Lab Report: Long term data acquisition using LabView

Chanon Janesiripanich 6205026

1 Lab objectives

1. To learn about using LabView along with other instruments to gather measurement data over a long period of time.
2. To determine the cooling constant in Newton's law of cooling of an insulated tumbler.

2 Lab equipments

1. A thermistor
2. A USB-6009 DAQ along with a PC with LabView installed
3. Three 3.3kΩ resistors
4. A prototype board for building the measurement circuit along with electrical wires
5. A thermometer
6. An insulated tumbler
7. A digital multi-meter

3 Determining the calibration curve of the thermistor

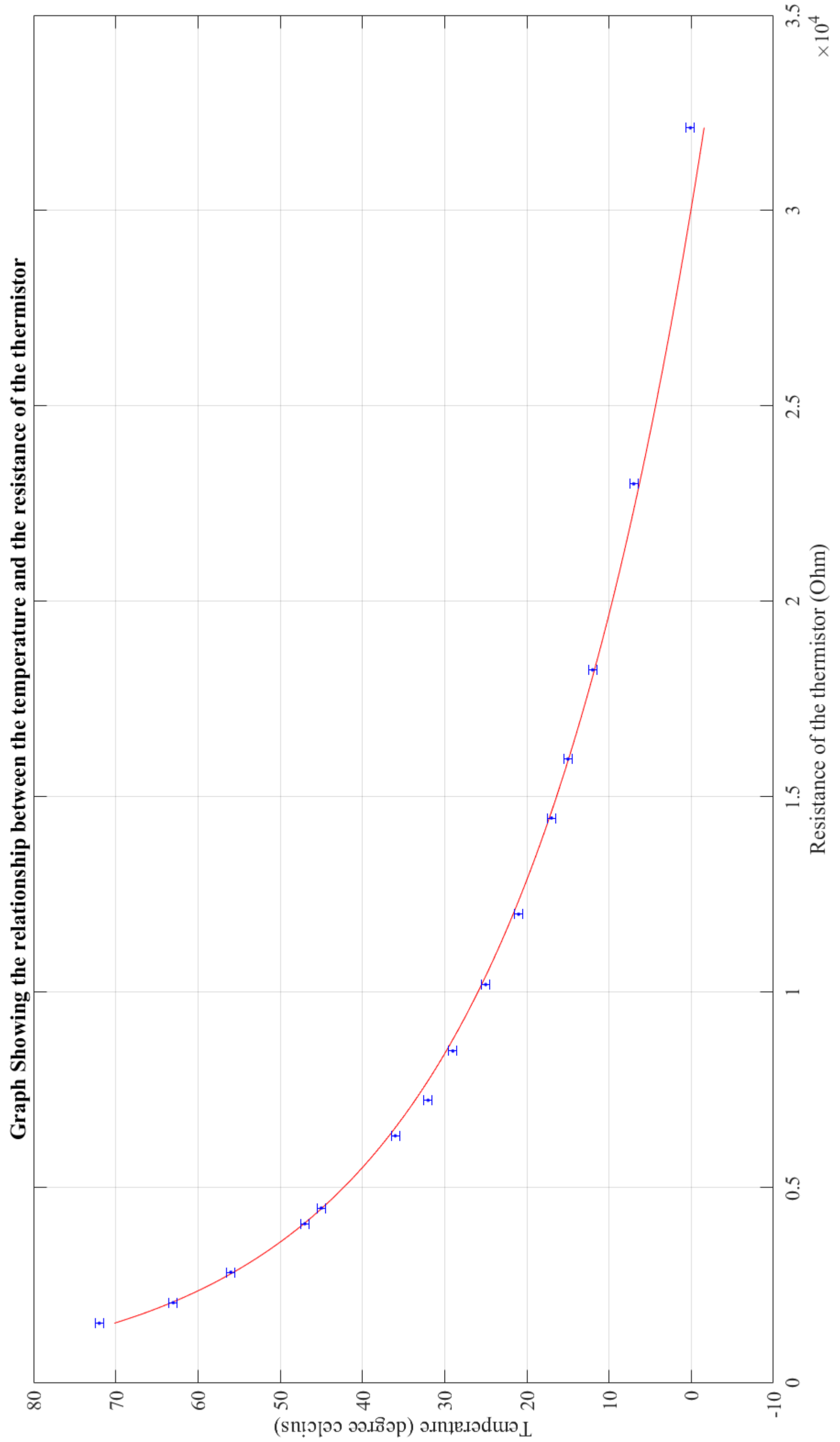
A thermistor is a type of temperature-sensitive resistor. Normally a reference temperature-resistance reference sheet will be provided along with the thermistor. However, in this experiment, the reference data sheet is not provided. Hence, it is necessary that the calibration curve showing the relationship between the temperature of the thermistor and its temperature be determined.

