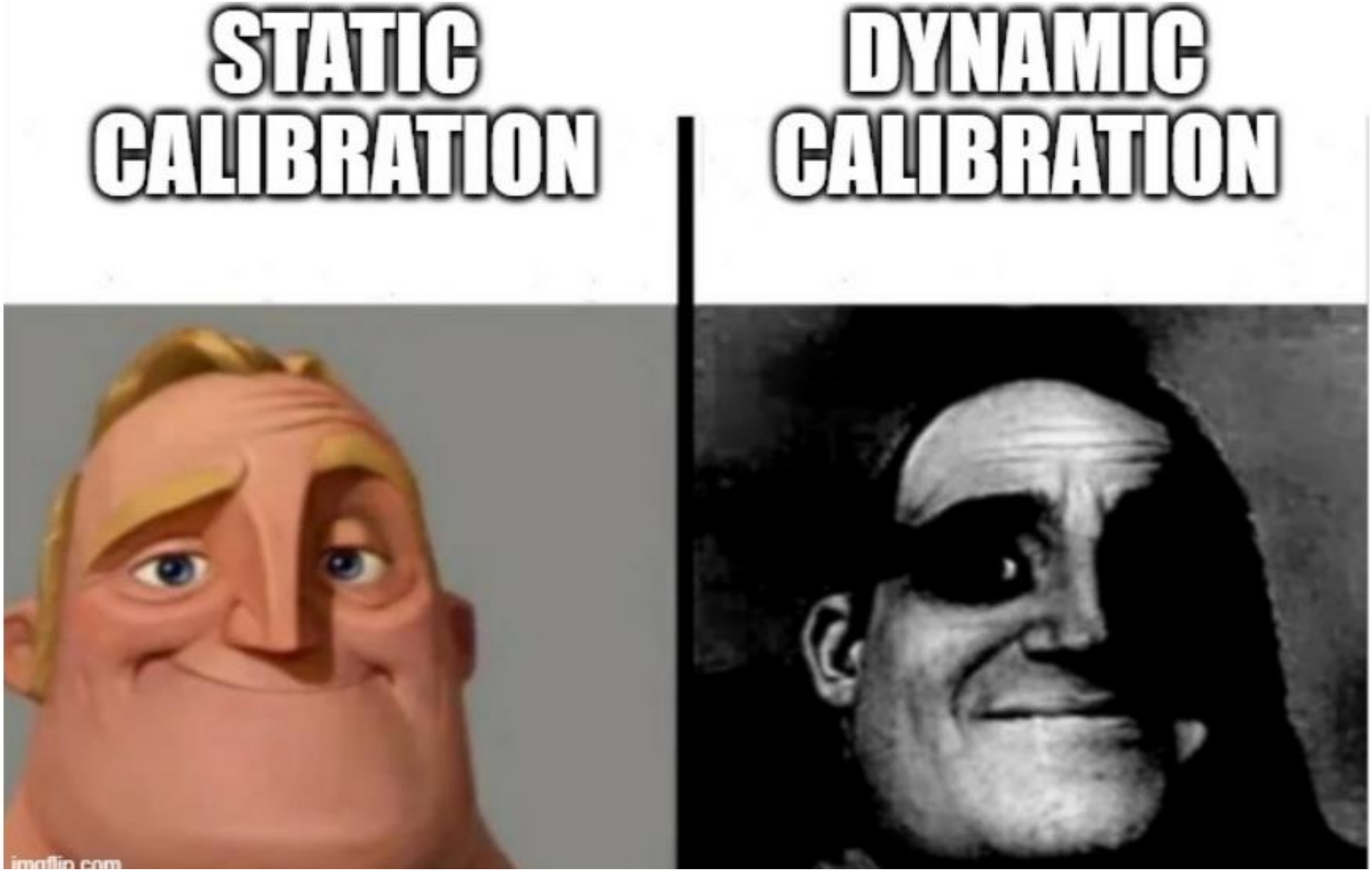
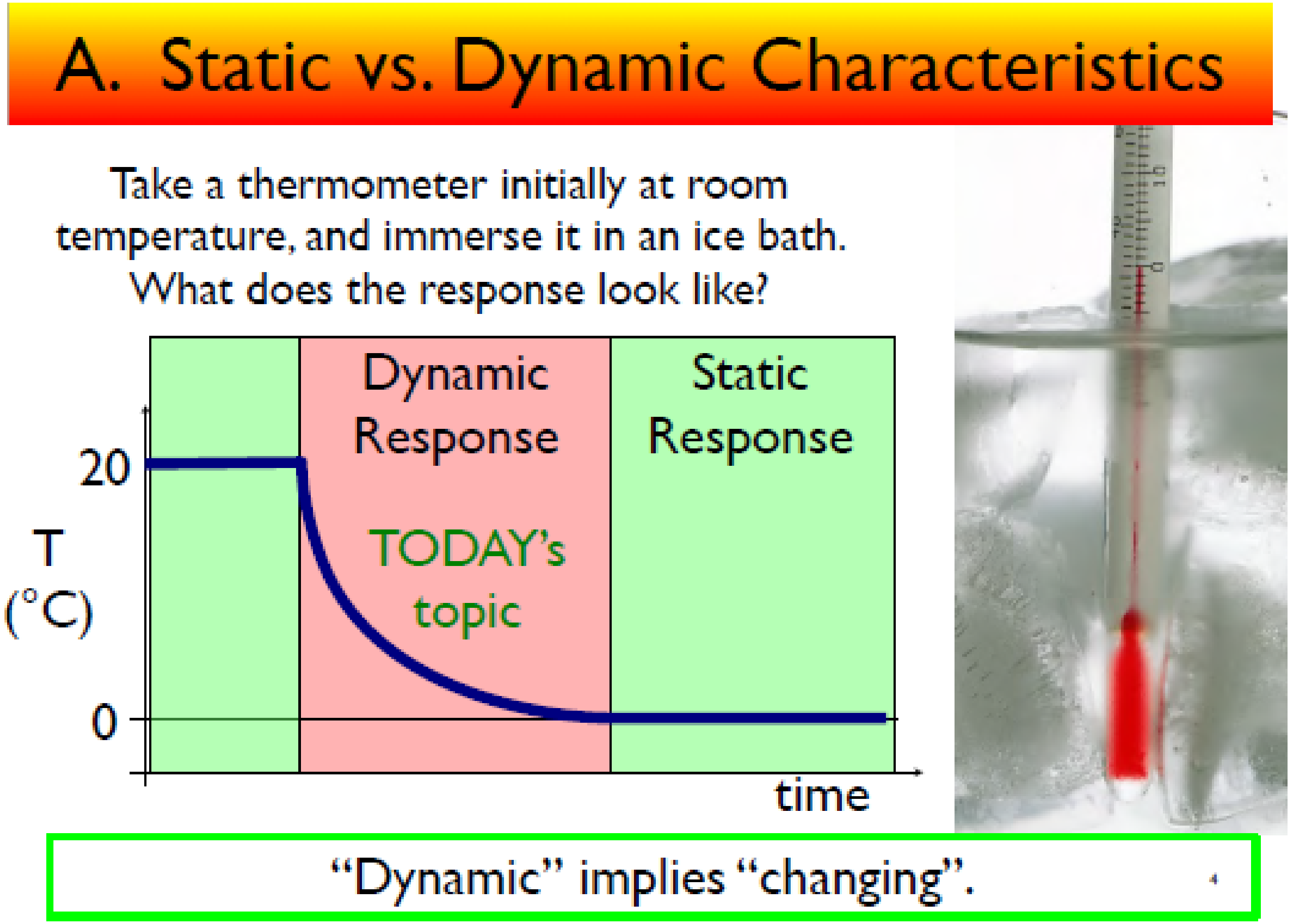
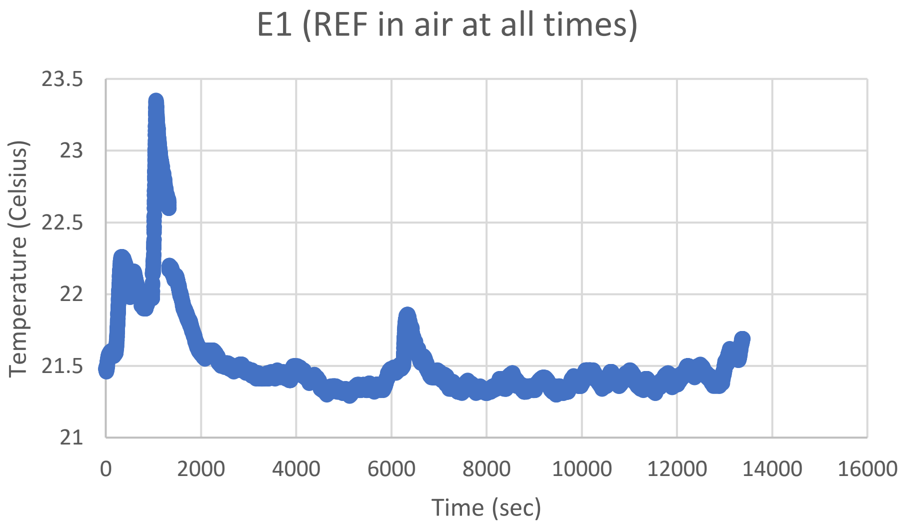

