Instrumentation and Measurement

Lab 3

Sensor Dynamic Characteristic

Date the Lab was performed (mm-dd-yy):01 / 26/2024

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Revision Number: Winter 2024

Submission Instruction:

Review the lab report before submitting and put a check mark (√) in the appropriate check box on the left if the item has been duly completed in your lab report. The bracket on the right side will be filled out by your instructor with your gained mark.

1. Scan and create .pdf of all pages.
2. Combine ALL pages of your lab report into a SINGLE .pdf file. Meaning, do not submit each Page of your lab report as a separate file
3. The lab report file must be named in the following manner: "Your First Name_YourLast Name.pdf",
4. Upload and submit the pdf of your lab report in Blackboard.

Marking:

☐	Section 1	[ ] / 15
☐	Section 2	[ ] / 15
☐	Section 3	[ ] / 20
☐	Assignment	[ ] / 50

Every 20 minutes late is subjected to 10 marks deduction from attendance.

Sensor Dynamic Characteristic

Objective:

1) Sensing the temperature by a resistor
2) Converting resistant change to electrical current
3) To observe the sensor dynamic response and analyze the sensor dynamic characteristic
4) Finding the sensor response time

1) RTD as A Sensing Element

1-1) The electrical resistance of the materials depends on the temperature. For example if the temperature of a copper wire increases then the resistance against electrical current will increase. This property is used to measure temperature and devices working with this concept are called RTD. RTD stands for Resistance Temperature Devices. An RTD is presented in Figure (L3-1). Take one of RTDs from the cabinet and measure the resistance between Red and Black wire.

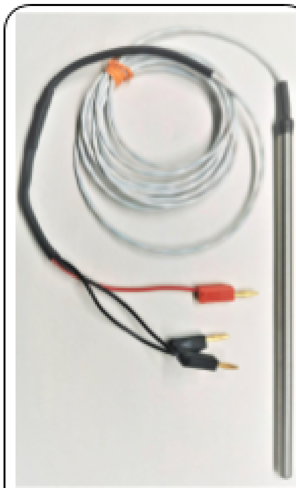


Figure (L3-1) - RTD

Resistance Value : 108.8 Ω

1-2) Take a water boiler and two glasses. Boil the water and fill one of the glasses with the boiled water and the other glass with the tap water. First put the sensor head in tap water and measure the resistance between red and black wire. Wait until the reading becomes stable. Then repeat the same experiment with hot water and record the value.

Resistance value for tap water: 108.5 Ω   Resistance value for hot water: 133.1 Ω

Change of Resistance = ΔR = $R_{Hotwater} - R_{Coldwater}$ = 133.1 − 108.5 = 24.6 Ω

Instructor Signature for section 1 ....

2) Converting the sensed quantity to Electrical Signal:

2-1) An RTD temperature Transmitter (LabVolt 6543-00) presented in Figure (L3-2) can be used to convert the RTD's ohm change to the electrical signal. Take one from the cabinet and set it up as below.

a. Provide a 24 VDC power supply to the module.
b. Connect the RTD red, black, black wires of the RTD to the module "100 Ω RTD" input socket.
c. Make "CALIBRATION SELECTOR" switch on "FIXED 0-100 ℃ "

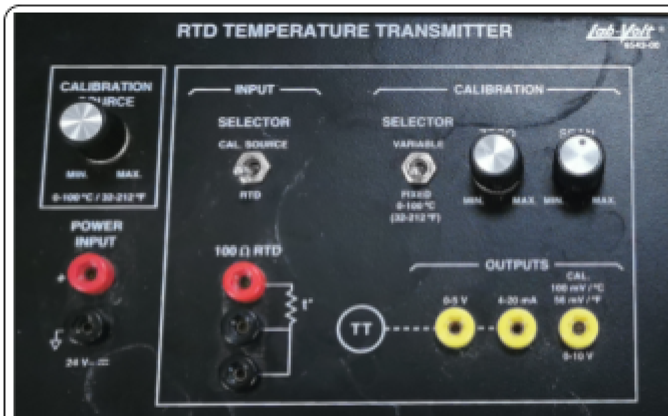


Figure (L3-2) - RTD Transmitter

2-2) Put the RTD in the tap water and measure the electric current which comes out of the "OUTPUTS 4-20 mA" socket of the module with a multimeter. Wait long enough until the measured mA stabilizes and write the value below. Repeat the same for Hot water

Transmitter output for tap water: 7.37 mA   Transmitter output for hot water: 16.85 mA

Instructor Signature for section 2 ....

3) Making Graph for measurement values:

3-1) Start the LVProsim software as it is explained in LAB 2. If you don't remember how, follow the instructions related to LVProsim startup procedure from the file in the blackboard.

3-2) After the LVProsim is started, In menu bar click on SETTINGS > SAMPLING INTERVAL and select 100 MS. Here is where you are setting up your software to read the measurement every 100 millisecond.

3-3) Again click on SETTINGS in Menu bar > SETTINGS > SET CHANNELS and fill out the form as Figure (L3-3) shows and click OK .

3-4) In the main screen of LVProsim you can see a window for the monitored variables. Click on the drop down menu and select "Temperature" and then *click on ADD*, after step 9 you should be able to see Figure (L3-4).

