# Techno India NJR Institute of Technology

# Course File

# Control System (5EX4-03)

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For Techno India NJR Institute of Technology
पँकज पोरवाल
Dr. Pankaj Kumar Porwal
(Principal)

**Syllabus:**

# RAJASTHAN TECHNICAL UNIVERSITY, KOTA

**Syllabus**

**III Year - V Semester: B.Tech. (Electrical And Electronics Engineering)**

**5EX4-03: CONTROL SYSTEM**

**Credit: 3** **Max. Marks: 150(IA:30, ETE:120)**

**3L+0T+0P** **End Term Exam: 3 Hours**

| SN | CONTENTS | HOURS |
|---|---|---|
| 1 | **Introduction:** Objective, scope and outcome of the course. | 01 |
| 2 | **Introduction to control problem**<br>Industrial Control examples. Mathematical models of physical systems. Control hardware and their models. Transfer function models of linear time-invariant systems.<br>Feedback Control: Open-Loop and Closed-loop systems. Benefits of Feedback. Block diagram algebra | 04 |
| 3 | **Time Response Analysis:**<br>Standard test signals. Time response of first and second order systems for standard test inputs. Application of initial and final value theorem. Design specifications for second-order systems based on the time-response.<br>Concept of Stability. Routh-Hurwitz Criteria. Relative Stability analysis. Root-Locus<br>technique. Construction of Root-loci.. | 09 |
| 4 | **Frequency-response analysis**<br>Relationship between time and frequency response, Polar plots, Bode plots. Nyquist stability criterion. Relative stability using Nyquist criterion – gain and phase margin. Closed-loop frequency response. | 06 |
| 5 | **Introduction to Controller Design**<br>Stability, steady-state accuracy, transient accuracy, disturbance rejection, insensitivity and robustness of control systems.<br>Root-loci method of feedback controller design.<br>Design specifications in frequency-domain. Frequency-domain methods of design.<br>Application of Proportional, Integral and Derivative Controllers, Lead and Lag compensation in designs.<br>Analog and Digital implementation of controllers | 10 |
| 6 | **State variable Analysis**<br>Concepts of state variables. State space model. Diagonalization of State Matrix. Solution of state equations. Eigenvalues and Stability Analysis. Concept of controllability and observability.<br>Pole-placement by state feedback.<br>Discrete-time systems. Difference Equations. State-space models of linear discrete-time systems. Stability of linear discrete-time systems | 06 |
| 7 | **Introduction to Optimal Control and Nonlinear Control**<br>Performance Indices. Regulator problem, Tracking Problem. Nonlinear system–Basic<br>concepts and analysis | 05 |
| | **TOTAL** | **41** |

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## Course Overview:

This course provides an introduction to linear systems, transfer functions, and Laplace transforms. It covers stability and feedback, and provides basic design tools for specifications of transient response. It also briefly covers frequency-domain techniques. It provides students a basic understanding of the concepts and techniques involved in designing control schemes for dynamic systems.

After completing the course students in-depth knowledge of concepts from classical control theory, understand the concept of transfer function and use it for obtaining system response, analyze dynamic systems for their stability and performance, and design controllers (such as Proportional-Integral-Derivative) based on stability and performance requirements will increase.

It is very important course for industrial application point of view because todays each system is a feedback control system and knowledge of designing the feedback control is very important. This eventually helps student to get recruit.

## Course Outcome:

| CO. NO. | Cognitive Level | Course Outcome |
|---|---|---|
| 1 | Synthesis | The student will be able to understand the general concept of a system and classifysystems into different types and represent a system using different techniques like block diagram, signal flow graph. |
| 2 | Synthesis | The student will be able to develop transfer function model of mechanical, electrical, thermal, fluid system and different control system components like servomotors, synchros, potentiometer, tacho-s etc. |
| 3 | Analysis | Students will be able to analyze system response and evaluate error dynamics in time domain. |
| 4 | Application | Students will be able to determine system stability using routh-hurtwitz (RH) criteria, root locus techniques in time domain and bode plot and nyquist technique in frequency domain |

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## Prerequisites:

1. System Modelling, Ordinary Differential Equations
2. A good grasp over Linear Algebra and Complex Analysis.
3. Prefer that they have completed a course on engineering mathematics that teaches complex variables and laplace transform.