The calibration curve is determined by submerging both the thermistor and the temperature in a container fill with water which is at a certain temperature. The temperature and the resistance of the thermistor is then measured using the thermometer and the digital multi-meter. From the gathered data, we have fitted the calibration curve using the equation

$$T = a - b\ln(R)$$

Where T and R are temperature and resistance respectively. The results of the curve fitting are as follow

$$\boxed{a = 243 \pm 5,\ b = 23.6 \pm 0.5}$$



Graph Showing the relationship between the temperature and the resistance of the thermistor
Temperature (degree celcius)
Resistance of the thermistor (Ohm)
$\times 10^4$
-10
0
10
20
30
40
50
60
70
80
0
0.5
1
1.5
2
2.5
3
3.5

4 Determining the cooling constant of the insulated tumbler systems

Newton's Law of Cooling stated that the change in temperature between any two system can be written as

$$\frac{\mathrm{d}T_1}{\mathrm{d}t} = k(T_2 - T_1)$$

In our cases, the two systems are the insulated tumbler along with the water inside it and the environment. Since the environment is kept at 25°C we can solve the differential equation to get

$$T = T_R - (T_R - T_0)e^{-kt}$$

For cases where $T_R > T_0$ and

$$T = T_R + (T_0 - T_R)e^{-kt}$$

For cases where $T_R < T_0$

To determine the constant k of the insulated tumbler systems, we created a bridge circuit in order to determine the resistance of the thermistor.

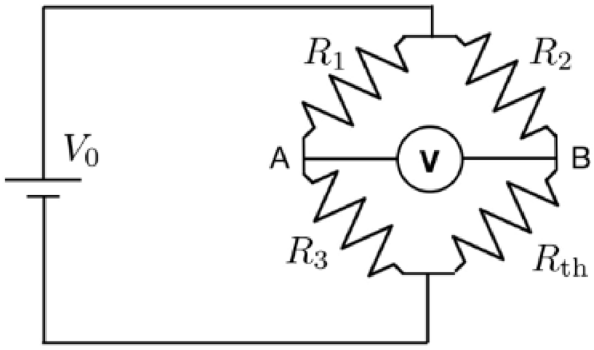


Figure 1: showing the bridge circuit used in this experiment

In our cases, we use $R_1 = R_2 = R_3 = 3.3\mathrm{k}\Omega$ and $V_0 = 4\mathrm{V}$. From the circuit diagram shown in Figure 2, we can determine the relationship between the voltage difference between each end of the bridge to be

$$V = V_0\left(\frac{R_3}{R_3 + R_1} - \frac{R_{\mathrm{th}}}{R_{\mathrm{th}} + R_2}\right)$$

Where R_{th} is the resistance of the thermistor. If we put in the value of known parameters and isolate the term with R_{th}, we will have

$$R_{\mathrm{th}} = (3.3\ \mathrm{k}\Omega)\left(\frac{2 - V}{2 + V}\right)$$

The Voltage difference measurement is done by the DAQ. The voltage difference of the bridge voltage is converted to the resistance of the thermistor and then the temperature of the system using the equations above and the calibration curve shown previously.