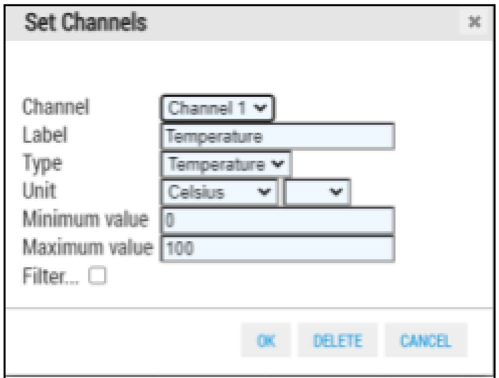


Figure (L3-3)

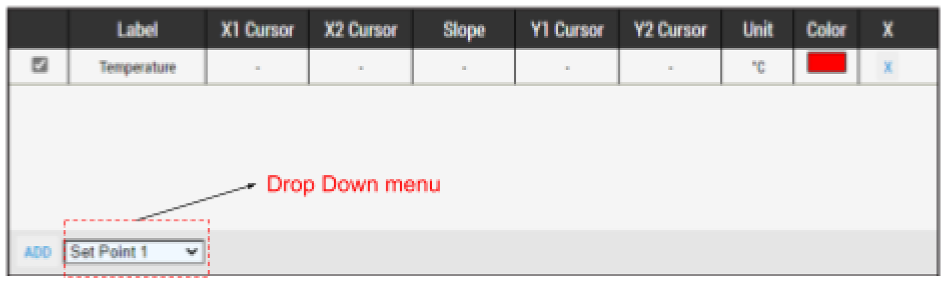


Figure (L3-4)- LVProsim User interface

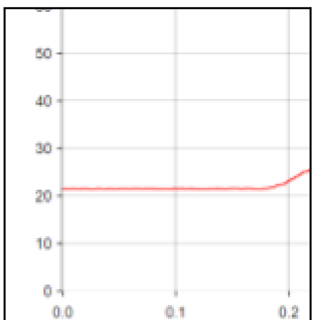


Figure (L3-5)

3-5) Connect to the 4-20 mA output of the RTD transmitter to the Input 1 of the interfacing module. wait a few seconds then you should be able to see a graph generated about 20 ℃ as Figure (L3-5) shows.

3-6) Now put the RTD in tap water and wait for a few seconds until your reading becomes stable(the graph will become flat).

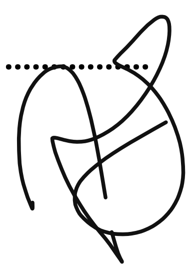
3-7) Then put the RTD in the hot water and look at the reading graph. The measured temperature will rise slowly and reach a final value. Pause the graph.

3-8) To read the time axis and Y axis. You can turn on the X and Y cursor as the example in Figure (L3-6) shows.

3-9) Put the Y cursors on the initial output and the final output and the X1 cursors on the trend starting time to rise and X2 on the settling time. Now take a screenshot *<u>from the whole page</u>* to submit. In your screen shot X1, X2, Y1 and Y2 values should be present similar to the Figure (L3-6).

Figure (L3-6)

Instructor Signature for section 3 ....



Assignment:

1) Consider your measurement in step 1-2, If we know the resistance of RTD at 0 ℃ is equal to 100 Ω and $\Delta R = R_0 \times \alpha \times \Delta T$ and $\alpha = 0.00385$. Calculate the tap and hot water temperature (Show calculations in steps) . α is known as temperature coefficient. It is a fixed value for every type of material. The RTD here is made of platinum.

Tap water: 22.08 ℃

$\Delta R = R_0 \cdot \alpha \cdot \Delta T$

$\Delta R = (108.5 - 100) = 8.5$

$\Delta T = \frac{\Delta R}{R_0 \cdot \alpha}$

$\Delta T = \frac{8.5}{100 \cdot 0.00385}$

$\Delta T = \frac{8.5}{0.385}$

$\Delta T = 22.08$

Hot water: 85.97 ℃

$\Delta R = 133.1 - 100 = 33.1$

$\Delta T = \frac{\Delta R}{R_0 \cdot \alpha}$

$\Delta T = \frac{33.1}{100 \cdot 0.00385}$

$\Delta T = \frac{33.1}{0.385}$

$\Delta T = 85.97$

2) Consider your measurement in step 2-2. The RTD as sensing element and The transmitter together make a temperature sensor. This sensor is a linear sensor and its measurement range is 0-100 ℃ and the output range is 4-20 mA. Calculate the measured temperature from measured mA in step 2-2 and show calculations in steps.

Tap water: 21.06 ℃

$O = a \cdot I + b$

$a = \frac{\Delta O}{\Delta T} = \frac{20-4}{100-0} = 0.16 \text{ mA/°C}$

$b = 4 \text{ mA}$

$7.37 = 0.16 \cdot I + 4$

$I = \frac{7.37 - 4}{0.16}$

$= 21.06$

Hot water: 80.31 ℃

$16.85 = 0.16 \cdot I + 4$

$I = \frac{16.85 - 4}{0.16}$

$= 80.31 °C$

3) Use the graph to find the time constant of the RTD and Transmitter as one instrument. Submit the graph indicating how you calculated the response time with your lab report.

Time Constant 7800 ms

$O_T = 20.556 + (70.22 - 20.556) \cdot 0.63$

$= 51.84$

$= 0.78 \text{ min}$

$0.78 - 0 - 0.639 = 0.131 \text{ min} \cdot 60\,000$

$= 7800 \text{ ms}$

4) Calculate the settling time and response time of the sensor.

Settling Time 39000 ms

$= 5 \cdot 7800$

$= 39000 \text{ ms}$

Response Time 31200 ms.

4×7800

$= 31200 \text{ ms}$

5) Develop and write the equation to calculate the temperature for every moment of time then calculate the measured temperature at second 3.

Measured Hot water temperature at second 3: .... ℃

$O_T = O_i + (O_A - O_i) \cdot (1 - e^{-\frac{t}{\tau}})$

$O_T = 21.06 + ((80.31) - 21.06) \cdot (1 - e^{-\frac{t}{7.8}})$

$= 39.98 °C$