STATIC CALIBRATION
DYNAMIC CALIBRATION

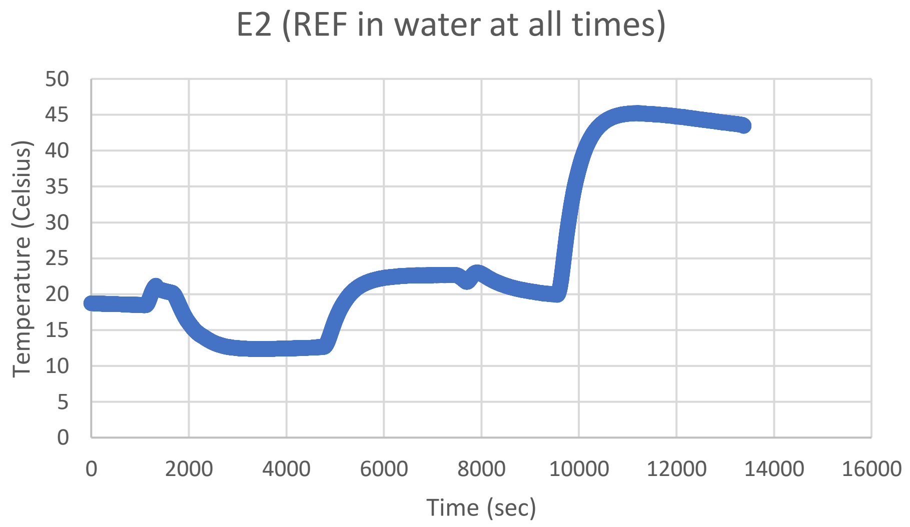
Concept overview

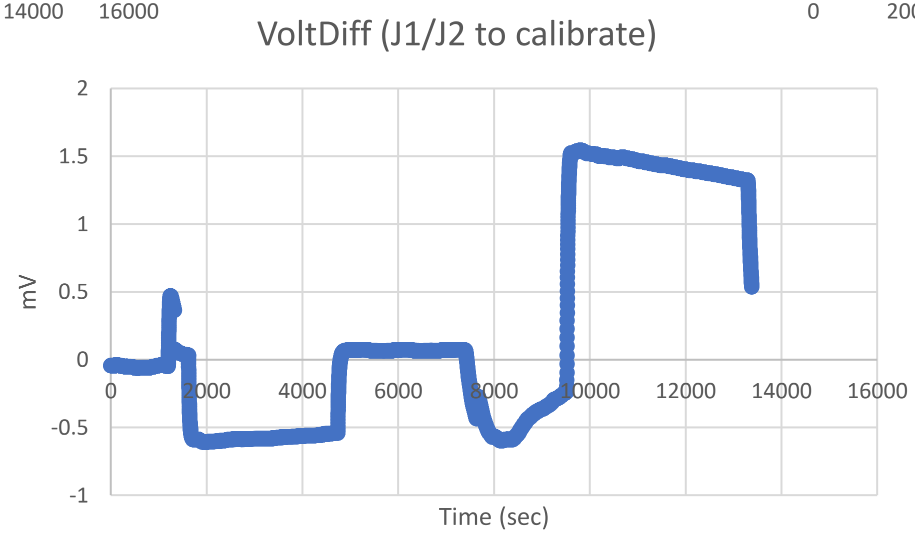


(Stull, 2023)

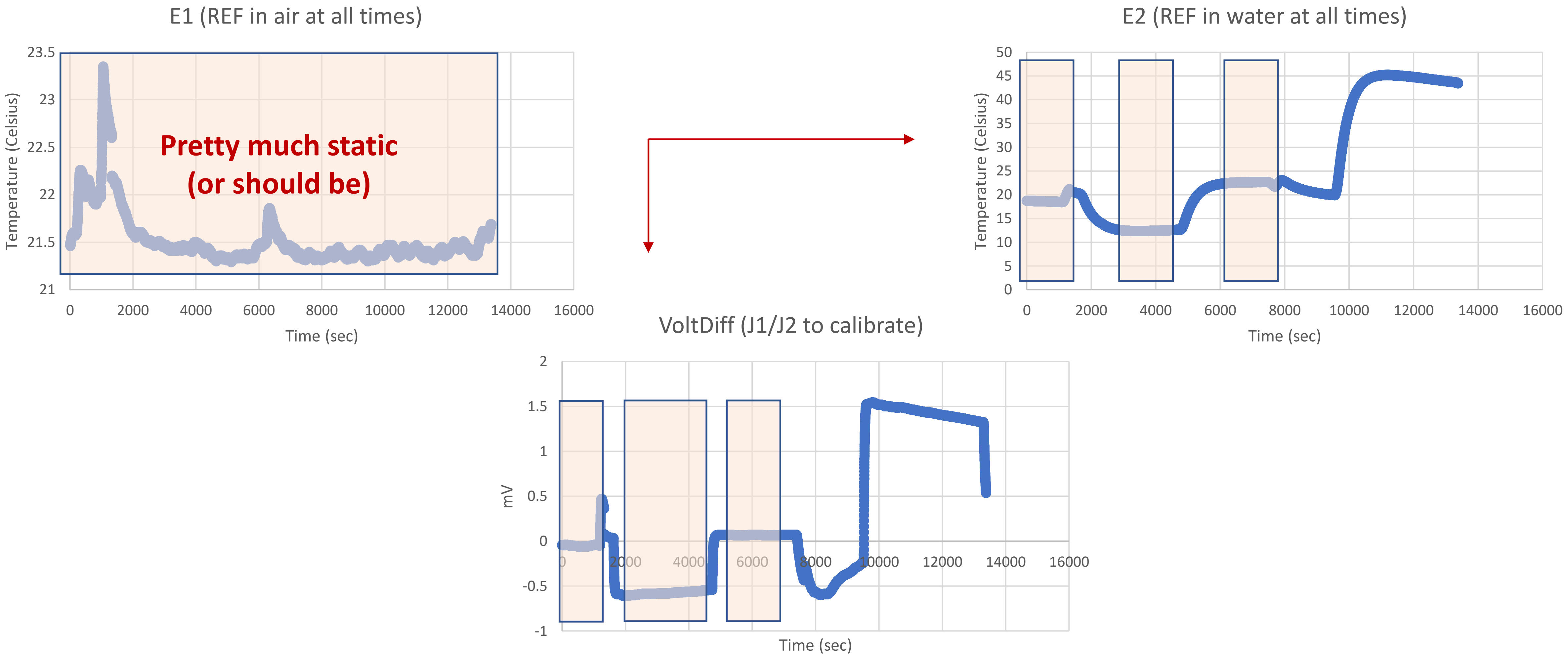
Data (raw)


E1 (REF in air at all times)
Temperature (Celsius)
23.5
23
22.5
22
21.5
21
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (sec)

