Alexandria University

Faculty of Engineering

Division of Communications & Electronics

EE391 Control Systems and Components

Sheet 1

1. A thermistor has a response to temperature represented by $R = R_o e^{-0.1T}$, where *R0* = 10,000 Ω, *R* = resistance, and *T* = temperature in degrees Celsius. Find the linear model for the thermistor operating at *T* = 20°C and for a small range of variation of temperature.

2. A laser printer uses a laser beam to print copy rapidly for a computer. The laser is positioned by a control input *r(t)*, so that we have

$$Y(s) = \frac{4(s + 50)}{s^2 + 30s + 200} R(s).$$

The input *r(t)* represents the desired position of the laser beam.
(a) If *r(t)* is a unit step input, find the output *y(t)*.
(b) What is the final value of *y(t)?*

3. A control engineer, N. Minorsky, designed an innovative ship steering system in the 1930s for the U.S. Navy. The system is represented by the block diagram shown in Figure E2.8, where Y(s) is the ship's course R(s) is the desired course, and A(s) is the rudder angle. Find the transfer function Y(s)/ R(s).

4. A four-wheel antilock automobile braking system uses electronic feedback to control automatically the brake force on each wheel. A block diagram model of a brake control system is shown in Figure E2.9, where $F_f(s)$ and F_r (s) are the braking force of the front and rear wheels, respectively, and R(s) is the desired automobile response on an icy road. Find $F_f(s)$/ R(s).

5. Off-road vehicles experience many disturbance inputs as they traverse over rough roads. An active suspension system can be controlled by a sensor that looks "ahead" at the road conditions. An example of a simple suspension system that can accommodate the bumps is shown in Figure E2.12. Find the appropriate gain K_1 so that the vehicle does not bounce when the desired deflection is R(s) = 0 and the disturbance is $T_d(s)$.

6. Find the transfer function

$$\frac{Y_1(s)}{R_2(s)}$$

for the multivariate system in Figure E2.14.

7. Determine the transfer function $V_o(s)/V(s)$ of the operational amplifier circuit shown in Figure E2.20. Assume an ideal operational amplifier. Determine the transfer function when $R_1 = R_2 = 100$ kΩ, $C_1 = 10$ uF, and $C_2 = 5$uF.

8. Determine the closed-loop transfer function $T(s) = Y(s)/R(s)$ for the system of Figure E2.23.

9. An amplifier may have a region of dead-band as shown in Figure E2.25. Use an approximation that uses a cubic equation $y = ax^3$ in the approximately linear region. Select a and determine a linear approximation for the amplifier when the operating point is $x = 0.6$.

10. A nonlinear amplifier can be described by the following characteristic:
$$v_o(t) = \begin{cases} v^2{}_{in} & , v_{in} \geq 0 \\ -v^2{}_{in} & , v_{in} < 0 \end{cases}$$
The amplifier will be operated over a range of ±0.5 volts around the operating point for v-m. Describe the amplifier by a linear approximation (a) when the operating point is v_{in} = 0 and (b) when the operating point is v_{in} = 1 volt. Obtain a sketch of the nonlinear function and the approximation for each case.

11. A bridged-T network is often used in AC control systems as a filter network. The circuit of one bridged-T network is shown in Figure P2.8. Show that the transfer function of the network is
$$\frac{V_n(s)}{V_{in}(s)} = \frac{1 + 2R_1Cs + R_1R_2C^2s^2}{1 + (2R_1 + R_2)Cs + R_1R_2C^2s^2}.$$

12. The source follower amplifier provides lower output impedance and essentially unity gain. The circuit diagram is shown in Figure P2.20(a), and the small-signal model is shown in Figure P2.20(b).This circuit uses an FET and provides a gain of approximately unity. Assume that $R_2 >> R_1$ for biasing purposes and that $R_g >> R_2$. (a) Solve for the amplifier gain. (b) Solve for the gain when $g_m = 2000$ uΩ and $R_s = 10$ kΩ where $R_s = R_1 + R_2$. (c) Sketch a block diagram that represents the circuit equations.

13. A two-transistor series voltage feedback amplifier is shown in Figure P2.24. This AC equivalent circuit neglects the bias resistors and the shunt capacitors. A block diagram representing the circuit is shown in Figure P2.24(b).This block diagram neglects the effect of h_{re}, which is usually an accurate approximation, and assumes that $R_2 + R_L >> R_1$ (a) Determine the voltage gain v_o/v_{in}. (b) Determine the current gain i_{c2}/i_{b1} (c) Determine the input impedance v_{in}/i_{b1} .

