GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

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

Course Title: Modern Control Technology
(Course Code: 4342405)

Diploma programmer in which this course is offered	Semester in which offered
Power Electronics	4th semester

1. RATIONALE

With the advancement of technology, control techniques have taken rapid strides with the introduction of different types of electrical, power electronics and instrumentation devices. This course is intended to enable the student to understand the facts, concepts, principles and applications of the control system and transfer function. After studying this course students will be able to apply these concepts to control different types of electrical and electronics systems used in the industry.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain feedback 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:

CO 1) Test different control systems.
CO 2) Develop transfer function of basic electrical circuits and devices.
CO 3) Develop overall system transfer function using block diagram reduction technique and signal flow graph.
CO 4) Test the performance of various feedback control system.
CO 5) Operate control system with different types of controller

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	-	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

*Following practical outcomes (PrOs) that are the sub-components 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'.*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1.	Test the performance of open loop and closed loop control system	I	2*
2.	Test the performance of DC/AC Position control system.	I	4
3.	Obtain transfer function using Scilab/Matlab /LabVIEW software.	II	2
4.	Study type of control system	II	2
5.	Study order of control system	II	2*
6.	Plot Pole-Zero location of feedback control system using Scilab/Matlab /LabVIEW software.	II	2*
7.	Obtain closed loop transfer function from block diagram using Scilab/Matlab /LabVIEW software.	III	2*
8.	Determine the damping ratio, damped frequency of oscillation and % overshoot for unit step response using Scilab/Matlab /LabVIEW software.	IV	2*
9.	Plot the time response for unit impule/step/ramp Input using Scilab/Matlab /LabVIEW software.	IV	2*
10.	Determine rise time; pick time and maximum overshoot using Scilab/Matlab /LabVIEW software.	IV	2*
11.	Study steady state error.	IV	2
12.	Study close loop system with disturbance.	IV	2
13.	Test the performance of ON-OFF controller	V	2*
14.	Test the performance of P controller	V	2*
15.	Test the performance of I controller	V	2*
16.	Test the performance of D controller	V	2*
17.	Test the performance of PI controller	V	2*
18.	Test the performance of PD controller	V	2
19.	Test the performance of PID controller	V	2*
	Minimum 14 Practical Exercises		**28* Hrs.**

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	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	**MATLAB:** MATLAB and Simulink available to a set number of faculty and students on personal and college-owned computers, for the purposes of completing academic coursework.	3,6,7,8,9,10
2	**Labview:** Recommended for applications that require advanced analysis or signal processing. Includes Base capabilities plus: Advanced analysis algorithms for curve fitting, differential equations, linear algebra, and more. Signal processing functions for signal measurement, filtering, and conditioning. Signal generation, operations, and control functions with PID and fuzzy logic.	3,6,7,8,9,10
3	**Basic Control System Trainer:** It provides with in depth knowledge of the basics of control systems like open loop, closed loop, Ist, IInd and IIIrd order systems active and passive, Type 0, 1, and 2 control systems. TECHNICAL SPECIFICATIONS :Signal Generator, Variable Square wave generator ,Variable DC Voltage (-12V to +12V),Unit Step InputLow -0.5V to 0.5V High -0.5V to +1V,Impulse generator with Amplitude -0.5V to +0.5V, Passive Components: Resistors 100E, 1K, 1K, 10K, 50K and 100K, Capacitors 1 nF, 10 nF, 10 nF, 100 nF, 1 uF and 1 uF, Inductors: 1 uH, 680 uH, 1 mH, 10 mH, 68 mH, and 100 mH, Active control circuit blocks:Open Loop System (Transistorized current source system:Error Amplifier,Amplifier with calibrated gain control.	1,4,5,11,12
4	**MULTI PROCESS CONTROL TRAINER:** Shell & Tube Type Heat Exchanger, Rotameter for tube & wheel flow meter for shell flow measurement, RTD Pt100 temp. Sensor, Separate Digital temperature Indicators for display of both inlet and outlet of shell and tube, Shell flow control using PID controller and control valve, 6KW industrial grade immersion Heater, Hot and Cold water circulation systems, All transducers are of 2 wires 4-20mA O/P and 4-20mA-process control output, Self contained, mobile and fully integrated teaching apparatus, Fault identification compatibility, A state of art of the high quality industrial grade heat exchanger. Heat exchange temp differential Dt around – 25 0C @ 200 LPH flow Provision for study of individual control element, Process control software for direct digital control of temp process with data acquisition Computer interface. Customized SCADA software for supervisory control and data acquisition, Online trend analysis, bar graph & charts. Man machine interface, GUI of process available.	13,14,15,16,17,18
5	**CONTROL TRAINER:** Facility to monitor behavior of the controller output (Un) & process variable (MV) either on PC screen or on CRO. Settable time constants. • P4/XP or latest version window based PID controller (DDC) software package with P, PI & PID control, Ratio & cascade control, three operating modes, Online graph drawing & data acquisition modes (SCADA). PC not in scope of supply • Can learn about different processes using simulated building blocks as well as real life processes using replaceable experiment panels/processes and built in square / triangle / sin function generator as disturbance. • Aesthetically designed injection molded electronic desk (master unit) carrying useful experiment resources like Power supplies, DPMs, Computer Interface, Analog PID controller with central slot to hold various replaceable experiment	13,14,15,16,17,18