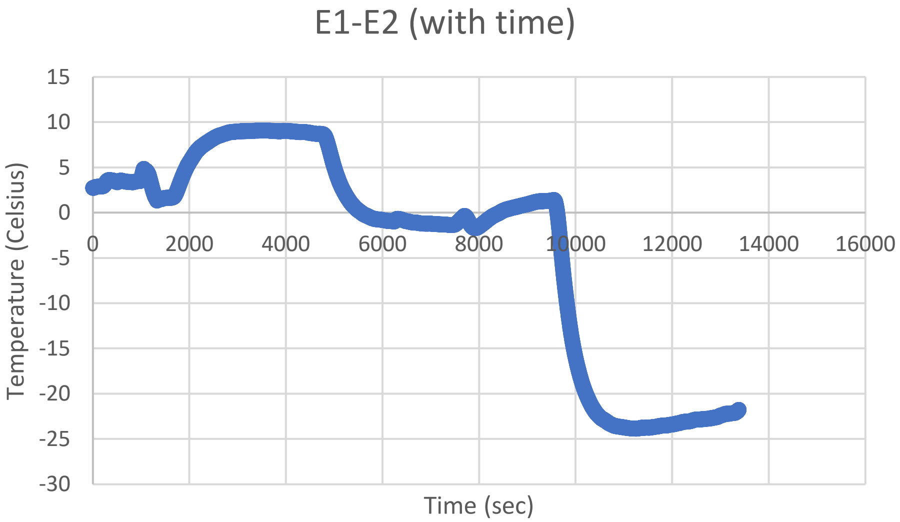

E2 (REF in water at all times)
Temperature (Celsius)
50
45
40
35
30
25
20
15
10
5
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (sec)

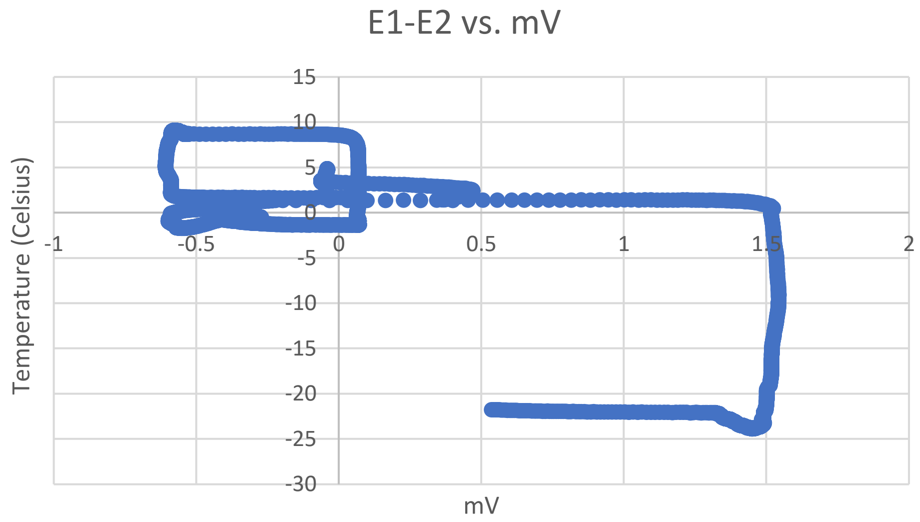

VoltDiff (J1/J2 to calibrate)
mV
2
1.5
1
0.5
0
-0.5
-1
0
2000
4000
6000
8000
10000
12000
14000
16000
Time (sec)

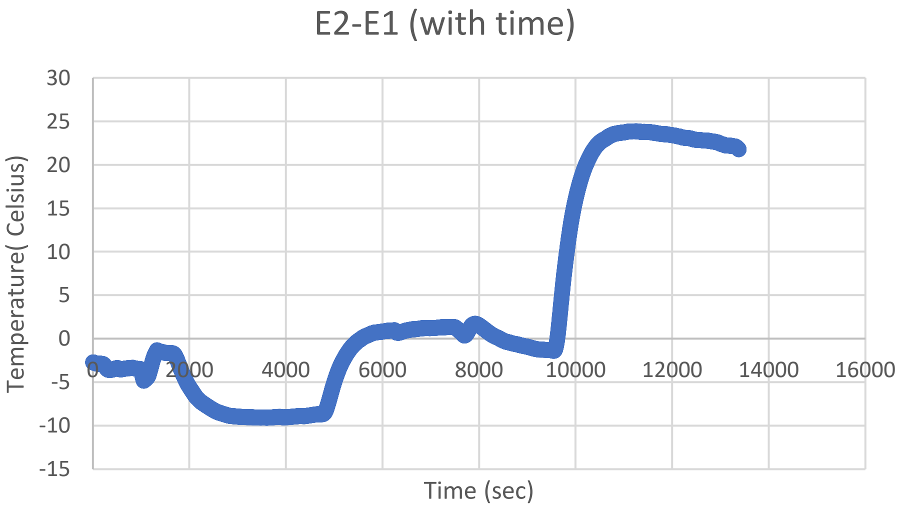
Data (raw)

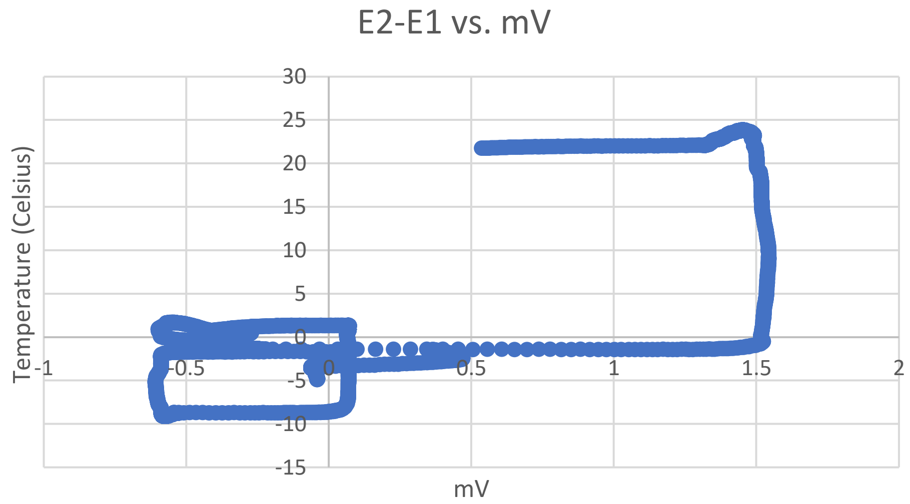

E1 (REF in air at all times)
Pretty much static
(or should be)
Temperature (Celsius)
Time (sec)
E2 (REF in water at all times)
Temperature (Celsius)
Time (sec)
VoltDiff (J1/J2 to calibrate)
mV
Time (sec)

