UC Berkeley

EE128 Homework #2

Due on 10/6/06 at 10am

(1) Textbook problem 3.38 (c)

3.38. Suppose that unity feedback is to be applied around the listed open-loop systems. Use Routh's stability criterion to determine whether the resulting closed-loop systems will be stable.

(c) $KG(s) = \frac{4(s^3+2s^2+s+1)}{s^2(s^3+2s^2-s-1)}$

(2) Textbook problem 3.39 (b), (e)

3.39. Use Routh's stability criterion to determine how many roots with positive real parts the following equations have:

(b) $s^5 + 10s^4 + 30s^3 + 80s^2 + 344s + 480 = 0.$

(e) $s^4 + 6s^2 + 25 = 0.$

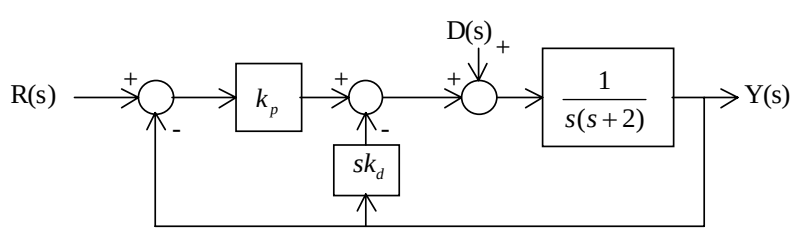
(3) Textbook problem 3.41

3.41. The transfer function of a typical tape-drive system is given by

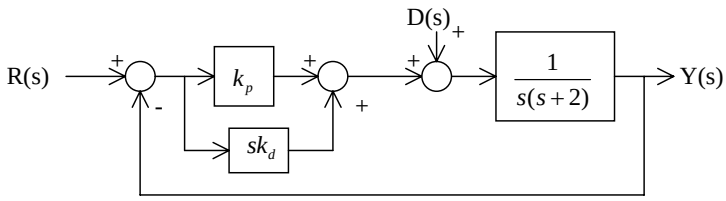
$$G(s) = \frac{K(s+4)}{s[(s+0.5)(s+1)(s^2+0.4s+4)]},$$

where time is measured in milliseconds. Using Routh's stability criterion, determine the range of K for which this system is stable when the characteristic equation is $1 + G(s) = 0$.

(4) Determine the value of k_p and k_d so that the system's step response has 5% overshoot and the DC gain from D(s) to Y(s) is less than 0.02. (Hint: find the DC gain first.)



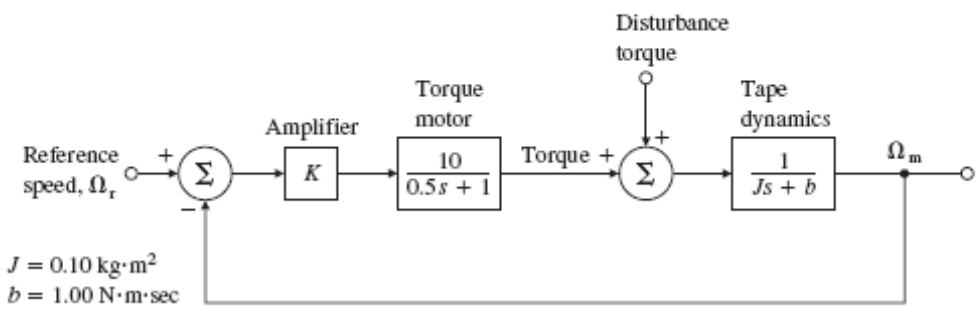
(5) Repeat Problem (4) for the following system. You may use MATLAB for this problem.



(5) For the same value of kp and kd, which system, the one in Problem (3) or the one in Problem (4), has a faster tracking performance and which one has a better disturbance rejection? You must justify your answer.

(6) Textbook problem 4.29

4.29. The transfer functions of speed control for a magnetic tape-drive system are shown in Fig. 4.48. The speed sensor is fast enough that its dynamics can be neglected and the diagram shows the equivalent unity feedback system.



(a) Assuming $\omega_r = 0$, what is the steady-state error due to a step disturbance torque of 1 N·m? What must the amplifier gain K be in order to make the steady-state error $e_{ss} \leq 0.001$ rad/sec?

(b) Plot the roots of the closed-loop system in the complex plane, and accurately sketch the time response $\omega(t)$ for a step input ω_r using the gain K computed in part (a). Are these roots satisfactory? Why or why not?

(c) Plot the region in the complex plane of acceptable closed-loop poles corresponding to the specifications of a 1% settling time of $t_s \leq 0.1$ sec and an overshoot $M_p \leq 5\%$.

(d) Give values for k_p and k_D for a PD controller that will meet the specifications.

(e) How would the disturbance-induced steady-state error change with the new control scheme in part (d)? How could the steady-state error to a disturbance torque be eliminated entirely?

(7) Textbook problem 4.31

4.31. We wish to design an automatic speed-control for an automobile. Assume that (1) the car has a mass m of 1000 kg, (2) the accelerator is the control U and supplies a force on the automobile of 10 N per degree of accelerator motion, and (3) air drag provides a friction force proportional to velocity of 10 N·sec/m.

(a) Obtain the transfer function from control input U to the velocity of the automobile.

(b) Assume the velocity changes are given by

$$V(s) = \frac{1}{s + 0.002} U(s) + \frac{0.05}{s + 0.02} W(s),$$

where V is given in meters per second, U is in degrees, and W is the percent grade of the road. Design a proportional-control law $U = -k_p V$ that will maintain a velocity error of less than 1 m/sec in the presence of a constant 2% grade.

(c) Discuss what advantage (if any) integral control would have for this problem.

(d) Assuming that pure integral control (that is, no proportional term) is advantageous, select the feedback gain so that the roots have critical damping ($\zeta = 1$).