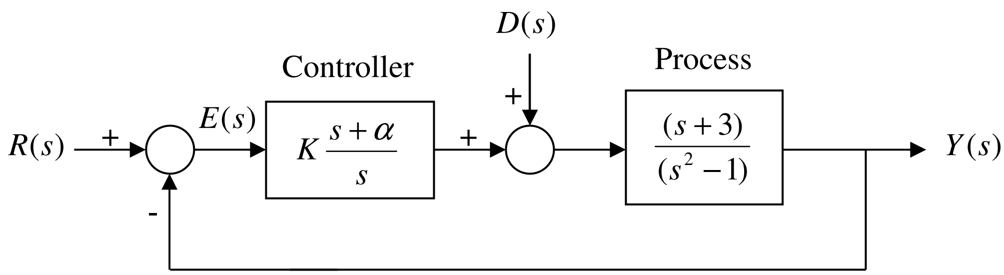
Concordia University

ELEC372 Fundamentals of Control Systems

Homework #6

Professor Amir G. Aghdam

1. (Automatic Control Systems by Farid Golnaraghi and Benjamin C. Kuo, Eighth Edition, John Wiley & Sons, Inc., 2010) "The block diagram of a linear control system is shown in the following figure, where $r(t)$ is the reference input and $d(t)$ is the disturbance.

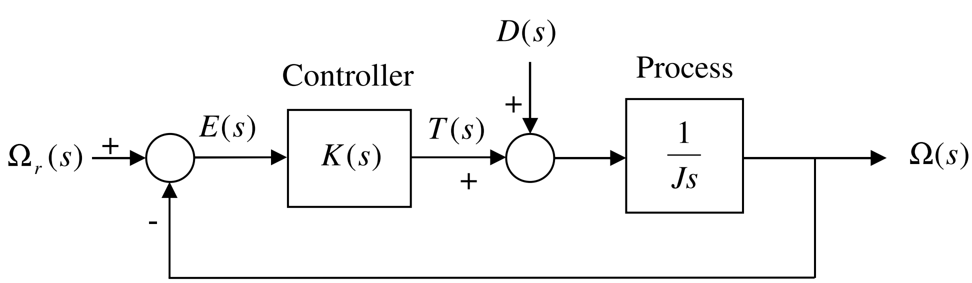


a) Find the position, velocity, and acceleration error constants of the system when $d(t)=0$ (note that the forward path consists of both controller and process).

b) Find the steady-state value of $e(t)$ when $d(t)=0$ and $r(t)=tu(t)$. Find the conditions on the values of α and K so that the solution is valid.

c) Find the steady-state value of $y(t)$ when $r(t)=0$ and $d(t)=u(t)$."

2. (Modern Control Engineering by Katsuhiko Ogata, 4th Edition, Prentice Hall, 2002) "The following block diagram shows a speed control system in which the output of the system is subject to a torque disturbance.



In the diagram, $\Omega_r(s)$, $\Omega(s)$, $T(s)$, and $D(s)$ are the Laplace transforms of the reference speed, output speed, driving torque, and disturbance torque, respectively. J

represents the moment of inertia of the process and is a positive constant. It is desired to eliminate as much as possible the speed errors due to torque disturbances.

a) Is it possible to cancel the effect of a constant disturbance torque on the output speed at steady state using a constant gain $K(s)=K$ (proportional controller)? If yes, for what values of K?

b) Is it possible to cancel the effect of a constant disturbance torque on the output speed at steady state using an integrator $K(s)=\frac{K_i}{s}$ (integral controller)? If yes, for what values of K_i?

c) Is it possible to cancel the effect of a constant disturbance torque on the output speed at steady state using a proportional-integral controller $K(s)=K+\frac{K_i}{s}$ (PI controller)? If yes, for what values of K and K_i?

d) Consider the controller obtained in part (c) and assume that the disturbance torque is zero. Find the type of the system, the acceleration error constant and the steady-state error due to a parabolic reference input $\omega_r(t)=\frac{1}{2}t^2u(t)$."

3. Apply a proper transformation and use the Routh-Hurwitz method to determine how many roots of the following equations are to the right of the line $\mathrm{Re}\{s\}=-1$.

   a) $s^2+5s+3=0$.

   b) $s^3+4s^2+4s+4=0$.

4. Problem P5.20 from 12th, 13th or 14th edition of the main textbook, but replace the denominator of the loop transfer function with (s+10)(s+12) (P5.19 from 8th, 9th, 10th or 11th edition).

5. Problem P6.7 from the 8th, 9th, 10th, 11th, 12th, 13th or 14th edition of the main textbook. If you have the 14th edition, use $F(s)=10(s+10)/((s+1)(s+100))$, a steady-state error of 1° instead of 2°, and a ramp signal of 100 rad/s instead of 75 rad/s.
   Note: K_a in this problem not to be confused with the acceleration error constant.

6. Using the RH criterion, find the number of RHP roots of the equation $s^4+4=0$.