Calibration curve / Transfer Equation

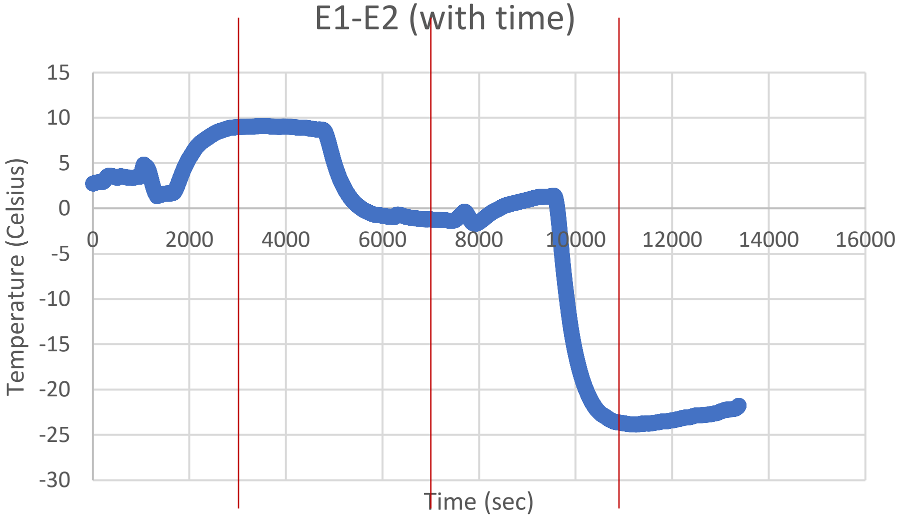


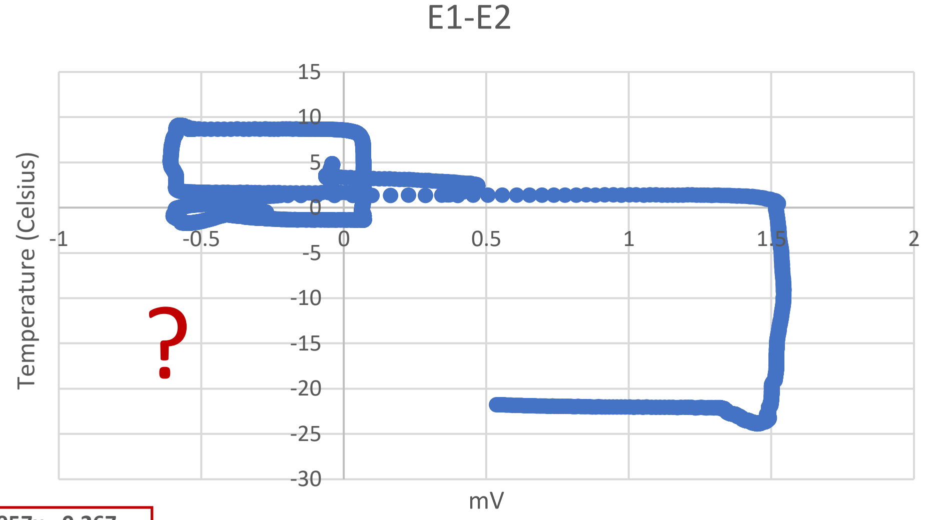


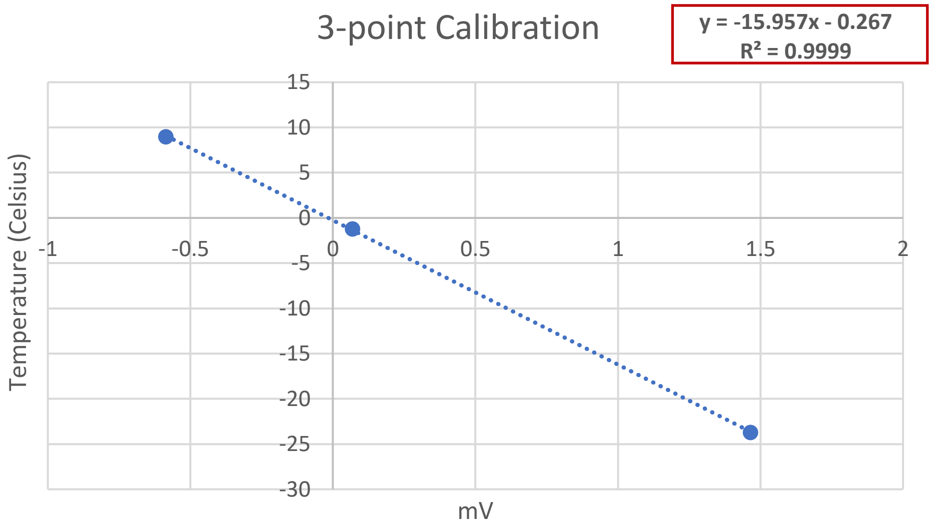




Calibration curve / Transfer Equation

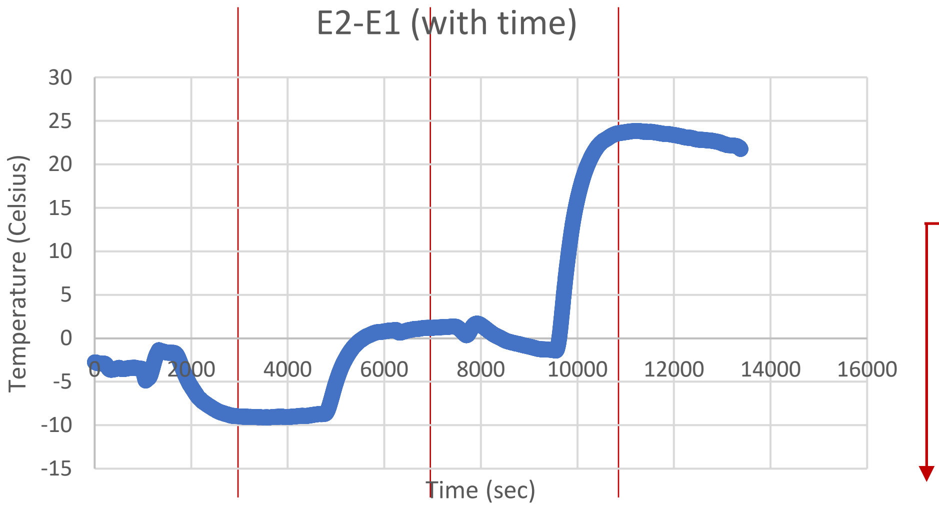


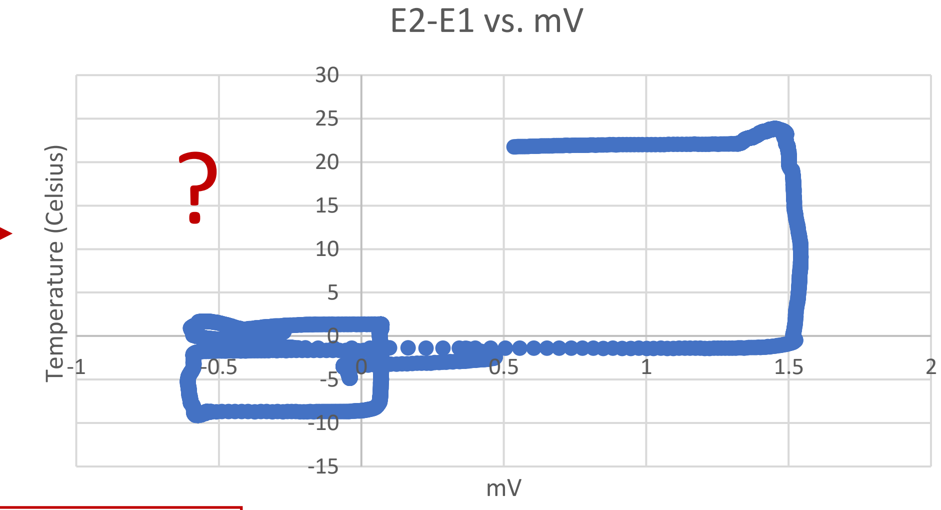


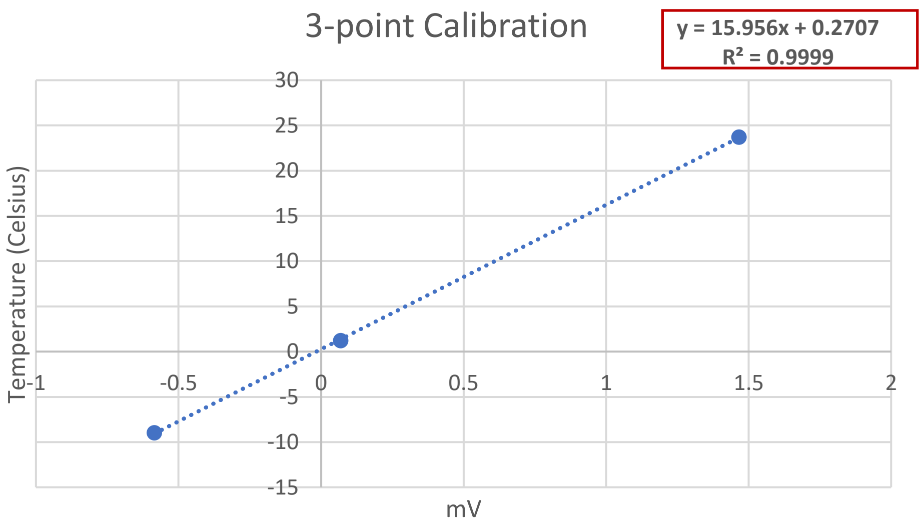


Explains the temperature difference between E1 and E2 (ref) readings for every change in mV (to be calibrated)

