16.06 Principles of Automatic Control

Problem Set 12 Issued: December 2, 2012
Due: December 7, 2012

Instructions: Do each problem on separate sheets of paper, and staple the sheets for each problem together. Write your name on each problem.

Problem 1

Do FP&E Problem 8.7

Problem 2

Do FP&E Problem 8.9

Problem 3

You are to design a compensator $K_d(z)$ for a unity feedback sampled data control system, where the plant is

$$G(s) = 5\,\frac{1}{(1+s/20)(1+s/4)}$$

where the sampling time is

$$T = 0.005 \text{ sec}$$

which meets the following specifications:

- Maximum overshoot $M_p \leq 0.20$
- Cross over frequency is $\omega_c = 100$ r/s
- The steady error to a unit step input is less than 0.5%

Assume that there is no processing delay, but you must still account for the effective delay of the zero-order hold.

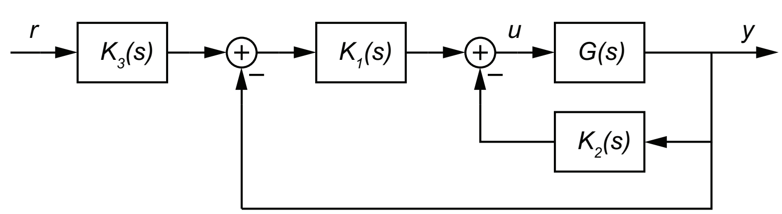
Problem 4

Time permitting, I will demo the best controllers the last week of class.

You are to design a control system (in continuous time) for the one degree of freedom helicopter demo in class. The transfer function for the plant is given by

$$G(s) = 0.0905\frac{s+43.8}{(s+2.26)(s+0.814)(s-0.639)}$$

where the input ranges from -1 to 1, and the output ranges from -0.5 to 0.5. You are to design a control system for the system, that best meets the desired control objectives. In particular, you are to choose K_1, K_2, and K_3 for the following block diagram:



Note that choosing $K_2(s) = 0$, $K_3(s) = 1$, and $K_1(s) = K(s)$ results in the traditional unity feedback controller. $K_2(s)$ is used for minor loop feedback. $K_3(s)$ may be used to pre-filter the reference, to shape the step response of the system. The reference input will be a step input of magnitude 0.05. Design the controller to optimize the following performance metrics:

1. The step response should be as fast as possible, given the other constraints below.
2. There should be minimal overshoot. The overshoot should not exceed 5%.
3. The magnitude of the control signal should not exceed 0.40.
4. The control system should be Type 1, so that the steady error due to a constant disturbance (such as would result from a change in the weight of the helicopter) are zero.
5. In addition, undesirable behaviors, such as long tails in the step response, are to be avoided.

I will judge the results based on these criteria, and present the best results in class.

Your results should be submitted online as a MATLAB m-file. Executing the m-file should leave in the workspace the three controller transfer functions, named `k1`, `k2`, and `k3`. Name the file `xyz.m`, where your initials are `xyz` (in lowercase). For example, your file might look something like:

```
% srh.m
%
% Controller for the helicopter demo by
% Steven R. Hall
s = tf([1 0],1);
k1 = 10*(1+s/1)/(1+s/10);
k2 = tf(0,1);
k3 = tf(1,1);
```

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