Program Name : **Diploma in Instrumentation / Instrumentation and Control**

Program Code : **IS / IC**

Semester : **Fifth**

Course Title : **Control Systems**

Course Code : **22541**

1. RATIONALE

Modern civilization is an indication of human endeavor to control nature's forces and to harness them for the benefit to mankind. The laws of nature are such that everything in this universe is controlled. Diploma engineers should be able to control the various parameters at desired value in industry. This course helps the students to understand and apply the concepts, principles and procedure of controlling various parameters in different processes in industry. Students will also able to apply the knowledge of given control systems for basic fault finding in industry.

2. COMPETENCY

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

- **Maintain the Control system components in Instrumentation systems.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following industry oriented COs associated with the above mentioned competency:

a. Identify the type of given control system.
b. Interpret the given control system for different input signals.
c. Test the stability of the given control system.
d. Maintain control action for controlling various processes.
e. Maintain different components in given control system.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme											
				Theory						Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	4	8	3	70	28	30*	00	100	40	50#	20	50	20	100	40

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment 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,* ***ESE *-End Semester Examination;* ***PA*** *- Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the

course, in all domains of learning in terms of the industry/employer identified competency depicted at the center of this map.

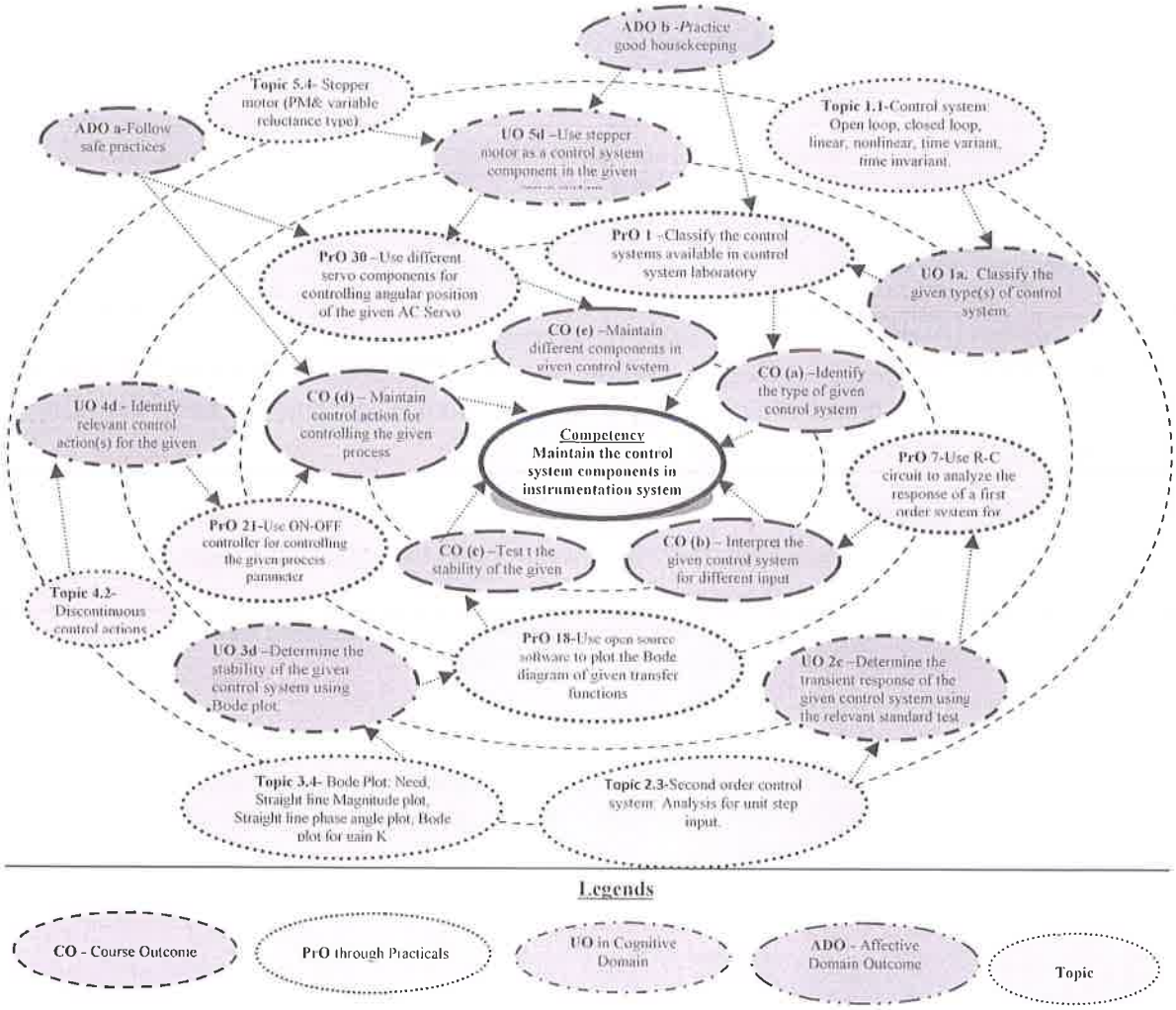

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Classify the control systems available in control system laboratory.	I	02*
2	Use open source software to find out the transfer function and order of the given system.	I	02*
3	Use open source software to represent the given transfer function in state variable form.	I	02*
4	Use open source software to obtain the state model of the given transfer function.	I	02
5	Use open source software to find the poles and zeroes of given transfer function.	II	02
6	Use open source software to find the transient response specifications of given second order transfer function.	II	02
7	Use R-C circuit to analyze the response of a first order system for	II	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	standard test inputs.		
8	Use open source software to analyze the response of first order RC circuit for the different standard inputs.	II	02
9	Use R-L-C circuit to analyze the response of a second order system for standard test inputs.	II	02*
10	Use open source software to analyze the response of first order R-L-C circuit for the different standard inputs.	II	02
11	Use the standard test signal generator to analyze the given Type 0 control system.	II	02*