14. An interacting control system with two inputs and two outputs is show in Figure P2.31. Solve for $Y_1(s)/R_1(s)$ and $Y_2(s)/R_1(s)$ when $R_2 = 0$.

15. A system consists of two electrical motors that are coupled by a continuous flexible belt. The belt also passes over a swinging arm that is instrumented to allow measurement of the belt speed and tension. The basic control problem is to regulate the belt speed and tension by varying the motor torques. An example of a practical system similar to that shown occurs in textile fiber manufacturing processes when yarn is wound from one spool to another at high speed. Between the two spools, the yarn is processed in a way that may require the yarn speed and tension to be controlled within defined limits. A model of the system is shown in Figure P2.32. Find $Y_2(s)/R_1(s)$, Determine a relationship for the system that will make K independent of R_1.

16. Find the transfer function for $Y(s)/R(s)$ for the idle speed control system for a fuel-injected engines shown in figure P2.33.

17. A feedback control system has the structure shown in Figure P2.35. Determine the closed-loop transfer function Y(s)/R(s) (a) by block diagram manipulation and (b) by using a signal-flow graph and Mason's signal-flow gain formula, (c) Select the gains K_1, and K_2 so that the closed -loop response to a step input is critically damped with two equal roots at s = -10. (d)Plot the critically damped response for a unit step input. What is the time required for the step response to reach 90% of its final value?

18. A system is represented by Figure P2.36. (a) Determine the partial fraction expansion and y(t) for a ramp input r(t) = t, t > 0. (b) Obtain a plot of y(t) for part (a), and find y(t) for t = 1.0 s. (c) Determine the impulse response of the system y(t) for t > 0. (d) Obtain a plot of y(t) for part (c) and find y(t) fort = 1.0 s.

19. To exploit the strength advantage of robot manipulators and the intellectual advantage of humans, a class of manipulators called extenders has been examined.The extender is defined as an active manipulator worn by a human to augment the human's strength. The human provides an input U(s), as shown in Figure P2.45. The endpoint of the extender is P(s). Determine the output P(s) for both U(s) and F(s) in the form

$$P(s) = T_1(s)U(s) + T_2(s)F(s)$$

20. A closed loop control system is shown in Figure P2.49.
    a) Determine the transfer function $T(s) = Y(s)/R(s)$
    b) Determine the poles and zeros of $T(s)$
    c) Use a unit step input, $R(s) = 1/s$ and obtain the partial fraction expansion for $Y(s)$ and the value of the residues.
    d) Plot y (t) and discuss the effect of the real and complex poles of T(s). Do the complex poles or the real poles dominate the response?

21. A closed-loop control system is shown in Figure P2.50.
    a) Determine the transfer function T(s) = Y(s)/R(s).
    b) Determine the poles and zeros of T(s).

c) Use a unit step input, R(s) = l/s, and obtain the partial fraction expansion for Y(s) and the value of the residues.
d) Plot y (t) and discuss the effect of the real and complex poles of T(s). Do the complex poles or the real poles dominate the response?

22. A system has a block diagram as shown in Figure AP2.2. Determine the transfer function

$$T(S) = Y_2(s)/R_1(s)$$

It is desired to decouple $Y_2(s)$from $R_1(s)$ by obtaining $T(S)$ = 0. Select $G_5(s)$ in terms of the other $G_i(s)$to achieve decoupling.

23. Consider the feedback control system in Figure AP2.3. Define the tracking error as

$$E(s) = R(s) - Y(s)$$

(a) Determine a suitable H(s) such that the tracking error is zero for any input R(s) in the absence of a disturbance input (that is, when $T_d(s) = 0$). (b) Using H(s) determined in part (a), determine the response Y(s) for a disturbance $T_d(s)$ when the input R(s) = 0. (c) Is it possible to obtain Y(s) = 0 for an arbitrary disturbance $T_d(s)$ when $G_d(s) \neq 0$? Explain your answer.

