# GUJARAT TECHNOLOGICAL UNIVERSITY

## ELECTRONICS (10), ELECTRONICS & COMMUNICATION (11), ELECTRONICS & TELECOMMUNICATION ENGINEERING (12)

CONTROL SYSTEM ENGINEERING

**SUBJECT CODE**: 2141004

B.E. 4th SEMESTER

**Type of course:** Modeling, performance analysis and control with potential application to engineering systems.

**Prerequisite:** Knowledge of Linear differential equations, Differential equations and its solution, and Laplace transform.

**Rationale:** This course explores the fundamentals of systems and control. The course has two primary focuses:

(1) Understanding and predicting system behavior, and
(2) Design and analysis of closed loop control systems.

**Teaching and Examination Scheme:**

| Teaching Scheme | | | Credits | Examination Marks | | | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|---|---|
| L | T | P | C | Theory Marks | | | Practical Marks | | | |
| | | | | ESE (E) | PA (M) | | ESE (V) | | PA (I) | |
| | | | | | PA | ALA | ESE | OEP | | |
| 4 | 0 | 2 | 6 | 70 | 20 | 10 | 20 | 10 | 20 | 100 |

**Content:**

| Sr. No. | Topics | Teaching Hrs. | Module Weightage |
|---|---|---|---|
| **1** | Introduction to Control Systems: Introduction, Brief History of Automatic Control, Examples of Control Systems, Engineering Design, Mechatronic Systems, The Future Evolution of Control Systems. | **3** | **5-6** |
| **2** | Mathematical Models of Systems: Differential Equations of Physical Systems, Linear Approximations of Physical Systems, The Laplace Transform, The Transfer Function of Linear Systems, Block Diagram Models, Signal-Flow Graph Models. | **6** | **12-14** |
| **3** | State Variable Models: The State Variables of a Dynamic System, The State Differential Equation, Signal-Flow Graph and Block Diagram Models, Alternative Signal-Flow Graph and Block Diagram Models, The Transfer Function from the State Equation , The Time Response and the State Transition Matrix. | **8** | **14-18** |
| **4** | Feedback Control System Characteristics: Error Signal Analysis, Sensitivity of Control Systems to Parameter Variations ,Disturbance Signals in a Feedback Control System, Control of the Transient Response, Steady-State Error, The Cost of Feedback. | **3** | **6-8** |
| **5** | The Performance of Feedback Control Systems: Test Input Signals, Performance of Second-Order Systems, Effects of a Third Pole and a Zero on the Second-Order System Response, The s-Plane Root Location and the Transient Response, The Steady-State Error of Feedback Control Systems, Performance Indices, The Simplification of Linear Systems. | **4** | **8-10** |
| **6** | The Stability of Linear Feedback Systems: The Concept of Stability, | **3** | **5-8** |

| | | | |
|---|---|---|---|
| | The Routh-Hurwitz Stability Criterion, The Relative Stability of Feedback Control Systems, The Stability of State Variable Systems. | | |
| **7** | The Root Locus Method: The Root Locus Concept. The Root Locus Procedure, Parameter Design by the Root Locus Method, Sensitivity and the Root Locus, Three-Term (PID) Controllers. | **4** | **6-9** |
| **8** | Frequency Response Methods: Frequency Response Plots, Frequency Response Measurements, Performance Specifications in the Frequency Domain, Log Magnitude and Phase Diagrams. | **5** | **7-8** |
| **9** | Stability in the Frequency Domain: Mapping Contours in the s-Plane, The Nyquist Criterion, Relative Stability and the Nyquist Criterion, Time-Domain Performance Criteria in the Frequency Domain, System Bandwidth, The Stability of Control Systems with Time Delays. | **6** | **10-12** |
| **10** | The Design of Feedback Control Systems: Approaches to System Design**,** Cascade Compensation Networks, Phase-Lead Design Using the Bode Diagram, Phase-Lead Design Using the Root Locus, System Design Using Integration Networks, Phase-Lag Design Using the Root Locus, Phase-Lag Design Using the Bode Diagram, Design on the Bode Diagram Using Analytical Methods. | **8** | **15-18** |

**Suggested Specification table with Marks (Theory):**

| **Distribution of Theory Marks** | | | | |
|---|---|---|---|---|
| R Level | U Level | A Level | N Level | E Level |
| 12-15 | 15-20 | 20-25 | 30-35 | 20-30 |

**Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate and above Levels (Revised Bloom's Taxonomy)**

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

**Reference Books:**


1. Modern Control System by Richarc C. Drof and Robert H. Bishop,11th Edition Person Int.
2. Modern Control Engineering by Katsuhiko Ogata, 4th Edition, Prentice Hall of India.
3. Automatic Control Systems by Benjamin C.Kuo, 8th Edition, Farid Golnaraghi, John Wiley & Sons.
4. Control Systems Engineering by Nagrath and Gopal New Age Publication
5. Feedback and Control Systems by Joseph J Distefano 2nd Edition TMH


**Course Outcome:**

At the successful completion of this course, a student will be able to:

1. Apply systems theory to complex real world problems in order to obtain models that are expressed using differential equations, transfer functions, and state space equations
2. Predict system behavior based on the mathematical model of that system where the model may be expressed in time or frequency domain
3. Analyze the behavior of closed loop systems using tools such as root locus, Routh Hurwitz, Bode, Nyquist, and Matlab
4. Design controllers using classical PID methods, root locus methods, and frequency domain methods.
5. Devise a safe and effective method of investigating a system identification problem in the lab
6. Write a report that effectively communicates the results of an analysis or design.

**List of suggested Experiments:**

1. Simulation of DC motor working
2. Simulation of synchros
3. Generating standard test signals i.e. step, ramp, unit impulse on a simulator
4. Analysis of time response of second order system
5. Effect of P, PD, PI, PID Controller on a second order systems.
6. Plotting root locus of a given transfer function using a simulator
7. Temperature control using PID
8. Plotting phase magnitude plot of a given transfer function with a simulator.
9. Obtaining frequency response of a common emitter amplifier and plotting on a Bode plot.
10. Simulation of a given transfer function using OPAMPs
11. Stability Analysis ( Root locus, Bode, Nyquist) of Linear Time Invariant System.
12. Study of a PLL as a closed loop control system on a simulator.

**Use SCILAB/MATLAB or other equivalent software as a simulator.**

**Design based Problems (DP)/Open Ended Problem:**

- Op Amp Differentiating Circuit, Pulse Generating Op Amp, OP Amp Control System, PLL
- Television Beam Circuit,
- Space Shuttle Rocket, Satellite Orientation Control, Roll Angle Control,
- Mars Rover Vehicle, Mars Guided Vehicle Control, Mars Rover,
- Disk Drive Read Write System, Rotating Disk Speed Control, Disk Drive Read .
- Wind Power,
- Embedded Computers,

**Lab Work:** MATLAB/SCILAB based assignments and simulations covering design, analysis and modelling of control systems relevant to curriculum.

**List of Open Source Software/learning website:**

Ng-spice/MATLAB, www.nptel.com

**ACTIVE LEARNING ASSIGNMENTS**: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.