CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Mechatronics) PROGRAMME

FIRST TO FOURTH SEMESTERS

FOR THE STUDENTS ADMITTED FROM THE
ACADEMIC YEAR 2014-2015 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING

(A Govt. Aided ISO 9001-2008 certified Autonomous Institution affiliated to Anna University)

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THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI - 625 015
DEPARTMENT OF MECHANICAL ENGINEERING

M.E MECHATRONICS PROGRAMME

Vision:

"Be a globally renowned school of engineering in Mechatronics"

Mission:

As a department, we are committed to

- Develop ethical and competent engineers by synergizing world class teaching, learning and research
- Establish state-of-art laboratories and to provide consultancy services to fulfill the expectations of industry and needs of the society
- Inculcate entrepreneurial qualities for creating, developing and managing global engineering ventures
- Motivate the students to pursue higher studies and research

Programme Educational Objectives (PEOs) of M.E. (Mechatronics)

PEO 1

Graduates will effectively design and develop products in the areas such as modeling and design, manufacturing, motion Control, Actuators and Sensors, Micro Devices, Intelligent Control, Automotive Systems and Robotics

PEO 2

The graduates will have aspiration for research in Mechatronics.

PEO 3

Graduates will possess analytical skills to access and troubleshoot technical problems.

Programme Outcomes (POs) of M.E. (Mechatronics)

Graduating Students of M.E. Mechatronics programme will have

Programme Outcomes (POs)		Graduate Attributes (GAs)
PO1.	An ability to apply knowledge of mathematics and science in solving problems that arise in Mechatronics	**Scholarship of Knowledge**
PO2.	An ability to design and conduct experiments, as well as to analyze and interpret data	**Critical Thinking**
PO3.	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	**Problem Solving**
PO4.	An ability to have the broad education necessary to understand the impact of engineering solutions in a global and societal context	**Research Skill**
PO5.	An ability to use the techniques, skills, and modern engineering tools necessary for carrying out Mechatronics Project.	**Usage of modern tools**
PO6.	An ability to function effectively as an individual and as a member or a leader in diverse teams, and in multidisciplinary activities that arise in carrying out Mechatronics Project.	**Collaborative and Multidisciplinary work**
PO7.	An ability to apply project, financial management principles and techniques individually/collaboratively in Mechatronics project planning, implementation and control	**Project Management and Finance**
PO8.	An ability to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions	**Communication**
PO9.	An ability to engage in independent and life-long learning for personal and societal development	**Life-long Learning**
PO10.	An ability to understand the professional and ethical responsibility	**Ethical Practices and Social Responsibility**
PO11.	An Ability to make corrective measures and learn from the mistakes without depending on external feed back	**Independent and Reflective Learning**

PEO – PO Matrix

POs / PEOs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
PEO1	S	S	S	S	S	M	M	L	M	L	L
PEO2	S	S	S	S	S	S	M	S	S	L	L
PEO3	L	L	M	L	S	S	S	M	S	S	S

Correlation: S – Strong; M-Medium; L-Low

Thiagarajar College of Engineering: Madurai-625015.

Department of Mechanical Engineering

M.E. DEGREE (Mechatronics) PROGRAMME

Scheduling of Courses

Sem.	Theory Courses						Practical/ Project
1st (24)	14MC110 Linear Algebra and Graph theory (4 credits)	14MC120A Principles of Mechanical Systems /14MC120B Principles of Electronics Systems (3 credits)	14MC 130 Sensors in Automation (4 credits)	14MC140 Fluid Power Automation (4 credits)	14MC150 Mechatronics System Design (4 credits)	14MC160 Automotive Electronics (4 credits)	14MC170 Automation Lab (1 credit)
2nd (24)	14MC210 Real Time Embedded System (3 credits)	14MC220 MEMS (4 credits)	14MCPX0 Elective -I (4 credits)	14MCPX0 Elective -II (4 credits)	14MCPX0 Elective – III (4 credits)	14MCPX0 Elective - IV (4 credits)	14MC270 Micro controller Lab (1 credit)
3rd (16)	14MCPX0 Elective -V (4 credits)	14MCPX0 Elective -VI (4 credits)	14MCPX0 Elective -VII (4 credits)	---	---	---	14MC 340 Project I (4 credits)
4th (12)	---	---	---	---	---	---	14MC410 Project II (12 credits)

Total Credits to be earned for the award of degree: 76

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015.

M.E. DEGREE (Mechatronics) PROGRAMME

COURSES OF STUDY

(For the candidates admitted from 2014-2015 onwards)

FIRST SEMESTER

Course Code	Name of the Course	Category	No. of Hours / Week			credits
			L	T	P	
THEORY						
14MC110	Linear Algebra and Graph theory	BS	3	1	-	4
14MC120A / 14MC120B	Principles of Mechanical Systems/ Principles of Electronic Systems	PC	3	0	-	3
14MC130	Sensors in Automation	PC	4	0	-	4
14MC140	Fluid Power Automation	PC	4	0	-	4
14MC150	Mechatronics System Design	PC	4	0	-	4
14MC160	Automotive Electronics	PC	4	0	-	4
PRACTICAL						
14MC170	Automation Lab	PC	-	-	2	1
Total			**22**	**1**	**2**	**24**

BS- Basic Sciences; HSS-Humanities and Social Sciences; ES-Engineering Sciences; PC-Programme Core; PE-Programme Elective; GE-General Elective; OC-One Credit Course; TC-Two Credit Course; SS-Self-Study Course (in the list of Programme Electives)

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015.

M.E. DEGREE (Mechatronics) PROGRAMME

SCHEME OF EXAMINATIONS

(For the candidates admitted from 2014-2015 onwards)

FIRST SEMESTER

Sl. No	Course code	Name of the Course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment	Terminal Exam *	Max. Marks	Terminal Exam	Total
THEORY								
1	14MC110	Linear Algebra and Graph theory	3	50	50	100	25	50
2	14MC120A	Principles of Mechanical Systems	3	50	50	100	25	50
	14MC120B	Principles of Electronics Systems.	3	50	50	100	25	50
3	14MC130	Sensors in Automation.	3	50	50	100	25	50
4	14MC140	Fluid Power Automation	3	50	50	100	25	50
5	14MC150	Mechatronics System Design	3	50	50	100	25	50
6	14MC160	Automotive Electronics	3	50	50	100	25	50
PRACTICAL								
7	14MC170	Automation Lab	3	50	50	100	25	50

* Terminal Examination will be conducted for maximum marks of 100 and subsequently be reduced to 50 marks for the award of terminal examination marks.

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015.

M.E. DEGREE (Mechatronics) PROGRAMME

COURSES OF STUDY

(For the candidates admitted from 2014-2015 onwards)

SECOND SEMESTER

Course code	Name of the Course	Category	No. of Hours/ Week			credits
			L	T	P	
THEORY						
14MC210	Real Time Embedded System	PC	3	0	-	3
14MC220	MEMS	PC	4	0	-	4
14MCPX0	Elective - I	PE	4	0	-	4
14MCPX0	Elective - II	PE	4	0	-	4
14MCPX0	Elective - III	PE	4	0	-	4
14MCPX0	Elective - IV	PE	4	0	-	4
PRACTICAL						
14MC270	Micro Controller Laboratory	PC	-	-	2	1
Total			**23**	**-**	**2**	**24**

BS- Basic Sciences; HSS-Humanities and Social Sciences; ES-Engineering Sciences; PC-Programme Core; PE-Programme Elective; GE-General Elective; OC-One Credit Course; TC-Two Credit Course; SS-Self-Study Course (in the list of Programme Electives)

Note:

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2 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015.

M.E. DEGREE (Mechatronics) PROGRAMME

SCHEME OF EXAMINATIONS

(For the candidates admitted from 2014-2015 onwards)

SECOND SEMESTER

Sl. No	Course code	Name of the Course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment	Terminal Exam *	Max. Marks	Terminal Exam	Total
THEORY								
1	14MC210	Real Time Embedded System	3	50	50	100	25	50
2	14MC220	MEMS	3	50	50	100	25	50
3	14MCPX0	Elective - I	3	50	50	100	25	50
4	14MCPX0	Elective - II	3	50	50	100	25	50
5	14MCPX0	Elective - III	3	50	50	100	25	50
6	14MCPX0	Elective - IV	3	50	50	100	25	50
PRACTICAL								
7	14MC270	Microcontroller Lab	3	50	50	100	25	50

* Terminal Examination will be conducted for maximum marks of 100 and subsequently be reduced to 50 marks for the award of terminal examination marks.

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M.E. DEGREE (Mechatronics) PROGRAMME

COURSES OF STUDY

(For the candidates admitted from 2014-2015 onwards)

THIRD SEMESTER

Course code	Name of the Course	Category	No. of Hours/ Week			credits
			L	T	P	
	THEORY					
14MC310	Digital Control using Micro controllers	PC	4	0	-	4
14MCPX0	Elective - V	PE	2	0	2	4
14MCPX0	Elective - VI	PE	4	0	-	4
	PRACTICAL					
14MC340	Project I	PC	-	-	8	4
	Total		**10**	**-**	**10**	**16**

BS- Basic Sciences; HSS-Humanities and Social Sciences; ES-Engineering Sciences; PC-Programme Core; PE-Programme Elective; GE-General Elective; OC-One Credit Course; TC-Two Credit Course; SS-Self-Study Course (in the list of Programme Electives)

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015.

M.E. DEGREE (Mechatronics) PROGRAMME

SCHEME OF EXAMINATIONS

(For the candidates admitted from 2014-2015 onwards)

THIRD SEMESTER

Sl. No	Course code	Name of the Course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment	Terminal Exam *	Max. Marks	Terminal Exam	Total
THEORY								
1	14MC310	Digital Control using micro controllers	3	50	50	100	25	50
2	14MCPX0	Elective - V	3	50	50	100	25	50
3	14MCPX0	Elective - VI	3	50	50	100	25	50
PRACTICAL								
4	14MC340	Project I	-	50	50	100	25	50

FOURTH SEMESTER

Sl. No	Course code	Name of the Course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment	Terminal Exam *	Max. Marks	Terminal Exam	Total
1	14MC410	Project II	-	50	50	100	25	50

* Terminal Examination will be conducted for maximum marks of 100 and subsequently be reduced to 50 marks for the award of terminal examination marks.

LIST OF ELECTIVE COURSES

Sl. No.	Course Code	Name of the Course	Credit
1	14MCPA0	Microcontroller & Programmable Logic Controller.	4
2	14MCPB0	Data Communication Networks	4
3	14MCPC0	Machine Vision and Applications	4
4	14MCPD0	Virtual Instrumentation	4
5	14MCPE0	Modeling and Simulation of Mechatronic systems	4
6	14MCPF0	Autonomous Vehicles	4
7	14MCPG0	Industrial Robotics	4
8	14MCPH0	Elements and Programming of CNC Machines	4
9	14MCPJ0	Computer Integrated Manufacturing	4
10	14MCPK0	Medical Electronics and Instrumentation	4
11	14MCPL0	Material Handling, Storage and Assembly Automation	4
12	14MCPM0	Soft Computing Techniques	4
13	14MCPN0	Robust Control	4
14	14MCPQ0	Control of Electric drives	4

Sub Code	Lectures	Tutorial	Practical	Credit
14MC110	3	1	-	4

14MC110 Linear Algebra and Graph theory 3:1

Preamble: A general theory of Mathematical systems involving addition and scalar multiplication of vectors has applications in all Engineering field. Mathematical systems of this form are called Vector spaces or linear spaces.

Linear systems of equations are associated with many problems in Engineering and Sciences, as well as with applications of mathematics to the social sciences and quantitative study of business and economic problems. Numerical methods are becoming more and more important in engineering applications, because of the difficulties encountered in finding exact analytical solutions.

Natural form of graphs is a set with logical or hierarchical sequencing, such as computer flow charts. It serves as a mathematical model for any system involving a binary relation.

This course aims at introducing linear Algebra, Numerical methods and Graph Theory to students of M.E (Mechatronics).

Course Outcomes: At the end of the course the student will be able to

1. Verify whether the given set is a vector space or not.
2. Determine whether the given vectors are linearly independent or not.
3. Determine the dimension of a vector space
4. Solve the given system of linear equations by Gauss elimination method and Gauss Jordan method.
5. Find the intermediate value from the given set of values.
6. Calculate the derivative and integration value of any function within the interval
7. Solve the first order linear differential equation by Euler Method.
8. List the different types of graphs
9. Predict whether the given graphs are isomorphic or not.
10. Compute the shortest path for given graph using Dijkstra's shortest path Algorithm

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	20
Apply	40	40	40	50
Analyse	20	20	20	20

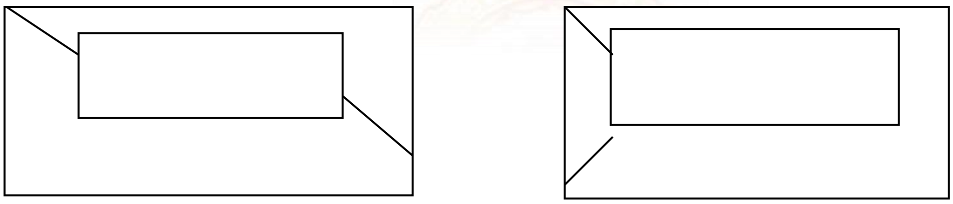
Course level learning objectives:

Remember

1. Let x, y, z be vectors in a vector space V. If $x + y = x + z$, then Show that y = z
2. Show that $\{e_1, e_2, e_{3,} (1,2,3)^T\}$ is a spanning set for R^3
3. List the Milne's predictor, corrector formula
4. Why is Trapezoidal rule so called?
5. Write the Trapezoidal rule to evaluate $\int_a^b f(x)dx$
6. Define complete bipartite graph.

Understand

1. Estimate the row space and column space of the matrix $A = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix}$
2. Estimate the dimension of the row space of the matrix $A = \begin{pmatrix} 1 & -2 & 3 \\ 2 & -5 & 1 \\ 1 & -4 & -7 \end{pmatrix}$
3. Write the two algorithms for building a minimal spanning tree.
4. Explain Dijkstra's algorithms with an example
5. Are the two graphs in the following figure isomorphic? Justify.



6. State two-point Gaussian quadrature formulas.

Apply

1. Compute the dimension of the subspace of R^4 spanned by

$$X_1 = \begin{pmatrix} 1 \\ 2 \\ -1 \\ 0 \end{pmatrix}, X_2 = \begin{pmatrix} 2 \\ 5 \\ -3 \\ 2 \end{pmatrix}, X_3 = \begin{pmatrix} 2 \\ 4 \\ -2 \\ 0 \end{pmatrix}, X_4 = \begin{pmatrix} 3 \\ 8 \\ -5 \\ 4 \end{pmatrix}$$

2. Show that an undirected graph has a Euler cycle if and only if it is connected and has all the vertices of even degree.

3. Construct the graph whose adjacency matrix is given below to see if is connected.

	X1	X2	X3	X4	X5	X6	X7	X8
X1	0	1	1	1	0	1	0	0
X2	1	0	1	0	1	0	1	0
X3	1	1	0	0	0	0	0	0
X4	1	0	0	0	0	0	1	0
X5	0	1	0	0	0	0	1	0
X6	1	0	0	0	0	0	0	0
X7	0	1	0	1	1	0	0	1
X8	0	0	0	0	0	0	1	0

4. Calculate the value of y (0.8) correct to 4 decimal places using RK method of fourth order given that $\frac{dy}{dx} = y - x^2,\ y(0.6) = 1.7579$

5. Given $\frac{dy}{dx} = 1 - y$ with y (0) =0. Calculate the following values:

(i) y (0.1) by Euler method

(ii) y (0.2) by modified Euler method

(iii) y (0.3) by improved Euler method

(iv) y (0.4) by Milne's method.

