CONTROL SYSTEMS **Course Code : 314337**

Programme Name/s : **Mechatronics**

Programme Code : **MK**

Semester : **Fourth**

Course Title : **CONTROL SYSTEMS**

Course Code : **314337**

I. RATIONALE

Control systems aims to maintain desired outputs or conditions by adjusting inputs which ensures that a system behaves in a predictable and desired manner. As a result, the control systems are widely gaining importance in industrial automation, production, robotics, and many other fields. This course will facilitate students to understand and apply the concepts, principles, and procedures of controlling various parameters in different processes used in industry as well as day to day life.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

Maintain the mechatronics control systems in industrial applications.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Interpret the type of control system.
- CO2 - Analyse the given control system for standard test input signal.
- CO3 - Examine the stability of given control system.
- CO4 - Use different control action for controlling various processes.
- CO5 - Maintain different servo system components in industrial applications.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
314337	CONTROL SYSTEMS	CSS	DSC	3	-	2	1	6	3	3	30	70	100	40	25	10	-	-	25	10	150

Total IKS Hrs for Sem. : 0 Hrs

Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA - Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment

Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination

Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 15 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Identify the given control system. TLO 1.2 Distinguish between the different types of control system. TLO 1.3 Determine transfer function of given control system. TLO 1.4 Optimize the transfer function of given system using block diagram reduction rules.	**Unit - I Overview of Control Systems** 1.1 Control System: Definition, block diagram 1.2 Types of Control System a) Open loop system: Block diagram, working, examples b) Closed loop system: Block diagram, working, examples c) Linear and Nonlinear system: Definition, examples d) Time Variant System and Invariant system: Definition, examples 1.3 Transfer Function: Definition, Transfer function of electrical circuits (RL, RC, LC & RLC circuits) using Laplace Transform 1.4 Block diagram reduction technique: Need, block diagram reduction rules, and numericals	Demonstration Lecture using Chalk-Board
2	TLO 2.1 Interpret time response of given control system. TLO 2.2 List the standard test input along with their laplace transform. TLO 2.3 Interpret time response of first order control system. TLO 2.4 Draw a labelled time response of second order system.	**Unit - II Time Domain Analysis** 2.1 Time Domain Analysis: Transient and steady state response. concept of poles, zeros, characteristics equation, order of system with numericals 2.2 Standard Test Inputs: Step, ramp, parabolic and impulse input (mathematical equation, response and their transfer function) 2.3 First Order System: Analysis for unit step input and their response 2.4 Second Order System: For unit step input (no derivation) and their response, effect of damping on system stability 2.5 Time Response Specifications: Peak time, rise time, settling time, delay time, peak overshoot (no derivation) and numericals	Lecture using Chalk-Board Hands-on Collaborative learning
3	TLO 3.1 List the types of system based on stability. TLO 3.2 Determine stability based on the location of poles in S-plane. TLO 3.3 Examine stability by using Routh's criterion. TLO 3.4 Determine the range of 'k' for conditionally stable system.	**Unit - III Stability Analysis** 3.1 Stability: Definition, types of system based on stability 3.2 Types of Stability: Absolute and Relative Stability. Stability analysis using location of poles in S-plane 3.3 Routh's Stability Criterion: Routh's array, statement, special cases. Stability analysis using Routh Array 3.4 Application of Routh's criterion: Determination of 'K' for conditional stability	Lecture using Chalk-Board Case Study Hands-on
4	TLO 4.1 Explain process control system with labelled diagram. TLO 4.2 Classify different control actions. TLO 4.3 Compare different control action modes on the basis of its different parameters.	**Unit - IV Process Controllers and Control Actions** 4.1 Process Control System: Block diagram, working 4.2 Control Action Mode: Definition, classifications 4.3 Discontinuous Mode: ON-OFF control action mode, output equation, operation, Neutral zone 4.4 Continuous Mode: Proportional, Integral, Derivative control actions (output equations, operation, responses and their applications only) 4.5 Composite Control Actions: a) PI Control action b) PD control action c) PID control action (output equation, operation and their responses only)	Lecture using Chalk-Board Case Study Demonstration

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
5	TLO 5.1 Describe the function of servo system along with its importance in control system. TLO 5.2 Describe working of different servo components for using as an error detector. TLO 5.3 Differentiate between AC servomotor, DC servomotor and stepper motor. TLO 5.4 Differentiate between AC and DC position control system.	**Unit - V Servo Systems and Components** 5.1 Servo System: Definition, block diagram, working 5.2 Servo Components: a) Potentiometer: construction, working, potentiometer as an error detector b) Synchro: construction, working, synchro as an error detector c) Rotary encoder: types, working, applications 5.3 Servo Motors: a) Servo motor: types, working, applications b) Stepper motor: types, working, applications 5.4 Position Control Systems: a) AC position control: block diagram and working b) DC position control: block diagram and working	Lecture using Chalk-Board Collaborative learning Demonstration

