Alexandria University
Faculty of Engineering
Electrical Engineering Department
Final-Term Exam (Spring 2013)

جامعة الإسكندرية
كلية الهندسة
قسم الهندسة الكهربية
امتحان نهاية الفصل الدراسي (ربيع ٢٠١٣)

Course Title and Code Number:
Control Systems and Components (EE391)
Third Year (Communications and Electronics)
Time Allowed: 3 Hrs

اسم المقرر والرقم الكودي له:
أنظمة التحكم ومكوناتها (EE391)
السنة الدراسية الثالثة (اتصالات و الكترونيات)
الزمن: ٣ ساعات

Part I (90 Minutes - 45 Marks)

Answer All Questions:

Question One: **(15 marks)**

For a unity feedback control system, if the open-loop transfer function is:

$$G(s) = \frac{K(s+3)(s+5)}{s(s^2-1)}$$

a) Draw a neat sketch of the root locus for $0 < K < \infty$, and determine the range of K for stability and the frequency of oscillation.
b) It is required that the dominant poles of the closed-loop have a damping ratio = 0.707. Estimate (approximately) the settling time and the corresponding gain K.

Question Two: **(15 marks)**

For a unity feedback control system, if the open-loop transfer function is:

$$G(s) = \frac{K}{s(1+0.2s)(1+0.1s)}$$

Plot the Bode diagram and find the gain margin, and phase margin for the following cases: $K = 1$, $K = 15$, and $K = 20$. Comment on the results.

Question Three: **(15 marks)**

The open-loop transfer function of a unity feedback control system is:

$$G(s) = \frac{0.32K}{s(s+1)(0.5s+1)}$$

If $K = 1$, plot the frequency response on the Nichols chart and find M_p, ω_p, ω_B, the gain margin, and phase margin . If the maximum closed-loop gain M_p is required to be $6\ db$, find the open-loop gain K.

Good Luck

Examiner: ***Dr. Adel El-Fahar***

Part II (90 Minutes - 45 Marks)

Attempt All Questions:

Question Four: **(12 marks)**

a) Derive the state-space realization of the following transfer function in observer form.

$$G(s) = \frac{Y(s)}{U(s)} = \frac{b_{n-1}s^{n-1} + b_{n-2}s^{n-2} + \cdots + b_1 s + b_0}{s^n + a_{n-1}s^{n-1} + \cdots + a_1 s + a_0}$$

b) Use block-diagram reduction or Mason's rule to find the transfer function for the system shown in Figure 1.

c) Write the state-space and output equations for the system shown in Figure in observer form.

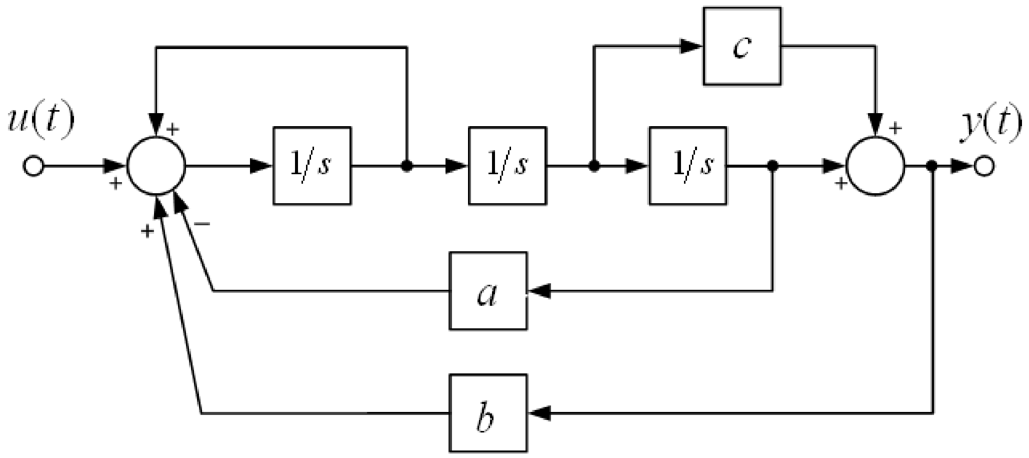

Figure 1

Question Five: **(12 marks)**

For the following differential equation:

$$\ddot{y} + 5\dot{y} + 6y = \ddot{u} + \dot{u} + 2u$$

a) Derive a state-space model in canonical diagonal form.

b) Draw the system block diagram, and clearly label the input, state variables, and output.

c) Derive an expression for the state-transition matrix $\Phi(t)$.

d) If the initial state $x(0) = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$, and the input is unit step, what is the state vector $x(t)$ for $t > 0$?

<u>Question Six:</u> **(8 marks)**

a) Draw a detailed block diagram and clearly label the input, state variables, and output for a SISO system in the following state-space form:

$$\dot{x}(t) = Ax(t) + bu(t)$$
$$y(t) = cx(t)$$

with a full-state feedback controller, a closed-loop state estimator, and a pre-scaling reference input tracker. What should be the relation between the state feedback and state estimator gains?

b) Briefly describe with the aid of equations a systematic method uses a suitable state-space transformation to calculate the state feedback gain $k = [k_1\ k_2 \ldots k_n]$ that places the closed-loop system poles at $p_1, p_2, \ldots p_n$ in the s-plane. What is the condition to be able to apply this method?

<u>Question Seven:</u> **(13 marks)**

Consider a second-order open-loop SISO system with the following state-space equations:

$$\dot{x}(t) = \begin{bmatrix} 2 & 1 \\ -1 & 1 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 2 \end{bmatrix} u(t)$$
$$y(t) = [1 \quad 1]x(t)$$

a) Check stability, observability, and controllability of the open-loop system.

b) If the system is controllable, design a full state-space feedback controller in the form of

$$u(t) = r(t) - kx(t)$$

to yield a 20% overshoot and a settling time of 2 seconds. Calculate the required value of *k*.

c) If the system is observable, design a closed-loop state estimators in the form:

$$\dot{\hat{x}}(t) = (A - lc)\hat{x}(t) + bu(t) + ly(t)$$

to respond 6 times as fast as the closed-loop system. Calculate the required value of *l*.

d) It is desired that the output *y(t)* follows a unit step input. Calculate the pre-scaling gain *E* for the reference input *r*(*t*).

Good Luck

*Examiner**: Dr. Mohammed Morsy***