TECHNICAL UNIVERSITY OF MOMBASA

Faculty of Engineering and Technology

Department of Electrical and Electronic Engineering

UNIVERSITY EXAMINATION FOR:

Bachelor of Science in Electrical Engineering

EEE 2507: CONTROL ENGINEERING IV

SPECIAL/SUPPLEMENTARY EXAMINATION

SERIES: SEPTEMBER 2018

TIME: 2 HOURS

DATE: SEPTEMBER 2018

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of **five** Questions; Question ONE is compulsory. In addition attempt any Other TWO Questions.

Do not write on the question paper.

Question ONE (Compulsory 30 marks)

(a) Industrial automatic controllers whose control actions are proportional, integral, proportional-plus- integral, proportional-plus- derivative and proportional-plus- integral-plus derivative are considered. The transfer functions of these controllers are respectively given below.

$$\frac{U(s)}{E(s)} = K_p$$

$$\frac{U(s)}{E(s)} = \frac{K_i}{s}$$

$$\frac{U(s)}{E(s)} = K_p(1+\frac{1}{\tau_i s})$$

$$\frac{U(s)}{E(s)} = K_p(1+\tau_d s)$$

$$\frac{U(s)}{E(s)} = K_p(1+\frac{1}{\tau_i s}+\tau_d s)$$

Where $U(s)$ is the Laplace transform of $u(t)$, the controller output, and $E(s)$ Laplace transform of $e(t)$, the actuating error signal. Sketch $u(t)$ versus t curves for each of the five types of controllers when the actuating error signal is:

i) $e(t)$ = unit-step function

ii) $e(t)$ = unit-ramp function

Assume that the numerical values of K_p, K_i, τ_i and τ_d are given as $K_p = 4$, $K_i = 2s^{-1}$ $\tau_i = 2\text{seconds}$ and $\tau_d = 0.8\text{seconds}$ (10 marks)

(b) Linearize the nonlinear equation $z = x^2 + 8xy + 3y^2$ in the region defined by $2 \le x \le 4, 10 \le y \le 12$ (6 marks)

(c) A plant is described in state space by the equation:

$\dot{x} = Ax + Bu$

Where $\text{A} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -35 & -27 & -9 \end{bmatrix}$, $\text{B} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$

The performance index is given by: $J = \int_0^\infty \left(x^T Q x + u^T R u \right) dt$ Where $Q = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, R = [1]$

Obtain:

i) The positive-definite solution matrix P of the Riccati equation

ii) The optimal feedback gain matrix K

iii) The eigenvalues of the matrix $A - BK$

(14 marks)

Question TWO

(a) Explain the describing function method for the analysis of nonlinear systems (6 marks)

(b) Using Lyapunov theory, find the sufficient conditions on a_1 and a_0 which guarantee that the point $x = 0,\ dx/dt = 0$ is stable for the equation $\frac{dx^2}{dt^2} + a_1 \frac{dx}{dt} a_0 x = 0$ (4 marks)

(c) A linear second-order servo is described by the equation $\ddot{e} = 2\zeta\omega_n \dot{e} + \omega_n{}^2 e = 0$

Where $\zeta = 0.15, \omega_n = 1, e(0) = 1.5, \dot{e}(0) = 0$

i) Determine the singular point

ii) Construct the phase trajectory, using the method of isoclines.

(10 marks)

Question THREE

(a) Find the control u which minimizes $J = \int_0^1 u^2 dt$ where $\dot{x} = u + ax,\ a$ is a constant, and

i) $x(0) = 1$

ii) $x(0) = 1,\ x(1) = 0$

(8 marks)

(b) The system

$\dot{x}_1 = x_2$

$\dot{x}_2 = -x_2 + u$

Is to be controlled so that its control effort is conserved; that is, the performance measure $J = \int_0^T \frac{1}{2} u^2 dt$ is to be minimized. Use the Hamiltonian method to find the governing path. Solve the problem completely when

$x_1(0) = 1,\ x_2(0) = 1$

$x_1(1) = 0,\ x_2(1) = 0$

(12 marks)

Question FOUR

(a) Figure Q 4(a) shows the block diagram representation of a process plant being controlled by a PID controller.

i) Find an expression for the complete response $C(s)$ when $R_1(s)$ and $R_2(s)$ act simultaneously.

ii) Using the Zeigler - Nichols Process Reaction method, determine values for K_1, T_i and T_d when $T_1 = 10$ seconds and $T_2 = 20$ seconds.

iii) Insert the values into the expressions found in (i).

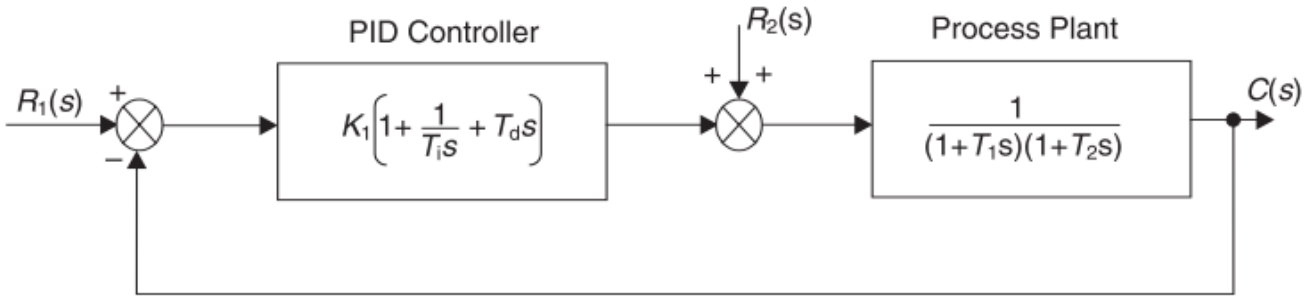

Figure Q 4(a) (12marks)

(b) A liquid level control system linearly converts a displacement of 2-3 meters into a 4-20mA control signal. A relay serves as the two-position controller to open or close an inlet valve. The relay closes at 12mA and opens at 10mA. Determine:

i) The relationship between displacement level and current

ii) The neutral zone or the displacement gap in meters

(8marks)

Question FIVE

(a) For the plant described by the equation $x(k+1) = 0.368x(k) + 0.632u(k)$

i) Find the control sequence so that the following performance index is minimized:

$$J = x^2(N) + \sum_{K=1}^{3} \left[x^2(k) + u^2(k) \right]$$

ii) Find the control sequence when $N \to \infty$

(8 marks)

(b) Explain the reasons for the popularity of digital control systems. (4 marks)

(c) Draw a block diagram for digital control of a given analog control system. (4 marks)

(d) Explain the structure and components of a typical digital control system. (4 marks)