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Identify open loop system available in laboratory. LLO 1.2 Demonstrate the working of open loop system available in laboratory.	1	Interpretation of open loop control system using traffic light controller or any open loop system available in laboratory	2	CO1
LLO 2.1 Identify closed loop system available in laboratory. LLO 2.2 Measure the various parameters for the closed loop temperature control system available in laboratory.	2	* Interpretation of close loop control system using temperature control system	2	CO1
LLO 3.1 Identify any open source software for control system. LLO 3.2 Implement given system using identified software.	3	Determination of transfer function and order of given system by using open-source or any other software	2	CO1
LLO 4.1 Implement given system using the open source software to identify poles and zeros.	4	Determination of poles and zeros of given transfer function by using open-source or any other software	2	CO2
LLO 5.1 Identify order of given control system. LLO 5.2 Verify the time response of identified system for standard test inputs.	5	* Interpretation of response of first order R-C circuit for the different standard inputs (any relevant software may also be used for implementation)	2	CO2
LLO 6.1 Identify order of given control system. LLO 6.2 Verify the time response of identified system for standard test inputs.	6	Interpretation of response of second order R-L-C circuit for the different standard inputs (any relevant software may also be used for implementation)	2	CO2
LLO 7.1 Determine the stability of given system using Routh's stability criteria.	7	* Verification of Routh's stability criteria of given control system by using open-source or any other software	2	CO3
LLO 8.1 Find the range of 'K' for conditionally stable system using Routh's criteria.	8	Determination of range of 'K' for deciding conditional stability of given control system using Routh's criteria	2	CO3
LLO 9.1 Identify the type of controller for given experiment. LLO 9.2 Verify the response of identified controller in the laboratory.	9	* Interpretation of characteristics of P/PI/PD controller for controlling the given process. (Any relevant software may also be used for implementation)	2	CO3
LLO 10.1 Identify the type of controller for given experiment. LLO 10.2 Verify the response of the PID controller.	10	* Interpretation of characteristics of PID controller for controlling the given process. (Any relevant software may also be used for implementation)	2	CO4
LLO 11.1 Connect potentiometers for using as an error detector. LLO 11.2 Determine the differential voltage between potentiometers.	11	* Interpretation of characteristics of potentiometer as an error detector	2	CO5
LLO 12.1 Use synchro as an error detector. LLO 12.2 Calculate the error voltage between potentiometers.	12	*Interpretation of characteristics of synchro as an error detector	2	CO5
LLO 13.1 Use AC servo system for position control. LLO 13.2 Calculate the angular position control of AC servo system.	13	* Determination of angular position of AC servo system	2	CO5
LLO 14.1 Use DC servo system for position control. LLO 14.2 Calculate the angular position control of DC servo system.	14	Determination of angular position of DC servo system	2	CO5
LLO 15.1 Use Stepper motor as servo component. LLO 15.2 Count the pulses of stepper motor required to complete one rotation.	15	Using stepper motor as servo system component for position control system	2	CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Activities

- Prepare a chart on comparison of different control actions in control system
- Prepare a chart of standard test inputs used in control system and steady state errors for given standard test inputs. Prepare a brief presentation along with report on it
- Prepare a chart of rules for block diagram reduction techniques and prepare a brief presentation along with report on it
- Perform market survey for availability of different servo components and prepare a report
- Perform simulation on any open source Virtual Labs on following topics and write a report on it a. Temperature control system b. Two Tank Water Level control c. Study of DC Motor d. Study and operation of the DC Speed and Position control setup e. Simulation of Control Systems

Micro project

- Simulate On-Off temperature and flow control loop system using process control simulator
- Build/ Test Potentiometer as an error detector
- Survey or Visit automation industry using PLC/SCADA/DCS/HMI system and prepare detailed report on it
- Build/ Test an automatic feedback temperature control system
- Build/ Test an automatic feedback water level control system
- Build/ Test an RC circuit and check its output response
- Build/ Test an RLC circuit and check its output response
- Prepare a report of Simulation on PI -control action on a given system for given step input and set point. Obtain the effect on output varying Kp, Ki, Kd of the system
- Prepare a report of Simulation on PD-control action on a given system for given step input and set point. Obtain the effect on output varying Kp, Ki, Kd of the system