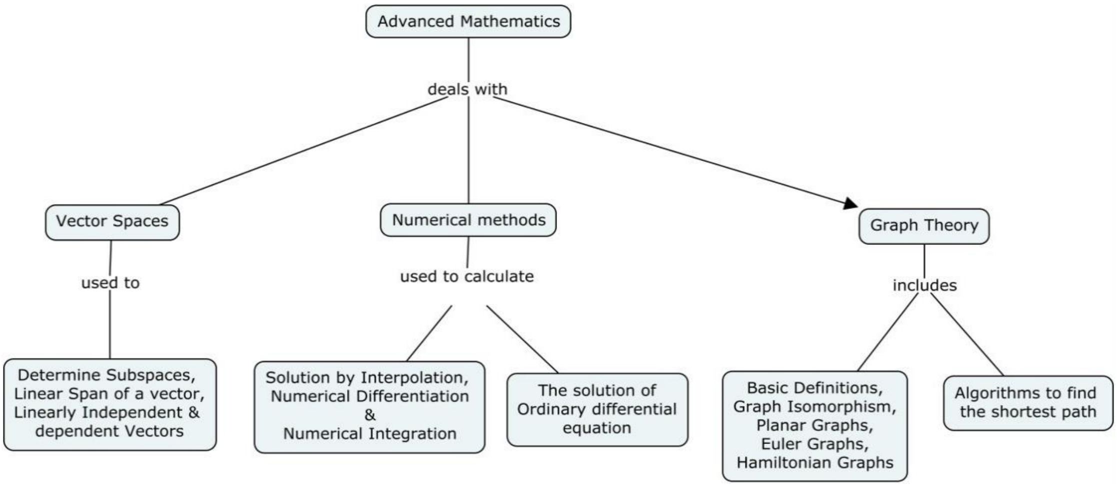
6. Compute the values of y (0.1) and y (0.2) given $y'' + y = 2; y(0) = 0, y(1) = 1$; using Taylor series method with h = 0.25.

Analyze:

1. A moving body is opposed by a force per unit mass of value cx and resistance per unit of mass of value bv^2, where x and v are the displacement and velocity of the particle at that instant. Find the velocity of the particle at x=0.1, 0.2,0.3 if originally at x=0 is 20 units.
2. A body of mass 'm' falling from rest is subject to the force of gravity and an air resistance proportional to the square of the velocity. If it falls through a distance 'x' and possess a velocity 'v' at that instant. Prove that

   $\frac{2kx}{m} = \log\left(\frac{a^2}{a^2 - v^2}\right)$, where $mg=ka^2$.

Concept Map:



Syllabus

VECTOR SPACE AND LINEAR TRANSFORMATION: Vector spaces – Subspaces – Linear spans – Linear independence and Linear dependence – Basis and Dimension – Linear transformation, Null space and range. **LINEAR ALGEBRA, INTERPOLATION, NUMERICAL DIFFERENTIATION AND INTEGRATION:** Gauss elimination method-Gauss Jordan method – Jacobi, Gauss- Seidel iterative Method –Lagrange's and Newton's divided difference interpolation - Newton's forward and backward difference interpolation – Numerical differentiation by finite differences – Trapezoidal, Simpson's 1/3 and Gaussian Quadrature formula. **NUMERICAL SOLUTION OF ORDINANRY DIFFERENTIAL EQUATIONS:** Numerical solution of first order ordinary differential equations by tailor series method – Euler Method- Fourth order Runge -Kutta Method – Multi step methods: Adam's Bash forth, Milne's Predictor Corrector methods. **FUNDAMENTALS OF GRAPHS:** Graphs-sub graphs-Graph Isomorphism- vertex degree: Eulerian Graphs- Planar Graphs- Hamiltonian paths.

ALGORITHMS- GRAPHS: Kruskal's algorithm- Dijkstra's shortest path Algorithm, Prim's Algorithm.

REFERENCE BOOKS:

1. Steven J. Leon , " **Linear Algebra with applications**", Macmillan publishing company, New York, 1990.
2. Jain, M.K, Iyengar, S.R.K, and Jain, R.K., "**Numerical methods for Scientific and Engineering Computation**", New Age International Publishers, New Delhi, 2003.
3. Bondy J.A. and Murthy, USR," **Graph Theory and Applications"**. Mc Millan Press Ltd, 1982.
4. Kumaresan, S, "Linear **Algebra – A geometric approach**", Prentice –Hall of India, New Delhi, 2000.
5. Friedberg, A.H., Insel, A.J. and Spence, L., "**Linear Algebra**", Prentice Hall of India, New Delhi, 2004.
6. Strang, G., "**Linear Algebra and its applications**", Thomson (Brooks/Cole),

New Delhi, 2005.
7. Faires, J.D. and Burder, R., "**Numerical Methods**", Brooks/Cole (Thomson Publications), New Delhi, 2002.
8. Gerald, C.F, and Wheatly, P.O., "**Applied Numerical Analysis**", Pearson Education, New Delhi, 2002.
9. Narasingh Deo, "**Graph Theory with Applications to Engineering and Computer Science**" PHI Learning Pvt. Ltd., 2004.

Course Contents and Lecture Schedule

Sl. No.	Topics	No. of Lectures
1	**VECTOR SPACE AND LINEAR TRANSFORMATION**	
1.1	Vector spaces	2
1.2	Subspaces	2
1.3	Linear spans	1
1.4	Linear independence and Linear dependence	1
1.5	Basis and Dimension	1
1.6	Linear transformation, Null space and range	2
2	**LINEAR ALGEBRA, INTERPOLATION, NUMERICAL DIFFERENTIATION AND INTEGRATION:**	
2.1	Gauss elimination method	1
2.2	Gauss Jordan method	1
2.3	Jacobi, Gauss- Seidel iterative Method	2
2.4	Lagrange's and Newton's divided difference interpolation	2
2.5	Newton's forward and backward difference interpolation	2
2.6	Numerical differentiation by finite differences	2
2.7	Trapezoidal, Simpson's 1/3 and Gaussian Quadrature formula	2
3	**NUMERICAL SOLUTION OF ORDINANRY DIFFERENTIAL EQUATIONS**	
3.1	Numerical solution of first order ordinary differential equations by tailor series method – Euler Method	2
3.2	Fourth order Runge -Kutta Method	1
3.3	Multi step methods: Adam's Bash forth, Milne's Predictor Corrector methods.	2
4	**FUNDAMENTALS OF GRAPHS**	
4.1	Graphs-subgraphs	2
	Graph Isomorphism, vertex degree,	2
4.2	Eulerian Graphs	2
4.3	Planar Graphs	1
4.4	Hamiltonian Paths	1

5	**ALGORITHMS - GRAPHS**	
5.1	Kruskal's algorithm	2
5.2	Dijkstra's shortest path Algorithm,	2
5.3	Prim's Algorithm	2
	Total	**40**

Course Designer:

1. A.P.Pushpalatha appmat@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
14MC120	3	-	-	3

14MC120 Principles of Mechanical Systems 3:0

Preamble: Mechanical Engineering is one of the major branches of the engineering practices and its principles are involved in the design, development and construction of physical devices and systems. It involves the production and usage of heat and mechanical power for the design, production, and operation of machines and tools. This course covers the mechanisms, transmission systems and machine tools to develop mechatronic systems.

Competencies: At the end of the course the student should be able to

1. Select suitable mechanism for a given environment.
2. Explain the different types of transmission system.
3. Determine the frequency of free, forced and damped vibrations of machine parts.
4. Design the shafts, screws and gears for mechanical systems
5. Explain the working principle of machine tools

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3	End-semester examination
1	Remember	20	20	20	20
2	Understand	30	30	30	30
3	Apply	50	50	50	50
4	Analyze	-	-	-	-
5	Evaluate	-	-	-	-
6	Create	-	-	-	-

Course Level Learning Objectives:

Remember:

1. What do you mean by Vibration Isolation and Transmissibility?
2. What is torsionally equivalent shaft?
3. Differentiate between machine and structure with examples.
4. Define coefficient of friction and angle of repose.
5. What are the advantages of using clutches in automobiles?
6. Identify the suitable kinematic chains to which the following mechanism belongs to: Elliptical trammel and pantograph

Understand:

1. Derive the frictional torque developed by single plate clutch using uniform wear theory.
2. Propose a mechanism to load part gradually and unload quickly. Sketch and explain its suitability

3. Suggest a suitable mechanism to convert rotary motion to reciprocating motion, comprising of minimum two sliding pairs. Sketch and explain its suitability.
4. Derive the natural frequency of free longitudinal vibrations using energy method and equilibrium method.
5. Derive the expression for the length of the open belt drives.
6. How bolts are manufactured in lathe? Explain the all the operations involved.

Apply

1. An engine mechanism is shown in Fig. 1. The crank CB = 100 mm and the connecting rod BA = 300 mm with center of gravity G, 100 mm from B. In the position shown, the crankshaft has a speed of 75 rad/s and an angular acceleration of 1200 rad/s^2. Find: 1. velocity of G and angular velocity of AB, and 2. acceleration of G and angular acceleration of AB 3. Velocity and acceleration of the slider A.

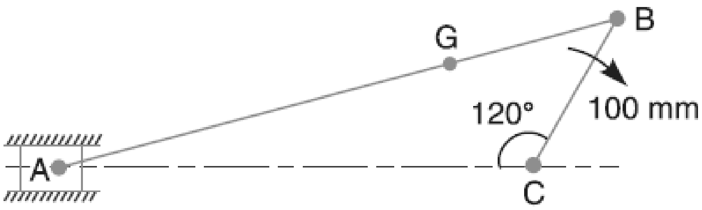


Figure 1

2. A conical pivot bearing supports a vertical shaft of 200 mm diameter. It is subjected to a load of 30 kN. The angle of the cone is 120º and the coefficient of friction is 0.025. Find the power lost in friction when the speed is 140 r.p.m., assuming 1. Uniform pressure; and 2. Uniform wear.

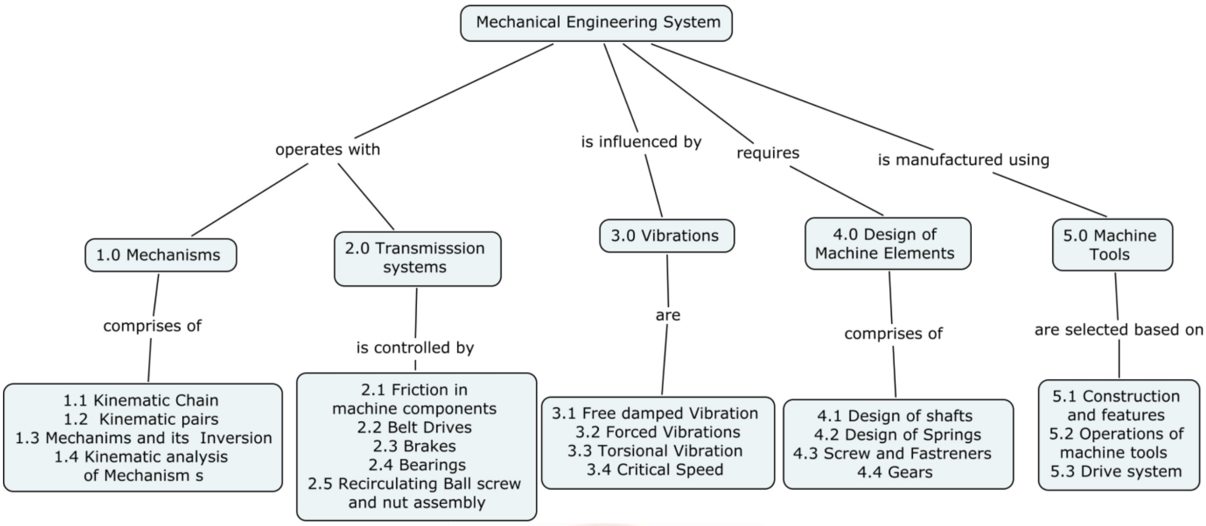
A steel shaft ABCD 1.5 m long has flywheel at its ends A and D. The mass of the flywheel A is 600 kg and has a radius of gyration of 0.6 m. The mass of the flywheel D is 800 kg and has a radius of gyration of 0.9 m. The connecting shaft has a diameter of 50 mm for the portion AB which is 0.4 m long; and has a diameter of 60 mm for the portion of BC which is 0.5 m long: and has a diameter of 40 mm for the portion CD which is 0.6 m long. Determine the natural frequency of the torsional vibrations. Also draw the node positions. The modulus of rigidity for the shaft material is 80 GN/ m^2.

1. A shaft has a number of collars integral with it. The external diameter of the collars is 400 mm and the shaft diameter are 250 mm. If the uniform intensity of pressure is 0.35 N/mm^2 and its coefficient of friction is 0.05, estimate: 1. power absorbed in overcoming friction when the shaft runs at 105 r.p.m. and carries a load of 150 kN, and 2. number of collars required

2. A multi-disc clutch has three discs on the driving shaft and two on the drive shaft. The outside diameter of the contact surfaces is 240 mm and inside diameter 120 mm. Assuming uniform wear and coefficient of friction as 0.3, find the maximum axial intensity of pressure between the discs for transmitting 25 kW at 1575 r.p.m.

3. The engine of a ship develops 440 kW and transmits the power by a horizontal propeller shaft which runs at 120 r.p.m. It is proposed to design a hollow propeller shaft with inner diameter as 0.6 of the outer diameters. Considering torsion alone, calculate the diameter of the propeller shaft if stress in the material is not to exceed 63 MPa and also the angular twist over a length of 2.5 m is not to be more than 1°. The modulus of rigidity of the shaft material is 80 GPa.

Concept Map



Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Mechanisms**	
1.1	Definition – Machine and Structure – Kinematic link, Kinematic pair and Kinematic chain	1
1.2	Classification of Kinematic pairs according to motion, Constraint & contact - Degrees of freedom	1
1.3	Crank rocker mechanisms - Single Slider crank chain mechanisms – Double Slider crank chain mechanisms – – applications	1
1.3.1	Inversion of Crank rocker mechanisms – applications	1
1.3.2	Inversion of Single Slider crank chain mechanisms – applications	1
1.3.2	Inversion of– Double Slider crank chain mechanisms – applications	1
1.4	Kinematic analysis and synthesis of simple mechanisms	1
1.4.1	Determination of velocity and acceleration of Single Slider crank chain mechanisms	2

No.	Topic	No. of Lectures
1.4.2	Determination of velocity and acceleration of Crank rocker mechanisms	2
2	**Transmission Systems**	
2.1	Types of friction	1
2.1.1	Friction in screw and nuts	1
2.1.2	Friction in pivot and collar – Friction in thrust and collar bearing	2
2.1.3	Friction in plate and disc clutches	2
2.1.4	Friction in Flat belt, V-belt and rope drives – creep in belts – Jockey pulley	1
2.2	Open and crossed belt drives – Ratio of tensions	1
2.2.1	Effect of centrifugal and initial tension in belts – Condition for maximum power transmission	2
2.3	Basics of brakes	1
2.4	Bearings and its classifications	1
2.4.1	Basics of Journal and rolling element bearings	
2.4.2	Basics of Hydrostatic and aerostatic bearings	1
2.5	Recirculating ball screw and nut assembly.	1
3	**Vibration**	
3.1	Free, forced and damped vibrations of single degree of freedom systems	3
3.2	Force transmitted to supports – vibration Isolation – vibration absorption	2
3.3	Torsional vibration of shafts – single and multi-rotor systems – geared shafts	2
3.4	critical speed of shafts	1
4	**Design of Machine Elements**	
4.1	Design of shafts for various types of loading	1
4.2	Design of helical compression springs	2
4.3	Design of screw and fasteners	1
4.4	Gear profile and geometry	1
4.4.1	Nomenclature of spur & helical gears	1
4.4.2	Nomenclature of worm and worm wheel	1
5	**Machine Tools**	

No.	Topic	No. of Lectures
5.1	Machine tool construction-features	1
5.2	Operations of lathe, milling machine drilling machine	1
5.3	Drive system for machine tools – mechanical, hydraulic and electric	2
5.3.1	Stepped and variable speeds- spindle speeds and feed drives-	2
5.3.2	Drives for linear and reciprocation motion generation	1
	Total Hours	**45**

Syllabus

Mechanisms: Definition – Machine and Structure – Kinematic link, pair and chain – classification of Kinematic pairs – Constraint & motion - Degrees of freedom – Slider crank – Single and double – Crank rocker mechanisms – Inversions – applications. Kinematic analysis and synthesis of simple mechanisms – Determination of velocity and acceleration of simple mechanisms .**Transmission Systems:** Types of friction – friction in screw and nuts – pivot and collar – thrust bearings – collar bearing – plate and disc clutches – belt (flat & vee) and rope drives – creep in belts – Jockey pulley – open and crossed belt drives – Ratio of tensions – Effect of centrifugal and initial tension – condition for maximum power transmission – basics of brakes, journal and rolling element bearings hydrostatic and aerostatic bearings –recirculating ball screw and nut assembly. **Vibration:** Free, forced and damped vibrations of single degree of freedom systems – force transmitted to supports – vibration Isolation – vibration absorption – torsional vibration of shafts – single and multi-rotor systems – geared shafts – critical speed of shafts. **Design of Machine Elements:** Design of shafts – Springs – screw and fasteners – Gear profile and geometry – nomenclature of spur & helical gears – worm and worm wheel **Machine Tools:** Machine tool construction-features – operations of lathe, milling machine, drilling machine – Drive system for machine tools – mechanical, hydraulic and electric stepped and variable speeds – spindle speeds and feed drives- linear and reciprocation motion generation

Reference Books

1. R.K. Bansal, and J.S. Brar." **Theory of Machines**" Fourth Edition, Laxmi Publications (P) ltd., New Delhi,2012
2. G.C.Sen. and A. Bhattacharya, "**Principles of machine tools**", New Central book Agency, 2009
3. Joseph Edward Shigley, Richard G Budynas, Keith J Nisbett, "**Mechanical Engineering Design**"- Nineth Edition Tata McGraw Hill International Edition, 2011.
4. Malhotra .D.R. and Gupta. H.C." Theory **of Machines**", Satya Prakasam, Tech. India Publications, 1989

5. Acherkan.N, "**Machine tool Design**", vol 3, MIR Publishers, 1978.
6. Gupta.BVR, "**Theory of Machines: Kinematics and Dynamics**" I. K. International Pvt Ltd, 2011.
7. N. K. Mehta, "**Machine Tool Design**", Tata McGraw hill Publications H, 2012.

