2.14/2.140 Lab 3

Assigned: Week of Mar. 3, 2014
Due: Week of Mar. 17, in your lab session.

Lab 3 continues with studies of a thermal control loop. You will design PI and PID controllers via experimental loop shaping. First, carefully measure the plant transfer function. Use this experimental data to design PI and PID controllers that achieve a phase margin of $45° \pm 5°$ with as high a crossover frequency as you can achieve. Experimentally measure the return ratio transfer function to confirm your design's crossover frequency and phase margin.

Note that you do not need to create a parametric model of the plant, but can work directly from the plant experimental magnitude and phase measurements. To do this, bring your plant data into Matlab as vectors of frequency, magnitude, and phase. On the basis of this data, design a controller that you think will work. Then use the Matlab command `[mag,phase] = bode(sys,w)`, where `w` is the vector of frequencies at which you have experimental plant data. This allows you to compute the controller magnitude and phase at all the experimentally measured frequencies. Then the return ratio magnitude is the controller magnitude multiplied by the plant magnitude frequency by frequency. In Matlab, you will use the dot multiply to do this: `magloop = magcontroller .* magplant`. Similarly, the return ratio phase is the controller phase added to the plant phase frequency by frequency. In Matlab, you will use the vector add to do this: `phaseloop = phasecontroller + phaseplant`. Then you can use plotting commands `loglog` and `semiologx` to make the return ratio magnitude and phase plots.

Specifically, we ask you to:

1. Experimentally measure an accurate plant transfer function. Try this measurement at several amplitudes so as to be confident that you are not seeing nonlinear effects. Document your measurements.

2. Use Matlab to design a PI controller to meet the specifications above for the measured plant data. Document your design approach and show return ratio Bode plots indicating the expected loop crossover and phase margin.

3. Experimentally implement your PI controller. Measure the closed loop small-signal step response. Also measure the return ratio Bode plot. How do your crossover frequency and phase margin compare with the design values?

4. Use Matlab to design a PID controller to meet the specifications above for the measured plant data. Document your design approach and show return ratio Bode plots indicating the expected loop crossover and phase margin.

5. Experimentally implement your PID controller. Measure the closed loop small-signal step response. Also measure the return ratio Bode plot. How do your crossover frequency and phase margin compare with the design values?

6. **For graduate students only:** Create a pole-zero-gain (PZK) model for the plant. (See Matlab help files for this model type.) Note that you may need to add some amount of time delay to your model to allow matching the phase. To match a fractional-order Bode plot magnitude roll-off, you can add sets of pole/zero doublets on the real axis. The relative spacing of these doublets sets the fractional order. Fit parameters to this model and compare with your experimental frequency response measurements to show the quality of the fit. Use this model to predict the closed-loop step response for your loops with the PI and PID controllers. How do these predictions compare with the measured step responses?

Checkoff in lab session: In this week's lab session demonstrate to one of the teaching staff your working controller and some experimental results. Progress shown in this checkoff will count towards half of your lab grade.

Answer sheets: At the start of next week's lab session you must submit your lab writeup. These write-ups are due at the start of the lab session, and will not be accepted late. Please attach to this lab assignment clearly labeled answers and plots for all the questions above. This lab report will count towards half of your lab grade.

It is key that you submit your lab report on time at the start of the lab session next week, as we will begin work on Lab 4 during that session.

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Spring 2014