Assignment

- Identify and classify the control systems available in control system laboratory
- Prepare a report and presentation on stability analysis based on special cases

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Traffic Light control system setup with red, yellow and green lights	1
2	Potentiometer as an error detector trainer kit	11
3	Characteristics of synchro Transmitter	12
4	AC Position control system	13
5	DC Position control system	14
6	Stepper motor trainer kit	15
7	ON-OFF controller: Heater, Temperature sensor and Relay	2
8	Softwares like SCILAB or MATLAB or MULTISIM or NI	3,4,5,6,7,8,9,10
9	Standard test signal generator kit : Step, Ramp and Parabolic signals. 1) First Order trainer 2) Second order trainer	5,6
10	Proportional PI, PD, PID controller and control system setup with ON-OFF Temperature control using PID Trainer	9,10
11	Cathode ray oscilloscope: Dual trace 50MHz	All
12	Multimeter 3 1/2 Digit: AC/DC, 0-200 V	All

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Overview of Control Systems	CO1	10	4	4	6	14
2	II	Time Domain Analysis	CO2	11	4	4	8	16
3	III	Stability Analysis	CO3	10	4	4	6	14
4	IV	Process Controllers and Control Actions	CO4	6	2	4	4	10
5	V	Servo Systems and Components	CO5	8	4	6	6	16
Grand Total				**45**	**18**	**22**	**30**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Continuous assessment based on process and product related performance indicators. Each practical will be assessed considering: -60% weightage to process -40% weightage to product

Summative Assessment (Assessment of Learning)

- End of Term Examination (Theory)

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO- 1	PSO- 2	PSO- 3
CO1	3	3	3	3	-	-	2			
CO2	3	3	3	3	-	-	2			
CO3	3	3	3	-	-	-	2			
CO4	3	-	-	3	2	2	3			
CO5	3	2	2	3	2	2	3			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	I. J. Nagrath & M. Gopal	Control System Engineering	New Age International Publishers, 2021, ISBN: 978-8195175581
2	K. Ogata	Modern Control Engineering	PHI, New Delhi (5th Edition), 2008, ISBN: 978-8131703118
3	C. D. Johnson	Process Control Instrumentation Technology	PHI Learning, 2015, ISBN: 978-9332549456
4	A. Anand Kumar	Control Systems	PHI (2nd Edition), 2014, ISBN: 978-8120349391
5	K.P. Ramchandran	Control Engineering	Willey India, Delhi, 2011 , ISBN: 978-8126522880,
6	Rajeev Gupta	Control System Engineering	NISE's, Willey India, 2018 ISBN: 8126571837
7	S.P. Eugene Xavier, Joseph Cyril Babu, J.	Principles of Control System	S. Chand, New Delhi, 2004, ISBN: 978-8121917780

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://www.tutorialspoint.com/control_systems/control_systems_introduction.htm	Control Systems - Introduction
2	https://www.tutorialspoint.com/control_systems/control_systems_quick_guide.htm	Control Systems - Quick Guide
3	https://www.tutorialspoint.com/control_systems/control_systems_feedback.htm	Control Systems - Feedback
4	https://www.tutorialspoint.com/control_systems/control_systems_mathematical_models.htm	Control Systems - Mathematical Models

Sr.No	Link / Portal	Description
5	https://www.tutorialspoint.com/control_systems/control_systems_block_diagrams.htm	Control Systems - Block Diagrams
6	https://www.tutorialspoint.com/control_systems/control_systems_time_domain_specifications.htm	Time Domain Specifications
7	https://electronicscoach.com/time-domain-analysis-of-control-system.html	Time Domain Analysis of Control System
8	https://www.tutorialspoint.com/control_systems/control_systems_stability.htm	Control Systems - Stability
9	https://www.tutorialspoint.com/control_systems/control_systems_controllers.htm	Control Systems - Controllers
10	https://www.electrical4u.com/types-of-controllers-proportional-integral-derivative-controllers/	Types of controllers
11	https://en.wikipedia.org/wiki/Servomechanism	Servo Systems
12	https://www.utmel.com/blog/categories/motors/introduction-to-servo-system	Servo Systems
13	https://www.scilab.org	SCILAB Software
14	https://www.mathworks.com/products/matlab.html	MATLAB Software
15	https://www.multisim.com	Multisim Software
16	https://www.youtube.com/watch?v=ApMz1-MK9IQ	MATLAB Practice
17	http://vlabs.iitkgp.ac.in/gps/ctrl/index.html	Virtual Labs
18	https://www.ni.com/en/support/downloads/software-products/download.multisim.html	NI MULTISIM Software

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students