## Course Outcome Mapping with Program Outcome:

| Course Outcome | Program Outcomes (PO's) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO. NO.** | **Domain Specific (PSO)** | | | | | **Domain Independent (PO)** | | | | | | |
| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
| CO1 | 2 | 1 | 2 | 1 | 3 | - | - | - | - | - | - | - |
| CO2 | 2 | 2 | 1 | 2 | 1 | - | - | - | - | - | - | - |
| CO3 | 1 | 2 | 2 | 1 | 2 | - | - | - | - | - | - | - |
| CO4 | 2 | 1 | 2 | 1 | 3 | - | - | - | - | - | - | - |
| 1: Slight (Low), 2: Moderate (Medium), 3: Substantial (High) | | | | | | | | | | | | |

## Course Coverage Module Wise:

| Lect. No. | Unit | Topic |
|---|---|---|
| 1 | **1** | **INTRODUCTION:** Objective, scope and outcome of the course. |
| 2 | **2** | **INTRODUCTION TO CONTROL PROBLEM** Industrial Control examples. |
| 3 | 2 | Mathematical models of physical systems. |
| 4 | 2 | Control hardware and their models. |
| 5 | 2 | Transfer function models of linear time-invariant systems |
| 6 | 2 | Feedback Control: Open-Loop and Closed-loop systems. |
| 7 | 2 | Benefits of Feedback. Block diagram algebra |
| 8 | **3** | **TIME RESPONSE ANALYSIS:** Standard test signals. |
| 9 | 3 | Time response of first and second order systems for standard test inputs. |
| 10 | 3 | Application of initial and final value theorem |
| 11 | 3 | Design specifications for second-order systems based on the time-response. Concept of Stability.. |
| 12 | 3 | Routh-Hurwitz Criteria. Relative Stability analysis. |
| 13 | 3 | Root-Locus technique. Construction of Root-loci |

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| | | |
|---|---|---|
| 14 | **4** | **FREQUENCY-RESPONSE ANALYSIS** Relationship between time and frequency response |
| 15 | 4 | Polar plots. |
| 16 | 4 | Bode plots. |
| 17 | 4 | Nyquist stability criterion. |
| 18 | 4 | Relative stability using Nyquist criterion – gain and phase margin. |
| 19 | 4 | Closed-loop frequency response |
| 20 | **5** | **INTRODUCTION TO CONTROLLER DESIGN** overview |
| 21 | 5 | Stability, steady-state accuracy, |
| 22 | 5 | Transient accuracy, disturbance re-jection, |
| 23 | 5 | Insensitivity and robustness of control systems. |
| 24 | 5 | Root-loci method of feedback controller design. |
| 25 | 5 | Design specifications in frequency-domain. |
| 26 | 5 | Frequency-domain methods of design. |
| 27 | 5 | Application of Proportional |
| 28 | 5 | Integral and Derivative Controllers, |
| 29 | **6** | **LEAD AND LAG COMPENSATION IN DESIGNS**. overview |
| 30 | 6 | Analog and Digital implementation of controllers |
| 31 | 6 | Analog and Digital implementation of controllers |
| 32 | 6 | State Variable Analysis Concepts of state variables. |
| 33 | 6 | State space model. Diagonalization of State Matrix. |
| 34 | 6 | Solution of state equations. Eigen values and Stability Analysis. |
| 35 | 6 | Concept of controllability and observability. |
| 36 | 6 | Pole-placement by state feedback. Discrete-time systems. |
| 37 | 6 | Difference Equations. State-space models of linear discrete-time systems. Stability of linear discrete-time systems |
| 38 | **7** | **INTRODUCTION**: Optimal Control |
| 39 | 7 | Nonlinear Control Performance Indices. |
| 40 | 7 | Regulator problem, |
| 41 | 7 | Tracking Problem. |
| 42 | 7 | Nonlinear system–Basic concepts and analysis |
| 43 | | Revision |
| 44 | | Revision |

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## Text/Reference Books:

1. Smarjit Ghosh, Control Systems: Theory and Applications, 2/e, Pearson Publisher. 2004
2. Dhannesh N. Manik: Control System, Cengage Learning. 2012
3. I. J. Nagrath and M. Gopal: Control Systems Engineering, 3rd Ed, New Age Publication.
4. K. R. Varmah: Control Systems, MGH 2010
5. Anandnatrajan et. al.: Control Systems Engineering, 4th ed., Scitech Pub.

