ANALOG CONTROLLER DESIGN

In this project, we will design an analog controller $C(s)$ for a given analog plant $P(s)$. The structure of the overall feedback control system, where r is the reference input, y is the output and d denotes disturbance or noise, is shown below.

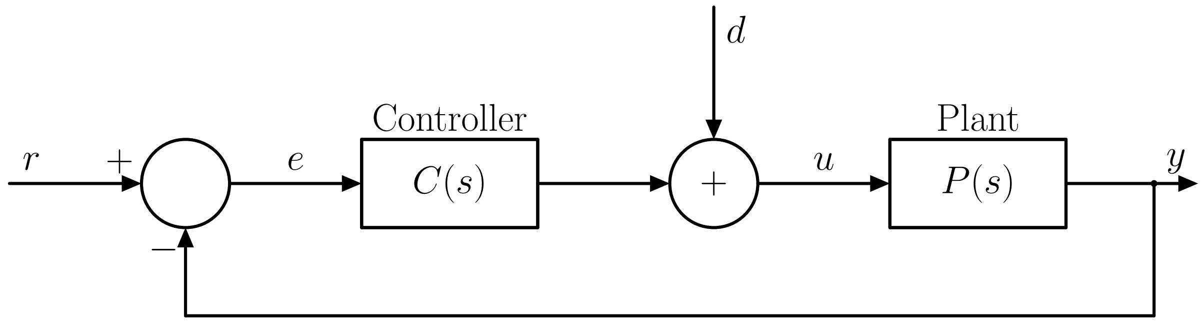

Figure 1: The feedback control system.

Let the transfer function of the plant be given by

$$P(s) = \frac{C}{aes^3 + (fa + be)s^2 + (bf + C^2)s}$$

where $C = 0.01$, $a = 0.01$, $b = 0.1$, $e = 0.5$ and $f = 1$. For the first 4 questions, assume that there is no disturbance; in other words, $d = 0$.

1. Is the plant $P(s)$ stable? Justify your answer analytically. Compute and plot the step response of the plant.

2. First, let's evaluate the performance of the feedback system in the presence of no disturbance. Design P, PI and PID controllers using the Ziegler–Nichols Method (you can use `tf`, `pid`, `feedback`, `step` commands on MATLAB). Choose a single value for the constant K_u by both using Routh–Hurwitz method (show your calculations) and by looking at the root locus diagram of the system. Draw it with the command `rlocus`. Which value did you choose? Why? (See lecture notes on ZN method.)

3. Plot the step response and find steady state error, rise-time, settling time and overshoot for
   (a) the plant $P(s)$
   (b) the closed-loop system with P control
   (c) the closed loop system with PI control
   (d) the closed-loop system with PID control

   for a duration of 10 seconds. Use $\Delta = 0.001$ s to sample the time vector.

4. Fine tune the PID controller coefficients so that the following design criteria are satisfied:

   - No steady state error
   - Percent overshoot less than 14%
   - Rise time less than 0.14 s

Explain your adjusting strategy in your own words.

5. Now, we would like to evaluate how the system responds to a step disturbance. Since linear systems satisfy the principle of superposition, assume that the reference signal r is zero and let d be a unit step. How would you adjust P, PI and PID controllers in the presence of a step disturbance? Plot system responses with P, PI and PID controllers for a step disturbance. Remember that you have designed two PID controllers. Which control strategy is more robust to step disturbance? Comment.

Note: You can submit the code for this homework in a single `.m` *file. There is no need for separate files for each question.*