Question Paper

Exam Date & Time: 30-Nov-2022 (09:00 AM - 12:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

MANIPAL INSTITUTE OF TECHNOLOGY
VII SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV/DEC 2022

Non-Linear Control Systems [ICE 4052]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) Identify and classify all equilibrium points of the given nonlinear system (3)

A) $\dot{x}_1 = -x_1 + 2x_1^3 + x_2$, $\dot{x}_2 = -x_1 - x_2$

[CO1, PO1, PO2, PO12, BL4]

B) Linearize the following system and check whether the origin is exponentially stable. Justify. (2)

$$\dot{x} = ax^3$$

[CO1, PO1, PO2, PO12, BL3]

C) Derive an expression for the coefficient K of $y_i = Kx_i$ using least squares estimation. Compute K for the following data points. (5)

Point ->	A	B	C	D	E
x_i	0	1	2	3	4
y_i	0.1	1.9	4.2	6.2	7.7

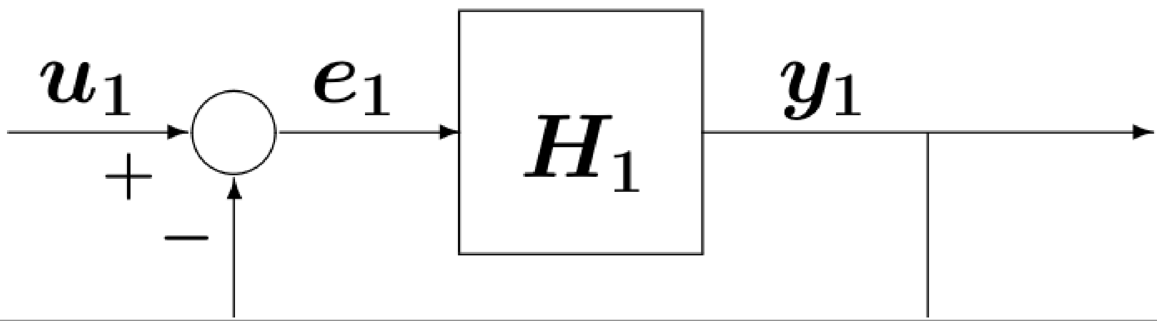
[CO4, PO1, PO2, PO12 BL4]

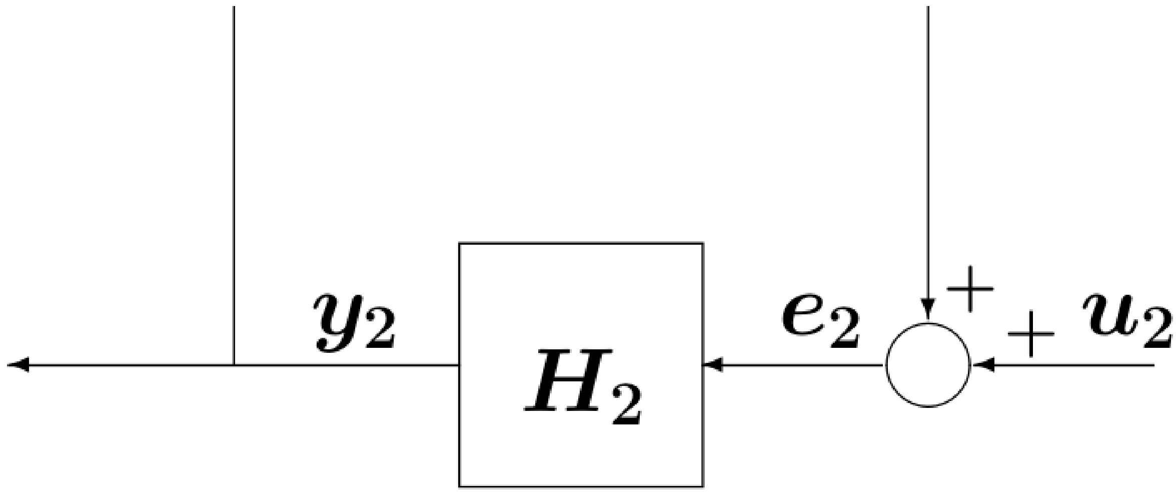
2) A) Linearize the given pendulum equation at input $T = T_{ss}$ taking states as θ and $\dot{\theta}$. Find conditions for the linearized system to be controllable. (3)

$$\ddot{\theta} + b\dot{\theta} + a sin\theta = cT$$

[CO3, PO1, PO2, PO3, PO4, PO5, PO12, BL4]

