

EE 448: Sensors and Actuators

Laboratory Module #3

Controlling the Temperature Board

Assigned: January 26, 2009

Due: 12:30 PM, Monday February 2, 2009 (In Class)

Objectives

The objective of this lab is to control the TCL board so that it tracks a step input. You will first design a controller in simulation, then increase the realism of your simulation to tune your gains, and then test your controller in hardware.

You Will Need...

To complete this module, you will need

1. Some time outside of the laboratory to work on your simulation and controller design.
2. A TCL Board, IO Card and Computer, configured the same way as in Module 2.

Build a Simulation

In *Simulink*, build a simulation of your system using the parameters you found in Module 2. For now, make an open loop model. Visualize the behavior for a step input on a *Simulink* scope and see how well it matches your data from last week.

Design a PI Controller

Define a PI controller of the form

$$G_c(s) = \frac{K_p s + K_i}{s}$$

and, ignoring the delay for now, cascade this with the model of the TCL board and put the system into a unity feedback configuration. Then write your model in the following form:

$$T(s) = \frac{(\omega_n^2/a)(s+a)}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

to determine the damping ratio ζ and the natural frequency ω_n . Next, find K_p and K_i so that the system is slightly underdamped ($\zeta = 0.9$) and has a rise time of approximately τ_b . Use the approximation to the rise time given by

$$T_r = \frac{2.16\zeta + 0.60}{\omega_n}.$$

Add your controller to your Simulink model and simulate the response to a step inputs of magnitude 10 degrees and -10 degrees.

Add Realism

Add saturation to the control signal and a transport delay (using the value you measured for τ_d) to your *Simulink* model. Save this with a different name. Also add a “back-off” gain before you controller. Tune the back-off gain until the system is not saturating constantly. The more saturation you have, the more integrator wind-up you will have. However, some saturation is okay, as this corresponds to an aggressive controller.

Finally, model the fact that there are indeed two blocks in the system, the bottom and the top blocks. Figure out a way to control the actual temperature of the top block by changing $r(t)$, the input to your controlled system.

Test Your Controller

Once you are satisfied with your design, try it out on the actual hardware with a step input (of magnitude ± 10 degrees). This will involve implementing your controller in LabView.

For Your Writeup: Show the step responses of all of your simulations and of the actual hardware. How well have you achieved the performance goals (zero steady state error and τ_b second rise time)?

For Your Writeup: Describe and explain the difference between the response of the ideal model (no saturation, delay or changing bottom block) with the response of the hardware.

For Your Writeup: Once your controller has arrived at steady state, touch the aluminum bar on your TCL board with your finger. Hold it until you get to steady state again. What happens?

For Your Writeup: Determine the best performance you can get from your controller by tuning the gains. What temperature range can you accurately track? How fast can you make the rise time and settling time?