Sensor First Order Response

As discussed in lecture, the relationship between the input and output (the transfer function) of a sensor has both a static and dynamic component. The static part (sensitivity) is usual described by a simple equation or graph relating the input (parameter being measured) to the output (voltage, current, resistance, etc.). The dynamic part is usually described by a differential equation. The dynamic response of many types of sensors can be described (or closely approximated) by a first order differential equation. For these sensors, the dynamic parameter of interest is the ***time constant***. Recall that for a step change of the input to a first-order system, the output response (y(t)) can be described by the following equation:

$$y(t) = y_\infty + \left(y_0 - y_\infty\right)e^{-t/\tau}$$

Where y_0 is the initial value of the response, y_∞ is the final value of the response and τ is the time constant.

In this experiment the static transfer function and time constant of an electronic temperature sensor will be investigated. The sensor is an LM34CZ (see datasheet). This device is designed to provide an output voltage with a static sensitivity of 10mV/°F. The device has three leads; +V (red), Vout (yellow), and ground (black). The LM34CZ used in this lab has been sealed in a small tube to prevent moisture from coming in contact with the electrical terminals. A three-conductor cable has been attached to the device. (**The sensor and cable connections are fragile. Handle them carefully**.) Connect the cable wires to the NI USB DAQ unit as shown in Figure 1.

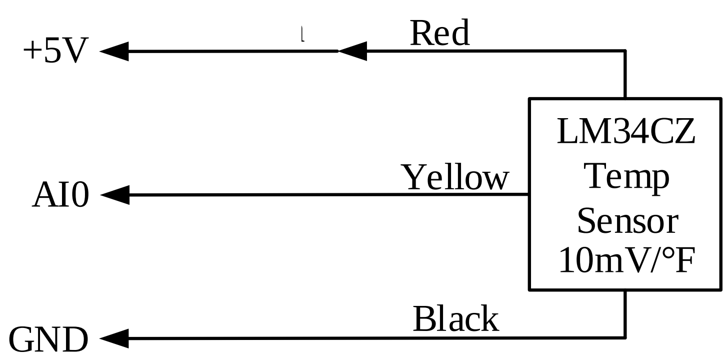

Figure 1. LM34CZ Wiring Diagram

Data will be obtained, displayed and saved using LabVIEW software and a USB DAQ unit. The laboratory instructor will provide you with the location of the software files.

Two temperature levels will be used to test the dynamic response of the LM34CZ. One temperature level will be maintained by a mixture of ice and water in a beaker. The other temperature level will be that of a beaker of room temperature water. The dynamic response of the temperature sensor will be measured by quickly transferring the sensor from one beaker to the other while measuring its output voltage at regular time intervals (~100ms).

The static sensitivity of the temperature sensor will be estimated by placing the sensor and a reference thermometer in a beaker of ice water then slowly heating the water to a temperature of about 50ºC. As the water is heated, the thermometer and temperature sensor output voltage readings will be recorded.

A thermocouple temperature probe with electronic signal processing unit connected to a DMM will be used as the temperature measurement reference.

Procedure

Time Constant

1. Connect the circuit shown in Figure 1.
2. Connect the USB DAQ unit to the lab PC with the provided USB cable. Wait for the blue LED on the DAQ unit to illuminate before proceeding.
3. Load the LabVIEW software to measure and chart the LM34CZ temperature sensor output voltage, "*LM34 Output Chart with NI USB DAQ.vi*"
4. Fill a small beaker about 1/3 full of water from the bottle provided. Add enough ice to make this beaker about 3/4 full. The mixture should be mostly ice.
5. Fill a large beaker about 1/2 full of room temperature water from the bottle provided.
6. Place the LM34CZ temperature sensor into the beaker of ice water. Gently move the sensor around in the mixture while keeping it submerged. Don't let the sensor touch the beaker sides or bottom as you are stirring.
7. Start the "*LM34 Output Chart with NI USB DAQ.vi*" by clicking the Run button. Monitor the output voltage of the LM34. When the voltage appears to stabilize, proceed to the next step.
8. Click the "Reset" button and quickly transfer the sensor to the beaker of room temperature water. Again, gently move the sensor around in the water while keeping it submerged.
9. Monitor the displayed LM34 output voltage. When the voltage appears to be changing very little, click the "Stop" button. Move the cursor into the charted data in the .vi window. Right click and select "X Scale" then "AutoScale X". Right click and select "Y Scale" then "AutoScale Y". Right click and select "Export" then "Export Data to Excel".
10. Repeat steps 8 – 10 except reverse the beakers. (Go from room temperature to the ice water bath.)

