Ref. No.: **Ex/EE/5/T/522A/2024**

BACHELOR OF ENGINEERING (ELECTRICAL ENGINEERING)
FIFITH YEAR SECOND SEMESTER - 2024

ADVANCED CONTROL THEORY

Time : 3 hours

Full Marks : 100
(50 marks for each part)

Use separate answer-scripts for each parts.

Part-I

Answer any three questions. Two marks are reserved for neatness.

Answer all parts of a question in the sequential order.

1.a) Explain the concept of "equilibrium" in the context of analysis of nonlinear systems.

b) Derive the "error dynamic model" of any nonlinear system and explain its advantage in control system analysis and design.

c) Explain with suitable sketches, the "Hard" and "Soft" nonlinearities observed in dynamic systems.

[3+(4+1)+8=16]

2. a) Explain the concept of stability of a nonlinear system when its equilibrium state lies in the n-dimensional state space. In this context, explain the concept of asymptotic stability, marginal stability, instability and domain of attraction.

b) When will you call a system to be "exponentially stable"?

c) Explain the first method of Lyapunov for the assessment of stability of nonlinear systems.

[(4+4)+2+6=16]

3. a) Compare the Jacobian Linearization and Feedback Linearization methods. Hence suggest which method would be useful in what situation.

b) Derive the control law for input-state feedback linearization for the following system:

$$\dot{x} = f(x) + g(x)u$$

[(6+2)+8=16]

[Turn over

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4. a) Describe the basic steps of Sliding Mode Controller design for the following second order nonlinear system:

$$\ddot{x} = f(\dot{x}, x) + u$$

where x is a scalar and f(.,.) be an uncertain function, where the estimate of f(.,.) is known and bounded as following:

$$\left| f(\dot{x}, x) - \hat{f}(\dot{x}, x) \right| \leq F(\dot{x}, x), \ \forall \dot{x}, x$$

b) Why "Chattering" is observed in Sliding Mode Controllers? What are the measures to reduce it?

[12+(2+2)=16]

5) Write short note **on any two** from the following: [8+8=16]

a) Various properties of phase plane portraits of any nonlinear system.

b) Phase plane portraits of second order LTI system with different damping ratios.

c) Krasovskii's method of determination of Lyapunov candidate function.

d) Various significant features of nonlinear systems.

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B. E. (ELECTRICAL ENGINEERING) 5TH YEAR 2ND SEMESTER EXAMINATION, 2024

Subject: ADVANCED CONTROL THEORY **Time: Three Hours** **Full Marks: 100**

Part II (50 marks)

Question No.		Answer ***Any Five*** questions (5×10)	Marks
Q1	(a)	(i) What is meant by Plant Uncertainty? How such uncertainties are classified?	2+2
		(ii) Discuss how the study of Robust Control facilitates one to take care of such uncertainties?	2
	(b)	Draw the block diagram of a generalized feedback control scheme involving plant with any one of such uncertainties.	4
Q2	(a)	(i) Define Sensitivity of a system with respect to variations in its parameter values.	2
		(ii) Show how feedback can be used to reduce the sensitivity in respect of changes in the plant parameters.	4
	(b)	For a negative unity feedback system with forward path transfer function $G(s) = \frac{1}{s+\alpha}$ Derive the expression for the sensitivity of the closed-loop system with respect to variations in the values of α.	4
Q3	(a)	Define Gain Margin (GM) of a system.	2
	(b)	(i) With the help of a block diagram show how an uncertain gain K with a multiplicative uncertainty can be represented.	4
		(ii) Assuming that the gain K varies between K_{min} and K_{max} derive the nominal gain and the perturbation range for an uncertainty factor that may have any real value of magnitude not exceeding unity.	4
Q4	(a)	(i) Define 2-norm and ∞-norm of a vector.	2+2
		(ii) Show that ∞-norm is always less than the 2-norm of a vector.	2
	(b)	Find 2-norm and ∞-norm for a continuous time function defined as $f(t) = \begin{cases} t & -5 < t < 3 \\ 0 & otherwise \end{cases}$	4

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Q5 (a) State Small Gain Theorem for robust stability. 2

(b) Consider a feedback control system with a feedback controller C and a plant with unstructured additive uncertainty given as

$$\tilde{G} = G + \Delta_A$$

where,

$\tilde{G}$ represents true plant dynamics,

G is a model of plant dynamics,

and Δ_A represents unstructured additive uncertainty.