24. Consider the unity feedback system described in the block diagram in Figure AP2.7. Compute analytically the response of the system to an impulse disturbance. Determine a relationship between the gain K and the minimum time it takes the impulse disturbance response of the system to reach y(t) < 0.1. Assume that K > 0. For what value of K does the disturbance response first reach at y(t) = 0.1 at t = 0.05?

25. Consider the cable reel control system given in Figure AP2.8. Find the value of A and K such that the percent overshoot is P.O. < 10% and a desired velocity of 50 m/s in the steady state is achieved. Compute the closed-loop response y(f) analytically and confirm that the steady-state response and P. O. meet the specifications.

Figures

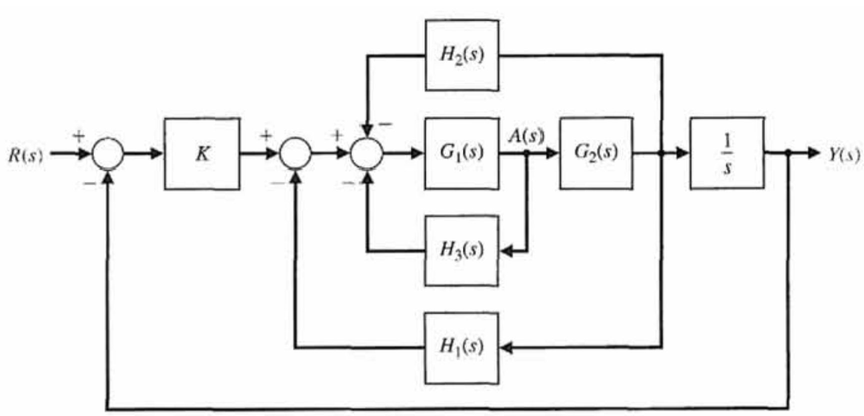


FIGURE E2.8 Ship steering system.

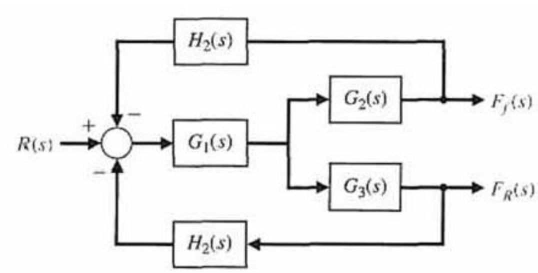


FIGURE E2.9 Brake control system.

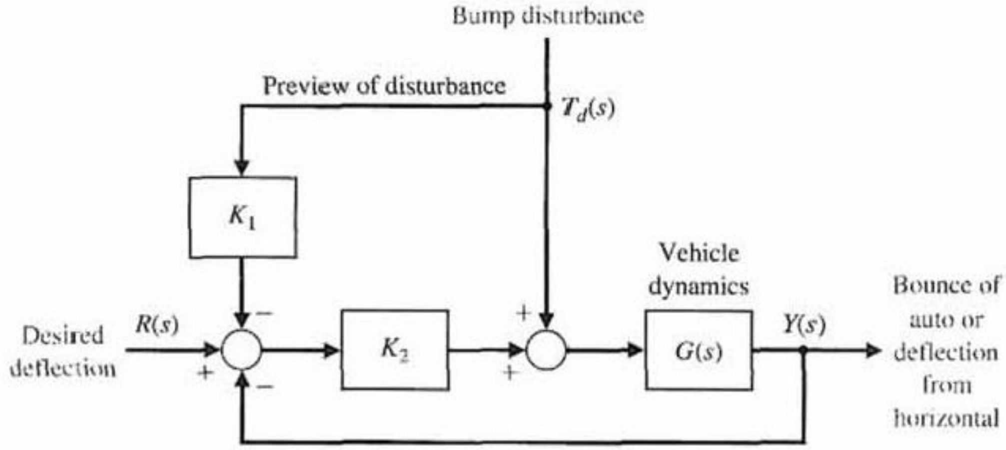


FIGURE E2.12 Active suspension system.

