (**all 3 of us** on the same email) with the subject line "LAB FINAL – AME20216".

A list of the TA email addresses can be found in Appendix B.

1. In the body of the email, type the following as **bullet points**:
    a. The **station number** of your lab bench. (Look for the green sign.)
    b. The **color** of the tape on the insulation.
    c. Are the red heater wires on the **top** or **bottom** of the pipe insulation?
    d. The heater **voltage**, **current**, and **power**.
2. Attach a plot of the temperature T (units of degrees C) as a function of distance z (units of inches) down the copper pipe. The plot should be saved as a PDF or JPEG.
3. Copy and paste the Matlab script you used to generate the plot into the body of the email below the bullet points from item 1. Do not attach it as a .m file.

Appendix A

Equipment Required

- Extech handheld DMM
- Keysight precision DMM
- Digital multimeter with minigrabber leads
- Breadboard with jumper wires
- Resistor kit (normally on lab bench)
- 10k Vishay NTC thermistor NTCLE413E213F102L (Digikey part # BC2647-ND)
- Lab stand with beaker clamp
- Variable DC power supply
- Insulated copper pipe with polyimide film heater
- Meter stick or ruler
- Rubber band
- Small binder clip
- Clothes pin
- Rubber band

Appendix B

TA Contact Info

Lab TAs

Mon. 3:00 – 5:00 – Ibu Akintola, iakintol@nd.edu

Tues. 1:00 – 3:00 – Philip Andrews, pandrew2@nd.edu

Tues. 3:30 – 5:30 – John Yost, jyost4@nd.edu

Weds. 3:00 – 5:00 – Thomas Hintz, thintz1@nd.edu

Thurs. 11:00 – 1:00 – Cody Cochran, ccochra4@nd.edu

Lab Instructors

John Ott – jott@nd.edu.

Paul Rumbach – prumbach@nd.edu