Assume that Δ_A is stable and its upper bound is known.

(i) Draw the block diagram of the system and derive the block diagram showing a generalized plant with unstructured additive uncertainty. 4

(ii) Obtain the condition that a feedback controller C must satisfy to ensure robust stability. 4

Q6 (a) With the help of block diagrams show the different ways an uncertainty can affect a nominal plant. 4

(b) Consider a control system consisting of the generalized plant $P(s)$ and the controller $K(s)$ as shown in Figure Q6(b). Obtain the transfer function that relates the controlled variable, $z(s)$, with the exogenous disturbances, $w(s)$. 6

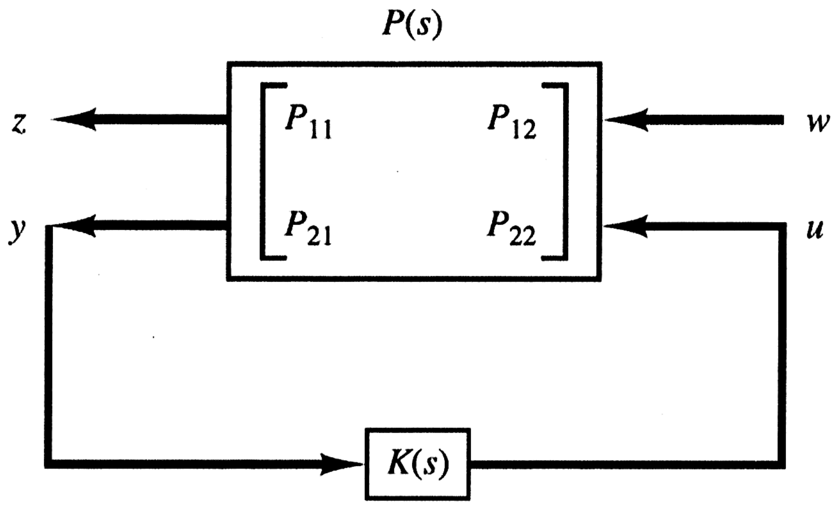

Figure Q6(b)

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Q7 (a) Define Interval Polynomial Family. 2

(b) State Kharitonov's Theorem related to robust stability. 2

(c) Consider a system with the characteristic equation given as

$$s^3 + a_2 s^2 + a_1 s + a_0 = 0$$

The uncertainties associated with the co-efficients are given as

$$8 \le a_0 \le 60$$

6

$$12 \le a_1 \le 100$$

$$7 \le a_2 \le 25$$

Derive the Kharitonov polynomials.

Q8 (a) Define Robust Stability and Robust Performance problems. 2

(b) Consider a feedback control system with unstructured multiplicative uncertainty as shown in Figure Q8(b) with

$$\tilde{G} = G(1 + \Delta_M)$$

where,

$\tilde{G}$: true plant dynamics,

G: model of plant dynamics and

Δ_M: unstructured multiplicative uncertainty.

Assume that Δ_M is stable and its upper bound is known.

(i) Develop the block diagram showing the generalized plant with unstructured multiplicative uncertainty. 4

(ii) Derive the conditions that the feedback controller K must satisfy to ensure robust performance such that the output $y(t)$ follows the input $r(t)$ as closely as possible. 4

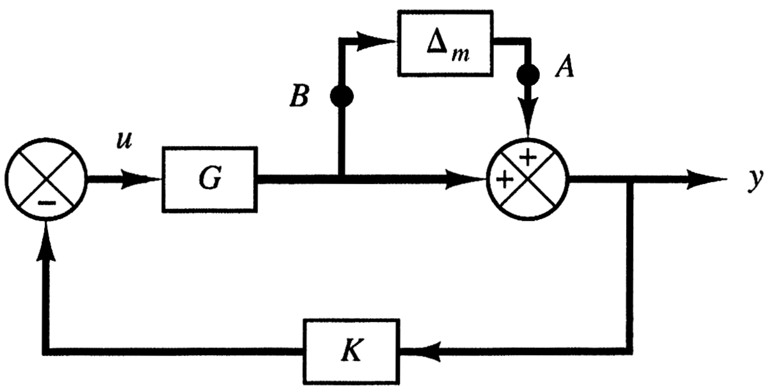

Figure Q8(b)