ChE 436 Lab Project

Temperature Control Lab

You are to work on this project in groups of two and turn in a common report for the group. The purpose of this project is to reinforce the concepts taught in class about dynamic process modeling and controller tuning. A write-up is required, showing all data, equations used, and intermediate and final results. The Temperature Control Kit can be accessed in the UO Lab.

Grading

This lab will count for 10% of your grade. Reports will be graded for accuracy and professionalism.

Problem Statement

1. Perform a doublet test on the system, varying the control output in manual mode. Make a graph to turn in with the report.
2. From the manual-mode test calculate FOPDT constants (τ_p, K_p, θ_p) fitting the data to the equation $\tau_p \frac{dx}{dt} = -x + K_p u(t-\theta_p)$.
3. Perform a stability analysis to determine the range of K_c values for which a P-only controller is expected to go unstable.
4. Obtain PI or PID tuning constants from ITAE and IMC correlations.
5. Use those tuning constants for PI or PID control on the temperature controller, and observe behavior for step changes in set point above and below the steady-state value.
6. Comment on the performance of the controllers using the calculated constants.
7. Tune the controller by adjusting the constants to improve performance.

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8. Derive the form of a first principles model for the relationship between input voltage and output temperature. There is no need to directly measure all parameters in the model; engineering judgement is sufficient. A tutorial help session is recorded http://youtu.be/dhV6yGh-iwU?t=4m
9. Simulate the first principles model and compare the results to the data that were collected during the doublet test. Adjust the parameters in your model to align the model and measured values.
10. Linearize the adjusted first principles model and compare it to the empirical model. Comment on the similarities or differences between the two.

Setup for the Temperature Control Device

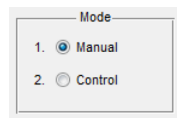
1. Plug in power supply to electrical outlet and USB connection to UO Lab computer
2. Download required files from course website and extract files from zipped archive
3. Open PID_GUI.m from extracted folder (not zipped folder)

ArduinoCode	9/9/2014 8:47 AM	File folder	
Collected Data	9/9/2014 11:01 AM	File folder	
Excel_FOPDT	9/9/2014 9:25 AM	File folder	
MatlabCode	9/9/2014 10:31 AM	File folder	
PID_GUI.m	9/9/2014 10:57 AM	MATLAB Code	19 KB

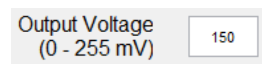
Obtain a Dynamic Model from Step Test Data

1. Click the green **Start** button.

2. Once the module has initialized, select **Manual** mode.

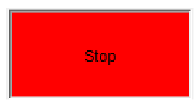


3. An input box will appear to allow changes to the input voltage.



4. Input manual values of output voltage to implement either a step, doublet, or PRBS input signal to the Arduino device. The *Enter* key is required to implement a change.

5. When the test is complete, select **Stop**.



6. Retrieve data from the Folder **Collected Data**. If multiple tests were performed, the data files are named according to the test time stamp.

Determine a FOPDT Model

Fit data to a FOPDT model using Excel, MATLAB, or another analysis tool. There is an Excel template in the folder **Excel_FOPDT**. Values from the generated data should be copied into the appropriate locations on the Excel worksheet as shown below.

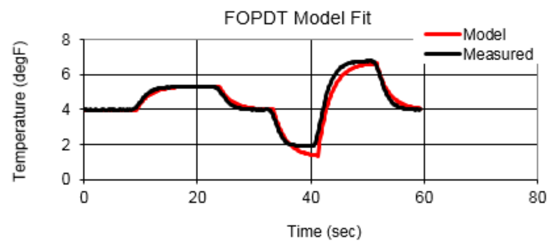
Insert	These	Values
time	Input	Measured
0.01667	70	3.9885658
0.16667	70	4.0013333
0.31667	70	3.9986239
0.46667	70	3.9908719
0.61667	70	3.9775105
0.76667	70	3.9935262

While it is not necessary to modify the columns that calculate the model mismatch, it may be necessary to fill down the equations in these columns if the number of data points exceeds the template default.

Don't change these columns, only copy down to match number of measurements					
Model	Model Slope	Model Intercept	Model with Delay	abs(error)	error^2
3.9885658	0	3.9885658	3.9885658	0	0
3.9885658	0	3.9885658	3.9885658	0.0127675	0.000163009
3.9885658	0	3.9885658	3.9885658	0.0100581	0.000101165
3.9885658	0	3.9885658	3.9885658	0.0023061	5.3181E-06

Values of K_p, τ_p, and θ_p can be obtained by either manually changing the values in the parameters section or using Excel Solver to find the values that minimize either the Sum of Squared Errors or else the Sum of Absolute Errors.

Model Parameters	
Kp (Gain)	0.135127622
tau (Time Constant)	2.229643365
theta (Time Delay)	2
Doesn't seem to change with solver	
Minimize Either of These	
Sum of Squared Errors	157.5540833
Sum of Absolute Errors	154.7466485



PID Controller Tuning

Once the FOPDT model (K_p, τ_p, and θ_p) is determined, use tuning correlations to select acceptable starting values for the PID controller (K_c, τ_I, and τ_D).

1. Click the green Start button.
2. Select Control model.
3. Enter **Proportional (P)**, **Integral (I)**, and **Derivative (D)** terms for the PID controller.
    a. Proportional (P) = K_c
    b. Integral (I) = $\frac{K_c}{\tau_I}$
    c. Derivative (D) = $K_c \tau_D$
4. Tune controller to achieve improved performance.
5. Select **Stop** when the test is complete.
6. Retrieve the saved data file from the **Collected Data** folder.