Course Designer:

1. V.Balasubramani vbmech@tce.edu

Sub code	Lectures	Tutorial	Practical	Credit
14MC120	3	0	-	3

14MC 120 Principles of Electronic Systems 3:0

Preamble: The course focus to impart the concept of Analog and Digital Electronic devices and Systems used in Industries for the students migrated to study Mechatronics form other branches of engineering. Also covers the basics of communication principles which are essential in today ICT era in all industries.

Competencies

At the end of the course the student will be able to:

1. Explain the working and applications of all Analog and Digital electronic devices.
2. Design the analog and Digital electronic circuits.
3. Design the logic circuits.
4. Explain the concept of modulation and demodulation techniques.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3/End-semester examination
1	Remember	20	20	20
2	Understand	50	30	30
3	Apply	30	50	50
4	Analyze	-	-	-
5	Evaluate	-	-	-
6	Create	-	-	-

Course level learning objectives:

Remember

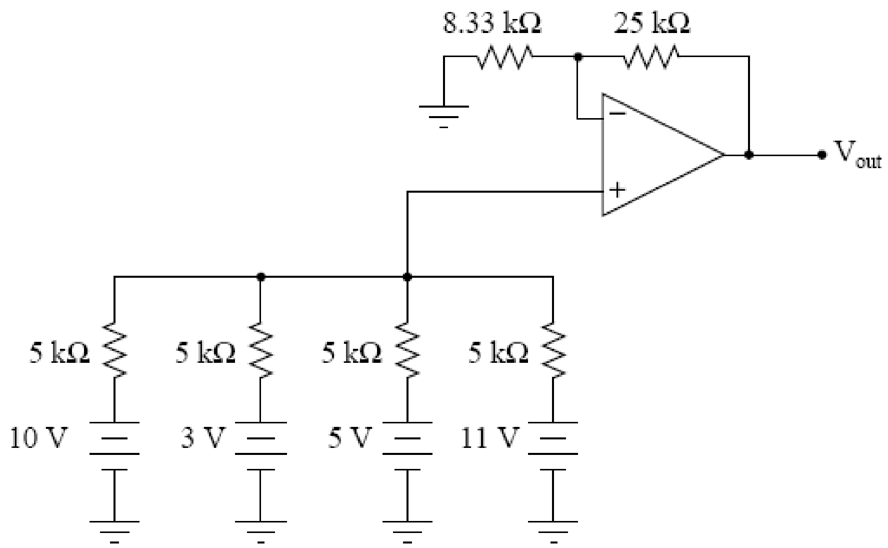
1. Define the static and dynamic resistance of a diode.
2. Give the applications of Zener diode.
3. Define the reverse recovery time of a diode.
4. Define off-set current and virtual ground in an op-amp.

Understand

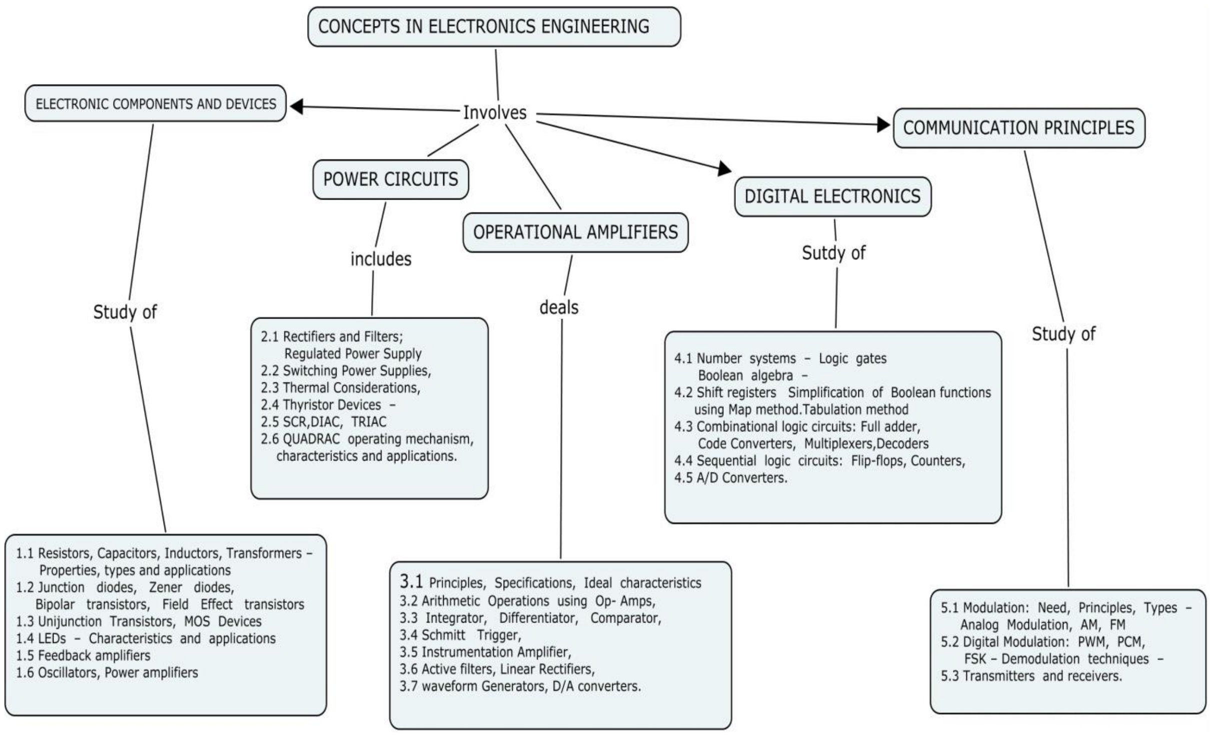
1. What are the advantages of IC over discrete component circuits?
2. What is a scale changer?
3. Mention the different types of DAC.
4. Explain the working of an instrumentation amplifier with neat sketch.

Apply

1. With neat sketch explain the 3-input inverting summing amplifier.
2. Design a synchronous decade counter
3. Design a 3 input Multiplexer
4. Discuss the operation of a transmitter and receiver circuit.
5. Determine the output voltage of the circuit shown below.



Concept Map



Syllabus

Electronic Components and Devices: Resistors, Capacitors, Inductors, Transformers – Properties, types and applications; Junction diodes, Zener diodes, Bipolar transistors, Field Effect transistors, Unijunction Transistors, MOS Devices, LEDs – Characteristics and applications; Feedback amplifiers, Oscillators, Power amplifiers. **Power Circuits:** Rectifiers and Filters; Regulated Power Supply – Switching Power Supplies, Thermal Considerations, Thyristor Devices – SCR, DIAC, TRIAC, QUADRAC – operating mechanism, characteristics and applications. **Operational Amplifiers:** Principles, Specifications, Ideal characteristics, Arithmetic Operations using Op-Amps, Integrator, Differentiator, Comparator, Schmitt Trigger, Instrumentation Amplifier, Active filters, Linear Rectifiers, waveform Generators, D/A converters. **Digital Electronics:** Number systems – Logic gates – Boolean algebra – Simplification of Boolean functions using Map method. Tabulation method – Combinational logic circuits: Full adder, Code Converters, Multiplexers, Decoders – Sequential logic circuits: Flip-flops, Counters, Shift registers–A/D converters. **Communication Principles:** Modulation: Need, Principles, Types – Analog Modulation, AM, FM – Digital Modulation: PWM, PCM, FSK – Demodulation techniques – Transmitters and receivers.

Reference Books:

1. Jocob Mill Man, "**Microelectronics Digital and Analog circuits & Systems**" – McGraw-Hill 2004.
2. Fanco, "**Design with Operational amplifiers and Analog Integrated Circuits**", TMH,2014(new edition)
3. Taub and Schilling," Principles **of Communicating systems**", 4th edition TMH, 2013(new edition)
4. Ray & Chaudary, "**Linear Integrated Circuits**", New Delhi 1991.
5. Malvino & Leach, "**Digital Principals & application**", TMH, 2002.

Course Contents

No	Topics	No. of Periods
1	**ELECTRONIC COMPONENTS AND DEVICES**	
1.1	Resistors, Capacitors, Inductors, Transformers – Properties, types and applications	1
1.2	Junction diodes, Zener diodes, Bipolar transistors, Field Effect transistors	1
1.3	Unijunction Transistors, MOS Devices	1
1.4	LEDs – Characteristics and applications	1
1.5	Feedback amplifiers	2
1.6	**Oscillators, Power amplifiers**	2
2	**POWER CIRCUITS**	

2.1	Rectifiers and Filters; Regulated Power Supply.	2
2.2	Switching Power Supplies,	2
2.3	Thermal Considerations, Thyristor Devices – SCR	2
2.4	**DIAC,**	1
2.5	TRIAC	1
2.6	QUADRAC operating mechanism, characteristics and applications.	2
3	**OPERATIONAL AMPLIFIERS**	
3.1	Principles, Specifications, Ideal characteristics.	1
3.2	Arithmetic Operations using Op- Amps.	1
3.3	**Integrator, Differentiator, Comparators.**	1
3.4	Schmitt Trigger.	1
3.5	Instrumentation Amplifier.	2
3.6	Active filters, Linear Rectifiers.	2
3.7	Waveform Generators, D/A converters.	2
4	**DIGITAL ELECTRONICS**	
4.1	Number systems – Logic gates – Boolean algebra – Shift registers	2
4.2	Simplification of Boolean functions using Map method. Tabulation method	1
4.3	Combinational logic circuits: Full adder, Code Converters, Multiplexers, Decoders	2
4.4	Sequential logic circuits: Flip-flops, Counters,	3
4.5	A/D Converters.	2
5	**COMMUNICATION PRINCIPLES**	
5.1	Modulation: Need, Principles, Types – Analog Modulation, AM, FM.	3
5.2	Digital Modulation: PWM, PCM, FSK – Demodulation techniques.	2
5.3	Transmitters and receivers.	2
	Total	45

Course Designer:

1. S. Arockiaedwinxavier- saexeee@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
14MC130	4	-	-	4

14MC130 Sensors in Automation 4:0

Preamble: Sensor is a device which produces electrical output in response to a specified measurand. Sensors play a vital role in manufacturing, machinery, aerospace, medicine and robotics. Most of the advancements of present day would be not possible without sensors. The main purpose of offering this course is to elaborate the theoretical and practical aspects of sensors, their classifications, static and dynamic characteristics, recent trends and their applications in automation.

Competencies

At the end of the course the students should be able to

1. Explain static and dynamic characteristics and operating principle of Inductive, capacitive, magnetic, piezo electric, radiation, electro chemical sensors.
2. Illustrate the importance of standard of calibration
3. Select suitable sensor for a given automobile, aeronautics, machine tools and manufacturing application

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test3/End-semester examination
1	Remember	20	20	20
2	Understand	60	40	40
3	Apply	20	40	40
4	Analyze	-	-	-
5	Evaluate	-	-	-
6	Create	-	-	-

Course level learning objectives:

Remember

1. List any four dynamic characteristics of transducers.
2. Define Gauge factor
3. Define sensitivity of a transducer
4. State Hall effect
5. List the applications of fiber optic sensors
6. List few nuclear radiation sensors

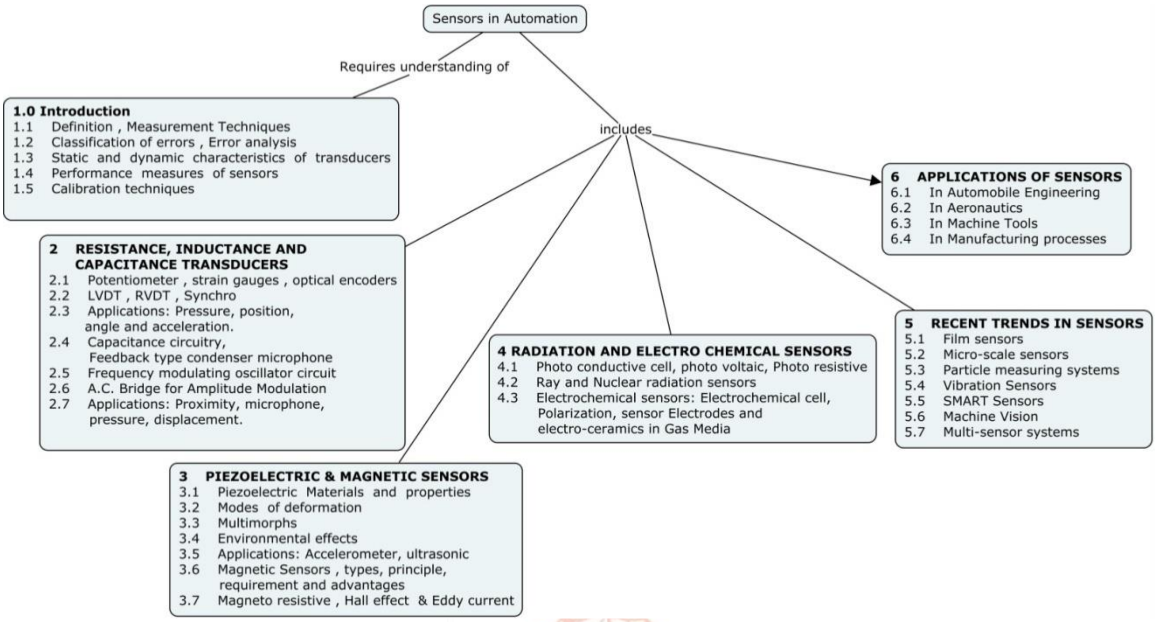
Understand

1. Explain various static and dynamic characteristics of transducers.
2. Summarize the role of error analysis in analyzing the performance of sensors
3. With suitable diagram explain the principle of operation and characteristics of LVDT.
4. Explain the principle of Hall Effect and its role in measurement of flux density.
5. Explain the principle of operation of any one nuclear sensor.
6. Illustrate the applications of micro scale sensors in automobile industry.