Calibration curve / Transfer Equation



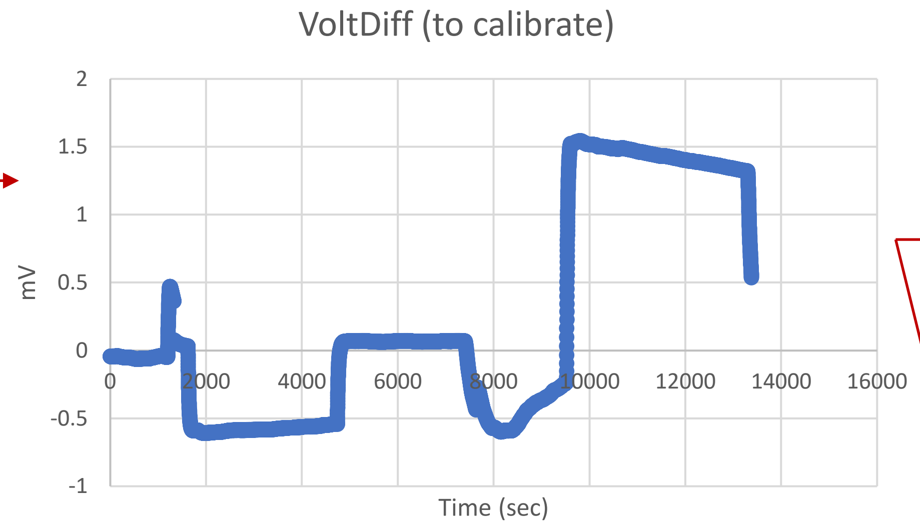


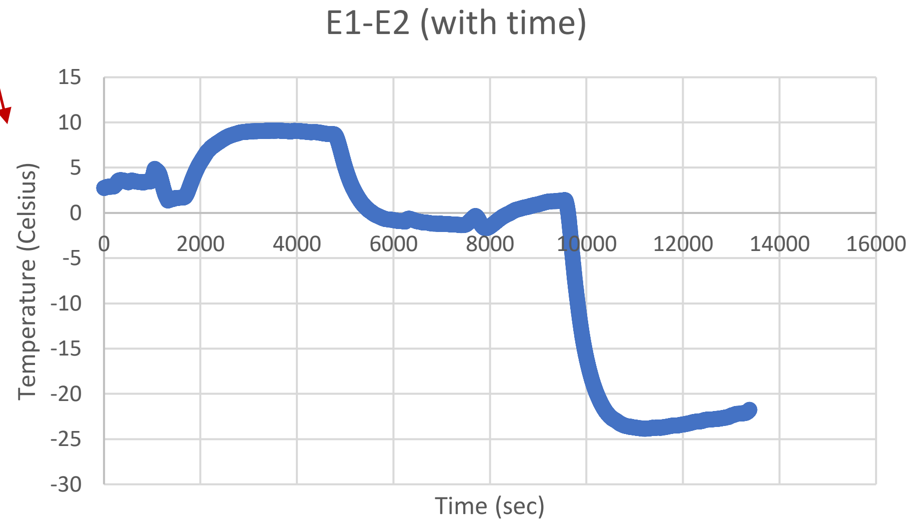


Explains the temperature difference between E2 and E1 (ref) readings for every change in mV (to be calibrated)