B) Show that the feedback connection shown in the figure is passive if H_1 and H_2 are passive. (2)





[CO2, PO1, PO2, PO3, PO4, PO5, PO12, BL5]

C) Design control input u using input state feedback linearization technique to stabilize the equilibrium point of the given system. (5)

Show all the steps in detail.

$$\dot{x}_1 = -2x_1 + ax_2 + \sin x_1,$$

$$\dot{x}_2 = -x_2 \cos x_1 + u \cos(2x_1)$$

[CO4, PO1, PO2, PO12, BL4]

3) Compute coefficients of the bounding functions for the system (3)

A) $\dot{x} = -x - x^3 + u$, $y = \tanh x + u$ for showing it as finite gain L_p stable.

[CO1, PO1, PO2, PO12, BL5]

B) Explain graphically tangent and secant method of linearization. Write equations for the coefficient. [CO4, PO1, PO2, PO12, BL3] (2)

C) Explain the concept of internal dynamics using given two linear systems: (5)

a) $\dot{x}_1 = x_2 + u$, $\dot{x}_2 = u$, $y = x_1$

b) $\dot{x}_1 = x_2 + u$, $\dot{x}_2 = -u$, $y = x_1$

Compute transfer functions, and plot output response for a step function. Comment on the response.
[CO4, PO1, PO2, PO12, BL4]

4) Given are the output equations (5)

A) $\dot{y}_i = a_i y_i + k_i u$ with $i = p$ for plant, and $i = m$ for model. Derive an equation for the dynamics of output error $e_o = y_p - y_m$ of Model Reference Adaptive Control (MRAC) in terms of the adaptive variables θ_1 and θ_2 as

$$\dot{e}_o = a_m e_o + k_p \phi_1 r + k_p \phi_2 (e_o + y_m)$$ along with $\dot{\phi}_1 = -\gamma e_o r$

and $\dot{\phi}_2 = -\gamma e_o [e_o + y_m]$. Deduce the simplified versions and zero output case.

[CO4, PO1, PO2, PO12, BL5]

B) Perform input output linearization on the following system (3)

$$\dot{x}_1 = \sin x_2 + (x_2 + 1)x_3$$

$$\dot{x}_2 = x_1^5 + x_3$$

$$\dot{x}_3 = x_1^2 + u$$

$$y = x_1$$

[CO4, PO1, PO2, PO12, BL4]

C) Write the linear approximation and first neglected term of (2)

a) $f(x) = \frac{1}{1+\Delta x}$, b) $g(x) = e^{\Delta x}$

[CO4, PO1, PO2, PO12, BL3]

5) Taking the sliding surface as $s = a_1 x_1 + x_2$, compute the region of validity for the following system. Plot this region. (4)

A) Explain in brief.

$$\dot{x}_1 = x_2 \quad \dot{x}_2 = h(x) - g(x)\beta(x)sgn(x)$$

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[CO5, PO1, PO2, PO4, PO5, PO12, BL4]

B) What are high gain observers? How are they different from the conventional observers? Explain the concept with a numerical example. (3)

[CO5, PO1, PO2, PO4, PO5, PO12, BL3]

C) Consider the nonlinear system (3)

$$\dot{x}_1 = x_1^2 - x_1^3 + x_2 \, , \dot{x}_2 = u$$

Using backstepping state as $z_2 = x_2 - \phi(x_1)$ with $\phi(x_1) = -x_1^2 - x_1$, choose suitable Lyapunov control candidate and show that the backstepping algorithm is stable.

[CO5, PO1, PO2, PO4, PO5, PO12, BL5]

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