Apply

1. The transfer characteristic of a platinum resistance is given as: $R_T = R_o\left(1 + aT + BT^2\right)$, with R_0 =100 ohm, a = $3.9 \cdot 10^{-3}$ K^{-1} and B=$-5.8 \cdot 10^{-7}$ K^{-2} Calculate the maximum non-linearity error relative to the line R(T) = R 0 (1 + a T),in a temperature range going from -50 °C to +100 °C. Express the error in % and in °C
2. A resistance strain gauge with gauge factor 2 is cemented to a steel member which is subjected to a strain of 1×10^{-6}. If the original resistance value of the gauge is 130 ohms, calculate the change in resistance.
3. Certain crystal has coupling coefficient of 0.32. Calculate the amount of electrical energy to be applied to produce and output of 7×10^{-6}J.
4. A thermistor has a resistance of 3980 ohm at ice point (0°C) and 794 ohms at 50°C. The resistance temperature relationship is given by R_T=a R_0 exp(b/T). Calculate the constants 'a' and 'b'. Also calculate the range of resistance to be measured in case the temperature varies from 40°C to 100°C.
5. A thickness measuring transducer system has a parallel plate capacitive sensor having pair of plates of area of 200 cm^2, which are separated by a distance of 0.02cm. A mica sheet of thickness 0.01±0.001 cm is begin passed between the plates. Calculate the variation of capacitance if the electric constant of mica is 8 and permittivity of air is 8.854×10^{-12} F/m.
6. A barium titanite crystal has dimensions of 5mmx5mmx1.5mm. The young's modulus of barium titanite is 12×10^6N/m. Its charge sensitivity is 150 PC/N and permittivity is 12.5×10^{-9}F/m. A capacitance of 10pF in parallel with 100MΩ resistance connected across the crystal. Calculate the RMS value of voltage under open circuit and load conditions when a force of 0. 0142.Sin100t N is applied to the crystal. Calculate the RMS value of deflection. The resistance of the crystal may be neglected.

Concept Map



Syllabus

Introduction Definition, Measurement Techniques, Classification of errors, Error analysis, Static and dynamic characteristics of transducers, Performance measures of sensors, Classification of sensors, calibration techniques. **Resistance, Inductance and Capacitance Transducers:** Potentiometer, strain gauges, optical encoders, LVDT, RVDT, Synchro, Microsyn, Applications: Pressure, position, angle and acceleration. Capacitance circuitry, Feedback type condenser microphone, frequency modulating oscillator circuit, Dynamic capacitance variation, A.C. Bridge for Amplitude Modulation, Applications: Proximity, microphone, pressure, displacement. **Piezoelectric & Magnetic Sensors: Piezoelectric** Materials and properties, Modes of deformation, Multimorphs, Environmental effects, Applications: Accelerometer, ultrasonic. Magnetic Sensors, types, principle, requirement and advantages: Magneto resistive, Hall Effect – Eddy current. **Radiation and Electro Chemical Sensors:** Photo conductive cell, photo voltaic, Photo resistive, Fiber optic sensors, Ray and Nuclear radiation sensors, Electro chemical sensors: Electrochemical cell, Polarization, sensor Electrodes and electro-ceramics in Gas Media. **Modern Sensors** Film sensors, micro-scale sensors, Particle measuring systems, Vibration Sensors, SMART sensors, Machine Vision, Multi-sensor systems **Applications of Sensors:** Applications and case studies of Sensors in Automobile Engineering, Aeronautics, Machine tools and Manufacturing processes.

Reference Books

1. Patranabis D.," **Sensor and Actuators**", Prentice Hall of India (Pvt) Ltd., 2005.
2. Renganathan S.," **Transducer Engineering**", Allied Publishers (P) Ltd., 2003.
3. Ernest O. Doebelin, "**Measurement systems Application and Design**", International Student Edition, VI Edition, Tata McGraw-Hill Book Company, 2011.
4. Bradley D.A., and Dawson, Burd and Loader, "**Mechatronics, Thomson Press India Ltd**", 2004.
5. Bolton W, "**Mechatronics**", Thomson Press, 2003.

Course Contents and Lecture Schedule

1	**INTRODUCTION**	
1.1	Definition, Measurement Techniques	1
1.2	Classification of errors, Error analysis	1
1.3	Static and dynamic characteristics of transducers	2
1.4	Performance measures of sensors	2
1.5	Calibration techniques	1
2	**RESISTANCE, INDUCTANCE AND CAPACITANCE TRANSDUCERS**	
2.1	Potentiometer, strain gauges, optical encoders	2
2.2	LVDT, RVDT, Synchro	2
2.3	Applications: Pressure, position, angle and acceleration.	2
2.4	Capacitance circuitry, Feedback type condenser microphone	2
2.5	frequency modulating oscillator circuit	2
2.6	A.C. Bridge for Amplitude Modulation	2
2.7	Applications: Proximity, microphone, pressure, displacement.	2
3	**PIEZOELECTRIC & MAGNETIC SENSORS**	
3.1	Piezoelectric Materials and properties	1
3.2	Modes of deformation	1
3.3	Multimorphs	1
3.4	Environmental effects	1
3.5	Applications: Accelerometer, ultrasonic	1
3.6	Magnetic Sensors, types, principle, requirement and advantages	1
3.7	Magneto resistive, Hall effect & Eddy current	2
4	**RADIATION AND ELECTRO CHEMICAL SENSORS**	
4.1	Photo conductive cell, photo voltaic, Photo resistive	2
4.2	Ray and Nuclear radiation sensors	1
4.3	Electrochemical sensors: Electrochemical cell, Polarization, sensor Electrodes and electro-ceramics in Gas Media	2

5	**MODERN SENSORS**	
5.1	Film sensors	1
5.2	Micro-scale sensors	1
5.3	Particle measuring systems	1
5.4	Vibration Sensors	1
5.5	SMART Sensors	1
5.6	Machine Vision	1
5.7	Multi-sensor Systems	1
6	**APPLICATIONS OF SENSORS**	
6.1	In Automobile Engineering	1
6.2	In Aeronautics	1
6.3	In Machine Tools	1
6.4	In Manufacturing processes	1
	Total	**45**

Course Designer:

1. Mr.M. Varatharajan - varatharajan@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
14MC140	4	-	-	4

14MC140 Fluid Power Automation 4:0

Preamble: The course aims at giving adequate exposure to hydraulic and pneumatic systems and design of hydraulic and pneumatic circuits. The course explains about the technology that deals with generation, control and transmission of power using pressurized fluid and design and setup various circuit need for industrial low-cost automation. The course also demonstrates Relay control systems and PLC systems and their programming.

Competencies

At the end of the course the student should be able to

1. Express the theory related to Fluid power and arising in the study of engineering problems and their applications.
2. Classify the pumps and motors and selected them for the required applications.
3. Design the hydraulic and pneumatic circuits based on the required movement and sequence.
4. Provide speed, pressure, direction control for the hydraulic and pneumatic circuits.

Assessment pattern

Sl. No	Bloom's category	Test 1	Test 2	Test 3 / End Semester Examinations
1	Remember	20	20	20
2	Understand	20	20	20
3	Apply	60	60	60
4	Analyze	-	-	-
5	Evaluate	-	-	-
6	Create	-	-	-

Course level learning objectives:

Remember

1. Define positive displacement pump
2. Name some positive displacement pump
3. List the parameters for selection a pump
4. What is the various type of hydraulic motors?
5. What is the control required for hydraulic circuits?
6. Name some pressure control valves
7. Why flow control is essential
8. What is FRL unit

Understand

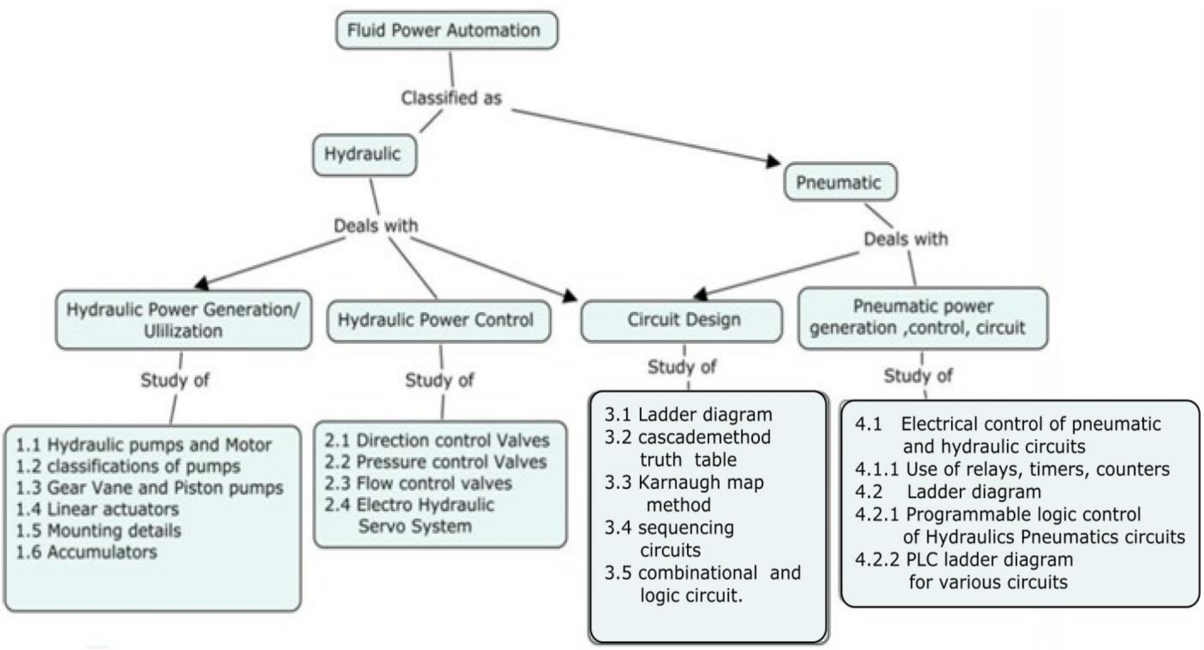
1. Compare the hydraulic and pneumatic
2. Distinguish between external and internal gear pump.
3. Describe the working principle cushioned cylinder

4. Distinguish between mechanical and Electro Hydraulic Servo Systems
5. Classify the pumps
6. Compare the meter-in and meter-out circuits

Apply

1. With neat sketch explain the working of the gear pump
2. Discuss in detail the 4/3 direction control valve with example.
3. Explain the cascade method of circuit design with example
4. Design a circuit for the A+B+A-B- using Karnaugh map method
5. Draw the ladder diagram for A+B+C-A-B-C+ and explain its operation
6. Explain the application of pressure Compensated flow control valve

Concept Map



Syllabus

Introduction: Need for Automation, Hydraulic & Pneumatic Comparison – ISO symbols for fluid power elements, Hydraulic, pneumatics – Selection criteria. **Fluid Power Generating/Utilizing Elements:** Hydraulic pumps and motor gears, vane, piston pumps-motors-selection and specification-Drive characteristics – Linear actuator – Types, mounting details, cushioning – power packs – construction. Reservoir capacity, heat dissipation, accumulators – standard circuit symbols, circuit (flow) analysis. **Control and Regulation Elements:** Direction flow and pressure control valves-Methods of actuation, types, sizing of ports-pressure and temperature compensation, overlapped and underlapped spool valves-operating characteristics-electro hydraulic servo valves-Different types- characteristics and performance. **Circuit Design:** Typical industrial hydraulic circuits-Design methodology – Ladder diagram-cascade, method-truth table-Karnaugh map method-sequencing circuits-combinational and logic circuit. **Electro Pneumatics & Electronic Control of Hydraulic and Pneumatic Circuits**: Electrical control of pneumatic and hydraulic circuits-use of relays, timers, counters, Ladder diagram. Programmable logic control of Hydraulics Pneumatics circuits, PLC ladder diagram for various circuits.

Reference Books

1. W. Bolton, "**Mechatronics, Electronic control systems in Mechanical and Electrical Engineering**" Pearson Education, 2011.
2. Peter Rohner, "**Fluid Power Logic Circuit Design"**, McMillan Prem, 1994.
3. Anthony Esposito," Fluid **Power with Applications**", Prentice-Hall, 2009
4. Eaton "**Hydraulics Training Services (Vickers)**", Industrial Hydraulics Manual 5th Ed. 2nd Printing 2008
5. Frank Yeaple, "**Fluid Power Design Handbook**", Third Edition, CRC Press
6. James L. Johnson "**Introduction to Fluid Power**" Delmar Thomson Learning Publishers, 2003.
7. **CMTI Handbook**, Tata McGraw-Hill Education, 2004.

Course content and lecture schedule

No	Topic	No. of Lectures
	Introduction	
	Need for Automation, Hydraulic & Pneumatic Comparison	2
1	**FLUID POWER GENERATING/UTILIZING ELEMENTS**	
1.1	Hydraulic pumps and Motor	2
1.2	Gear, Vane and Piston motors	1
1.3	Gear, Vane and Piston pumps	2
1.3.1	Selection and specification-Drive characteristics	1
1.4	Linear actuator – Types	2
1.5	Cylinder mounting details	1
1.5.1	Cushioning cylinder	1
1.5.2	power packs – construction	1
1.5.3	Reservoir capacity – heat dissipation	1
1.6	Accumulators	1
1.6.1	standard circuit symbols, circuit (flow) analysis	1
2	**CONTROL AND REGULATION ELEMENTS**	
2.1	Direction control Valves types	1
2.2	Flow control valves - types	1
2.3	pressure control - types	1
2.3.1	Methods of actuation – types	1
2.3.2	sizing of ports	1
2.3.3	pressure and temperature compensation,	1
2.3.4	overlapped and under lapped spool valves, operating characteristics	1

2.4	electro hydraulic servo valves- Different types- characteristics and performance	2
3	**Circuit Design**	
3	Typical industrial hydraulic circuits design methodology	1
3.1	Ladder diagram	1
3.2	Cascade method Truth table	1
3.3	Karnaugh map method	1
3.4	Sequencing circuits	1
3.5	combinational and logic circuit	2
4	**ELECTRO PNEUMATICS & ELECTRONIC CONTROL OF HYDRAULIC AND PNEUMATIC CIRCUITS**	
4.1	Electrical control of pneumatic and hydraulic circuits	1
4.1.1	Use of relays, timers, counters	2
4.2	Ladder diagram	1
4.2.1	Programmable logic control of Hydraulics Pneumatics circuits	2
4.2.2	PLC ladder diagram for various circuits	1
	Total	**40**

Course Designer

1. M.Elango memech@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
14MC150	4	-	-	4

14MC150 Mechatronics System Design 4:0

Preamble: Mechatronics is the synergistic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and manufacturing processes. It relates to the design of systems, devices and products aimed at achieving an optimal balance between basic mechanical structure and its overall control. It will cover a wide range of application areas including consumer product design, instrumentation, manufacturing methods, computer integration and process and device control. An engineering PG Mechatronics student needs to understand the basic concepts, properties and interfacing off controls and drives in Mechatronics System Design.

Competencies

At the end of the course the students should be able to

1. Explain difference between traditional and Mechatronic design approach.
2. Explain types of hydraulic /pneumatic drives and controls.
3. Explain the installation procedure of a real time data acquisition system.
4. Develop a data acquisition for a Mechatronic system.
5. Develop a data acquisition and control system.

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test3	End-semester examination
1	Remember	20	20	20	20
2	Understand	60	40	20	30
3	Apply	20	40	60	50
4	Analyze	-	-	-	-
5	Evaluate	-	-	-	-
6	Create	-	-	-	-

Course level learning objectives:

Remember

1. Define Mechatronics.
2. List the functions of structures in a Mechatronic system.
3. Define directional control valve.
4. List the types of Hydraulic motors.
5. Define Nyquist sampling Theorem.
6. Define over framing.

