Furthermore, we extended the root locus method for the design of several parameters for a closed-loop control system. Then the sensitivity of the characteristic roots was investigated for undesired parameter variations by defining a root sensitivity measure. It is clear that the root locus method is a powerful and useful approach for the analysis and design of modern control systems and will continue to be one of the most important procedures of control engineering.

SKILLS CHECK

In this section, we provide three sets of problems to test your knowledge: True or False, Multiple Choice, and Word Match. To obtain direct feedback, check your answers with the answer key provided at the conclusion of the end-of-chapter problems. Use the block diagram in Figure 7.74 as specified in the various problem statements.

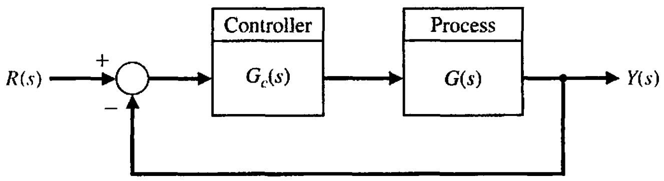


FIGURE 7.74 Block diagram for the Skills Check.

In the following **True or False** and **Multiple Choice** problems, circle the correct answer.

1. The root locus is the path the roots of the characteristic equation (given by $1 + KG(s) = 0$) trace out on the s-plane as the system parameter $0 \leq K < \infty$ varies. *True or False*
2. On the root locus plot, the number of separate loci is equal to the number of poles of $G(s)$. *True or False*
3. The root locus always starts at the zeros and ends at the poles of $G(s)$. *True or False*
4. The root locus provides the control system designer with a measure of the sensitivity of the poles of the system to variations of a parameter of interest. *True or False*
5. The root locus provides valuable insight into the response of a system to various test inputs. *True or False*
6. Consider the control system in Figure 7.74, where the loop transfer function is

$$L(s) = G_c(s)G(s) = \frac{K(s^2 + 5s + 9)}{s^2(s + 3)}.$$

Using the root locus method, determine the value of K such that the dominant roots have a damping ratio $\zeta = 0.5$.

a. $K = 1.2$

b. $K = 4.5$

c. $K = 9.7$

d. $K = 37.4$

In Problems 7 and 8, consider the unity feedback system in Figure 7.74 with

$$L(s) = G_c(s)G(s) = \frac{K(s + 1)}{s^2 + 5s + 17.33}.$$

7. The approximate angles of departure of the root locus from the complex poles are

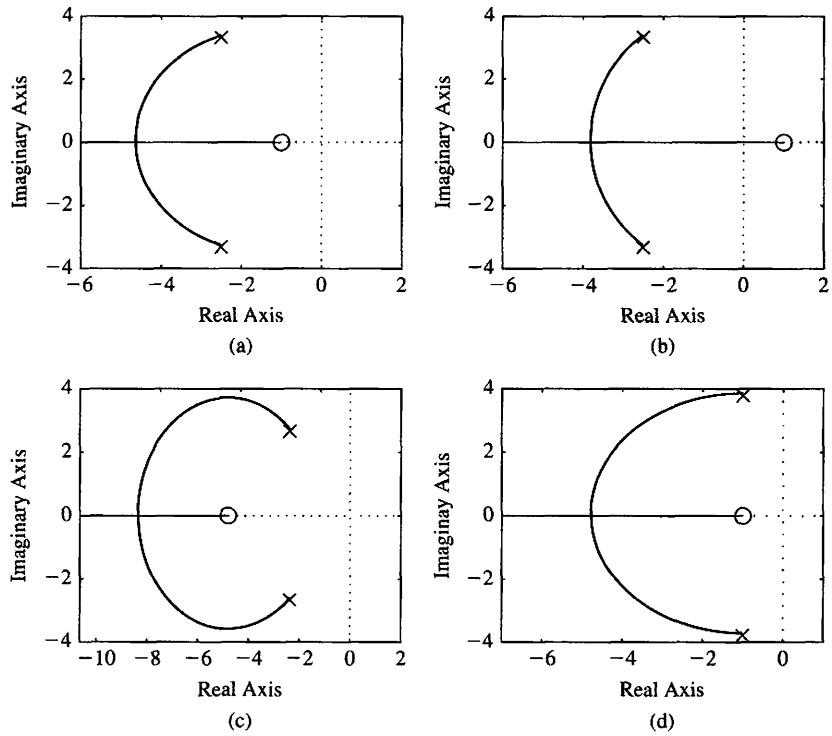
a. $\phi_d = \pm 180°$

b. $\phi_d = \pm 115°$

c. $\phi_d = \pm 205°$

d. None of the above

8. The root locus of this system is given by which of the following



9. A unity feedback system has the closed-loop transfer function given by

$$T(s) = \frac{K}{(s + 45)^2 + K}.$$

Using the root locus method, determine the value of the gain K so that the closed-loop system has a damping ratio $\zeta = \sqrt{2}/2$.

a. $K = 25$

b. $K = 1250$

c. $K = 2025$

d. $K = 10500$

10. Consider the unity feedback control system in Figure 7.74 where

$$L(s) = G_c(s)G(s) = \frac{10(s + z)}{s(s^2 + 4s + 8)}.$$

Using the root locus method, determine that maximum value of z for closed-loop stability.

a. $z = 7.2$

b. $z = 12.8$

c. Unstable for all $z > 0$

d. Stable for all $z > 0$

In Problems 11 and 12, consider the control system in Figure 7.74 where the model of the process is

$$G(s) = \frac{7500}{(s + 1)(s + 10)(s + 50)}.$$

11. Suppose that the controller is

$$G_c(s) = \frac{K(1 + 0.2s)}{1 + 0.025s}.$$

Using the root locus method, determine the maximum value of the gain K for closed-loop stability.

a. $K = 2.13$

b. $K = 3.88$

c. $K = 14.49$

d. Stable for all $K > 0$

12. Suppose that a simple proportional controller is utilized, that is, $G_c(s) = K$. Using the root locus method, determine the maximum controller gain K for closed-loop stability.

a. $K = 0.50$

b. $K = 1.49$

c. $K = 4.49$

d. Unstable for $K > 0$

13. Consider the unity feedback system in Figure 7.74 where

$$L(s) = G_c(s)G(s) = \frac{K}{s(s + 5)(s^2 + 6s + 17.76)}.$$

Determine the breakaway point on the real axis and the respective gain, K.

a. $s = -1.8, K = 58.75$

b. $s = -2.5, K = 4.59$

c. $s = 1.4, K = 58.75$

d. None of the above

In Problems 14 and 15, consider the feedback system in Figure 7.74, where

$$L(s) = G_c(s)G(s) = \frac{K(s + 1 + j)(s + 1 - j)}{s(s + 2j)(s - 2j)}.$$