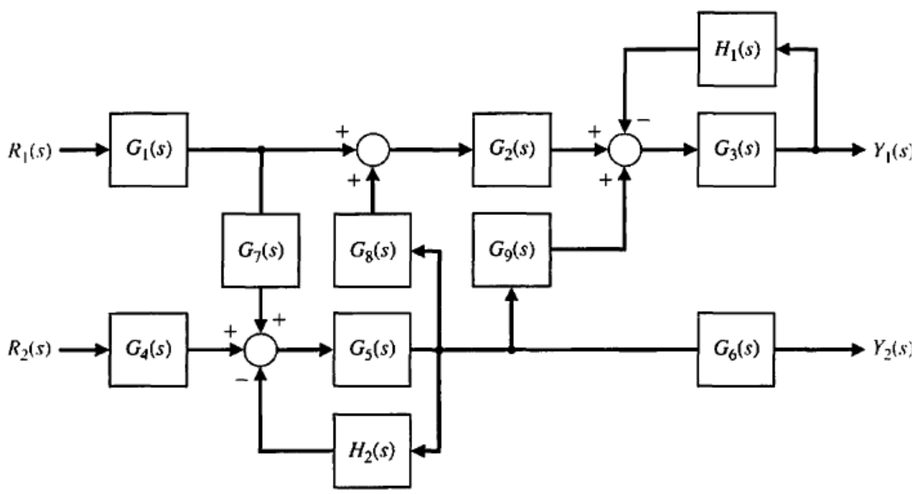


FIGURE E2.14 Multivariable system.

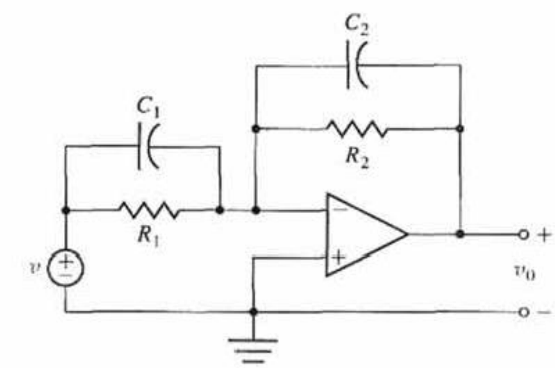


FIGURE E2.20 Op-amp circuit.

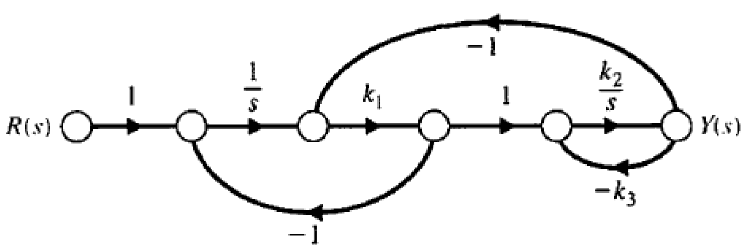


FIGURE E2.23 Control system with three feedback loops.

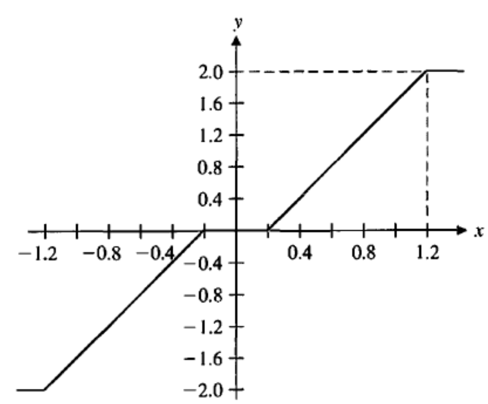


FIGURE E2.25 An amplifier with a deadband region.

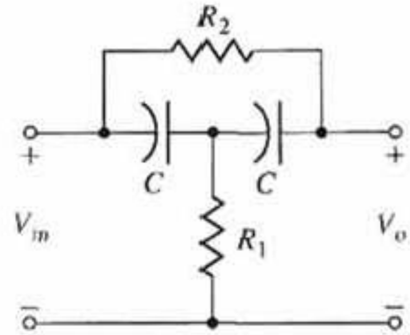


FIGURE P2.8 Bridged-T network.

