Worksheet: Dynamic Model Regression

Learning Objectives

- Collect Heater–Thermistor data with the Temperature Control Lab (TCLab).
- Formulate a simulation model that predicts T1 and T2 given heater inputs.
- Estimate model parameters by minimizing the prediction error versus measurements.
- Quantify accuracy with Mean Absolute Error (MAE) and compare alternative models.
- Document results with clear figures, tables, and a short discussion.

Estimated Time Allocation (≈60 minutes)

	Section	**Time**
1	Data Collection (TCLab)	15 min
2	Model Setup & Simulation	15 min
3	Parameter Estimation / Regression	20 min
4	Validation & Reporting	10 min

1) Data Collection (15 min)

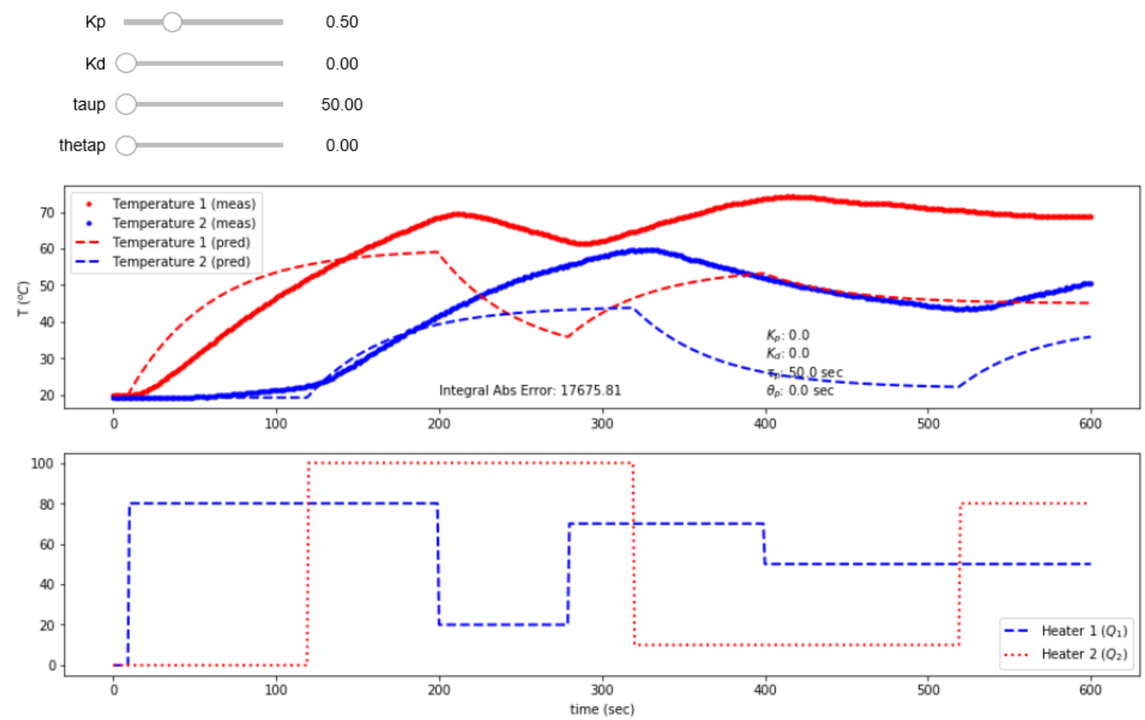
Goal: obtain time-series of inputs (Q1, Q2) and outputs (T1, T2) suitable for parameter estimation.

- Use the TCLab hardware (or the online simulator if hardware is unavailable).
- Design a stimulus that excites the dynamics (e.g., steps, PRBS, or multilevel sequences). Avoid changing both heaters at the exact same time.
- Record: time (s), Q1 (%), Q2 (%), T1 (°C), T2 (°C).
- Record at least 15 minutes of data.
- Store data to CSV (e.g., columns: time,Q1,Q2,T1,T2).

2) Model Setup & Simulation (15 min)

Start from the two-heater energy-balance model you used previously. Keep the structure consistent so that only parameters (e.g., gains, heat-transfer coefficients) are adjusted.

- Inputs: Q1(t), Q2(t). Outputs: T1(t), T2(t).
- Parameters to estimate (examples): Kp, Kd, taup, thetap.
- Use the same ambient temperature T_∞ you measured/assumed during data collection.
- Generate data and load **data.csv** to use with simulator.



`FOPDT Simulator: Adjust Kp, Kd, taup, and thetap to achieve lowest Integral Abs Error`

3) Parameter Estimation / Regression (20 min)

Estimate parameters by minimizing the discrepancy between measurements and predictions.

Objective (minimize):

$J(\theta) = \Sigma\, |T1_i - \check{T}1_i(\theta)| + \Sigma\, |T2_i - \check{T}2_i(\theta)|$ (sum over training samples i)

Mean Absolute Error (MAE):

$MAE = (1/N)\, \Sigma\, |T1_i - \check{T}1_i(\theta)| + (1/N)\, \Sigma\, |T2_i - \check{T}2_i(\theta)|$

- Adjust sliders to minimize MAE.
- Stop criteria: MAE improvement < small tolerance.

4) Validation & Reporting (10 min)

- Compare predicted vs. measured T1 and T2.
- Report the final parameter values.
- Compute and report MAE for training.
- Include plots / screenshots: (a) inputs Q1,Q2 vs. time (b) T1/T2 measured vs. predicted.
- Briefly discuss: Are residuals biased? Are transients captured? Any unmodeled delays?

Results Summary Tables

Final Estimated Parameters (θ):

Parameter	Description	Value / Units
Kp	Gain (W per %)	
Kd	Heat Transfer Between T1 / T2	
taup	Time Constant	
thetap	Dead Time (Delay)	

Model Accuracy:

Metric	T1 + T2	Notes
MAE		
Max |Error|		

Short Answer Prompts (include 1-2 sentences each)

1. How did the estimated parameters compare to starting guess values? Any surprises?

2. What parts of the dynamics are best/worst captured by the model?

3. Suggest a model improvement (e.g., sensor offset, higher order model, conduction term).

4. If you re-designed the input sequence for better identifiability, what would you change and why?

Quick Checklist

- CSV file with time,Q1,Q2,T1,T2 created and archived.
- Simulation code runs with any parameter and reproduces measured time grid.
- Parameters adjusted to minimize MAE for T1 and T2.
- Figures included: inputs, measured vs. predicted.
- Short answers completed and results summary tables filled.

Additional Information

https://apmonitor.com/pdc/index.php/Main/ArduinoEstimation2