Program Name : **Diploma in Automation and Robotics**

Program Code : **AO**

Semester : **Fourth**

Course Title : **Control System and Components**

Course Code : **22476**

1. RATIONALE

Modern civilization is an indication of human endeavor to control nature's forces and to harness them for the benefit of mankind. The laws of nature are such that everything in this universe is controlled. Diploma engineers should be able to control 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 industries related to Automation and Robotics. Students will also be 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 systems and components in Automation and Robotics 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:

1. Choose the relevant control strategy for the given control system.
2. Interpret the given control system for different input signals and test the stability.
3. Maintain control action for controlling various processes.
4. Maintain various Pneumatic and Hydraulic Actuators in the given control system.
5. Maintain various Electromechanical Actuators in the 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 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.

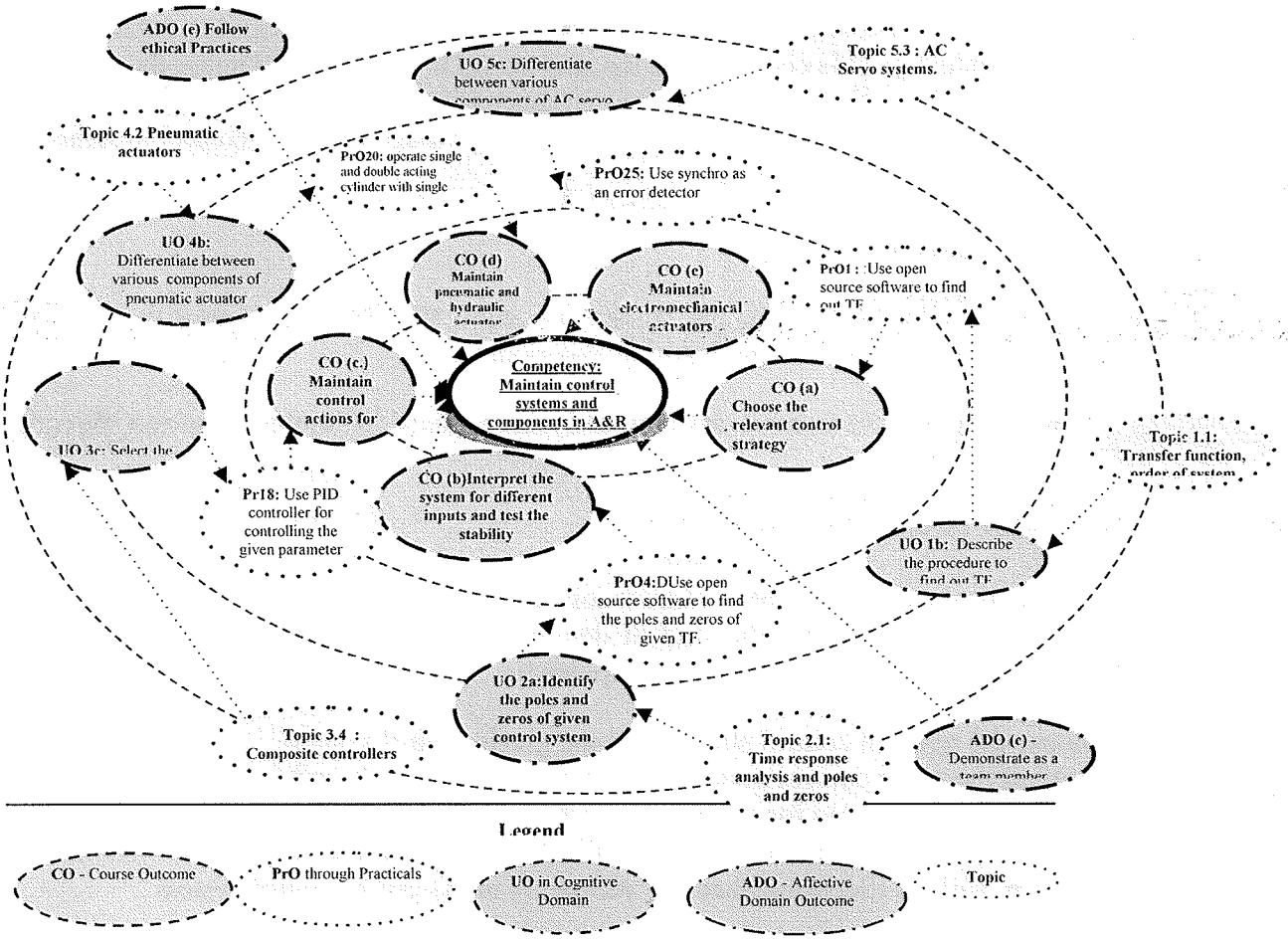


Figure 1 - Course Map

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	Use open source software to find out the transfer function of the given system.	I	2*