Static Sensitivity

11. Load the LabVIEW software to measure and display the LM34CZ temperature sensor output voltage, "*LM34 Output Voltage with NI USB DAQ.vi*"
12. Fasten the LM34 temperature sensor to the thermocouple probe with rubber bands. Be sure that the ends of the probes are as closely aligned as possible.
13. Using the larger beaker, add ice and water to form a mixture of about 200ml.
14. The hot plate power should be off, and the hot plate should be at room temperature. Place the large beaker (with the ice water, thermocouple probe, and LM34) onto the hot plate.
15. Click the "Run" button on the VI to start monitoring the sensor voltage.
16. Place the LM34/Thermocouple into the ice water bath. Allow the temperature and voltage readings to stabilize while gentle stirring the mixture. Add ice if necessary to obtain a thermometer temperature reading less than or equal to 5ºC. Pour out liquid water to keep about 200ml of ice water mixture in the beaker. Record the temperature and LM34 output voltage.
17. Set the hot plate power to position #7.
18. Carefully monitor the thermometer reading and the LM34 output voltage as the water heats up. Record the temperature and voltage readings for temperatures as shown in the table below. After taking the 50 ºC data, **immediately turn off the hot plate. Remove the beaker after it has cooled down.**
19. Be sure to turn off the power to the electronic signal processing unit connected to the DMM.

At the end of the experiment, please discard the water from the beakers in the bucket provided. Please wipe up any spills promptly. Thank you.

Nominal Temperature (ºC)	Actual Thermometer Reading (ºC)	LM34 Output Voltage (Volts)
(Ice-water slush)		
5ºC		
10 ºC		
15 ºC		
20 ºC		
25 ºC		
30 ºC		
35 ºC		
40 ºC		
45 ºC		
50 ºC		

Results

Part 1: Time Constant

An estimate for the time constant should be obtained by a linear least-squares fit using this data as discussed in class. (Something about taking the logarithm of the error fraction or something??)

Recall the Error Fraction…

$$\Gamma(t) = \frac{y_\infty - y(t)}{y_\infty - y_0} = e^{-t/\tau}$$

Note that your data will probably need to be shifted to account for the time delay when moving the LM34 temperature sensor between the two beakers. In other words, the t = 0 point should be adjusted and any long tail removed before calculating Γ(t).

Part 2: Static Sensitivity

1. Plot the LM34 output voltage vs. temperature and have Excel generate a trendline.
2. Determine the measured static sensitivity.
3. Compare the measured static sensitivity to the data sheet value.

Lab Report Tips

1. Read section 3.3 in the textbook BEFORE writing your report.
2. There are two separate experiments (Time Constant and Static Sensitivity) that are performed in this lab. Therefore, you will need two separate apparatus diagrams.
3. For the Time Constant experiment, you will capture a large amount of data. Do NOT include this data in your report in table format. Make a chart of this data (voltage vs. time) and include it in the Experimental Data section. Be sure to properly label the chart and axes, including the units on each axis. Rescale the axes to center the data, as necessary.
4. For the Static Sensitivity experiment, do include the full table on page 3 of the instructions in the Experimental Data section. You will probably want to enter this data into Excel for charting.
5. For the Time Constant results, there are no expected values for the time constants. You will need to extract the experimental time constants from the data. Note that you may need to truncate some of the data that was gathered. If you have a flat line at the beginning of the data, that should be removed. And, if there is a long tail at the end of your data with the voltage not changing, that can also be removed. The data you operate on should look like the graphs on slides 4 and 5 of the ME345W_Zero_and_First_Order PowerPoint file posted on Canvas. You will then take this truncated data and manipulate it to make a chart in Excel that looks like slide 8 of this PowerPoint file.
   Even though there is no expected value for the time constants, you can still check the time constant values that you extracted from the experimental data against the experimental data. These checks won't tell you if your results match theory, but they do ensure that your calculations were correct. Include these checks in your report in the Summary of Results section.