GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)

Semester- IV

Course Title: Control Instrumentation System

(Course Code: 4341702)

Diploma program in which this course is offered	Semester in which offered
Instrumentation and Control Engineering	4th Semester

1. RATIONALE

In the present industrial scenario, it is desired that instrumentation diploma engineers be able to identify, classify, mathematically model, stabilize and maintain the different Control Instrumentation Systems. They are required to implement the planned Plant Control Instrumentation Systems. Hence, this course has been designed to fulfill this purpose.

2. COMPETENCY ('Program Outcome' according to NBA Terminology)

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire following competency:

- Learn different types of control system, mathematical modeling, response and stability of control system.

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

a) Differentiate different types of Control Systems
b) Construct Transfer Function of various Control System
c) Obtain output from applied inputs using time response method
d) Apply stability criteria for system stability determination
e) Understand the importance of frequency response for system stability determination

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*): 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 sub-components of the 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 control parameters viz. set point, controlling variable, actuating signal, controlled variable, manipulated variable etc. in a given control loop.	1	2
3	Identify various blocks of a given open loop and closed loop system.	1	2
4	Convert an open loop system into a closed loop and observe the difference in output using a control simulator.	1	4
5	To obtain a transfer function from given poles and zeros using simulation software.	2	2
6	To obtain zeros and poles from a given transfer function using simulation software.	2	2
7	Derive transfer function for a given block diagram using simulation software.	2	4
8	Obtain Transfer function of given electrical and mechanical systems.	2	2
9	Obtain equivalent voltage analogous system (series electrical system) from given mechanical translational motion system (mass-spring-dashpot).	2	2
10	To find Unit step, ramp, impulse response of first order system using simulator.	3	4
11	Observe output of first order system with control simulator. Compare it with theoretical output and find out reasons if there is any difference.	3	4
12	To obtain the time response of a given second order system with its damping frequency using simulation software.	3	4
13	To find out the time domain specification of a second order system using simulation software.	3	2
14	Find out the roots of a given transfer function and decide stability.	4	2
15	Determine stability for various system using Routh criteria	4	4
16	To plot the root locus for a given transfer function of the system using simulation software.	4	2
17	To obtain a bode plot for a given transfer function of the system using simulation software. Calculate gain margin and phase margin.	5	2
18	Observe the effect of increasing and decreasing gain margin and phase margin for a given system using a control simulator.	5	4
19	Compare various parameters of time response and frequency response for given system using a control simulator.	5	4

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..*

S. 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**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

i. CRO
ii. Function generator
iii. Workbench
iv. Control Simulator kit

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 competency.

a) Work as a leader/a team member.
b) Follow safety practices while using electrical appliances.
c) Practice environmental 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:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of Revised Bloom's taxonomy in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Major Learning Outcomes ('Course Outcomes' in Cognitive Domain according to NBA terminology)		Topics and Sub-topics	
Unit – I Introduction to Control System	1a	Draw and explain the block diagram of the control system.	1.1	Introduction
	1b	List requirement of good control system.	1.2	Requirement of a good control system
	1c	Explain open loop control system with block diagram and example.	1.3	Open loop and Closed loop system
	1d	Explain closed loop with block diagram and example.		
	1e	Compare open loop and closed loop system.		

	1f	Compare Feedback and Feed Forward systems.	1.4	Feedback and Feed Forward system
	1g	Classify types of control systems.	1.5	Classification of Control systems: ● Linear and Nonlinear systems ● Continuous Time and Discrete Time Systems ● Deterministic and Stochastic Control Systems ● Time Varying and Time Invariant Control Systems ● Lumped Parameter and Distributed Parameter control systems ● Single Input - Single output and Multiple Input - Multiple Output Control Systems
Unit – II Mathematical Modeling	2a	Explain importance of mathematical models in control systems	2.1	Mathematical Modeling • Introduction • Importance • Examples ➢ electrical systems ➢ mechanical system
	2b	Obtain Mathematical Models of Given system		
	2c	Narrate the concept of Transfer function	2.2	Transfer Function • Definition • Structure • Different properties • Merits and demerits • Different parameters ➢ Poles ➢ Zeros ➢ Characteristics equation • Procedure • Transfer function of RLC series and RLC parallel Circuit • Transfer function of Mechanical Translational & Rotational system. • Methods of finding Transfer function ➢ BDR & SFG
	2d	Explain Different properties of Transfer Function		
	2e	State Merits and demerits of Transfer Function		
	2f	Define Different parameters of Transfer Function		
	2g	Explain procedure to determine the Transfer Function		
	2h	Derive the transfer function for RLC series, Parallel and Mechanical translational rotational system		
	2i	List different method for finding transfer function.		