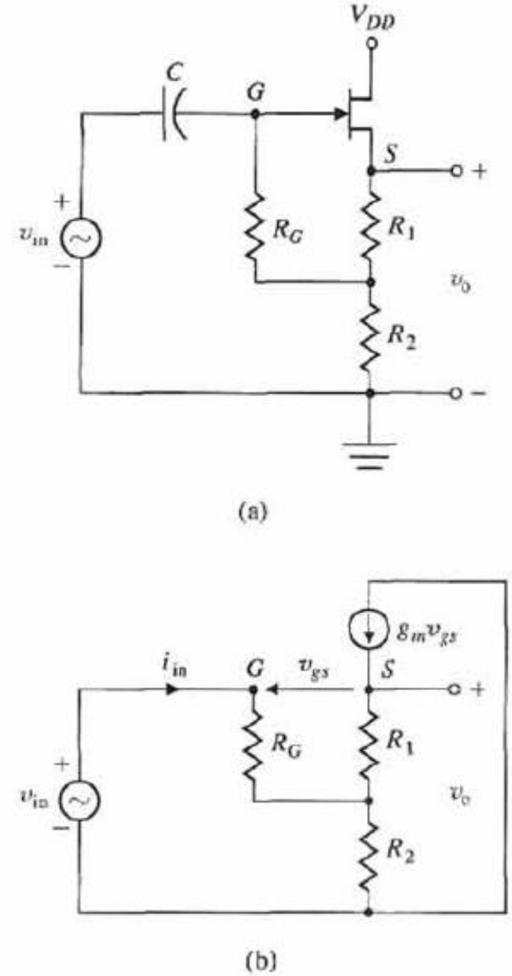


FIGURE P2.20 The source follower or common drain amplifier using an FET.

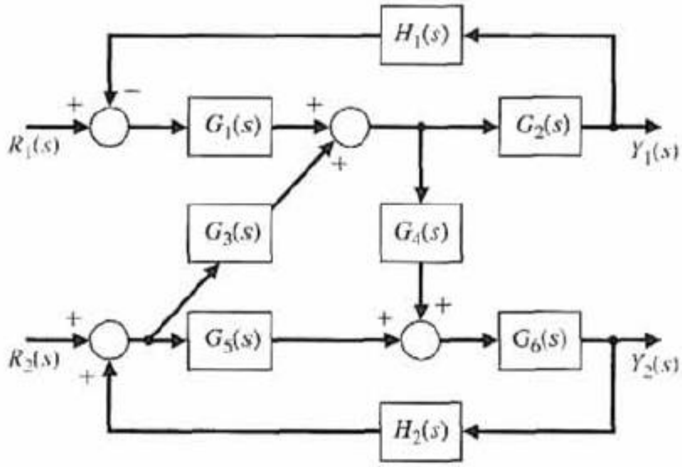


FIGURE P2.31 Interacting System.

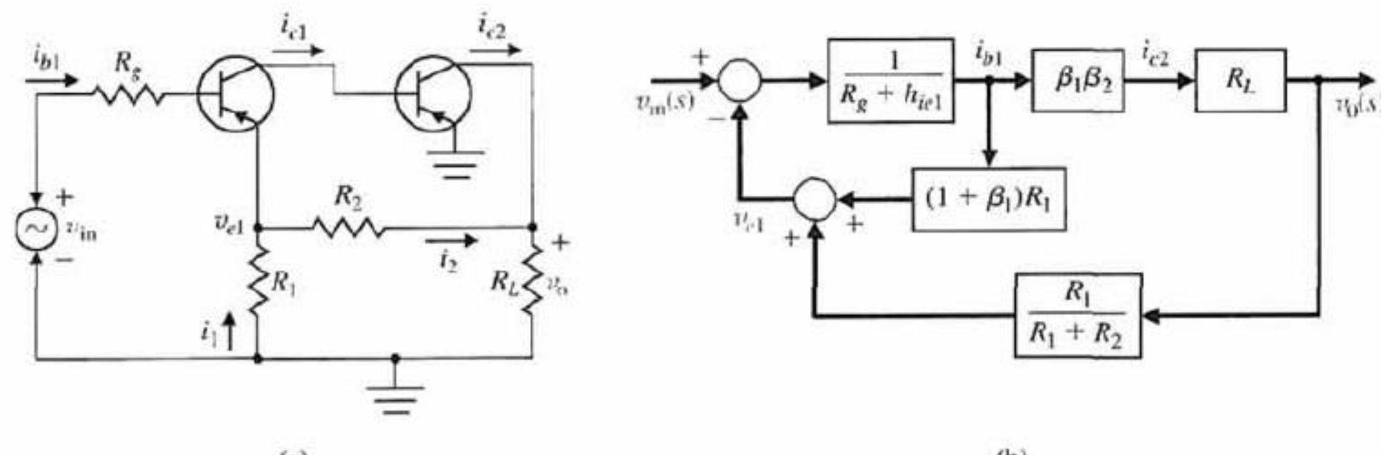


FIGURE P2.24 Feedback amplifier.