S. No.	Equipment Name with Broad Specifications	PrO. No.
	panels / processes. • Connection through sturdy 4mm Banana sockets & Patch cords, Students workbook & Instructor's Guide provided.	

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 error free measurement rules during measurement.
c) 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:

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	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Introduction to Control Systems.	1.a Describe the history and significance of control system in engineering. 1.b Describe Open loop and closed loop control system. 1.c Describe control system components. 1.d Differentiate Open and closed loop control system.	1.1 Brief Historical development of control system, James watt's fly ball governor, Need for control system, Types. 1.2 Open loop and closed loop control system with block diagram, definition. 1.3 Control system components: actuator, feedback, controller and sensor. 1.4 Comparison: Open loop and closed loop control systems.
	1.e Explain open loop control system with example. 1.f Explain close loop control system with example.	1.5 Example of open loop control system: traffic control system, washing machine, etc. 1.6 Example of closed loop control system: temperature control system, water level control system, position control system.
	1.g Classify control system with an example.	1.7 Classification: Process control system, Sequentially Controlled System, Motion Control system, Numerical Control system.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	1.h Explain the power of feedback control system as an enabling green engineering	1.8 Principle of green energy, classification of green energy, example- smart grid control system.
Unit– II Mathematical modeling of control system.	2a. Explain the significance of Laplace transform in control system. 2b. Transform frequency domain to S- domain and S- domain to frequency domain for control system function.	2.1 Laplace transform: Significance, Basic Laplace transform theorem 2.2 Transformation from time domain functions to S- domain function and vice versa; Important Laplace transform pairs.
	2c. Define transfer function, poles and zeros. 2d. Plot Poles Zeros location in s-plane of given systems. 2e. Derive open loop, feed forward and closed loop transfer function.	2.3 Definition: Transfer function, poles and zeros. 2.4 Poles and Zeros location in S-Plane. 2.5 Open loop and closed loop transfer function using block diagram.
	2f. Derive Transfer function of linear systems. 2g. Classify control system by their type and order	2.6 Transfer function of simple RLC network, field controlled dc motor, armature controlled dc motor. 2.7 Classification based on order and type.
	2h. Simulate system using control system design software.	2.8 Simulation of control system using Scilab/ Matlab /LabVIEW software that contains poles, zeros, transfer function and plot.
Unit – III Block diagrams and signal flow graphs.	3a Define rules for block diagram reduction technique. 3b Reduce block diagram using block diagram reduction technique. 3c Draw signal flow graph from block diagram. 3d Apply Mason's Gain formula to determine overall transfer function of feedback control system.	3.1 Rules: summing point, tack-off point, blocks in cascade, blocks in parallel, moving take off point, moving summing point, interchanging two summing points, eliminating forward loop, eliminating of summing point in closed loop and eliminating unity feedback control system. 3.2 Block diagram reduction technique examples. 3.3 Representation of signal flow graph from block diagram, rues for signal flow graph. 3.4 Mason's Gain formula, Examples
Unit – IV Performance	4a. Explain Error signal analysis in control system	4.1 Error signal analysis using block diagram.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
of feedback control system.	4b. Explain disturbance and sensitivity of signals in feedback signal.	4.2 Disturbance: definition, rejection; sensitivity: definition
	4c. State the features of Step, Ramp, Parabolic and Impulse signal 4d. Describe Time response of first order control system using Unit-impulse and Unit-Step Response with sketches.	4.3 Input test signals: Step, Ramp, Parabolic and Impulse signal. 4.4 Time response of a first order control system. Unit-impulse and Unit-Step Response.
	4e. Describe time response of second order control system 4f. Define various specification of transient response of control system with example. 4g. Explain steady state error of feedback control system. 4h. Explain Mars rover control system 4i. Explain Hubble space telescope control.	4.5 Time response of second order control system with different parameter like damping ratio, undamped natural frequency. 4.6 Specification: Delay time, rise time, pick time maximum overshoot, steady state time, examples. 4.7 Steady state error of feedback control system. 4.8 Mars rover control system with and without feedback. 4.9 Hubble space telescope pointing system with reduce block diagram, system design and system response to unit step.
Unit– V Basic Control action and Controller Characteristics.	5a Classify controller 5b Explain ON-OFF control action. 5c Explain Proportional control action. 5d Explain Integral control action. 5e Explain Derivative control action. 5f Explain Proportional plus integral control action 5g Explain Proportional plus Derivative control action 5h Explain Proportional plus integral plus Derivative control action 5i Explain the effect of integral and derivative control on the system performance.	5.1 Classification: ON-OFF, P, I, PI, PD, PID controllers. 5.2 ON-OFF controller with dead zone, example. 5.3 P- Control action with example. 5.4 I- Control action with block diagram and example. 5.5 D- Control action with block diagram and example. 5.6 PI- Control action with block diagram and example. 5.7 PD- Control action with block diagram and example. 5.8 PID- Control action with block diagram and example. 5.9 Effect of integral and derivative control action on system performance.