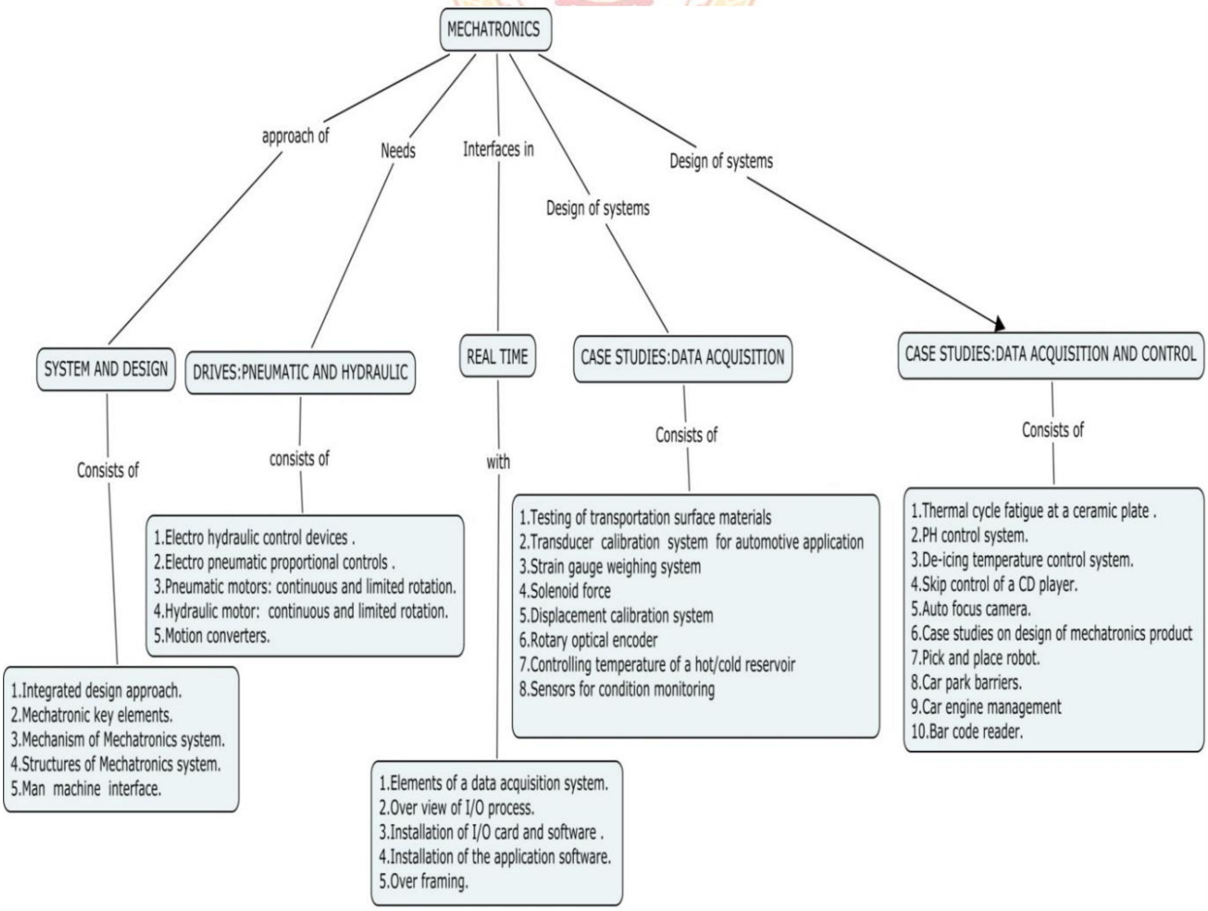
Understand

1. Differentiate Traditional and Mechatronic Approach.
2. Discuss about various types of design process of a product.
3. Explain about functioning of vane type hydraulic motor.
4. Discuss about the elements involved in a data Acquisition system.
5. Explain about the process of installing a data acquisition system.

Apply

1. Develop a Mechatronic system for weighing using strain gauge.
2. Develop a condition monitoring system using sensors for an automated manufacturing system.
3. Develop a Mechatronic system for PH control.
4. Develop a mechatronic system for Auto focusing in a camera.
5. Design and develop a car park barrier system.

Concept Map



Syllabus

SYSTEMS AND DESIGN: Mechatronics systems – Integrated design issue in Mechatronics – Mechatronic key elements, Mechatronics approach – Adaptive control and distributed control system – Design process – Type of design – Integrated product design – Mechanism, load condition, design and flexibility – structures – man machine interface, industrial design and ergonomics, information transfer, safety. **CONTROL AND DRIVES:** Control devices – Electro hydraulic control devices, electro pneumatic proportional controls – Rotational drives – pneumatic motors: continuous and limited rotation – Hydraulic motor: continuous and limited rotation – motion converters, fixed ratio, invariant motion profile, variators. **REAL TIME INTERFACING:** Real time interface – Introduction, Elements of a data acquisition and control system, over view of I/O process, installation of I/O card and software – Installation of the application software – over framing. **CASE STUDIES – I:** Case studies on data acquisition – testing of transportation surface materials transducer calibration system for automotive application – Strain gauge weighing system – solenoid force – Displacement calibration system – Rotary optical encoder– controlling temperature of a hot/cold reservoir – sensors for condition monitoring –mechatronic control in automated manufacturing. **CASE STUDIES II:** Case studies on data acquisition and control – thermal cycle fatigue at a ceramic plate – PH control system. De-icing temperature control system – skip control of a CD player – Auto focus camera. Case studies on design of mechatronics product –pick and place robot – car park barriers – car engine management – bar code reader.

Reference Books:

1. Brian morriss, "**Automated manufacturing Systems – Actuators Controls, Sensors and Robotics**", McGraw Hill International Edition, 1995.
2. Bolton, "**Mechatronics – Electronic control systems in mechanical and electrical engineering**, 5th edition, Pearson, 2013.
3. Devadas Shetty, Richard A. Kolkm, "**Mechatronics system design**", PWS publishing company, 1997.
4. Bradley, D. Dawson, N.C. Burd and A.J. Loader, "**Mechatronics: Electronics in product and process**", Chapman and Hall, London, 1991
5. Gopal, "**Sensors: A comprehensive survey Vol I & Vol VIII**", BCH publisher, New York.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**INTRODUCTION: SYSTEMS AND DESIGN**	
1.1	Mechatronics systems – Integrated design–	2
1.2	Mechatronic key elements	2
1.3	Adaptive control and distributed control system	1

1.4	Type of design – Integrated product design	1
1.5	Mechanism	1
1.6	Structures	1
1.7	Man, machine interface, industrial design and ergonomics, information transfer, safety.	1
2	**CONTROL AND DRIVES:**	
2.1	Control devices – Electro hydraulic control devices.	2
2.2	Electro pneumatic proportional controls.	1
2.5	Pneumatic motors: continuous and limited rotation	2
2.6	Hydraulic motor: continuous and limited rotation	2
2.7	Motion converters- fixed ratio, invariant motion profile, variators.	2
3	**REAL TIME INTERFACING:**	
3.1	Real time interface – Introduction.	2
3.2	Elements of a data acquisition and control system.	2
3.3	Over view of I/O process.	1
3.4	Installation of I/O card and software.	1
3.5	Installation of the application software.	1
3.6	Over framing.	2
4	**CASE STUDIES – I:**	
4.1	Testing of transportation surface materials	1
4.2	calibration system for automotive application	1
4.3	Strain gauge weighing system	1
4.4	Displacement calibration system	1
4.5	Controlling temperature of a hot/cold reservoir	2
4.6	Sensors for condition monitoring	2
4.7	Mechatronic control in automated manufacturing.	1
5	**CASE STUDIES II:**	
5.1	Thermal cycle fatigue at a ceramic plate	1
5.2	PH control system	1
5.3	De-icing temperature control system	1
5.4	skip control of a CD player	1
5.5	Auto focus camera	1
5.6	Pick and place robot	1
5.7	Car park barriers	1
5.8	Car engine management	1
5.9	Bar code reader.	1
	Total	**45**

Course Designer:

1. Mr.T.Vivek-tvivek@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
14MC160	4	-	-	4

14MC160 Automotive Electronics 4:0

Preamble: This course is intended for learning the Fundamentals of Automobile Engineering, and application of electronics to automotive. This course covers the basics of automotive engines, different types of sensors and actuators, Engine control functions, Fuel delivery systems, different types of transmission control systems, Electromagnetic Interference and Electronic Dashboard Instruments.

Competencies

At the end of the course the students should be able to

1. Identify the major components of an automotive
2. Explain the components of Electronic Engine Management
3. Explain the working principles of various sensors and actuators.
4. Explain various electronic controls applied to engine related systems.
5. Explain the Automotive Transmission Control Systems.
6. Recognize automotive monitoring and diagnostic systems

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test3/End-semester examination
1	Remember	20	20	20
2	Understand	50	50	50
3	Apply	30	30	30
4	Analyze	-	-	-
5	Evaluate	-	-	-
6	Create	-	-	-

Course level learning objectives:

Remember

1. Name the major components of the engine
2. Write brief notes on automotive electrical and electronic subsystems
3. Describe how the effect of fuel slosh is overcome in fuel quantity measurement
4. Write the effect of imperfect combustion in an engine and how the effect can be reduced.
5. State the advantage of electronic steering control.
6. Discuss in detail the ignition system set up in automobiles.

Understand

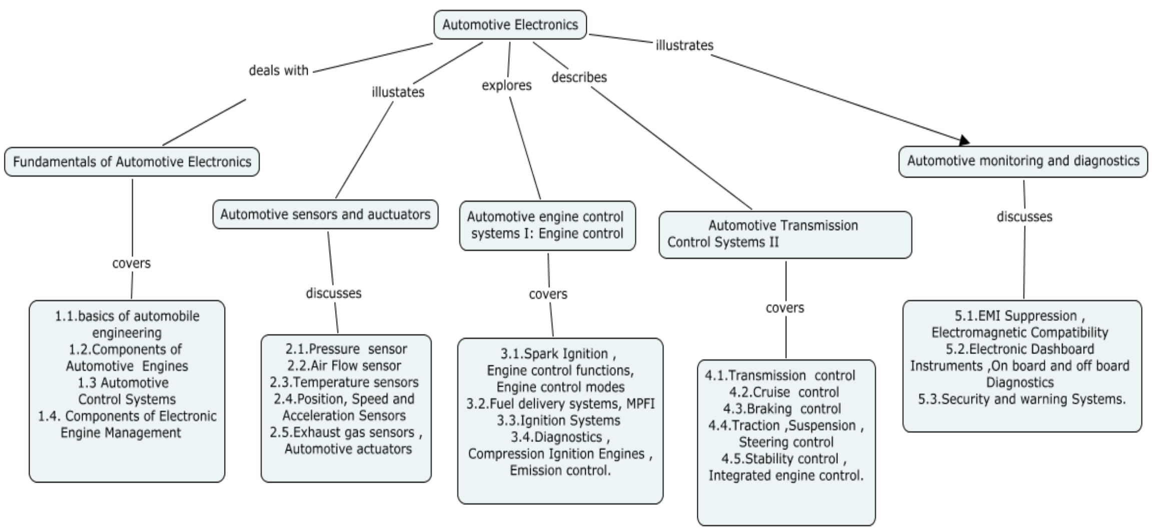
1. Explain the working principle of acceleration sensor.
2. Explain the working principle of temperature sensor.
3. Explain various stepper motor-based cruise control.
4. Describe the working principle of fuel injector with necessary diagrams. Also Validate the fuel injector signal.
5. Discuss in detail the ignition system set up in automobiles.
6. Illustrate the working principle of Exhaust Gas Recirculation actuator.

Apply

1. Apply the Wheatstone bridge to sense the mass air flow rate in an engine.
2. Illustrate the application of magnetic reluctance concept in crankshaft angular Position sensor.
3. Justify the need for power steering in automotive.
4. The input parameters set by the driver in the instrumentation panel are following.

   Starting Time – 5 pm, Total distance of journey – 800 Km, Vehicle speed – 70 Kmph, Fuel flow – 4 liter per hour, Fuel cost per liter – Rs.75. Calculate the following trip information if fuel quantity available is 60 liters after traveling 450 Km from the starting point. i)fuel economy ii) Distance to empty fuel tank iii) Estimated time of arrival iv) average fuel cost spent so far.
6. Determine the change in thermistor resistance if the sensor output voltage is increased from 4V to 8V in a coolant temperature sensor with 12 V supply and 2 ohms fixed resistance.

Concept Map:



Syllabus

Fundamentals of Automotive Electronics: Introduction to Automobile Engineering, Automotive Engines, Automotive Control Systems – Components of Electronic Engine Management – Current trends in Automobiles. **Automotive sensors and actuators:** Introduction – Basic Arrangement – Automotive applications of Pressure, Flow, Temperature sensors – Position, Speed and Acceleration Sensors – Exhaust gas sensors – Engine knock, Engine torque sensors – Automotive actuators. **Automotive engine control systems:** Objectives – Spark Ignition Engines: Engine control functions, Engine control modes, Fuel delivery systems, MPFI, Ignition Systems, Diagnostics – Compression Ignition Engines – Emission control. **Automotive Transmission Control Systems:** Transmission control - Cruise control – Braking control – Traction control –Suspension control – Steering control – Stability control – Integrated engine control. **Automotive monitoring and diagnostics:** Electromagnetic Interference (EMI) Suppression – Electromagnetic Compatibility – Electronic Dashboard Instruments – On board and off board Diagnostics – Security and warning Systems.

Reference Books

1. William B. Ribbens, "**Understanding Automotive Electronics**" – 7th Edition, Butterworth, Heinemann Wobum, 2012(New edition).
2. Tom Weather Jr and Cland C. Hunter, "**Automotive Computers and Control System**" Prentice Hall Inc., New Jersey.
3. Young A.P. and Griffths, L., "**Automobile Electrical Equipment**", English Language Book Society and New Press.
4. Crouse, W.H, "**Automobile Electrical Equipment**" McGraw Hill Book Co Inc., New York, 1955.
5. Robert N Brady, "**Automotive Computers and Digital Instrumentation**", Areston Book Prentice Hall, Eagle Wood Cliffs, New Jersey, 1988.
6. R.K. Jurgen, "**Automotive Electronics Handbook**", McGraw Hill 2nd Edition.

Course Contents and Lecture Schedule

No	**Topics**	**No. of Lectures**
1	**Fundamentals of Automotive Electronics**	
1.1	Introduction to Automobile Engineering,	1
1.2	Components of Automotive Engines	3
1.3	Automotive Control Systems	1
1.4	Components of Electronic Engine Management – Current trends in Automobiles.	3
2	**Automotive sensors and actuators**	
2.1	Pressure sensor,	1

2.2	Air Flow sensor	1
2.3	Temperature sensors	1
2.4	Position, Speed and Acceleration Sensors	3
2.5	Exhaust gas sensors, Automotive actuators	3
3	**Automotive engine control systems I: Engine control**	
3.1	Spark Ignition, Engine control functions, Engine control modes	2
3.2	Fuel delivery systems, MPFI	2
3.3	Ignition Systems	2
3.4	Diagnostics – Compression Ignition Engines – Emission control.	2
4	**Automotive Transmission Control Systems II**	
4.1	Transmission control	1
4.2	Cruise control	2
4.3	Braking control	2
4.4	Traction control – Suspension control – Steering control	2
4.5	Stability control – Integrated engine control.	2
5	**Automotive monitoring and diagnostics**	
5.1	Electromagnetic Interference (EMI) Suppression – Electromagnetic Compatibility.	2
5.2	Electronic Dashboard Instruments – On board and off board Diagnostics.	2
5.3	Security and warning Systems.	2
	Total	40

Course Designers:

1. Mr.R.Medeswaran-medes@tce.edu

Sub Code	Lectures	Tutorial	Practical	Credit
14MC170	-	-	3	1

14MC170 Automation Lab 0:1

Objective:

To make the students learn the basic concepts of hydraulics and pneumatics and its applications in the area of manufacturing process.

List of Experiments:

1. Simulation of Hydraulic / Pneumatic circuits using Automation Studio.
2. Simulation of Hydraulic / Pneumatic circuits using Fluid sim/Hydro sim.
3. Design and implementation of Cascading circuit A+B+B-A- using Pneumatic Components.
4. Design and implementation of Sequential circuit A+B+A-B- using Pneumatic Components.
5. Design and implementation of Sequential circuit A+B+A-B- using electro Pneumatic Components and PLC.
6. PLC-based Experiment-Car Park Barrier.
7. Level control system using PLC.
8. Edge detection using Machine vision.
9. DC servo motor Control System.
10. Strain gauge data acquisition system using Lab VIEW.
11. Pick and place / path tracking using Robot.
12. PC based Temperature Measurement and Data logging.
13. LVDT based displacement measurement using LabVIEW.