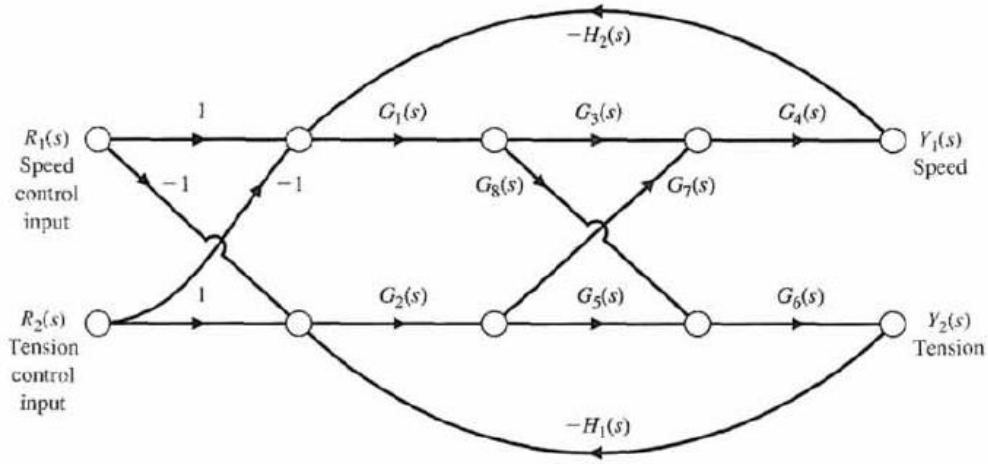


FIGURE P2.32 A model of the coupled motor drives.

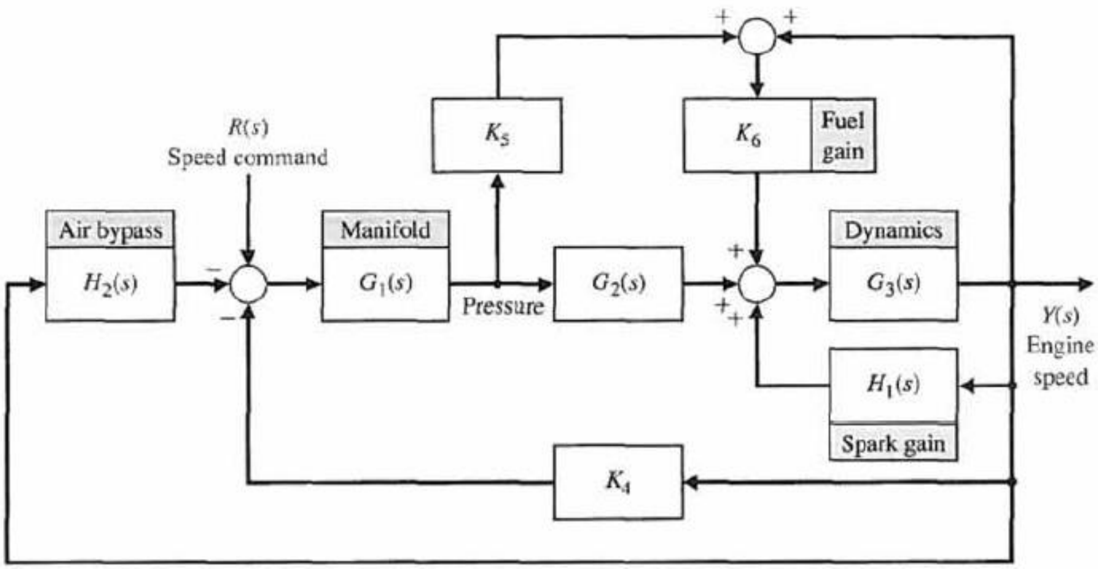


FIGURE P2.33 Idle speed control system.