2	Use open source software to represent the given transfer function in state variable form.	I	2*
3	Use open source software to obtain the state model of the given transfer function.	I	2
4	Use open source software to find the poles and zeros of given transfer function.	II	2*
5	Use an R-C circuit to analyze the response of a first order system for standard test inputs.	II	2*
6	Use open-source software to analyze the step response of a first order system for various time constants.	II	2*
7	Use R-L-C circuit to analyze the response of a second order system for standard test inputs.	II	2*
8	Use open-source software to analyze the step response of a second order system for various cases of damping factors.	II	2*
9	Use open-source software to find the transient response specifications of a given second order transfer function.	II	2
10	Use the standard test signal generator to analyze the given Type 0 control system.	II	2
11	Use open-source software to analyze the given Type 0 control system.	II	2*
12	Use open-source software to analyze the given Type 1 control system.	II	2
13	Use open-source software to find the Routh's table and hence analyze the stability of the given control system.	II	2*
14	Use an ON-OFF controller for controlling the given process parameter.	III	2*
15	Use a Proportional controller for controlling the given process parameter.	III	2*
16	Use a PI controller for controlling the given process parameter.	III	2*
17	Use a PD controller for controlling the given process parameter.	III	2
18	Use a PID controller for controlling the given process parameter.	III	2*
19	Use open-source software to verify the equation of PID controller	III	2*
20	Use Electro-Pneumatics Trainer kit to operate single acting and double acting cylinder with single solenoid valve (direct actuation and relay actuation)	IV	2*

21	Use Electro-Pneumatics Trainer kit to apply AND and OR logic using two manual controls for forward stroke of a double acting cylinder (with direct actuation of solenoid and with relay)	IV	2*
22	Use Electro-Pneumatics Trainer kit to operate double acting cylinder with single solenoid valve and double solenoid valve (with and without manual forward stroke and automatic return stroke as it reaches forward end) and for continuous operation with double solenoid valve	IV	2
23	Use Electro-Pneumatics Trainer kit to operate two double acting cylinders electro pneumatically (Sequence of motion: A+B+A-B- and A+B+B-A-)	IV	2*
24	Use Electro-Pneumatics Trainer kit for single cycle ON and OFF delay operation of single acting cylinder using single solenoid valve (use OFF delay timer for solenoid actuation) and double acting cylinder using double solenoid valve	IV	2
25	Use Electro-Pneumatics Trainer kit to operate double acting cylinder using double solenoid valve with capacitive sensor,inductive sensor and photoelectric sensor	IV	2
26	Use Electro-Pneumatics Trainer kit to operate double acting cylinder using double solenoid valve and lamp with P/I converter and pressure sensor and for multi cycle operation with electrical limit switch.	IV	2
27	Use open-source simulation for the operation of Hydraulic actuator	IV	2*
28	Use potentiometer as an error detector.	V	2
29	Use synchro as an error detector.	V	2*
30	Use different servo components for controlling the angular position of the given DC Servo system	V	2*
31	Use different servo components for controlling angular position of the given AC Servo system	V	2
32	Use a stepper motor as a servo system component and measure its speed by applying generated pulses.	V	2
		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 %
1	Preparation of experimental setup.	20
2	Setting and operation.	20
3	Safety measures.	10
4	Observation and recording.	10
5	Interpretation of result and conclusion.	20
6	Answer to sample questions.	10
7	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. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
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/ INSTRUMENTS REQUIRED

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	Any Open source software to find out poles, zeros, TF, SSR, time response and stability of the given system and for PID stimulation	1,2,3,4,,6,8,9,11,12,13 ,19
2	Standard test signal generator kit: Step, Ramp, and parabolic signals.	10
3	Type 0 system trainer kit	10
4	On-off controller: heater, Temperature sensor , Relay.	14
5	Proportional, PI, PD, PID controllers and the control system setup	15,16,17,18

6	Electro pneumatic trainer kit	20-26
7	Any open-source simulation for the operation of pneumatics and Hydraulic actuator	27
8	Potentiometer as an error detector trainer kit.	28
9	Synchro transmitter, control transformer and power supply.	29
10	D.C. Position control system trainer kit.	30
11	A.C. Position control system trainer kit.	31
12	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 variable for the given system.	1.1 Control system: Open loop, closed loop, linear, non linear, time variant, 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 and Stability**	2a. Identify the poles and zeros of a 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. 2e. Explain the conditions for stability of the given control system. 2f. Determine the stability of the given control system using Routh's stability criteria.	2.1 Time domain analysis: Transient and steady state response, Standard test inputs (Step, Ramp, Parabolic and Impulse), Poles and zeros. 2.2 First order control system:Analysis for unit step input, Concept of time constant. 2.3 Second order control system: Analysis for unit step input, Concept and effect of damping. 2.4 Time response specifications(no derivations) Tp, Ts, Tr, Td, Mp, e_{ss}; numerical Problems. 2.5 Steady state analysis: Type 0, type 1, type 2 systems, Steady state error and error constants. 2.6 Stability: Definition of stability, Analysis of stable and unstable systems based on the location of the Poles in the S-plane, Relative stability and marginal stability. 2.7 Routh's stability criterion:method, Numerical Problems for stable and unstable systems, Range of K for the system to be stable (No special cases of auxiliary equation and zero in the first column)
Unit –III **Process Control Actions**	3a. Explain with sketches the discontinuous control actions used for controlling the given process control system. 3b. Differentiate between the basic continuous control actions used in the process control system. 3c. Select suitable composite continuous control action for controlling the given process control system. 3d. Identify relevant control action(s) for the given process control system with justification and sketches.	3.1 Process control system: Block diagram, function of each block. 3.2 Discontinuous control actions - two position or ON-OFF: Operation, differential gap 3.3 Continuous control actions- proportional, integral and derivative: operation, output equations, corresponding transfer function, Response graph. 3.4 Composite controllers - PI, PD, PID controllers : operation, output equations, Response graph, comparison, application 3.5 Electronic op-amp based PI, PD, PID controllers: circuit diagram, equations.