12	Use open source software to analyze the given Type 0 control system.	II	02
13	Use the standard test signal generator to analyze the given Type 1 control system.	II	02*
14	Use open source software to analyze the given Type 1 control system.	II	02
15	Use the standard test signal generator to analyze the given Type 2 control system.	II	02*
16	Use open source software to analyze the given Type 2 control system.	III	02
17	Use open source software to find the Routh's table and hence analyze the stability of the given control system.	III	02*
18	Use open source software to plot the Bode diagram of given transfer functions and hence analyze the stability of the given control system.	III	02*
19	Use ON-OFF controller for controlling the given process parameter.	IV	02*
20	Use Proportional controller for controlling the given process parameter.	IV	02
21	Use PI controller for controlling the given process parameter.	IV	02
22	Use PD controller for controlling the given process parameter.	IV	02
23	Use PID controller for controlling the given process parameter.	IV	02*
24	Use open source software to verify the equation of P controller	IV	02
25	Use open source software to verify the equation of PI controller	IV	02
26	Use open source software to verify the equation of PD controller	IV	02
27	Use open source software to verify the equation of PID controller	IV	02
28	Use potentiometer as an error detector.	V	02
29	Use synchro as an error detector.	V	02*
30	Use different servo components for controlling the angular position of the given DC Servo system	V	02*
31	Use different servo components for controlling angular position of the given AC Servo system	V	02*
32	Use stepper motor as a servo system component and measure its speed by applying generated pulses.	V	02
	Total		**64**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 24 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student*

reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S.No.	Performance Indicators	Weightage in %
a.	Preparation of experimental set up	20
b.	Setting and operation	20
c.	Safety measures	10
d.	Observations and Recording	10
e.	Interpretation of result and Conclusion	20
f.	Answer to sample questions	10
g.	Submission of report in time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Practice energy conservation.
d. Demonstrate working as a leader/a team member.
e. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. 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
- 'Organizing Level' in 2nd year
- 'Characterizing Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTSREQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Open source software	2,3,4,5,6,8,10,12,14,16,17,18, 24, 25, 26
2	Standard test signal generator kit: Step, Ramp, and parabolic signals.	7,9,11,13,15
3	Type 0 system trainer kit	11
4	Type 1 system trainer kit	13
5	Type 2 system trainer kit	15
3	On-off controller: heater, Temperature sensor, Relay.	19
4	Proportional, PI, PD, PID controllers and the control system setup	20, 21, 22, 23
5	Potentiometer as an error detector trainer kit.	28