Calibration curve / Transfer Equation

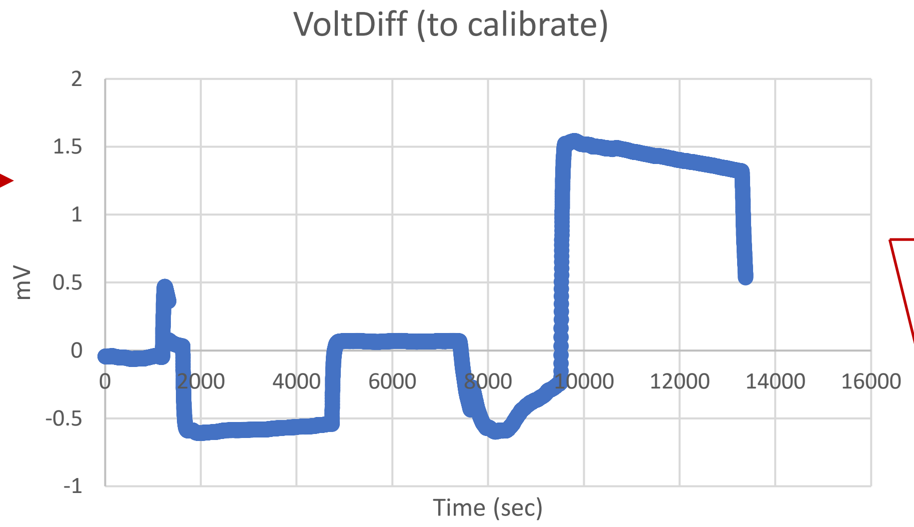
$y = -15.957x - 0.267$
$R^2 = 0.9999$

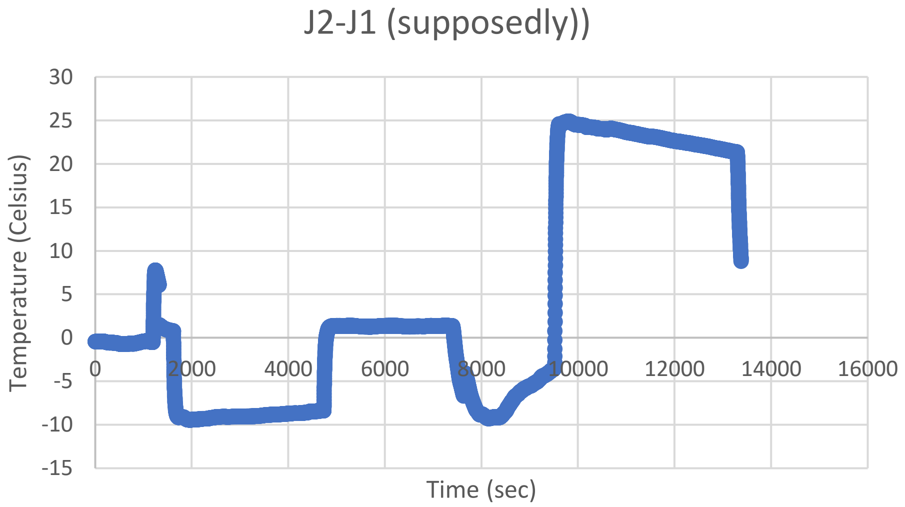


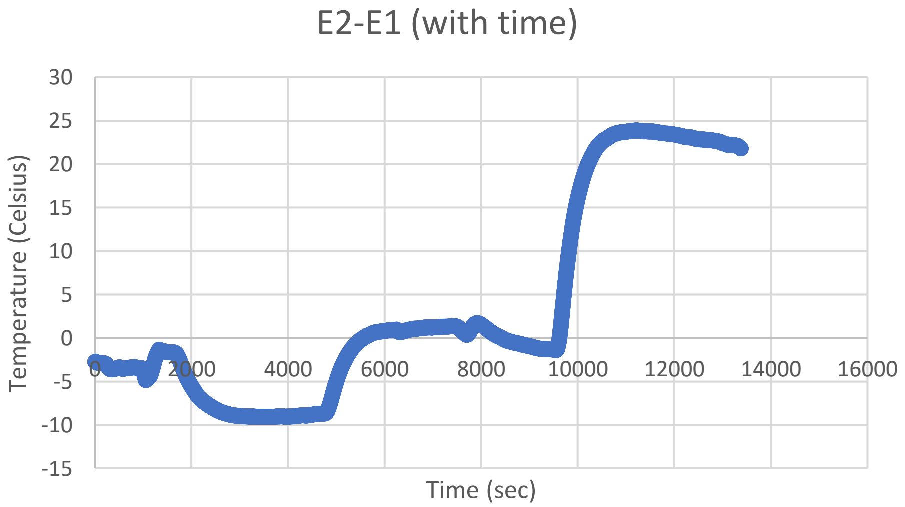


Calibration curve / Transfer Equation

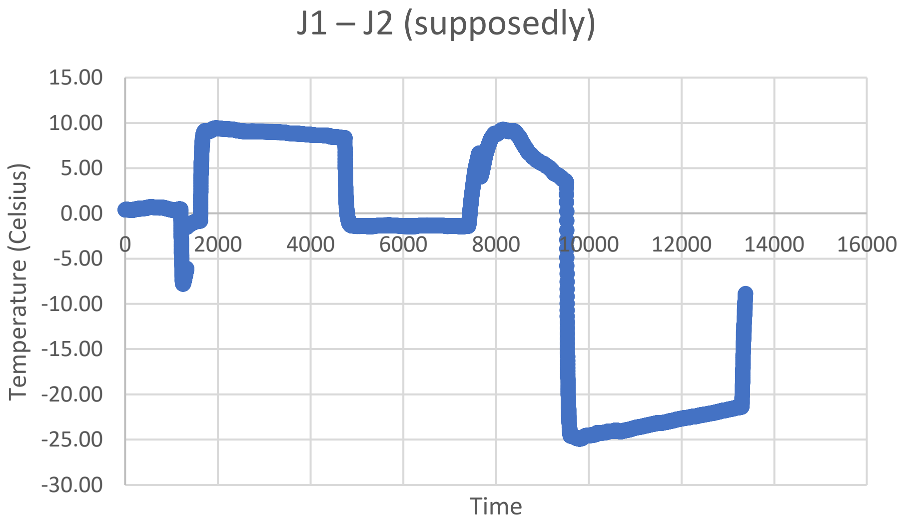
y = 15.956x + 0.2707
R^2 = 0.9999

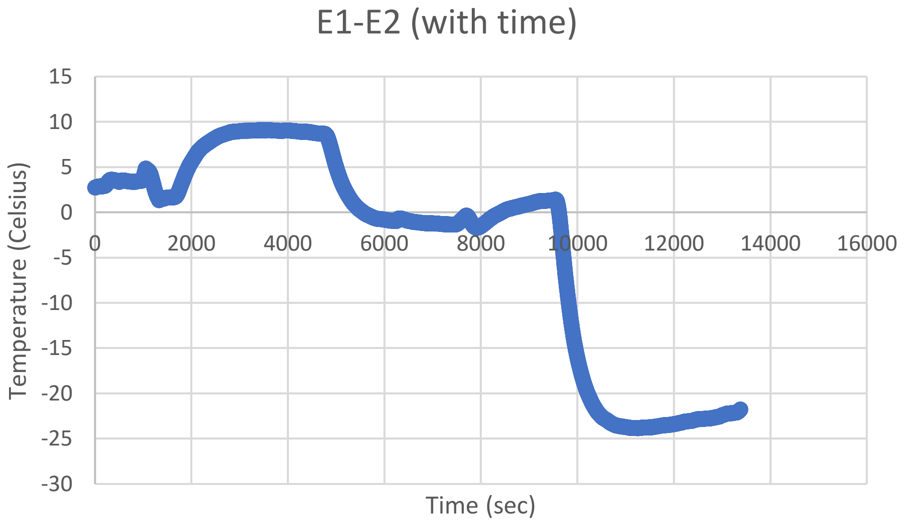






1. Plot both temperature traces from your thermocouples (E2, and the temperature values calculated from the calibration equation for J2) on **one graph**, indicating the areas on the graph that represent the dynamic response **to each step input** (decreasing from room temperature to the icy water temperature, and increasing from room temperature to the hot water temperature). /2

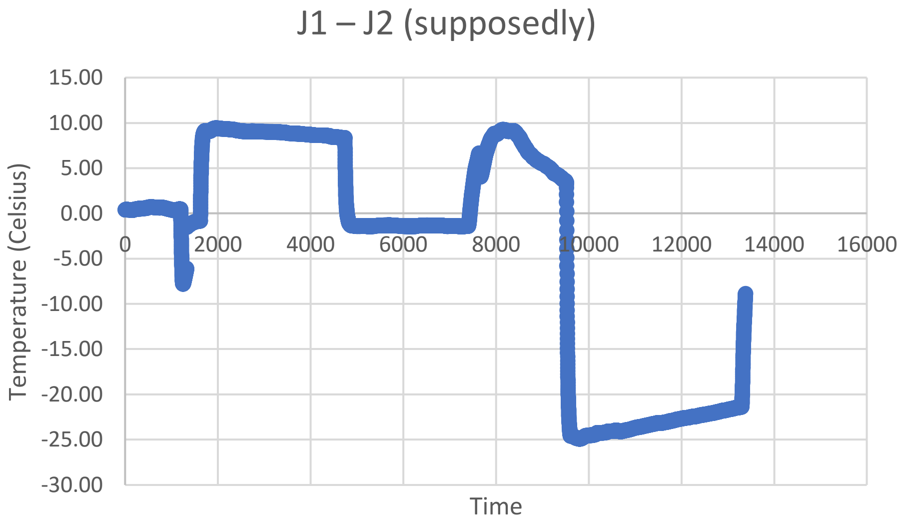


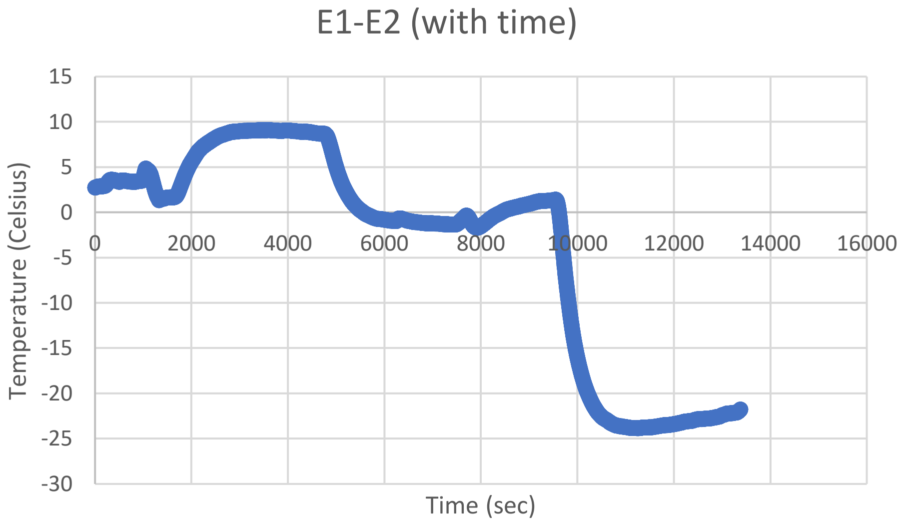


THIS IS THE RATIONALE TO GET J1!!!

\+ Reference Water Temperature (E2) + Merge plots (two time series in one)

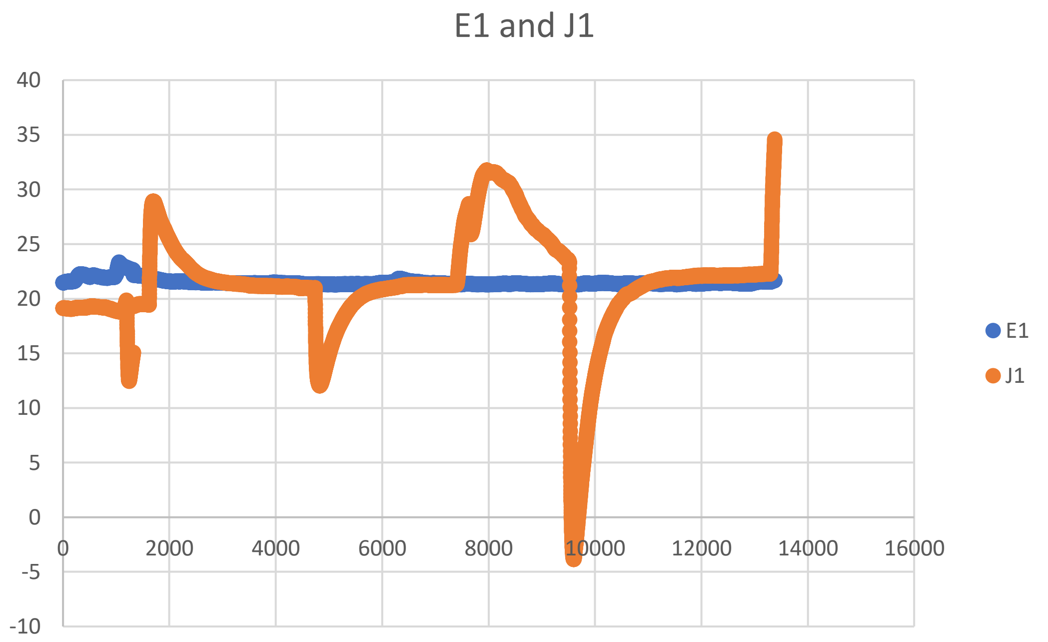
1. Plot both temperature traces from your thermocouples (E2, and the temperature values calculated from the calibration equation for J2) on **one graph**, indicating the areas on the graph that represent the dynamic response **to each step input** (decreasing from room temperature to the icy water temperature, and increasing from room temperature to the hot water temperature). /2





