Roll No.:…………….

National Institute of Technology, Hamirpur (HP)-177005

Name of the Examination: M.Tech. (End Semester Examination)		**Academic Session:** 2020-21	
Branch	: Signal Processing & Control	**Semester**	: 1^{st}
Course Name	: Nonlinear Systems	**Course Code**	: EE – 633
Time	2 Hours	**Max. Marks**	50

Note: (i) Attempt all the questions. All parts of a given question should be attempted in continuation.
(ii) Assume any missing data while making suitable explanation for the choice made.
(iii)Show all the underlying steps in a systematic manner, wherever required.
(iv) Write your Name, Roll No., Subject Code & Subject Name on first sheet of answer-sheet and put your signature and date on all the sheets at the bottom.
(v) The scanned answer-sheets as a single file with file name xxxxxxEE633.pdf where xxxxxx represents Roll Number should be uploaded within 15 minutes after completion of examination on google classroom.
(vi) Delay in submission of answer-sheet may lead to deduction in marks or rejection of answer sheet.
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Q. No.1: Obtain the state space model of the system described by following transfer function using parallel decomposition or parallel programming and draw the corresponding model:

$$\boldsymbol{T}(\boldsymbol{s}) = \frac{\boldsymbol{y}(\boldsymbol{s})}{\boldsymbol{u}(\boldsymbol{s})} = \frac{2s^{\mathbf{2}} + 6s + 5}{s^{\mathbf{3}} + 4s^{\mathbf{2}} + 5s + 2}$$

Also check the controllability and observability of the system directly from the obtained model.

4+3=(7)

Q. No.2: A 2^{nd} order control system has description in state space form as follows:

$$\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix} = \begin{bmatrix}0 & 1\\ -1 & -2\end{bmatrix}\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix} + \begin{bmatrix}1\\ -1\end{bmatrix}r(t)$$

The output of the system is given as $y(t) = [1 \quad -1]\begin{bmatrix}x_1(t)\\ x_2(t)\end{bmatrix}$. Obtain the state and output response of the system when the initial conditions are given as $\begin{bmatrix}x_1(0)\\ x_2(0)\end{bmatrix} = \begin{bmatrix}0\\ 1\end{bmatrix}$ and the system is excited by input $r(t) = e^{-\mathbf{2}\boldsymbol{t}}u(t)$.

(7)

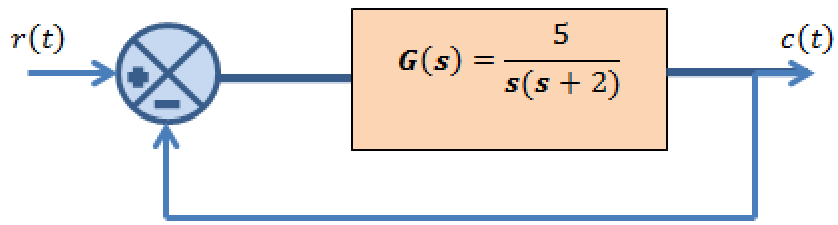
Q. No.3: What are the requirements for designing a pole placement based controller for a linear control system? Consider a 3^{rd} order control system having description in state space form as follows:

$$\boldsymbol{T}(\boldsymbol{s}) = \frac{\boldsymbol{y}(\boldsymbol{s})}{\boldsymbol{u}(\boldsymbol{s})} = \frac{10}{\boldsymbol{s}(\boldsymbol{s}+\mathbf{1})(\boldsymbol{s}+\mathbf{2})}$$

Design a state feedback based linear controller for the above system which will place the closed loop dominant poles at $s_{1,2} = -2 \pm j4$ and additional pole at $s_3 = -10$ to have the desired performance from the system.

(6)

Q. No.4: A unity feedback system is described by $G(s) = \frac{5}{s(s+2)}$. Draw the isoclines and the phase trajectory for a step input $r(t) = u(t)$ assuming the initial conditions to be $c(0) = -1$ and $\dot{c}(0) = 0$, where $r(t)$ is the input and $c(t)$ is the output.



(6)

Q. No.5: A second order system is represented as $\begin{bmatrix} \dot{x}_1(t) \\ \dot{x}_2(t) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix} \begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix}$. Assuming matrix Q to be identity matrix, solve the Liapunov equation for matrix P. Comment on stability using Liapunov theory. If stable, then also construct the corresponding Liapunov function.

(6)

Q. No.6: "In case of practical systems with nonlinearity, harmonic linearization of output signal of nonlinearity happens naturally." Justify this statement. Also derive the describing function for ideal relay nonlinearity with dead-zone.

(8)

Q. No.7 Attempt any two parts out of the following:

(a): Consider a second order system

$$\dot{x}_1(t) = -x_1(t) + \alpha\cos(x_2(t))$$
$$\dot{x}_2(t) = -x_1^2(t) + u(t)$$

Design a suitable feedback linearization controller so that the system could be stabilized. Also comment on the stability result.

(b) Explain LaSalle Invariant set theorem.

(c) Determine the singular points of the system having following differential description and explain the nature of corresponding singular point:

$$\ddot{y}(t) + \dot{y}(t) + y^3(t) = 0$$

5+5=(10)

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