	2j	Define various terminologies of Block diagram method	2.3	Block diagram method • Definitions • Advantages and disadvantages Rules • Examples • Canonical form or simple form of feedback control system • T. F. of simple closed loop system
	2k	State Advantages and disadvantages of block diagrams		
	2l	Explain rules to reduce given block diagram		
	2m	Solve the given block diagram		
	2n	Derive Canonical form or simple form of feedback control system		
	2o	Obtain T. F. of simple closed loop system		
	2p	Define various terminologies Signal flow graph	2.4	Signal flow graph • Definitions • Advantages and disadvantages • Rules • Mason's gain formula • Steps for solving SFG using Mason's gain formula • Examples • Comparison of BDR & SFG
	2q	State Advantages and disadvantages of Signal flow graph		
	2r	Explain rules to reduce given Signal flow graph		
	2s	Explain Mason's gain formula		
	2t	Obtain T. F. of simple closed loop system using Signal flow graph Method		
	2u	Compare BDR & SFG		
	2v	Define System Analogy	2.5	System Analogy • Concept • Advantages • Different system analogies: Force-voltage & force-current
	2w	state the Advantages of analogous system		
	2x	Construct system analogy of the given system		
Unit – III Time Response Analysis	3a	Describe the concept of Time response analysis	3.1	Introduction to Time response • concept of time response • transient response • steady state response
	3b	Define time response, transient response, steady state response.		
	3c	List and draw Standard test signals.	3.2	Standard test signals • Step signal • Ramp Signal • Parabolic Signal • Impulse signal
	3d	State the equations of Standard test signals.		

	3e	Define Characteristic equation, Order of the system and Type of the system.	3.3	Time Response of first order system to step input ● Characteristic equation ● Order & type of system. ● Derivation of time response of first order system for step input.
	3f	Draw and explain with derivation time response of 1 st order system for unit step input only.		
	3g	Define Damping Ratio & Natural frequency of oscillation.	3.4	Time Response of second order system to step input. ● Damping Ratio & Natural Frequency of Oscillation ● Time Response specification. ➢ Rise Time ➢ Delay time ➢ Peak time ➢ Maximum overshoot ➢ Settling time
	3h	Draw time response of second order system with unit step input only.		
	3i	Define following terms- delay time td, rise time tr, peak time tp, maximum overshoot Mp, settling time.		
	3j	Derivation of steady state error. Describe steady steady state error constants.	3.5	Steady-state errors and error constants ● Static error Position constant Kp ● Static error velocity constant Kv ● Static error acceleration constant Ka ● Steady state error for step ramp, parabolic input for type 0, 1 & 2 systems.
	3k	Describe steady state error of control system for step, ramp, parabolic input and type-0, 1, 2 systems.		
Unit – IV Stability Analysis	4a	Describe the concept of stability.	4.1	Stability ● Introduction ● BIBO stability ● Necessary condition for stability ● Fundamentals of various Systems ➢ Stable ➢ Unstable ➢ Marginally stable/Oscillatory
	4b	Classify Control system stability according to location of the roots of characteristic equation (poles of the system).		
	4c	State necessary conditions for stability		
	4d	State Routh-Hurwitz Criteria for stability.	4.2	● Routh stability criteria ● Difficulties in formulation of routh table ➢ Difficulty 1 ➢ Difficulty 2
	4e	Determine stability of given characteristic equation using Routh-Hurwitz Criteria.		

