

GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)**Competency-focused Outcome-based Green Curriculum-2023 (COGC-2023)****Semester - IV****Course Title: Control Engineering****(Course Code : 4344102)**

Diploma programme in which this course is offered	Semester in which offered
AUTOMATION AND ROBOTICS	FOURTH

1. RATIONALE

A control engineering is a discipline that applies automatic control theory to design systems in such a way as to achieve desired control of operation of the system. Control engineering has an essential role in a wide range of control systems. It seeks to understand physical systems using mathematical modeling in terms of inputs, outputs and various components with different behavior. This course will facilitate students use the different control systems used in various range of applications from simple to complex control systems which are used for controlling machines or processes.

2. COMPETENCY

The aim of this course is help the students to attain the following competency through various teaching learning experiences:

- **Learn different types of control systems, mathematical modeling, response and stability of control system, various modes of control action.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills should be taught to acquire different learning outcomes in cognitive, psychomotor and affective domain for the achievement of the following CO's:

CO1: Identify different types of Control Systems

CO2: Formulate mathematical model & transfer function for physical systems.

CO3: Employ time domain analysis to predict and diagnose transient performance parameters of the system for standard input functions

CO4: Apply different types of analysis in time domain and frequency domain to explain the nature of stability of the system.

CO5: Identify the needs of different types of controllers to ascertain the required Dynamic response from the system.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	100

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

Legends: **L** - Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** - End Semester Examination.

5. SUGGESTED PRACTICAL EXERCISES:

The following practical outcomes (PrOs) are the subcomponents of the Course Outcomes (Cos). Some of the PrOs marked ‘*’ are compulsory, as they are crucial for that particular CO at the ‘Precision Level’ of Dave’s Taxonomy related to ‘Psychomotor Domain’.

Sr. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs Required
1	To study the simulation software for simulation of control system design.	-	2
2	Identify various blocks of a given open loop and closed loop system.	1	2
3	Convert an open loop system into a closed loop and observe the difference in output using simulation software.	1	2
4	Plot the pole-zero configuration in the s-plane for a given transfer function using simulation software.	2	2
5	Determine the transfer function for a given closed loop system in block diagram representation.	2	2
6	Determine steady state errors for a given transfer function.	2	2
7	Plot unit step response of given first order transfer function using simulation software.	3	2
8	Plot unit step response of given second order transfer function and finds delay time, rise time, peak time and peak overshoot using simulation software.	3	2

9	Determine the time response of a given system subjected to any arbitrary inputs.	3	2
10	Plot the root locus for a given transfer function using simulation software.	4	2
11	Plot bode plot for given transfer function and also determine relative stability using gain margin & phase margin using simulation software.	4	2
12	Simulate the P and PI controller for a given transfer function for unit step input using simulation software.	5	2
13	Simulate the PD and PID controller for a given transfer function for unit step input using simulation software.	5	2

Note

- i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.
- ii. The following are some **sample** 'Process' and 'Product' related skills (more may be added / deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in % *
1	Prepare of experimental setup/simulation circuit	20
2	Operate the equipment setup or simulation circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
Total		100

* Weightage of particular PrO may vary as per experiments.

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to use in uniformity of practical's in all institutions across the state.

- I. CRO
- II. Function Generator
- III. Workbench
- IV. Control Simulator Kit
- V. Simulation Softwares
- VI. Computer System

7. AFFECTIVE DOMAIN OUTCOMES

The following *sample* Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this course competency.

- Work as a leader/a team member (while doing a micro-project).
- Follow safety practices while using D.C. and AC supply and electrical equipment.
- Work as a group member (while performing experiments and taking readings)
- Practice environmentally friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year.
- 'Organization Level' in 2nd year.
- 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY:

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for the development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on the attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit I Introduction to Control System	<p>1a. Define Important terms related to Control Systems.</p> <p>1b. Classify types of control systems.</p> <p>1c. Describe Open loop and Closed loop control system with block diagram & examples.</p> <p>1d. State advantages & disadvantages of Open loop & Closed loop Control System.</p> <p>1e. Compare Open loop & Closed loop control system.</p> <p>1f. List requirement of ideal control system.</p>	<p>1.1 Background</p> <p>1.2 Important Term Definition System, Control System, Plant, Controller, Input, Output, Disturbance</p> <p>1.3 Classification of Control System</p> <p>1.4 Open Loop Control System</p> <ul style="list-style-type: none"> • Definition & Block Diagram • Advantages • Disadvantages • Real time Examples <p>1.5 Closed Loop Control System</p> <ul style="list-style-type: none"> • Definition & Block Diagram • Advantages • Disadvantages • Real time Examples <p>1.6 Comparison of Open loop and Closed loop Control System</p> <p>1.7 Requirements of an Ideal Control System.</p>