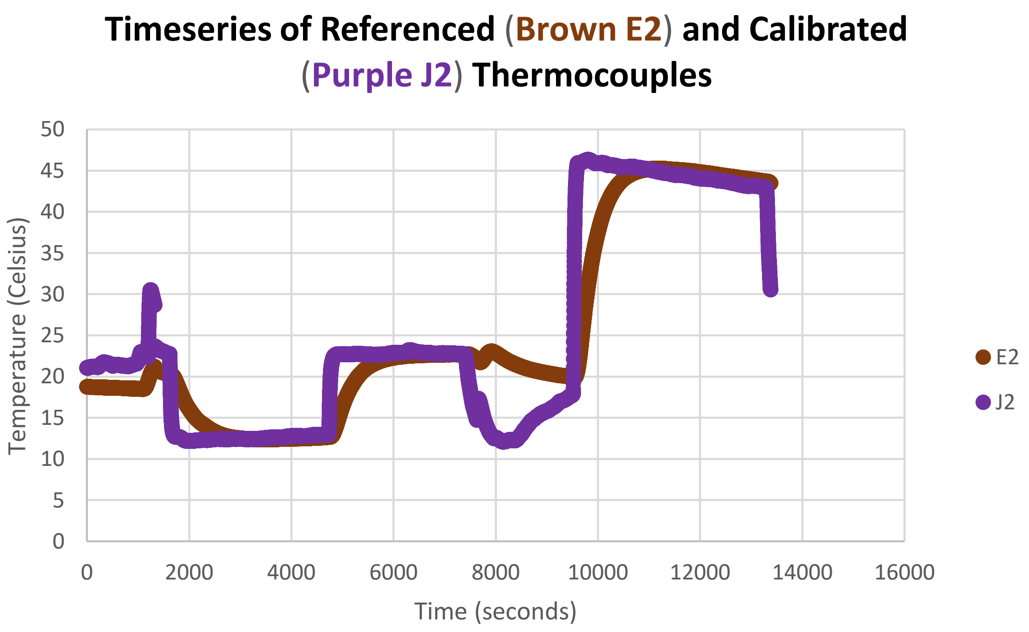
THIS IS THE RATIONALE TO GET J1!!!

(E2) =



1. Plot both temperature traces from your thermocouples (E2, and the temperature values calculated from the calibration equation for J2) on **one graph**, indicating the areas on the graph that represent the dynamic response **to each step input** (decreasing from room temperature to the icy water temperature, and increasing from room temperature to the hot water temperature). /2

YOUR PLOT SHOULD LOOK LIKE THIS! (DIFFERENT FROM PREVIOUS)

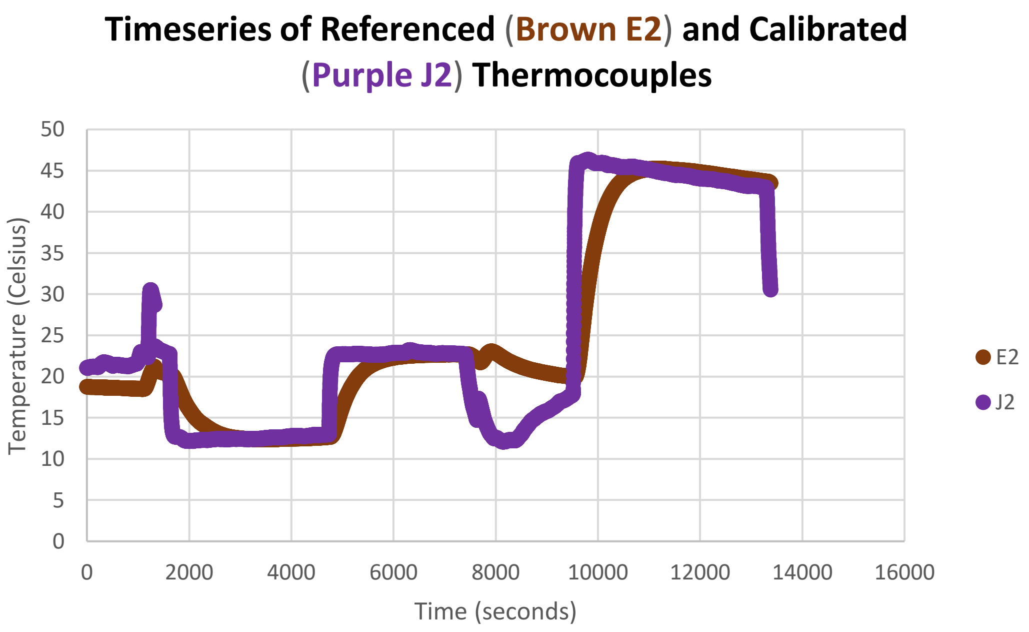


Which are the Dynamic response intervals?

For what steps? (ice cold, tap col, tap hot)

+ Why are they still so different? Was it a successful calibration?

2. Estimate the time constant, τ, for each sensor (be careful with your units!): a. By eye using the graph. /4
b. Experimentally, using the method described in section (2.2.1) in the textbook /4

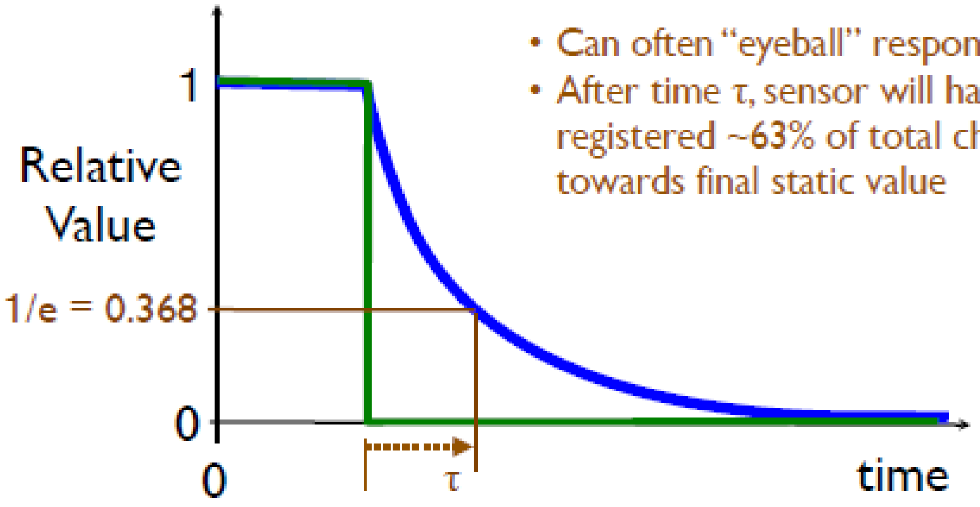


Response Time τ (tau)

If response is exponential, then…

- **τ is e-folding time, or time when relative value is 1/e = 0.368**

  (e is Euler's number = base of natural ln = 2.71828…)



- Can often "eyeball" response time τ
- After time τ, sensor will have registered ~63% of total change towards final static value

(Stull, 2023)

2. Estimate the time constant, τ, for each sensor (be careful with your units!): a. By eye using the graph. /4
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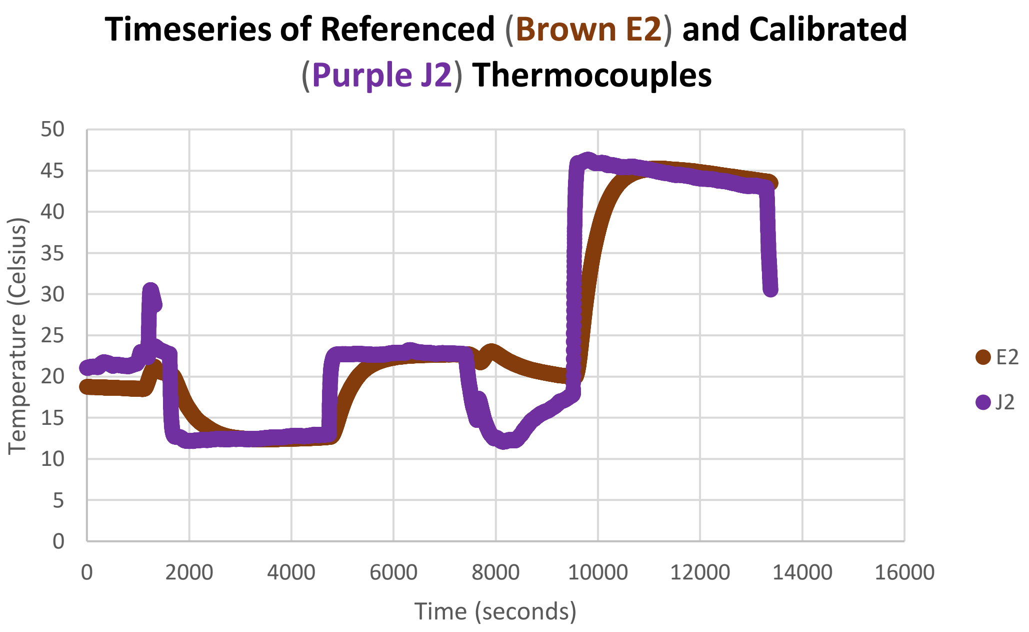
Meteorological Measurements and Instrumentation – Harrison (2015)