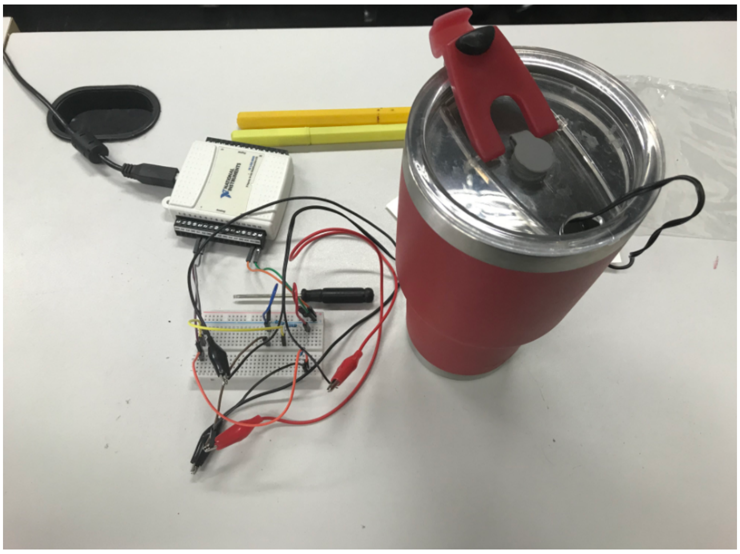


Figure 2: Picture of the experimental setup

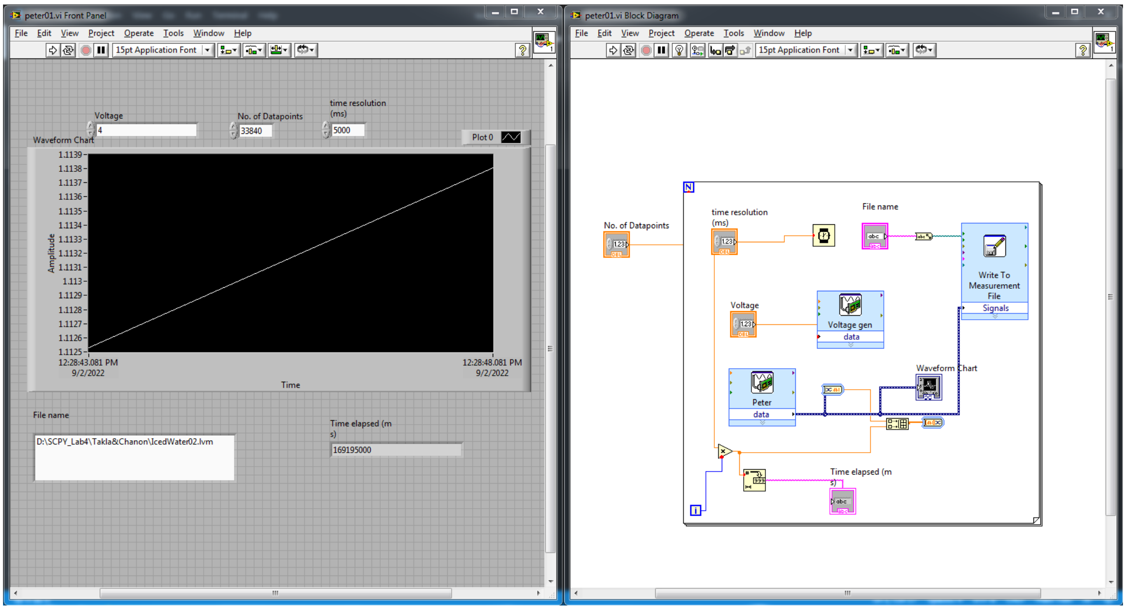


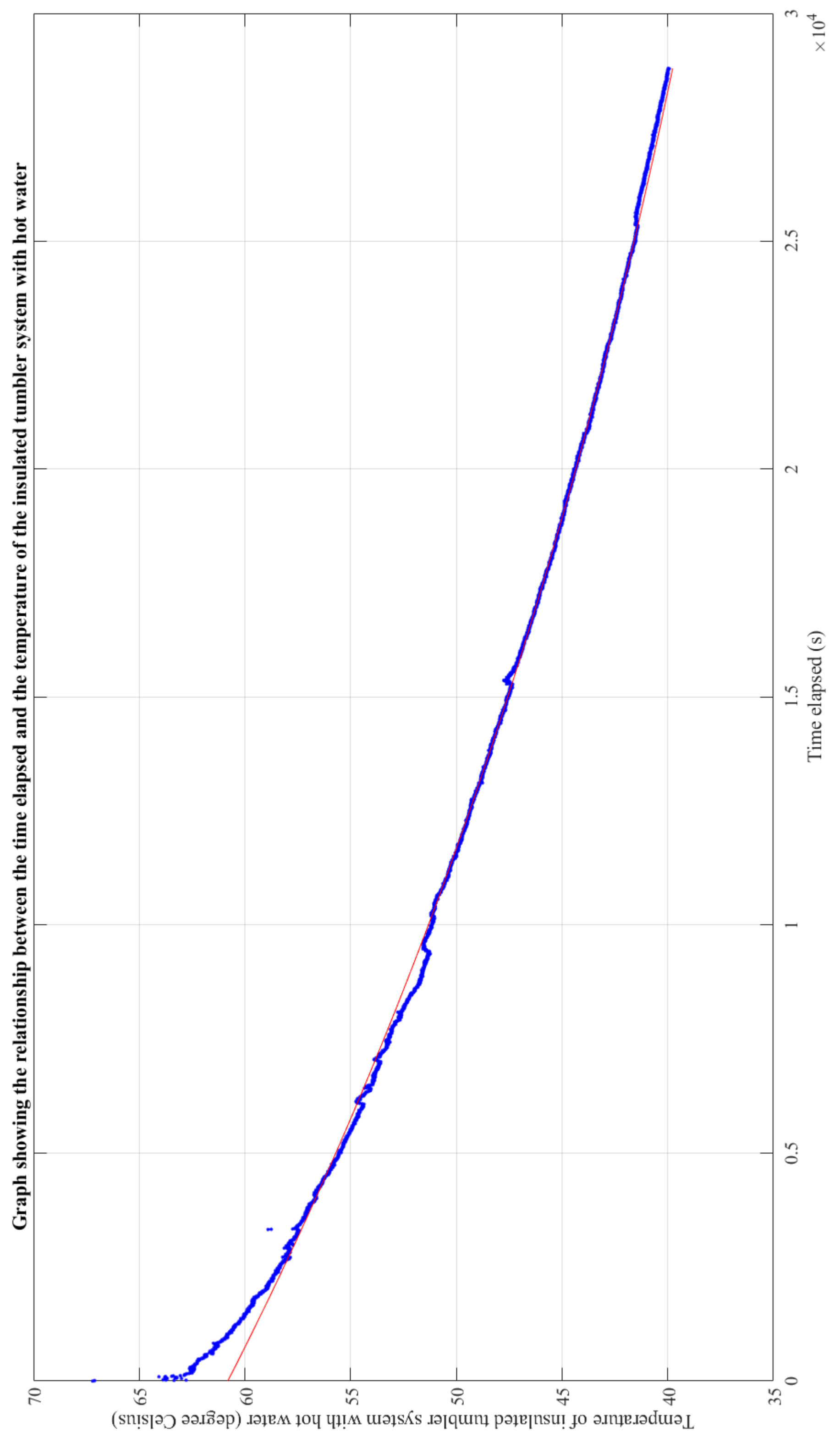
Figure 3: Picture of the LabView program written to perform the long term data acquisition