<p>Unit II Mathematical Modeling</p>	<p>2a. Define transfer function</p> <p>2b. State Merits and demerits of Transfer Function</p> <p>2c. Define Different parameters of Transfer Function</p> <p>2d. Derive the transfer function for RLC series, Parallel and Mechanical translational and rotational systems. (for standard single component of each system)</p> <p>2e. Derive mathematical differential equation for given linear simple RLC series circuit and mechanical translational systems(having only mass, spring and damper as elements)</p> <p>2f. List different methods for finding transfer function.</p> <p>2g. Define various terminologies of Block diagram method. Explain rules to reduce given block diagram</p> <p>2h. Draw block diagram for armature controlled and field controlled dc motor.</p> <p>2i. Derive mathematical model (mathematical equations) of armature controlled & field controlled dc motor</p> <p>2j. Define various terminologies</p>	<p>2.1 Transfer Function</p> <ul style="list-style-type: none"> ● Definition ● Advantages & Disadvantages ● Poles & Zeros of transfer function ● Characteristic equation ● Transfer function of standard RLC series Circuit.(having only one each of R, L,C component) ● Transfer function of standard RLC parallel Circuit.(having only one each of R, L,C component) ● Transfer function of standard mechanical Translational system and mechanical Rotational system. <p>2.2 Methods of finding Transfer function</p> <ul style="list-style-type: none"> ● BDR & SFG <p>2.3 BDR</p> <ul style="list-style-type: none"> ● Definition ● Block Diagram & ● Mathematical model (mathematical equations) of D.C. Motor <ol style="list-style-type: none"> 1. Armature Controlled dc Motor 2. Field Control dc motor <p>2.4 Signal flow graph</p> <ul style="list-style-type: none"> ● Definitions ● Mason's gain formula ● Steps for solving SFG using
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	<p>of Signal flow graph</p> <p>2k. Explain Mason's gain formula</p> <p>2l. Obtain T. F. of simple closed loop system using Signal flow graph Method (simple system having max four individual loops.</p> <p>2m. Construct system analogy of the given system (from simple linear mechanical translational system to electrical equivalent)</p>	<p>Mason's gain formula</p> <p>2.5 System analogy</p> <ul style="list-style-type: none"> • Force-voltage analogy • Force-current analogy
<p>Unit III</p> <p>Time Response Analysis of Control System</p>	<p>3a. Define time response, transient response, steady state response.</p> <p>3b. List and Draw standard test signals.</p> <p>3c. Explain Standard test signals with their equations.</p> <p>3d. Define Characteristic equation, Order of the system and Type of the system.</p> <p>3e. Draw and explain with derivation time response of 1st order system for unit step input only.</p> <p>3f. Define Damping Ratio & Natural frequency of oscillation.</p> <p>3g. Draw time response of second order system with unit</p>	<p>3.1 Time response.</p> <ul style="list-style-type: none"> • Introduction • Transient & Steady State Response <p>3.2 Standard test signals</p> <ul style="list-style-type: none"> • Step signal • Ramp Signal • Parabolic Signal • Impulse signal <p>3.3 Time response of first order system to step input</p> <ul style="list-style-type: none"> • Order & type of system. • Characteristic equation. • Derivation of time response of first order system for step input. <p>3.4 Time response of second order system to step input</p> <ul style="list-style-type: none"> • Damping Ratio & Natural

	<p>step input only.</p> <p>3h. Define following terms- delay time t_d, rise time t_r, peak time t_p, maximum overshoot M_p, settling time.</p> <p>3i. Derivation of steady state error.</p> <p>3j. Describe steady state error constants.</p> <p>3k. Describe steady state error of control system for step, ramp, parabolic input and type-0, 1, 2 systems.</p>	<p>Frequency of Oscillation</p> <ul style="list-style-type: none"> • Time Response specification. <ol style="list-style-type: none"> 1. Rise Time 2. Delay time 3. Peak time 4. Maximum overshoot 5. Settling time <p>3.5 Steady state error & error constant</p> <ul style="list-style-type: none"> • Static error Position constant K_p • Static error velocity constant K_v • Static error acceleration constant K_a • Steady state error for step ramp, parabolic input for type 0, 1 & 2 systems.
<p>Unit-IV Concept of Stability</p>	<p>4a. Describe the concept of stability.</p> <p>4b. Classify Control system stability according to location of the roots of the characteristic equation (poles of the system).</p> <p>4c. State necessary conditions for stability.</p> <p>4d. State Routh Criteria for stability.</p> <p>4e. Determine stability of given characteristic equation using Routh Criteria.</p> <p>4f. Describe the concept of root locus in brief.</p> <p>4g. State the rules for construction of Root Locus.</p> <p>4h. Derive root locus for given example.(max up to type 1, order 3)</p>	<p>4.1 Stability</p> <ul style="list-style-type: none"> • Introduction • BIBO stability • Necessary condition for stability • Fundamentals of various Systems <ol style="list-style-type: none"> 1. Stable 2. Unstable 3. Marginally stable/Oscillatory <p>4.2 Routh stability criteria</p> <p>4.3 Difficulties in formulation of routh table</p> <ul style="list-style-type: none"> • Difficulty 1 • Difficulty 2