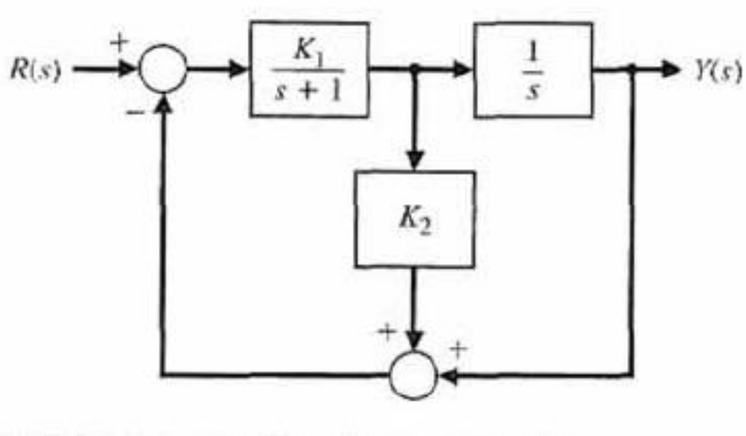


FIGURE P2.35 Multiloop feedback system.

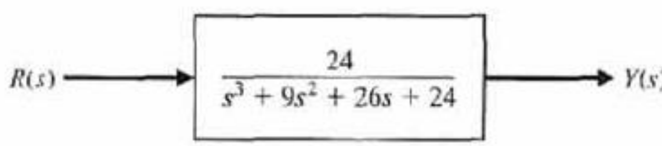


FIGURE P2.36 A third-order system.

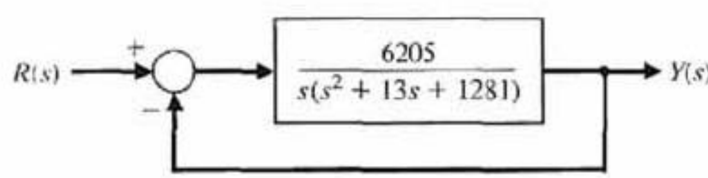


FIGURE P2.49 Unity feedback control system.

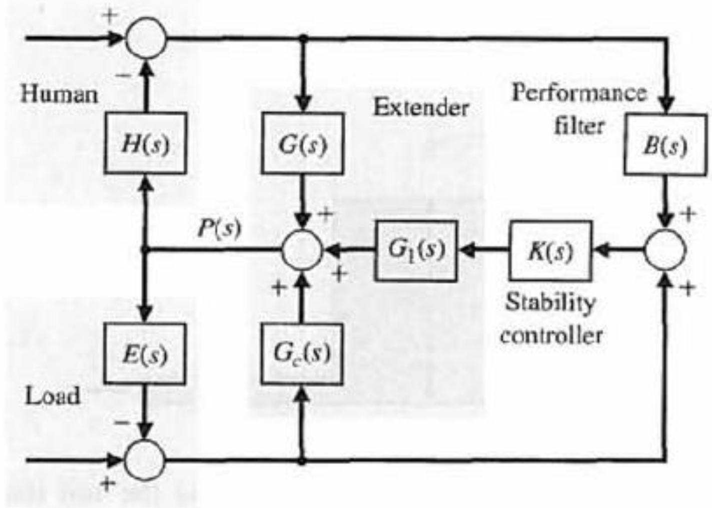


FIGURE P2.45 Model of extender.

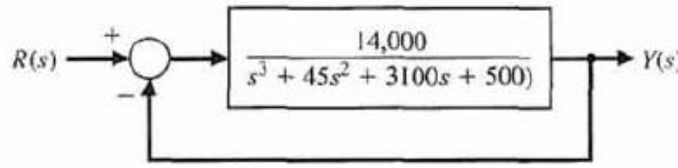


FIGURE P2.50 Third-order feedback system.

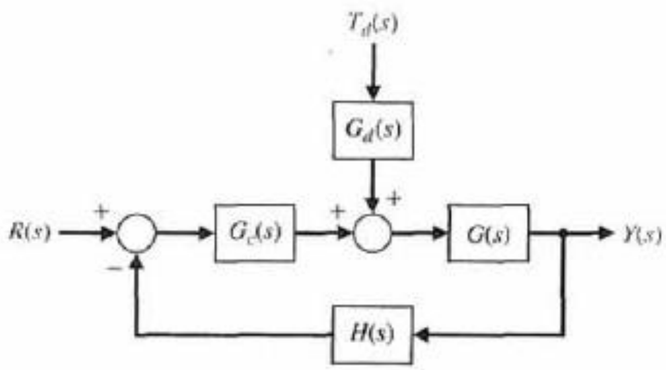


FIGURE AP2.3 Feedback system with a disturbance input.