Heat Budget for Temperature Sensor

Equation for thermometer response is:

$$\frac{dT_s}{dt} = -\frac{(T_s - T_a)}{\tau}$$

(Eqn. 4 rearranged and with slightly. T_a is T_{air})

- This is a **first-order** response (because it contains no higher than a first-order derivative)
- If T_a is constant, then T_s approaches T_a and steady (static) state is reached where $\partial T_s/\partial t = 0$
- Similar first-order equations can be derived for many other meteorological sensors

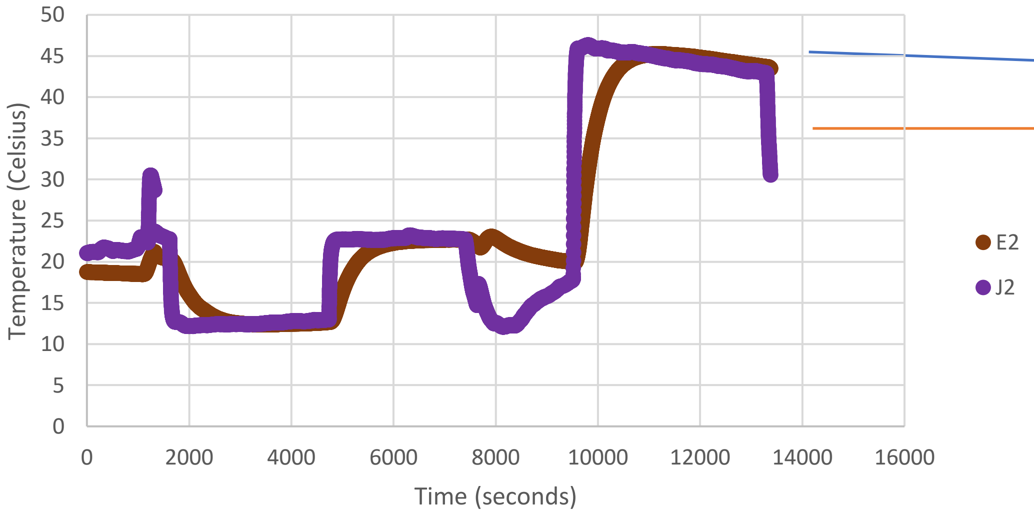
18

(Stull, 2023)

3. Your time constant for each thermocouple should be different. Which term(s) in the sensor time constant are different for your two sensors? /2

Meteorological Measurements and Instrumentation – Harrison (2015)

Timeseries of Referenced (Brown E2) and Calibrated (Purple J2) Thermocouples



rearrange

Heat Budget for Temperature Sensor

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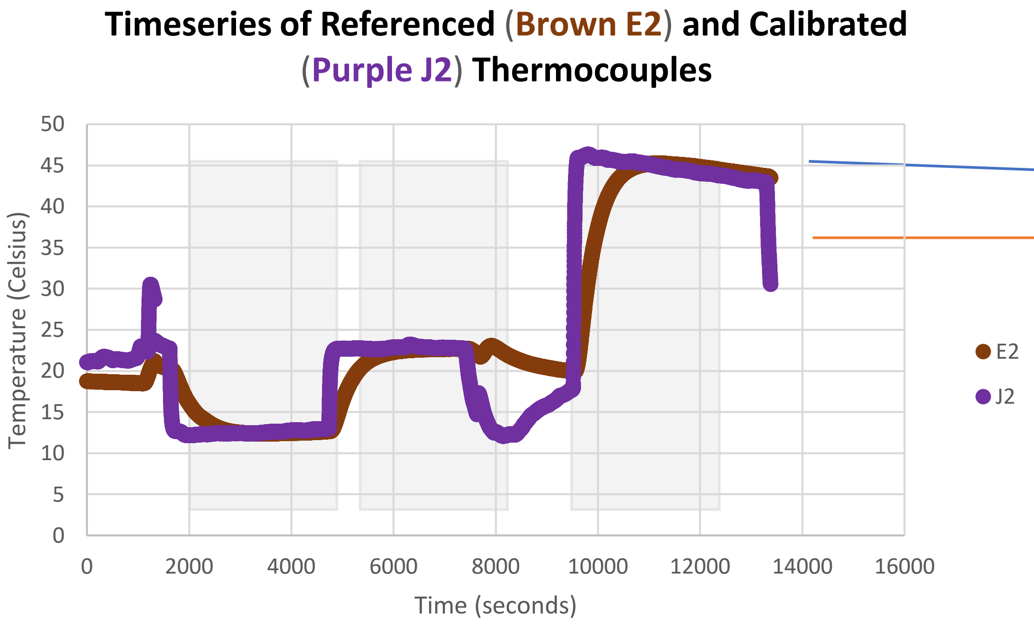
(Stull, 2023)

4. List the assumptions we are making when determining τ. If you got different answers for the step increase and decrease (for the same sensor), why do you think this is? /4

Meteorological Measurements and Instrumentation – Harrison (2015)



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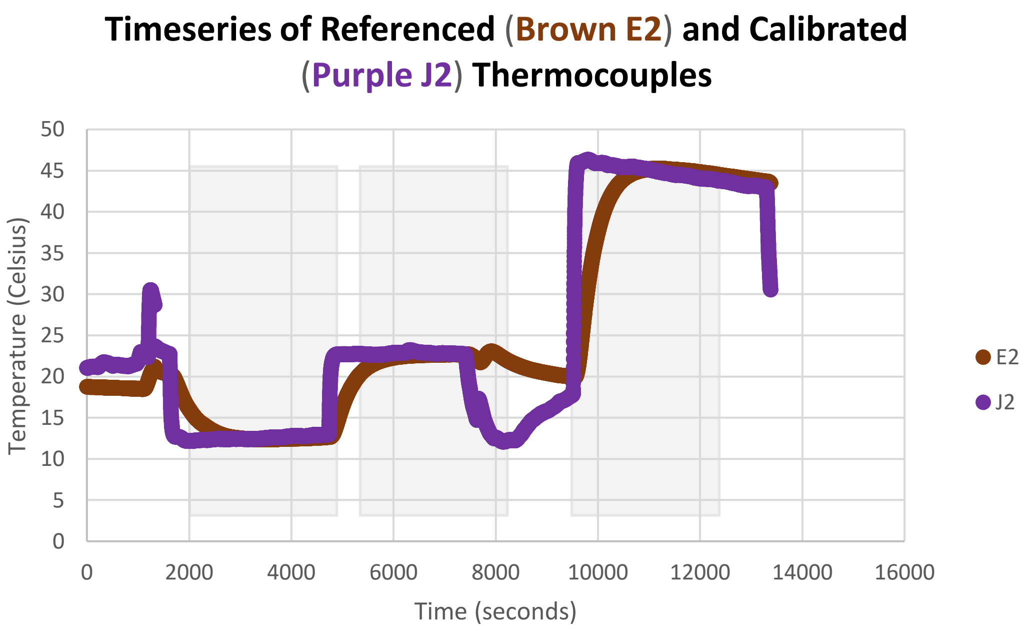
18

(Stull, 2023)

5. In previous labs, we have recorded data at a maximum frequency of 1 second. Why did we record at a higher frequency for this lab? /1

Meteorological Measurements and Instrumentation – Harrison (2015)



Now, some of you recorded in 1s timesteps (instead of 10 Hz)

10 Hz => 1/f = 1/10 => 10 measurements per second

If this is the case,

Use a frequency of 0.1 Hz, in other words, average your data by 10 seconds, redo the previous steps, and observe the differences in your answers

Why did this happen?

Why we need a higher frequency?