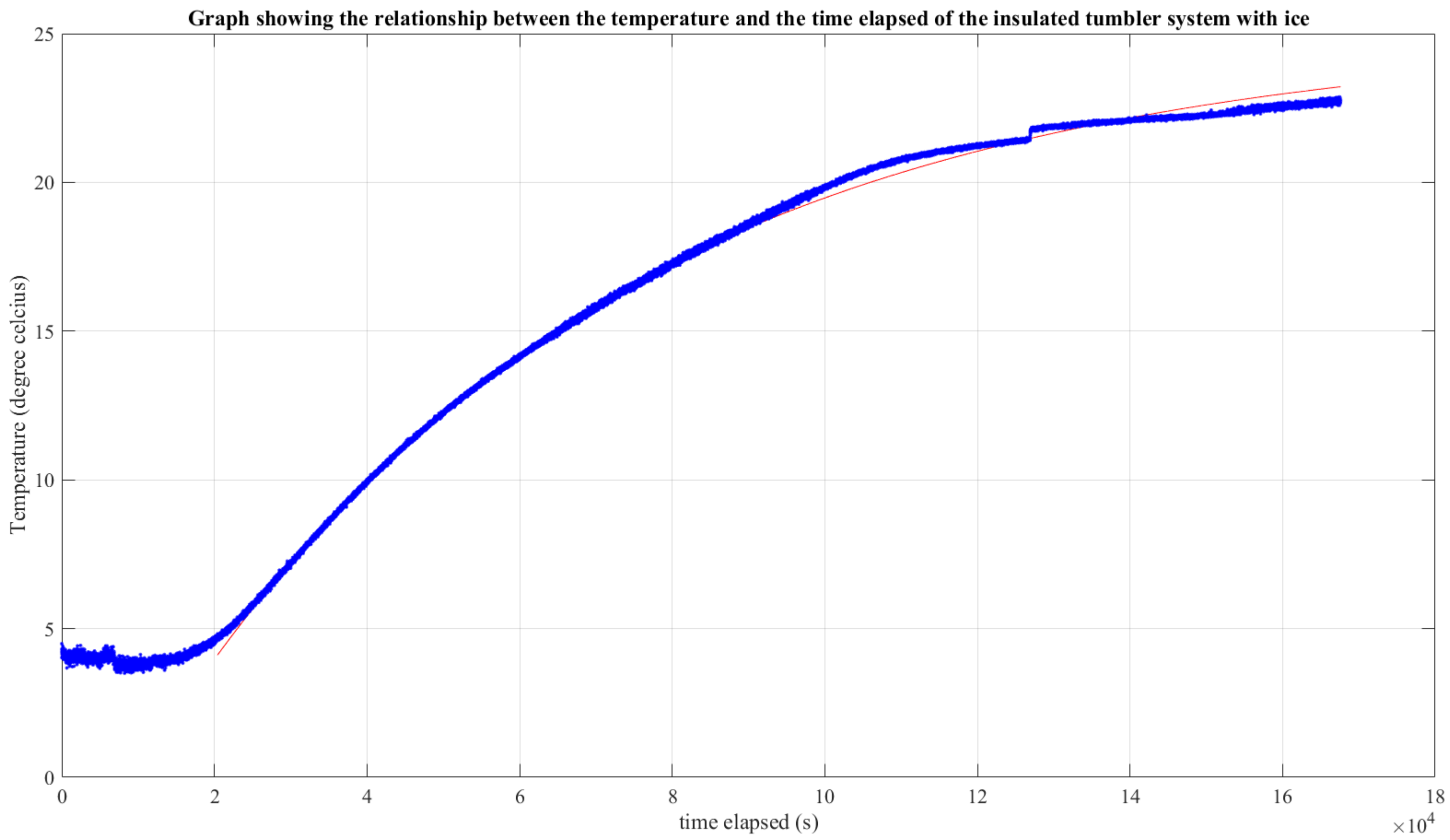
The first insulated tumbler system that we performed the experiment on initially contain some amount of hot water, the data is then acquired by the DAQ every 5 seconds for 8 hour. The data gathered is then processed using the equations and calibration curve mentioned above. The temperature data is then fitted with the solution of the Newton's law of cooling. From the curve fitting, we have determined the cooling constant k_{hot} to be