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Open source software	2,3,4,5,6,8,10,12,14,16,17,18, 24, 25, 26
6	Synchro transmitter, control transformer and power supply.	29
7	D.C. Position control system trainer kit.	30
8	A.C. Position control system trainer kit.	31
9	Stepper motor trainer kit.	32

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– I Fundamentals of control systems	1a. Classify the given type(s) of control system. 1b. Describe the procedure to determine the transfer function of the given control system. 1c. Determine the transfer function of the given control system. 1d. Form the state variables for the given system.	1.1 Control system: Open loop, closed loop, linear, nonlinear, time variant and time invariant. 1.2 Transfer function: order of a control system (0, 1, 2), transfer function with respect to R-C and R-L-C electrical circuits, 1.3 Block diagram reduction technique: Need, reduction rules. 1.4 State space representation: Advantages, state variables identification, State space models from transfer functions.
Unit– II Time response analysis	2a. Identify the poles and zeroes of given control system with justification. 2b. Explain the salient features of the given type of test inputs/ responses/control system. 2c. Determine the transient response of the given control system using the relevant standard test inputs. 2d. Determine the steady state response of the given control system using the relevant standard test input signals.	2.1 Time domain analysis: Transient and steady state response, Concept of Poles and zeros ;examples 2.2 Standard test inputs :Step, Ramp, Parabolic and Impulse: mathematical equation, graph, transfer function 2.3 First order control system: Analysis for unit step input, Concept of time constant. 2.4 Second order control system: Analysis for unit step input, Concept, and effect of damping. 2.5 Time response specifications (no derivations) Tp, Ts, Tr, Td, Mp, Ess; numerical Problems. 2.6 Steady state analysis: Type 0, type 1, type 2 systems, Steady state error and error constants.
Unit-III Stability of Control systems	3a. Explain the conditions for stability of the given control system. 3b. Determine the stability of the given control system	3.1 Stability :Definition of stability, Analysis of Stable, unstable, critically stable and conditionally stable system, Relative stability, Location of the Poles in the S-plane for stable and unstable systems.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	using Routh's stability criteria. 3c. Explain frequency response specifications of the given control system. 3d. Determine the stability of the given control system using Bode plot.	3.2 Routh's stability criterion: Different cases and conditions (statement method), Numerical Problems. 3.3 Frequency Response Analysis method: Concept, Advantages and Disadvantages, Frequency response specifications. 3.4 Bode Plot: Need, Straight line Magnitude plot, Straight line phase angle plot, Bode plot for gain K, poles and zeros at origin, and 1^{ST} order system, Analyze stability from Bode plot using Gain margin and Phase margin.
Unit –IV Process Control Actions	4a. Explain with sketches the discontinuous control actions used for controlling the given process control system. 4b. Explain with sketches the basic continuous control actions used for controlling the given process control system. 4c. Explain with sketches the composite continuous control actions used for controlling the given process control system. 4d. Identify relevant control action(s) for the given process control system with justification and sketches.	4.1 Discontinuous control actions - two position or ON-OFF: Operation, neutral zone 4.2 Continuous control actions-proportional, integral and derivative: operation, output equations, corresponding transfer function, Response graph. 4.3 Composite controllers - PI, PD, PID controllers : operation, output equations, Response graph, comparison, application 4.4 Electronic op-amp based PI, PD, PID controllers: circuit diagram, equations.
Unit-V Position control systems	5a. Identify the components of a given servo system with justification. 5b. Explain different components of given DC servo system. 5c. Explain different components of given AC servo system. 5d. Use stepper motor as a control system component in the given servo system. 5e. Choose the relevant servo system for the given situation with justification.	5.1 Servo system: concept, generalized block diagram. 5.2 DC servo system: functional diagram, potentiometer as an error detector, DC servo motor - characteristics, difference from a normal DC motor 5.3 AC servo system: functional diagram, Synchro, Synchro transmitter, control transformer, synchro as an error detector, applications, AC servo motor-characteristics, difference from a normal 2 phase induction motor. 5.4 Stepper motor (PM and variable reluctance type): Working and applications, comparison with DC servo motor.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'*