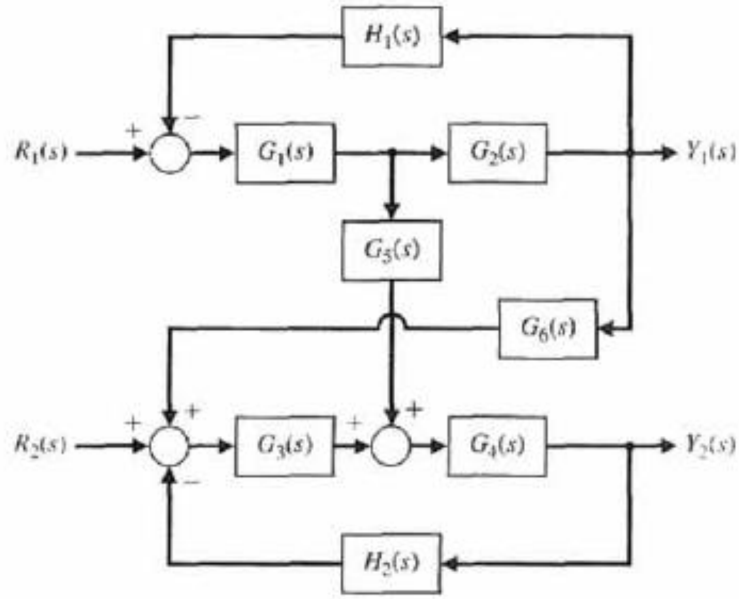
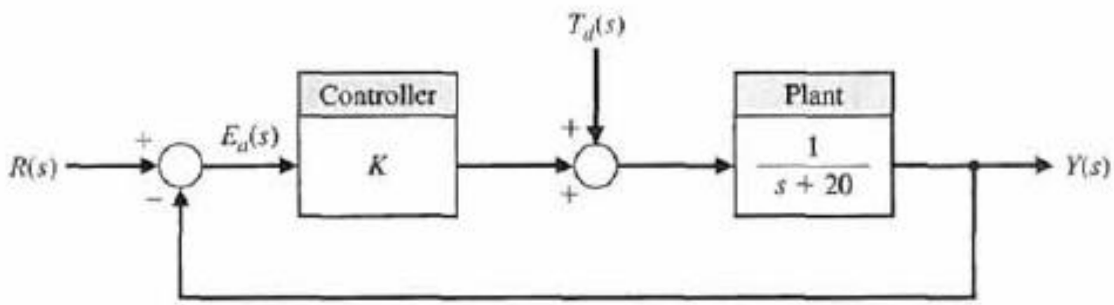


FIGURE AP2.2 Interacting control system.

FIGURE AP2.7 Unity feedback control system with controller $G_c(s) = K$.



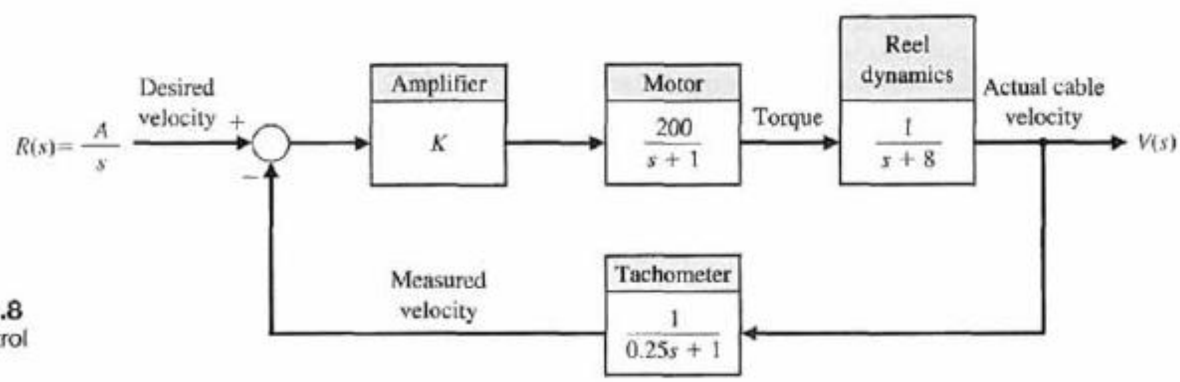


FIGURE AP2.8 Cable reel control system.