## Teaching and Learning resources:

| | |
|---|---|
| **NPTEL Course Link** | https://nptel.ac.in/courses/107/106/107106081/<br>https://nptel.ac.in/courses/108/106/108106098/ |
| **Quiz** | https://quizizz.com/admin/quiz/5f31cc43d8a6f3001b6f2f9e/control-system |
| **Notes** | https://sites.google.com/site/eeenotes2u/courses/control-systems |

## Assessment Methodology:

1. Assignments one from each unit.
2. Midterm subjective paper where they have to solve the given problem. (Twice during the semester)
3. Final paper at the end of the semester subjective

## Previous Year Question Paper:

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0230040

5E5043

Roll No. ______________________ [Total No. of Pages : 3

# 5E5043

## B.Tech. V- Semester (Back) Examination, November - 2019
## Electrical Engineering
## 5EE3A Control System
## (Common EE, EX)

**Time : 3 Hours**

**Maximum Marks : 80**
**Min. Passing Marks : 28**

***Instructions to Candidates:***

*Attempt any **Five** questions, selecting **one question from each unit**. All Questions carry **equal** marks. Schematic diagrams must be shown wherever necessary. Any data you feel missing suitably be assumed and stated clearly. Units of quantities used/calculated must be stated clearly.*

### UNIT - I

1. a) Explain and verify the following statements :

   i) The control of traffic by glowing the LED's (red, yellow and green) is the example of open loop system where as control of traffic by the policeman is the example of closed loop control system.

   ii) A blind person walking on the road is closed loop control system.

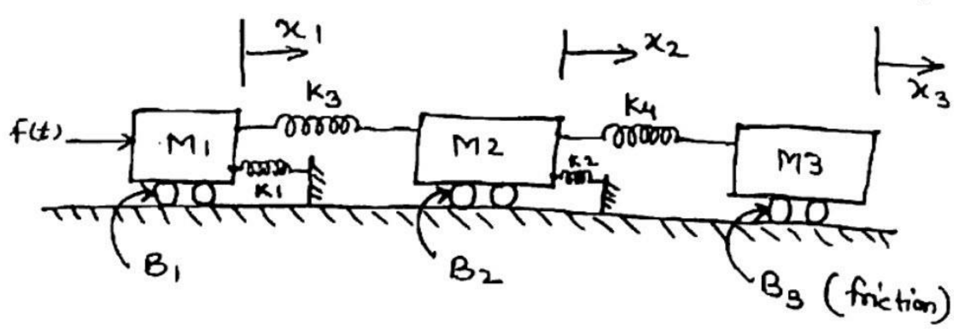
   **(4×2=8)**

   b) Obtain the solution of the differential equation given below

   $2\frac{dx}{dt} + 8x = 10$; given x(D+)=2. **(8)**

**(OR)**

1. Obtain a mathematical model and electrical analogous circuit (F-V and F-I) for the given system. **(16)**



## UNIT - II

2. a) A second order control system is represented by a transfer function given below

$$\frac{\theta_0(s)}{T(s)} = \frac{1}{Js^2 + fs + k}$$

Where $\theta_0$ is the proportional output and T is the input torque. A step input of 10 Nm is applied to the system and test result are given below

i) $M_p = 6\%$

ii) $t_p = 1 sec$,

iii) The steady value of the output is 0.5 radian. Determine the values of J, f and k.  **(10)**

b) Determine the time response of first order control system. **(6)**

**(OR)**

2. Derive the expression for steady state error for various inputs (unit - step; unit - ramp, unit - parabolic) and systems (Type - 0, Type - 1, Type - 2). **(16)**

## UNIT - III

3. a) Using Routh - Hurwitz criterion determine the relation between k and T so that unity feedback control system whose open loop transfer function given below is stable.

$$G(s) = \frac{k}{s[s(s+10)+T]}$$ **(8)**

b) Determine the stability of a system whose overall transfer function is given below

$$\frac{C(s)}{R(s)} = \frac{2s+5}{s^5 + 1.5s^4 + 2s^3 + 4s^2 + 5s + 10}$$

if the system is found unstable, how many roots it has with positive real part? **(8)**

**(OR)**

3. Sketch the root locus for the open loop transfer function of a unity feedbackcontrol system given below and determine

i) The value of k for $\xi = 0.5$

## Unit - IV

4. a) Explain sampled data control system. **(8)**

   b) Find the z-transform of the following function $f(k) = k + \sin 2k;\ k \geq 0$ **(8)**

**(OR)**

4. a) Define z-transform. Explain 'z' and 's' domain relationship. **(8)**

   b) Write a short note on Initial value theorem and final value theorem of 'z'-transform. **(8)**

## UNIT - V

5. The open loop transfer function of a unity feedback control system is given by

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

Design a suitable compensator such that the system will have $k_r = 10$ and P.M. = 50°. **(16)**

**(OR)**

5. a) Derive the formula for steady state error ($e_{ss}$) of PI control. **(8)**

   b) Write short note on (any two)

      i) Proportional control

      ii) Integral control

      iii) Derivative control

**(4×2=8)**