Unit-IV **Pneumatic and Hydraulic Actuators**	4.a. Compare pneumatic and hydraulic circuitry 4.b. Differentiate between various components of Pneumatic actuators. 4.c. Differentiate between different components of Hydraulic actuators 4.d. Choose the relevant actuator for the given situation with justification	4.1 Basic principles of pneumatic and hydraulic circuitry, Comparison of pneumatic and hydraulic circuitry and their applications 4.2 Pneumatic actuators: • Single acting and double acting cylinder, Directional control valve • Principles of pneumatic control,Pneumatic circuit diagram • Basic Pneumatic circuits (flow amplification, signal inversion, memory, delay, single acting cylinder control, double acting cylinder control) 4.3 Hydraulic actuators:Linear -Single acting, double acting,Double Rod Cylinder 4.4 Selection of actuators based on principle of operation, performance characteristics, maximum loading condition, safety
Unit-V **Electromechanical Actuators**	5a. Identify the components of a given servo system with justification. 5b. Explain different components of the given DC servo system. 5c. Differentiate between various components of the given AC servo system. 5d. Use a stepper motor as a control system component in the given servo system. 5e. Choose the relevant Electromechanical actuators for the given application	5.1 Electromechanical actuators: concept and types (Servomotor , stepper motor, DC motors,Solenoid Actuators, Brushless DC motor), Concept and generalized block diagram of Servo system. 5.2 DC servo system: functional diagram, potentiometer as error detector, DC servo motor - characteristics, difference from a normal DC motor. 5.3 AC servo system: functional diagram, synchro as error detector, AC servo motor-characteristics, difference from a normal 2 phase induction motor. 5.4 Stepper motor (PM and variable reluctance type): Working and applications 5.5 Principle and working of Solenoid Actuators and Brushless DC 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 FOR QUESTION 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 and stability	18	02	06	10	18
III	Process Control actions	08	02	04	06	12
IV	Pneumatic and Hydraulic Actuators	14	02	06	06	14
V	Electrical Actuators	10	02	04	06	12
	Total	**64**	**12**	**24**	**34**	**70**

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 the effect of damping on the response of different types of control systems.
g. Prepare a chart on the 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 learning outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/subtopics.
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/subtopics*** which are 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. Video programs/YouTube may be used to teach various topics and sub topics.
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 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 preferably be ***individually*** undertaken to build up the skill and confidence in every student to become a 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 a 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 a micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are 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. Build / test opamp based P controller for the given type of control loop.
g. Build / test opamp based PI controller for the given type of control loop.
h. Build / test op amp based PD controller for the given type of control loop.
i. Build / test op amp based PID controller for the given type of control loop.
j. Build a model of Single acting cylinder
k. Build a model of double acting cylinder
l. Build /test Potentiometer as an error detector for the given control system.

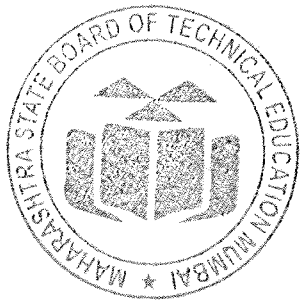
13. SUGGESTED LEARNING RESOURCES

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	Control Systems	Varmah K.R	Tata McGraw Hill, New Delhi,2010 ISBN: 9780070678750
3	Modern Control Engineering	Ogata K.	Pearson India, Noida,Fifth edition ISBN: 978-9332550162

4	Modern Control Systems	Dorf Richard, Bishop Robert	Pearson India, Noida, Twelfth edition ISBN: 978-9332518629
5	Process Control Instrumentation Technology	Johnson C. D.	Prentice hall of India, NewDelhi,2015 ISBN: 978-9332549456
6	Hydraulics and Pneumatics	Andrew A. Parr	Elsevier Science & Technology Books, March1999, ISBN: 0750644192

14. SUGGESTED SOFTWARE / LEARNING WEBSITES:

A. www.scilab.org/scilab
B. www.nptel.ac.in/courses/108101037/
C. www.nptel.ac.in/courses/101108056/23
D. www.nptel.ac.in/courses/108101037/3
E. www.nptel.ac.in/courses/108101037/14
F. www.nptel.ac.in/courses/108101037/46
G. www.nptel.ac.in/courses/108105062/12
H. www.nptel.ac.in/courses/108101037/20
I. www.nptel.ac.in/courses/108103008/12
J. www.electrical4u.com/control-engineering
K. www.automationfederation.org/filestore/af/resources/control
L. https://fluidsim.en.uptodown.com/windows/download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