		Category	L	T	P	Credit
14MC210	**REAL TIME EMBEDDED SYSTEM**	PC	3	0	0	3

Preamble

Necessity is the mother of invention and embedded systems are inventions that were fuelled by the idea of making pre-programs to perform a dedicated narrow range of functions as part of large systems. Embedded systems and real time operating systems are fast achieving ubiquity, blurring the lines between science fiction and hard reality. Real-time operating systems are created for a special application. Very often industrial or automotive applications, implemented as embedded systems, must provide timely responses in order to perform the required operation. Further, in general, real time requirements typically refer to applications that are expected to react to the events of some kind of controlled process. This course deals real time embedded system concepts, terminologies. Last but not least this course also deals some important case studies regarding real time embedded system.

Prerequisite

Digital Systems

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Define various types of systems, definitions and operating hardware’s	Remember
CO2	Explain the concept of design and development of embedded system	Understand
CO3	Explain about real time systems	Understand
CO4	Explain the realization of real time systems in hardware	Understand
CO5	Select suitable real time software’s and design procedure to solve engineering issues in industries.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	L	M	L	M	L	L		M		L		M
CO2.	L	L	L	L	S	L		L		L		L
CO3	L	L	L	L	S	L		L		L		L
CO4	S	M	S	L	M	M		M		M		M
CO5	L	L	L	S	L	M		S		S		S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	20	20	20
Understand	70	50	40	50
Apply	-	30	40	30
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define "Embedded system".
2. Differentiate embedded hardware units and devices in a system.
3. Define real time systems.

Course Outcome 2 (CO2)

1. Explain the design process in embedded system.
2. With neat sketch explain the concept of state machine
3. Explain about system design languages.

Course Outcome 3 (CO3)

1. Discuss any one timing techniques on PC compatibles.
2. Briefly explain the concept of Multi threading.
3. Explain about different levels of data integrity.

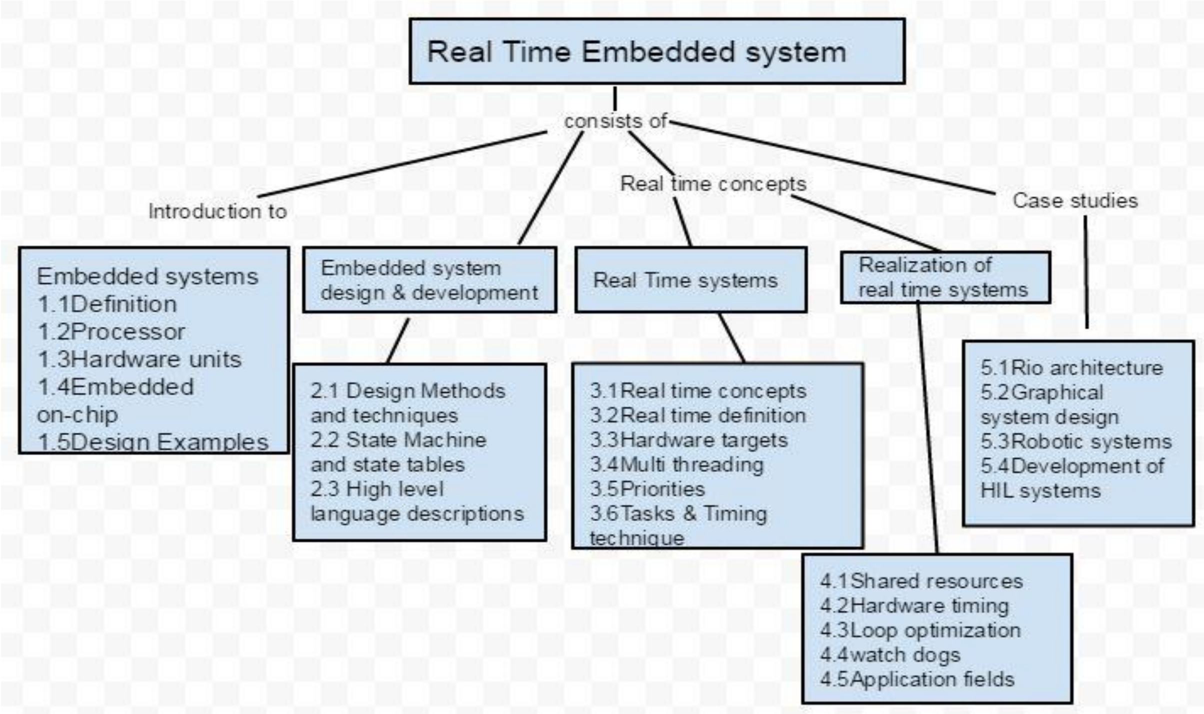
Course Outcome 4 (CO4)

4. Explain how loop optimization can be done.
5. Explain Hardware timing in real time systems.
6. Explain about watch dogs.

Course Outcome 5 (CO5)

1. Select suitable real time system to solve problems in aero space industries.
2. Select suitable real time technique to identify damaged bolts in industries.
3. With neat sketch discuss the RIO architecture-based applications in industries.

Concept Map



Syllabus

Introduction to Embedded systems: Definition- Processor embedded into a system- Embedded hardware units and devices-Embedded software in a system- Examples of embedded systems- Embedded System-ON-Chip (Soc) and use of VLSI circuit design technology- Design process in embedded system- Formalization of embedded system- Design Process and Design Examples-Classification of embedded systems.

Embedded System Design and Development: Design Methods and techniques – Models and languages – State Machine and state tables in embedded design – High level language descriptions of S/W for embedded system, Java based embedded system design.

Real Time Systems: Real time concepts-Real time definition-Hardware Targets-Communication- Multi threading- Priorities-Tasks- Timing techniques on PC compatibles

Realization of Real Time Systems: Shared resources- Hardware timing- Loop optimization- watch dogs- Application fields

Case Studies in Real Time Embedded Systems: Introduction to RIO architecture – Elements of Graphical system design - Specific examples of time-critical and safety-critical embedded systems applications in automotives, aerospace and manufacturing like Development of Machine Vision based conveyor system – Development of Autonomous Embedded Intelligent Robotics systems – Development of HIL system.

Reference Books

1. D.M.Auslander, J.R.Ridgely, J.D.Ringgenberg, "**Control Software for Mechanical Systems Object-Oriented Design in a Real-Time world**", Pearson Education, 2002.
2. Gajski, D.D. Vahid, F., Narayan S., "**Specification and Design of Embedded Systems**", PTR Prentice Hall, 1994.
3. Raj Kamal," Embedded **Systems Architecture, Programming and Design**", 2nd Edition, Tata McGraw-Hill.
4. Herma K., **Real Time Systems – Design for distributed Embedded Applications**, Kluwer Academic, 1997.
5. Philip A. Laplante, "Real **time systems Analysis and Design – An Engineer's Handbook**", IEEE computer society press PHI, 2nd Ed. 1997. (2,3,4)
6. Allan. V. Shaw, "**Real Time systems and software**", John Wiley & Sons (4,5)

Course contents and Lecture Schedule

S. No	Topic	No. of lectures
1.	**Introduction to Embedded systems:**	
1.1	Definition- Processor embedded into a system	1
1.2	Embedded hardware units and devices	1
1.3	Embedded software in a system, Examples of embedded systems	1
1.4	Embedded System-ON-Chip (Soc) and use of VLSI circuit design technology	1
1.5	Design process in embedded system Formalization of embedded system	1
1.6	Design Process and Design examples, Classification of embedded systems.	2
2	**Embedded System Design and Development**	
2.1	Design Methods and techniques	2
2.2	Models and languages	2
2.3	State Machine and state tables in embedded design	2
2.4	High level language descriptions of S/W for embedded system, Java based embedded system design	2
3	**Real time systems**	

3.1	Real time concepts-Real time definition	2
3.2	Hardware targets-Communication	2
3.3	Multi threading- Priorities	2
3.4	Tasks- Timing techniques on PC compatibles	2
4	**Realization of real time systems**	
4.1	Shared resources- Hardware timing	2
4.2	Loop optimization	2
4.3	watch dogs- Application fields	1
5	**Case studies in real time embedded systems**	
5.1	Introduction to RIO architecture	2
5.2	Elements of Graphical system design	2
5.3	Specific examples of time-critical and safety-critical embedded systems applications	2
5.4	Development of Autonomous Embedded Intelligent Robotics systems	2
5.5	Development of HIL system.	2
	Total	38

Course Designers:

1. Dr. M. Saravanan mseee@tce.edu
2. Mr. P. Vairaprakash Vairaprakash@tce.edu

14MC220	MICRO ELECTRO MECHANICAL SYSTEMS	Category	L	T	P	Credit
		PC	4	0	0	4

Preamble

Micro Electro Mechanical System (MEMS) contains components of sizes less than one millimeter. MEMS achieve some engineering functions by electro mechanical or electro chemical means. In general, a sensor, an actuator and a signal transduction unit form the MEMS device. Automobile, Aerospace, Health care are some of the areas where MEMS found applications. Natural science, Mechanical, Electrical, Chemical, Materials and Industrial Engineering are the disciplines involved in design, Manufacture and Packaging of MEMS devices. This course provides a comprehensive treatment with synergetic integration of wide spectrum of discipline in science and engineering to cater the multidisciplinary nature of Mechatronics.

Prerequisite

Engineering Mathematics, Engineering Physics, Engineering Chemistry Materials Science, Thermodynamics, Heat Transfer, Fluid mechanics Engineering Mechanics

Course Outcome

After successful completion of the course the student will be able to

CO 1.	Explain the working principles MEMS and Microsystems	Understand
CO 2.	Solve problems in scaling laws applicable to miniaturization.	Apply
CO 3.	Explain Materials for MEMS and Microsystems	Understand
CO 4.	Describe micro-system fabrication and Micro-manufacturing	Understand
CO 5.	Solve problems related to design of MEMS devices	Apply
CO 6	Explain the packaging aspects of Micro System	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO3.	S	L	M	S	L							
CO4.	S	L	M	S	L							
CO3	S	S	M	S	L							
CO4	S	S	M	S	L							
CO5.	S	L	M	S	L							
C06	S	L	M	S	L							
C07	S	L	M	S	L							
CO8	S	L	M	S	L							

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	50	50	50	50
Apply	30	30	30	30
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Distinguish microelectronics from MEMS.
2. Define the term MEMS.
3. Define shape memory alloys.
4. Write note on the advantages of miniaturization.
5. Explain in detail the application of MEMS in automobile industry.
6. With neat diagram explain the functioning of micro pressure sensor.

Course Outcome 2 (CO2):

1. Record two types of scaling laws used in micro-systems.
2. Write the scaling formula for a simple rectangular block.
3. Explain in detail, the Trimmer matrix to represent force scaling with related acceleration, time and power density required for scaling of systems in motion.
4. Give a report on scaling in heat conduction and heat convection.
5. Estimate the associated changes in the acceleration, time and power supply to actuate a MEMS component if its weight is reduced by a factor 20.
6. Estimate the variation of the total heat flow and the time required to transmit heat in a solid with a reduction of size by factor of 10. What will happen if the solid is of sub micrometer level.

Course Outcome 3 (CO3):

1. State the reason for which materials like silicon, Gallium Arsenide, germanium, quartz is preferred for sensors and actuators.
2. Draw the diagrams of three designated planes of silicon, showing number of atoms present.
3. Define smart materials.
4. With neat diagram explain the Czkchralski method for growing single crystal silicon.
5. Explain in detail the role silicon and its compounds in MEMS.
6. Write detail notes on polymer materials used MEMS and microsystems.

Course Outcome 4 (CO4)

1. Distinguish between wet and dry etching.
2. Outline the general principle of diffusion process.
3. Name three mask materials used in etching.
4. Explain the general procedure of photolithography. Use neat diagrams.
5. Explain surface lithography with neat diagram.
6. Using neat diagrams explain LIGA process.

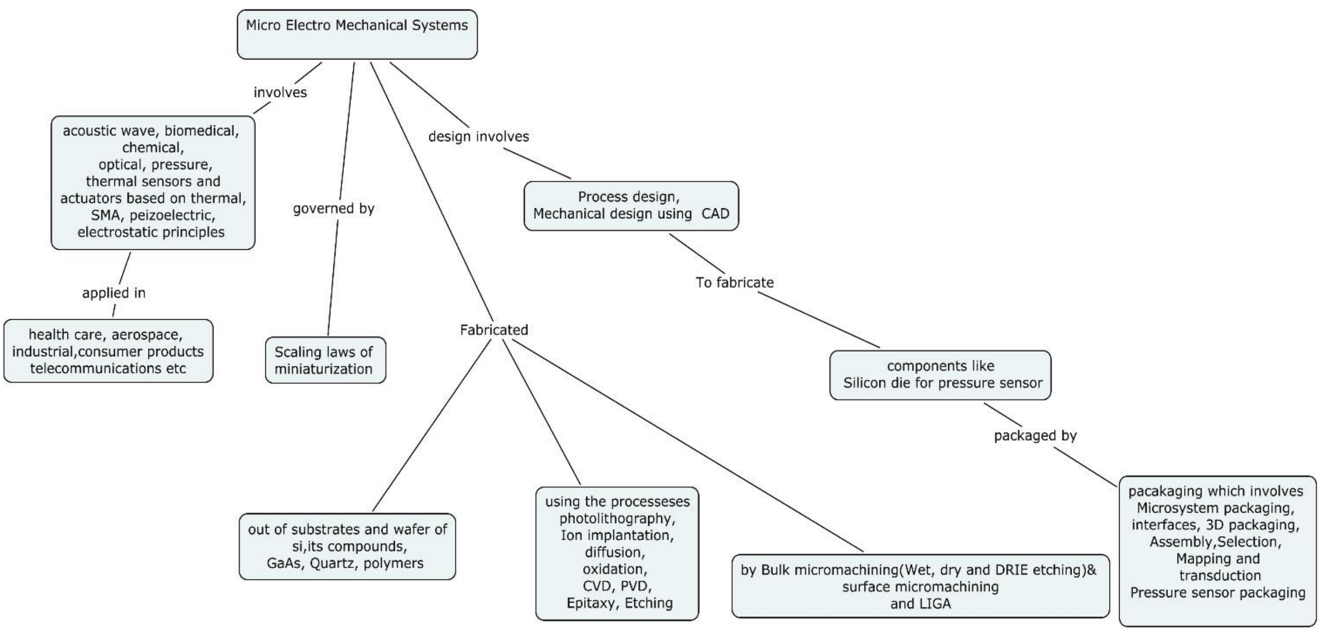
Course Outcome 5 (CO5)

1. Outline the major difference between mechanical engineering design and MEMS design.
2. Tell the importance of signal mapping in MEMS transduction system.
3. List the important three databases need to present in CAD package for MEMS.
4. With the help of a flow chart, provide overview of the necessary ingredients involved in microsystem design.
5. Demonstrate the mechanical design of a silicon die for a micro-pressure sensor.

Course Outcome 6 (CO6)

1. Mention the objectives of packaging of MEMS device
2. State the advantages of anodic bonding.
3. With suitable sketches, bring out the differences between microelectronics and MEMS packaging.
4. Explain various aspects of Signal mapping and transduction.
5. Illustrate the steps involved in packaging of pressure sensor.