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

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 Systems	8	6	8	0	14
II.	Mathematical modeling of control system.	10	4	8	6	16
III.	Block diagrams and signal flow graphs	5	0	3	7	10
IV.	Performance of feedback control system.	12	4	10	6	20
V.	Basic Control action and Controller Characteristics.	5	2	5	3	10
Total		42	16	34	22	70

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

***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions 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 vary slightly 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 conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Interpret various control system available in daily life.
b) Prepare block diagram of daily used open loop and closed loop control system.
c) Make a chart of Example of open loop and closed loop control system.
d) Make a chart of applications of control systems in the field of power electronics.

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/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students for indexing open and closed loop control system.
g) Guide students for selecting a proper controller for specific applications.

12. SUGGESTED MICRO-PROJECTS

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-project is 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 dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14-16 (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:

a) **Make a Presentation for open loop and closed loop control system with an example.**
b) **Make a presentation of various controller used for feedback control system.**
c) **Design a position/level/motion etc., control system using various sensors.**

13. SUGGESTED LEARNING RESOURCES:

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Modern Control Systems	Dorf Richard, Bishop Robert	Pearson, ISBN: 9789332518629
2	Automatic Control Systems.	Saeed Hasan S.	Katson ISBN:9788190691925
3	Modern Control Engineering	Ogata Katsuhiko	Springer ISBN 9789332550162
4	Linear control systems	Bimbhra P.S.	Khanna Publishers ISBN: 9788174093103

14. SOFTWARE/LEARNING WEBSITES

a) https://www.vlab.co.in
b) https://nptel.ac.in
c) https://www.classcentral.com
d) https://swayam.gov.in/
e) https://shodhganga.inflibnet.ac.in/
f) https://onlinecourses.nptel.ac.in/

15. PO-COMPETENCY-CO MAPPING

Semester IV	Modern Control Technology(4342405)						
	POs and PSOs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	Maintain feedback control system.						

CO 1) Test different control systems.	-	2	-	1	1	-	1
CO 2) Develop transfer function of basic electrical circuits and devices.	2	2	3	2	2	1	2
CO 3) Develop overall system transfer function using block diagram reduction technique and signal flow graph.	1	2	2	-	-	1	1
CO 4) Test the performance of various feedback control system.	1	3	3	2	2	1	3
CO 5) Operate control system with different types of controller.	-	1	1	1	3	2	3

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

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	**Mr. Sunil Patel HOD (I/C) – Power Electronics Department.**	**Dr. S. & S. S. Ghandhy college of engineering & Technology, Surat**	**9898073753**	**powssg@gmail.com**
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