			4.3	• Introduction to Root Locus Concept. • Rules for construction of Root Locus. • Root Locus of RLC series & Parallel circuit.
	4f	Describe the concept of root locus in brief.		
	4g	State the rules for construction of Root Locus.		
	4h	Derive root locus for RLC series & Parallel circuit.		
Unit – V Frequency Response Analysis using Bode plot	5a	Describe the concept of Bode plot in brief.	5.1	Introduction
	5b	Describe frequency response.	5.2	Frequency response
	5d	Explain frequency domain specification.	5.3	Frequency Domain Specification
			5.4	Log Scales
			5.5	Standard form of GH (jw)
			5.6	Bode plot of standard factors
	5e	State benefits of Bode plots.	5.8	Benefits of bode plots
	5f	List steps for solving Bode plots.	5.9	Steps for solving bode plots
	5g	Draw Bode plot for first order systems only.	5.10	Examples of bode plot up to first order system only

Note: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	**Introduction to Control System**	5	7	3	4	14
II	**Mathematical Modeling**	10	3	4	7	14
III	**Time Response Analysis**	10	7	3	4	14
IV	**Stability Analysis**	8	4	7	3	14
V	**Frequency Response Analysis using Bode plot**	9	3	4	7	14
	Total	**42**	**24**	**21**	**25**	**70**

Legends: *R = Remember; U = Understand; A = Apply and above levels (Bloom's revised 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.*

10. SUGGESTED LIST OF STUDENT ACTIVITIES

Following is the list of proposed student activities such as:

i. Students may be asked to collect photographs using the internet which is relevant to field application of various topics and have to prepare learning materials using it.

ii. Teachers guided self learning activities, Course/library/internet/lab based mini projects, industrial visit etc.
iii. Students activities like: course/ topic based seminars, Internet based assignments.
iv. Students should deliver a seminar in groups on advances/latest trends in Control Instrumentation System.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

i. Take small instrumentation components to the class when teaching
ii. Give simple numerical to students
iii. Internet based home assignments
iv. Mini project

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her at the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be individually undertaken to build up the skill and confidence in every student to become problem solver so that he/she contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, 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 total duration of the micro-project should not be less than 16 (sixteen) student engagement hours during the course. The student ought to submit a 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:

a. Models of control system.
b. Laboratory Kits for Control Instrumentation System.
c. Chart / Model Preparation
d. Prepare Presentation

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Books	Author	Publication
1	Control Systems Engineering	Nagrath & Gopal	New Age International
2	Linear Control System	B.S.Manke	Khanna publication
3	Feedback Control Systems	Dr. S D. Bhide & Barapte	Tech max Publication
4	Control Systems Engineering	S.K. Bhattacharya	Pearson Education

14. List of Software/Learning Websites

i. www.nptel.com
ii. https://demonstrations.wolfram.com/SimulationOfFeedbackControlSystemWithControllerAndSecondOrde/

iii. https://www.mathworks.com/discovery/simulation-software.html
iv. http://controlsystemsacademy.com/0019/0019.html
v. https://octave-online.net/
vi. https://www.wolframalpha.com/examples/science-and-technology/engineering/control-systems
vii. https://www.scilab.org

15. PO-COMPETENCY-CO MAPPING

Semester IV	Control Instrumentation System (Course Code: 4431702)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design / develop-ment of solutions	PO 4 Engineering Tools, Experimen-tation & Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Manage-ment	PO 7 Life-long learning
Competency	Learn different types of control system, mathematical modeling, response and stability of control system.						
CO1:Identify different types of control systems.	3	2					3
CO2:Determine transfer functions of simple systems by various methods.	2	2	3	1			
CO3: Analyze simple systems by time response method.(up to first order and for step input only.	2	2	3	2			
CO4: Use stability criteria for system stability determination.	1	2	3	2	1		

CO:5 Apply frequency response(Bode plot) method to find stability of first order control systems.	1	2	3	2			

*Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

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