Concept Map



Syllabus

Overview of MEMS and Micro Systems: MEMS and Microsystems, products, Evolution of micro-fabrication, Micro system and Microelectronics, The multidisciplinary nature of MEMS, Miniaturization, applications of micro systems in automotive, health care, aerospace, and telecommunication fields.
Working Principles of Microsystems: Introduction, micro sensors: Acoustic waves, optical, chemical, pressure, thermal, biomedical and bio sensors. Microactuation: using thermal forces, shape memory alloys, piezoelectric crystals and electrostatics forces. MEMS with micro actuators: microgrippers, micromotors, microvalves, micropumps, micro accelerometer.
Materials for MEMS and Microsystems: Introduction, substrate and wafers, active substrate materials, silicon, silicon compounds, silicon piezo resistors, polymers and packaging materials.
Microsystem fabrication process: Introduction, Photolithography, ion implantation, diffusion, oxidation, chemical vapour deposition, physical vapour deposition(sputtering), Deposition by epitaxy, wet and plasma etching.
Overview of Micromanufacturing: introduction, bulk micromachining, surface micromachining, the LIGA process.
Scaling law in miniaturization: Introduction to scaling, scaling in rigid body dynamics, electrostatic forces, electromagnetic forces, electricity, fluid mechanics and heat transfer.
Microsystems design: Introduction, Design considerations, Process design, Mechanical design, Design of silicon die for micro pressure sensor, introduction to CAD for MEMS.
Microsystem packaging: Need of packaging, Comparison of Micro electronics and MEMS packaging, Design case: pressure sensor packaging

Text Book

1. Tai –Ran Hsu, “**MEMS and Microsystem: Design and Manufacture**”, Tata McGraw Hill, First Edition, 2002.

Reference Books

1. G.K. Ananthasuresh, K.J.Vinoy, S.Gopalakrishnan, K.N. Bhat and V.K. Athrae “**Micro and Smart System**”, Wiley India Pvt Ltd, First edition, 2010
2. Chang Liu , “**Foundation of MEMS**” 2nd Edition, Pearson education, 2012.
3. Marc J Madou: “**Fundamentals of microfabrication and nanotechnology**”, Three volume set 3rd revised Edition, Taylor and Francis, 2011
4. Gad El Hak(Editor), “**The MEMS Hand Book**”, Three volume set, 2nd revised Edition. CRC press, 2005.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	Overview of MEMS and Micro Systems:	
1.1	MEMS and Microsystems, products, Evolution of micro-fabrication, Micro system and Microelectronics	2
1.2	The multidisciplinary nature of MEMS, Miniaturization,	2
1.3	applications of micro systems in automotive, health care, aerospace, and telecommunication fields	2
1.4	Working Principles of Microsystems:	
1.5	Introduction, micro sensors: Acoustic waves, optical, chemical, pressure, thermal, biomedical and bio sensors.	3
1.6	Micro actuation: using thermal forces, shape memory alloys, piezoelectric crystals and electrostatics forces.	2
1.7	MEMS with micro actuators: microgrippers, micromotors, microvalves, micropumps, micro accelerometer, microfluidics	2
2	Scaling law in miniaturization:	
2.1	Introduction to scaling, scaling in rigid body dynamics, electrostatic forces,	1
2.2	electromagnetic forces, electricity, fluid mechanics and heat transfer	2
3	Materials for MEMS and Microsystems:	
3.1	Introduction, substrate and wafers, active substrate materials	1
3.2	silicon as substrate material, silicon compounds, silicon piezo resistors	1
3.3	Gallium Arsenide, Quartz, polymers and packaging materials.	1
4	Microsystem fabrication process:	
4.1	Introduction, Photolithography	1
4.2	ion implantation, diffusion	1
4.3	oxidation	1
4.4	chemical vapour deposition	2
4.5	physical vapour deposition(sputtering), Deposition by epitaxy,	1
4.6	wet and plasma etching	2
	Overview of Micromanufacturing:	
4.7	introduction, bulk micromachining,	1
4.8	surface micromachining, The LIGA process	2

Module No.	Topic	No. of Lectures
5	Microsystems design:	
5.1	Introduction, Design considerations	2
5.2	Process design,	2
5.3	Mechanical design	2
5.4	Design of silicon die for micro pressure sensor	2
5.5	Introduction to CAD for MEMS	3
6	Microsystem packaging:	
6.1	Introduction, mechanical packaging of microelectronics, microsystem packaging, interfaces, packaging technologies	2
6.2	3D packaging, assembly of microsystems, selection of packaging materials,	2
6.3	signal mapping and transduction	1
6.4	Design case: pressure sensor packaging	2
	Total	48

Course Designers:

1. **Dr. G.Kumaraguruparan gkgmech@tce.edu**

14MC270	MICROCONTROLLER LAB	Category	L	T	P	Credit
		PC	0	0	1	1

Preamble

To introduce about basics of microcontroller programming and their applications. Students will be equipped with the basic knowledge of microprocessor, microcontroller interfacing and their applications

Prerequisite

Nil

Syllabus

1. Single precision and double precision operations
2. Sorting of array of numbers with 1, 2 precisions
3. LED display/ LCD display/7 segment display interface
4. Realization of Timer and counter
5. Interrupt handling- Single and multiple interrupts
6. ADC and DAC characteristics measurement
7. Establishing serial communication.
8. Stepper motor control (Single motor and two motor).
9. Measurement with load cell.
10. Temperature measurement with thermocouple and thermistor.
11. Temperature control.
12. Light control.

Course Designers:

1. Dr. K. Hariharan dept of ECE khh@tce.edu

14MCPA0	**MICROCONTROLLER AND PLC**	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

This course attempts to make the students familiar with the architecture and instruction set of 8-bit micro controllers. Intel 8051 microcontroller is considered for more detailed treatment of 8-bit architecture and assembly language programming as they serve as any application development in microcontrollers used in tiny embedded system. PLC is a different variant systems design hardware which is currently popular in the electronic automation area. PLC Programming with Ladder language is covered in detailed manner. The outcome of this course is to help students acquire knowledge in the industrial automation system design using microcontroller and PLC

Prerequisite

Course Name: Digital Electronics, Microprocessor.

Course Outcomes

On the successful completion of the course, students will be able to

CO1- Define microcontroller and its components	Remember
CO2- Exemplify the instruction sets and addressing modes in microcontroller	Understand
CO3- Develop assembly program for peripherals (Time, Counter, serial)	Apply
CO4- List components along with its functions in PLC	Remember
CO5- Exemplify the functionality of PLC	Understand
CO6- Develop PLC program for an automobile application	Apply
CO7- Identify the sensors for a given problem with microcontroller and PLC	Apply
CO8- Develop a system with pseudocode and flowchart for PLC /Microcontroller	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO5.	L	L	L	S	S						L
CO6.	L	L	L	S	S						L
CO7.	M	M	L	S	S		M	M	M		M
CO8.	M	M	M	S	S	S	S	S	S		S
CO9.	S	S	S	S	S	S	S	S	S		S
CO10.	S	S	S	S	S	S	S	S	S		S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	20	0	20
Understand	30	40	50	30
Apply	40	40	50	50
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define microcontroller.
2. State the clock frequency for 8051.
3. Define 8951 controller.

Course Outcome 2 (CO2):

1. Give the difference between MOVC and MOVS instructions
2. List the instructions related to external data memory
3. Exemplify the instruction used in code memory

Course Outcome 3 (CO3):

1. Develop ASM program for 8051 to access timer peripheral
2. Explain about establishing serial communication in microcontroller.
3. Develop ASM program to invoke interrupt routing

Course Outcome 4 (CO4):

1. Define PLC.
2. Explain about bouncing of a switch.
3. Explain about de bouncing of a switch.

Course Outcome 5

1. List the sensors and its physical parameters it senses.
2. Explain about interfacing thermocouple with PLC.
3. Explain about interfacing Light sensor with PLC.

Course Outcome 6 (CO6):

1. Develop ladder program for a PLC to access timer.
2. State the way of Setting up timer ON and OFF in PLC.
3. Develop ladder program for PLC to interface analog sensor.

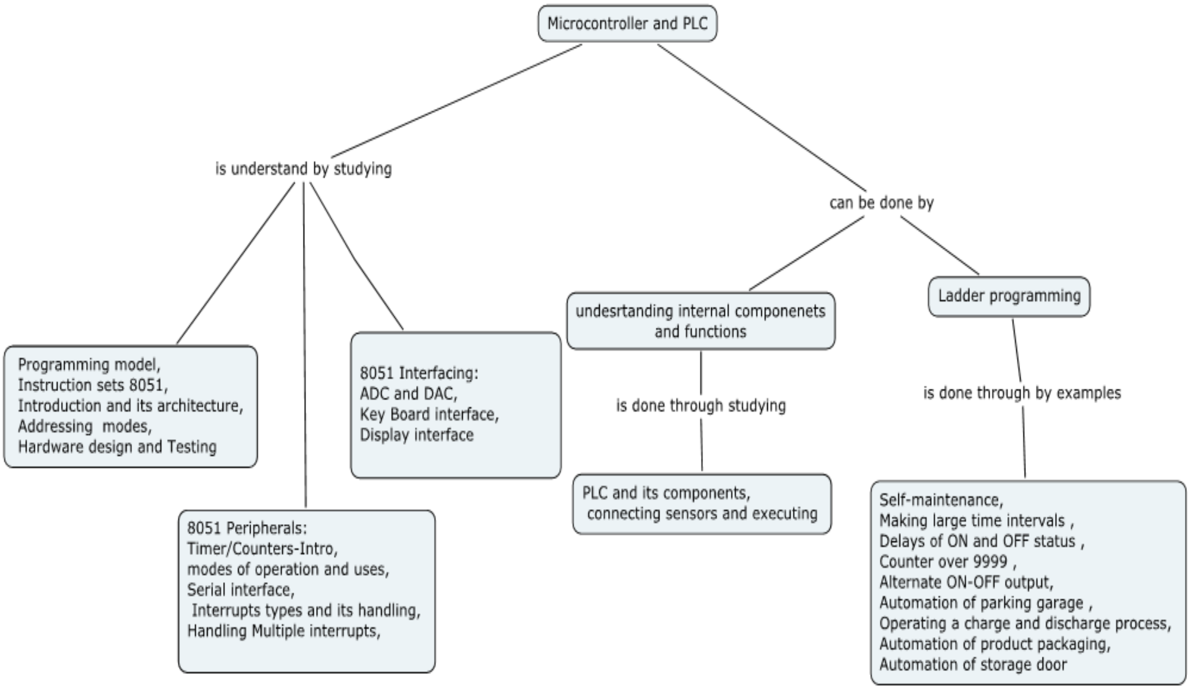
Course Outcome 7

1. State the advantages of using PLC over PC.
2. State various applications of PLC.
3. Develop a PLC ladder coder for counting external event using timer in PLC.

Course Outcome 8

1. Develop a ladder program for PLC for automation of parking garage.
2. Develop a ladder program for PLC for automation of product packaging,

Concept Map



Syllabus

Intel 8-bit Microcontroller: Programming model, Instruction sets 8051, Introduction and its architecture, Addressing modes,8051 Hardware design and Testing. **8051 Peripherals:** Timer/Counters-Intro, modes of operation and uses, Serial interface, Interrupts types and its handling, Handling Multiple interrupts, **8051 Interfacing**: ADC and DAC, Key Board interface-Lead per key and Matrix KB, Display interface- LED and LCD. Introduction to single board computer-Rasperypi. **Programmable Logic controller:** PLC and its components, connecting sensors and executing devices. **PLC Programming:** Ladder diagram, PLC programs for Self-maintenance, making large time intervals, Delays of ON and OFF status, Counter over 9999, Alternate ON-OFF output, Automation of parking garage, Operating a charge and discharge process, Automation of product packaging, Automation of storage door

Reference Books/Learning Resources

1. kennath ayala, **“8051 Microcontroller”**, Cengage Learning, 2010
2. Nebojsa Matic, **“Introduction to PLC controllers”**, Mikro-e Edition, Online Free

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Intel 8-bit Microcontroller**	
1.1	Programming model of 8051/8951	2
1.2	Instruction sets in 8051	2
1.3	Architecture	2
1.4	Addressing modes	2
1.5	8051 Hardware design and Testing	2
2	**8051 Peripherals:**	
2.1	Timer/Counters	2
2.2	modes of operation	2
2.3	Serial interface	2
2.4	Interrupts types and its handling	2
	Handling Multiple interrupts	2
3	**8051 Interfacing**:	
3.1	ADC and DAC	2
3.2	Key Board interface- Lead per key and Matrix KB	2
3.3	Display interface- LED and LCD	2
3.4	Single board computer-Rasperypi	1
4	**Programmable Logic controller:**	
4.1	PLC and its components	3
4.2	connecting sensors and executing	3
5	**PLC Programming**	
5.1	Ladder diagram	3
5.2	PLC programs -	2
5.2.1	Self-maintenance	1
5.2.2	Making large time intervals	1
5.2.3	Delays of ON and OFF status	1
5.2.4	Counter over 9999	1
5.2.5	Alternate ON-OFF output	1
5.2.6	Automation of parking garage	1

Module No.	Topic	No. of Lectures
5.2.7	Operating a charge and discharge process	1
5.2.8	Automation of product packaging	2
5.2.9	Automation of storage door	1
	Total	48

Course Designers:

1. Dr. K. Hariharan khh@tce.edu

14MCPB0	DATA COMMUNICATION NETWORKS	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

The proliferation of wireless devices in Mechatronic systems such as sensor networks, mobile robots and Unmanned Aerial vehicles signify the need for a clear understanding on working of wireless networks and architectures. Data transfer in a wireless network involves study on the data format and the network structure. This course aims at providing an insight into these aforesaid elements. Furthermore, this course covers the basics of Computer Networks and wireless network standards like GSM and IEEE 802.11 architecture in detail. The working of wireless sensor and ad hoc networks is required to choose the right architecture for a specific Mechatronic system. This course covers the architecture, topologies, and applications of Ad hoc and Sensor networks.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Define the terminologies, protocols and concepts in networks	Remember
CO2	Explain the network types and architectures	Understand
CO3	Describe the cellular network operations	Understand
CO4	Illustrate the operation of Ad hoc and Sensor Networks	Understand
CO5	Select a suitable solution for interconnecting systems	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	L	L	L	S						L	S
CO2	S	S	S	S	S						M	S
CO3	S	L	L	L	M						L	S
CO4	S	M	S	M	S						L	S
CO5	S	S	S	S	S						M	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	40	40	40	40
Understand	60	40	40	40
Apply	-	20	20	20
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the five important components of Data communication.
2. Define Network architecture.
3. Mention the role of GSN in the GPRS architecture.
4. Underline the impact of hidden and exposed terminals on throughput of Ad hoc networks.
5. Distinguish between Ad hoc Networks and Sensor Networks.

Course Outcome 2 (CO2):

1. Describe the modulation and spread spectrum techniques for wireless transmission.
2. Explain the Protocol Architecture of IEEE 802.11.
3. Outline the services and features of TCP.
4. Describe the process of file transfer in FTP.

Course Outcome 3 (CO3)

1. Categorize GSM components explaining their functionality.
2. Infer on how and when handover is performed in GSM.
3. Explain the sub systems and control channels in GSM.
4. Summarize the problems in traditional transport layer solutions when used in a Mobile environment.

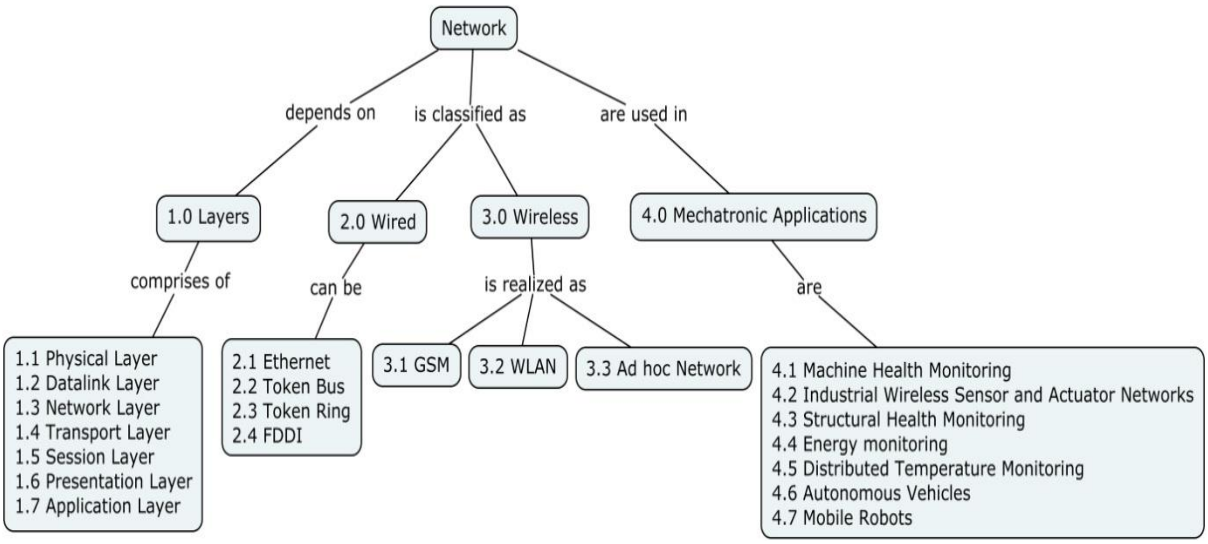
Course Outcome 4 (CO4)

1. Describe the ways by which data is disseminated in Sensor Networks.
2. Outline the challenges and design issues in Routing for Wireless Sensor Networks.
3. Comprehend the major issues that affect the design, development and performance of an Ad hoc Network.
4. Explain the working, significant features and limitations of Ad hoc On-demand Distance Vector routing protocol.
5. Review the Sender-Initiated Contention based MAC protocols in Ad hoc networks.