9. SUGGESTED SPECIFICATION TABLE FORQUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Fundamentals of control system	14	04	04	06	14
II	Time response analysis	18	02	06	08	16
III	Stability Analysis of Control systems	16	02	06	08	16
IV	Process Control actions	08	02	06	04	12
V	Control system components	08	02	06	04	12
Total		**64**	12	**28**	**30**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may 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 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. Prepare a report on the market survey for availability of different Servo components.
b. Prepare a report on the market survey for availability of different controllers.
c. Visit nearby process industries and prepare a report on control systems used.
d. Visit nearby engineering institutes and prepare a report on different control systems used in that institute laboratory.
e. Prepare a chart on comparison of different control actions.
f. Prepare a chart on effect of damping on the response of different types of control systems.
g. Prepare a chart on effect of location of poles on the stability of different types of 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/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.

f. Use proper equivalent analogy to explain different concepts.
g. Use Flash/Animations to explain various control actions.

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. 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 s/he 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 dated work diary consisting of individual contribution 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 micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. Similar micro-projects could be added by the concerned faculty:

a. Build/test an automatic feedback temperature control system.
b. Build/test an automatic feedback water level control system.
c. Build/test RC circuit and check its output response.
d. Build/test RLC circuit for a stable system using MATLAB.
e. Build / test ON-OFF controller for the given type of control loop.
f. Simulate Bode plot of given system using MATLAB and improve the stability of the system by varying necessary parameters.
g. Built / test opamp based P controller for the given type of control loop.
h. Built / test opamp based PI controller for the given type of control loop.
i. Built / test opamp based PD controller for the given type of control loop.
j. Built / test opamp based PID controller for the given type of control loop.
k. Built / test Potentiometer as an error detector for the given control system.
l. Troubleshoot faulty equipment/kit available in control system lab.

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Control System Engineering	Nagrath I.J, M. Gopal	New age International, New Delhi, Sixth edition, ISBN: 9788122420081
2	Modern Control Engineering	Ogata K.	Pearson India, Noida, Fifth edition ISBN: 978-9332550162
3	Process Control Instrumentation Technology	Johnson C. D.	PHI Learning, NewDelhi,2015 ISBN: 978-9332549456
4	Control Systems Engineering	Nise Norman S	Willey India, Delhi, Sixth Edition ISBN:978-8126519477
5	Control System Engineering using MATLAB	Sivanandan S. N. Deepa S. N.	Vikas Publication House, New Delhi,2012 ISBN:9788125937104
6	Principles of Control Systems	S.P. Eugene Xavier Joseph Cyril Babu, J.	S. Chand, New Delhi,2014 ISBN:9788121917780

S. No.	Title of Book	Author	Publication
7	Control Systems	Anand Kumar	PHI Learning, NewDelhi,2014 ISBN:9788120349391
8	Control Systems	Varmah K.R	McGraw Hill, New Delhi,2010 ISBN: 9780070678750

14. SOFTWARE/LEARNING WEBSITES

a. www.scilab.org/scilab
b. www.nptel.ac.in/courses/101108056/23
c. www.nptel.ac.in/courses/108101037/3
d. www.nptel.ac.in/courses/108101037/14
e. www.nptel.ac.in/courses/108101037/46
f. www.nptel.ac.in/courses/108105062/12
g. www.nptel.ac.in/courses/108101037/20
h. www.nptel.ac.in/courses/108103008/12
i. www.nptelvideos.com/control_systems/
j. www.electrical4u.com/control-engineering
k. www.automationfederation.org/filestore/af/resources/control