$$\boxed{k_{\text{hot}} = (3.077 \pm 0.001) \times 10^{-5}}$$

The second insulated tumbler system that we performed the experiment on initially contained some amount of iced water. Data acquisition method and data analysis method are the same as the previous system. From curve fitting, we have determined that the cooling constant is

$$\boxed{k_{\text{cold}} = (1.671 \pm 0.002) \times 10^{-5}}$$


Graph showing the relationship between the time elapsed and the temperature of the insulated tumbler system with hot water
Time elapsed (s)
Temperature of insulated tumbler system with hot water (degree Celsius)
$\times 10^4$
0
0.5
1
1.5
2
2.5
3
35
40
45
50
55
60
65
70


Graph showing the relationship between the temperature and the time elapsed of the insulated tumbler system with ice
Temperature (degree celcius)
0
5
10
15
20
25
time elapsed (s)
0
2
4
6
8
10
12
14
16
18
$\times 10^4$

5 Conclusion, questions and answers

5.1 Conclusion

In this experiment, we have learned how to use LabView along side DAQ to perform long-term data acquisition. We have determined the calibration curve of the given thermistor. We also have determined two cooling constants of two different tumbler system to be $k_{\text{hot}} = (3.077 \pm 0.001) \times 10^{-5}$, $k_{\text{cold}} = (1.671 \pm 0.002) \times 10^{-5}$. Additionally, in the data acquired from the cold tumbler system, we can see that since the system initially starts with ice, the temperature of the system briefly stay the same. This is due to the ice slowly melting away. After some time, the ice all melts back into water and the system starts behaving according to Newton's law of cooling.

5.2 Questions and Answers

1. What's the range of the temperature measured in this experiment? At which resistance of the thermistor do the temperature values measured in this experiment relates to?
   - The temperature measured in this experiment ranges from $0°\text{C} - 70°\text{C}$. Which corresponds to 1.5kΩ-33kΩ
2. What's the appropriate values of R_1, R_2, R_3 used in the bridge circuit?
   - The appropriate values of R_1, R_3 should be in the same order as one another and the value of R_3 should be in the same order as the resistance of the thermistor. This is because by using the appropriate values of R_1, R_2, R_3, we can be sure that the bridge voltage will be somewhat centered around 0 and thus increasing the data resolution of the acquired voltage.
3. If the DAQ used in this experiment operates at 14-bit. What is the resolution of the data acquired.
   - according to $V_{\text{resolution}} = V_{\max}/2^n$ where n is the amount of bit. In our cases, we set the maximum voltage the DAQ will be able to acquire to be at 4V. This implies that the resolution will be $V_{\text{resolution}} = 4/2^{14} \approx 0.0002$
4. What's the benefit gained from acquiring data over 6 days instead of 6 hours
   - The longer time other benefits besides the increase in data points such as observing interesting change in the system such as the ice-melting period and the convergence on the ambient temperature of the system.
5. What's the benefit of using the bridge circuit?
   - It allows us to maximize resolution of the data gathered by DAQ by making the data gathered somewhat centered around 0. Additionally, it also allowed us to measure the voltage difference of the bridge circuit which is arguably more precise than measuring the resistance of the thermistor directly.