	<p>4i. Describe the concept of Bode plot in brief.</p>	<p>4.4 Introduction to Root Locus Concept.</p> <p>4.5 Rules for construction of Root Locus. Simple examples of Root Locus e.g. $G(s)=k/S(S+4)$</p> <p>4.6 Frequency Response Analysis using Bode plot</p> <ul style="list-style-type: none"> • Brief concept of bode plot. • Gain Margin • Phase Margin • Gain crossover frequency • Phase crossover frequency
<p>Unit-V Theory of Controllers</p>	<p>5a. Classify modes of control action</p> <p>5b. List types of discontinuous controller.</p> <p>5c. Explain two position controllers.</p> <p>5d. Explain Proportional, Integral and Derivative mode controllers.</p> <p>5e. Comparison of P, I and D controller.</p> <p>5f. Explain P-I, P-D and PID mode controllers.</p> <p>5g. Sketch output for various modes of controller for step change only.</p>	<p>5.1 Introduction</p> <p>5.2 Classification of Controllers</p> <p>5.3 Discontinuous Controllers</p> <ul style="list-style-type: none"> • Two position • Three position • Multiposition <p>5.4 Continuous Controllers</p> <ul style="list-style-type: none"> • Proportional Mode • Integral Mode • Derivative Mode • Comparison among P,I and D Controllers <p>5.5 Composite Control Modes</p> <ul style="list-style-type: none"> • Proportional-Integral Mode • Proportional-Derivative Mode • Proportional-Integral-Derivative-Mode

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN:

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Control System	6	7	7	-	14
II	Mathematical Modeling	12	4	10	7	21
III	Time Response Analysis of Control System	8	4	7	3	14
IV	Concept of Stability	10	3	4	7	14
V	Theory of Controllers	6	3	4	-	7
Total		42	21	32	17	70

Legends: R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)

Note: This specification table provides general guidelines to assist students for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related *co-curricular* activities which can be undertaken to accelerate the attainment of the various outcomes in this course. Students should perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidence for their (student's) portfolio which may be useful for their placement interviews:

- Do analysis of first and second order control systems using various free control simulators.
- Present seminar on various topics from course content.
- Prepare Poster on various topics from course content.
- Visit nearby engineering industries and prepare a report on different processes available and control systems used to control it.
- Internet survey of different control systems.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

- a) Massive open online courses (*MOOCs*) may be used to teach various topics/subtopics.
- b) Guide student(s) in undertaking micro-projects.
- c) Show animation/ video related to course content.
- d) Co-relating the importance of content of this course with other practical applications.
- e) Industrial visit for practical exposure.
- f) Quiz competition across intercollege branch students.
- g) Organize workshops by experts from industry.
- h) Guide students on how to address issues on environment and sustainability

12. SUGGESTED PROJECT LIST

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, in the fifth and sixth semesters, the number of students in the group should *not exceed three*.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about 12-14 (*fourteen to sixteen*) *student engagement hours* during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

1. Models of control system.
2. Chart / Model Preparation
3. Prepare Presentation
4. Build/Test various opamp based controllers for a given control loop.
5. Prepare report on market survey for different controller availability.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Control Systems Engineering	Nagrath I.J.;Gopal M.	New Age International, New Delhi
2	Linear Control Systems	B.S.Manke	Khanna publication

3	Control System Engineering	S.K.Bhattacharya	Pearson Publication
4	Automatic Control Systems	S. Hasan Saeed	Katson Books
5	Modern Control Engineering	Ogata K.	Tata McGraw hill, New Delhi
6	Process Control Instrumentation Technology	Johnson C. D.	PHI Learning, New Delhi

14. SOFTWARE/LEARNING WEBSITES

- www.nptel.ac.in/courses
- www.mathworks.com/discovery/simulation-software.html
- www.controlsystemsacademy.com/0019/0019.html
- www.octave-online.net/
- www.electrical4u.com/control-engineering
- www.Controlsystem.co.in
- www.sc.iitb.ac.in/
- www.scilab.org

15. PO-COMPETENCY-CO MAPPING:

SEMESTER IV	CONTROL ENGINEERING (Course Code : 4344102)						
	POs						
Competency & Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7
	Basic & Discipline specific knowledge	Problem Analysis	Design/development of solution	Engineering Tools, Experimentation & Testing	Engineering practices for society, sustainability & environment	Project Management	Life-long learning
Competency							
CO1	3	2	-	-	-	-	3
CO2	3	2	3	1	-	-	2
CO3	3	2	3	2	1	-	2
CO4	2	2	3	2	2		2
CO5	3	-	-	2	1		2

Legend: '3' for high, '2' for medium, '1' for low and '-' for no correlation of each CO with PO.

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE**Member – Board of Studies (GTU), Electrical and Allied branches**

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