Course Outcome 5 (CO5)

1. An organization is granted the address 211.17.180.01 /24, The administrator wants to create 32 subnets.
   a. Calculate the subnet mask.
   b. Calculate the number of addresses in each subnet.
   c. Calculate the first and last address in subnet 1.
   d. Calculate the first and last address in subnet 32.
2. In an IPV4 packet, if the value of HLEN is 1000 in binary, how many bytes of options are being carried away by this packet? An IPV4 packet has arrived with a few hexadecimal digits as follows 0x 45000028000100000102. Compute the number of hops the packet can travel before being dropped.

Concept Map



Syllabus

Networks: Networks types - Network Models – Layers: Physical, Datalink, Network, Transport, Session, Presentation, Application - **Wired Network**: Ethernet, Token Bus, Token Ring, Fiber Distributed Data Interface (FDDI) - CAN - **Wireless Network** - Global System for Mobile Communications (GSM): GSM Entities, Call Routing in GSM, General Packet Radio Service (GPRS) – Third Generation Networks - Radio Frequency Identification – Zigbee - Wireless LANs: IEEE 802.11 WLAN, Architecture and Services, Physical Layer, Medium Access Control (MAC) - Ad hoc Networks: Mobile Ad hoc Network (MANET) - Table-driven routing protocols, On Demand routing protocols - Wireless Sensor Networks: Classification, MAC and Routing protocols, Energy Efficient Routing, Geographic Routing – **Applications**: Machine Health Monitoring, Industrial Wireless Sensor and Actuator Networks, Structural Health Monitoring, Energy monitoring, Distributed Temperature Monitoring , Autonomous Vehicles, Mobile Robots

Reference Books

1. **“Data Communications and Networking”**, 5th Edition, Behrouz Forouzan, Mc Graw Hill, 2013
2. William Stallings, "**Wireless Communications and Networks**" Pearson / Prentice Hall of India, 2nd Ed., 2009
3. C.Siva Ram Murthy and B.S.Manoj, “**Ad hoc Wireless Networks Architectures and protocols”**, 2nd edition, Pearson Education, 2007
4. **“Mobile Computing - Technology, Applications and Service Creation”,** Asoke K. Talukdar, Tata McGraw-Hill Education, 2ed, 2010
5. **“Wireless Networking”**, Anurag Kumar, D. Manjunath, Joy Kuri, Morgan Kaufmann Publishers (Elsevier), 2008

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Networks**	
1.0	Networks types	1
1.1	Layers	1
1.1.1	Physical Layer	1
1.1.2	Datalink Layer	1
1.1.3	Network Layer	1
1.1.4	Transport Layer	1
1.1.5	Session Layer	1

Module No.	Topic	No. of Lectures
1.1.6	Presentation Layer	1
1.1.7	Application Layer	1
2	**Wired Network**	
2.1	Ethernet	1
2.2	Token Bus	1
2.3	Token Ring	1
2.4	Fiber Distributed Data Interface (FDDI), CAN	3
3	**Wireless Network**	
3.1	Global System for Mobile Communications (GSM)	1
3.1.1	GSM Entities	1
3.1.2	Call Routing in GSM	1
3.1.3	General Packet Radio Service (GPRS)	1
3.1.4	Third Generation Networks	1
3.1.5	Introduction to Radio Frequency Identification, Zigbee	3
3.2	Wireless LANs	2
3.2.1	IEEE 802.11 WLAN	1
3.2.2	Architecture and Services	1
3.2.3	Physical Layer	1
3.2.4	Medium Access Control (MAC)	1
3.3	Ad hoc Network	1
3.3.1	Mobile Ad hoc Network (MANET)	1
3.3.1.1	Table-driven routing protocols	1
3.3.1.2	On Demand routing protocols	1
3.3.2	Wireless Sensor networks	2
3.3.2.1	Classification	1
3.3.2.2	MAC and Routing protocols	1
3.3.2.3	Energy Efficient Routing	1
3.3.2.4	Geographic Routing	1
4.0	**Applications**	
4.1	Machine Health Monitoring	1
4.2	Industrial Wireless Sensor and Actuator Networks	1
4.3	Structural Health Monitoring	1
4.4	Energy monitoring	1

Module No.	Topic	No. of Lectures
4.5	Distributed Temperature Monitoring	1
4.6	Autonomous Vehicles	2
4.7	Mobile Robots	2
	Total	48

Course Designer:

Dr. G. S. R. Emil Selvan emil@tce.edu

14MCPC0	MACHINE VISION AND APPLICATIONS	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

Machine Vision (MV) is industry application-oriented subset of computer vision. It is the study of methods and techniques whereby artificial vision systems can be constructed and usefully employed in manufacturing applications. Machine vision integrates image capture systems with digital input/output devices and computer networks to provide real time quality control and for general control of manufacturing equipment such as automated assembly systems and robotic manipulator. Manufacturers accept machine vision systems due to its high-speed, high-magnification, 24-hour operation, and/or repeatability of measurements for visual inspection applications.

Machine Vision (MV) systems can be applied in almost any industry. Historically the first systems were deployed in the semi-conductor and automotive industries due to their highly intensive use of industrial automation within these industries. Modern vision systems can be applied across a hugely diverse range of industry sectors, these industries include: Automotive, Semi-conductor, Electronics, Medical Devices and Pharmaceutical, Printing and Packaging, Food Processing, Solar Production and Process Engineering

Prerequisite

Course Outcomes

On the successful completion of the course, students will be able to

CO1:	Explain the components of a machine vision system and their functions	Understand
CO2:	Select the appropriate sensor and illumination techniques of machine vision system for the given manufacturing application	Apply
CO3:	Select suitable image processing technique for the specified manufacturing requirement	Apply
CO4:	Select suitable components of machine vision system for the given manufacturing applications such as part identification, counting, measurement and gauging	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	L	-	L	-	-	-	-	L	L	-	-
CO2	S	L	M	L	L	M	-	M	M	-	L
CO3	S	L	M	L	L	M	-	M	M	-	L
CO4	S	L	M	L	L	M	-	M	M	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	10	-	10
Understand	40	30	40	30
Apply	40	60	60	60
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

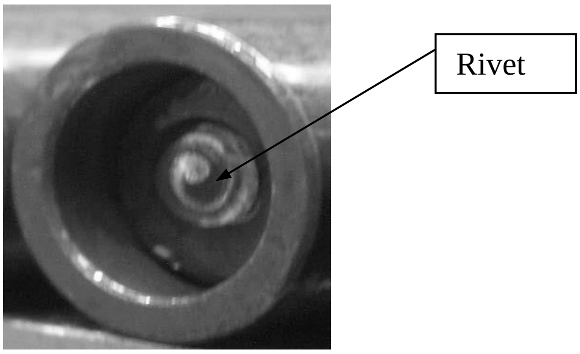
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. With suitable block diagram, explain the components of a machine vision system.
2. Explain about working of CCD camera with neat diagram.
3. Explain the operation of image acquisition system and its functions.
4. Explain the flow of information between the components of a machine vision system.

Course Outcome 2 (CO2):

1. Suggest suitable sensor and illumination techniques required for a palletizing operation in a manufacturing cell where the robot must pick up the parts from an incoming chute and deposit them onto pallet. The pallet has four rows that are 50 mm apart and six columns that are 40 mm apart. The plane of the pallet is assumed to be parallel to XY plane. The rows of the pallet are parallel to the X-axis and the columns of the pallet are parallel to the Y-axis. The objects are to be picked up are about 25 mm tall. Suggest suitable actions to be taken and show the step by step procedure for the implementation of robotized palletizing operation. Make judicious assumptions if required and justify them.
2. In the production of floating bearings, the bearing and the shafts are riveted. Due to material and processing influences, the diameter of the rivet needs to be inspected. Every rivet has to be checked as shown in figure.



The diameters of two similar rivets have to be inspected; the task can be categorized into a measurement application. The nominal size of the rivets lies in a range of 3 mm to 4 mm; it is placed in front of a disk. The surface color of the disk might change due to material changes. The rivet material does not change. The bearings can be covered with an oil film. The 100% inspection of every part has to be performed inline. The nominal size of the rivet is 3.5 mm, and the required accuracy is 0.1 mm. The inspection used to be performed manually. The diameter of the rivet needs to be measured with an accuracy of 0.1 mm. The processing result has to be presented immediately. The maximum processing time is 2 s; the cycle time is 2.5s. A direct insight into the rivet is possible. The maximum space for installing equipment is 500 mm. The distance between the cameras and the computer is 5 m. A certain protection class is not necessary. Propose suitable image acquisition technique for this application.

Course Outcome 3 (CO3):

1. Discuss the effect of sampling rate and the quantization on the images of size: 432x576, 108x144, 54x72 and 27x36.
2. With suitable example, explain the use of binary morphology operations in a vision-based sorting application.
3. Describe the steps involved in recognising the objects (spanners with different orientations) from a captured image by an acquisition system as shown in figure.1. Also, suggest the method of measuring dimensions of the object.

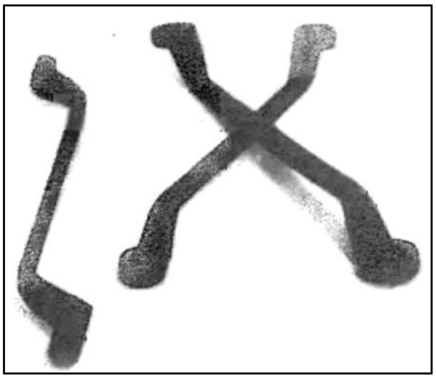


Figure. 1

Course Outcome 4 (CO4):

1. Design a machine vision system to measure the dimensions of the threaded part moving in a slow speed conveyor as shown in figure 2.

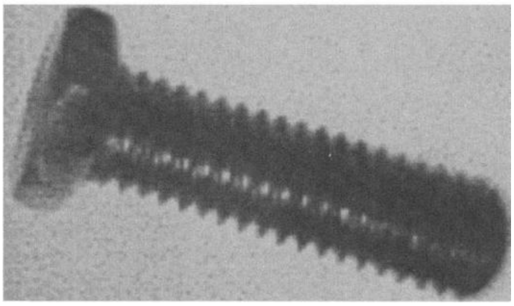


Figure 2

2. Suggest a suitable machine vision system to segregate the components shown in figure 3. Make judicious assumptions if required and justify them.

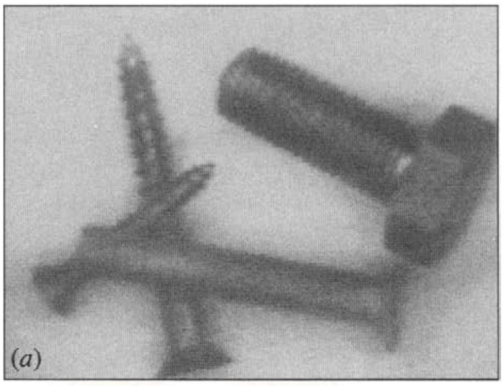
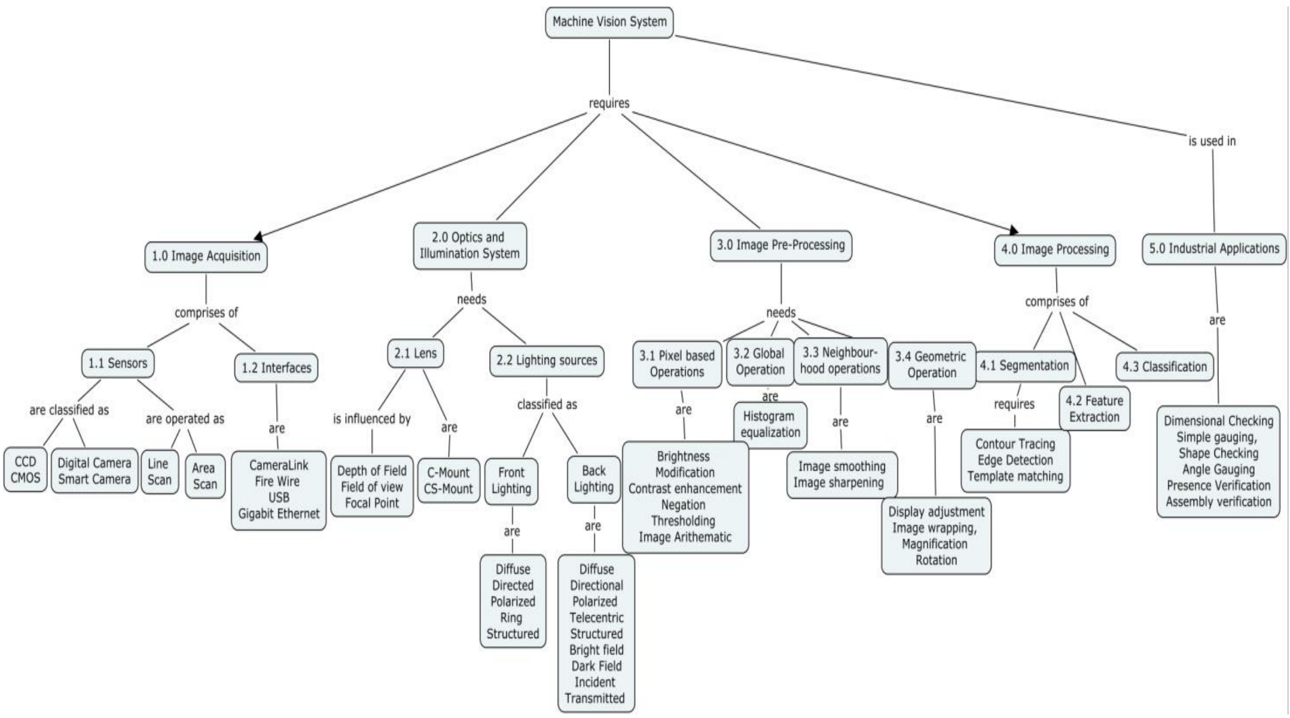


Figure 3

Concept Map



Syllabus

Image Acquisition: Solid State Sensors – Operation of Charge Coupled Device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) Sensors – Colour Sensors – Properties of Sensors. Digital cameras – control of image capture – Characteristic values – industrial operating conditions. Control of Line Scan and Area scan cameras. Image Data Transfer – Digital Camera Interfaces – Camera Link, Fire Wire, USB and Gigabit Ethernet.

Optics and Illumination: Optical foundations: Depth of field, Field of view and focal point - F number, Thin Lens, Imaging Equation, Depth of Field, Typical Imaging Situations, Aberrations, Lens Selection – Mounts, Telecentric lens, Fisheye lenses and endoscopes. Light Sources, Types of Light Filters, Types of Lighting: Front lighting – Diffuse, Directed, Polarized, Ring and Structured; Back lighting – Diffuse, Directional, polarized Telecentric, Structured, Bright field, Dark Field, Incident and Transmitted Lighting.

Image Pre-processing: Gray Scale Transformations: Point operation – brightness modification, Contrast enhancement, negation and thresholding Image Arithmetic: Image Addition, Subtraction and Averaging, Minimum and Maximum of two images. Global operation – Histogram equalization. Neighborhood operation – Image smoothing and image sharpening - Types of Filters: Linear Filters, Median Filter, Morphological and Non-Linear Filters. Geometric operation – Display adjustment, image wrapping, magnification and rotation.

Image Processing: Segmentation: Regions of Interests (ROIs) - Threshold Determination from Histogram, Contour Tracing: Pixel correctness, Generating Object Contours, Contour representation, Edge based Methods: Edge probing and Edge Detection, Template matching: Operation. **Feature Extraction**: Geometric features – Enclosing rectangle, area, perimeter and centroid. **Classification:** Nearest Neighbor classifier.

Applications: Dimensional Checking: Simple gauging, Shape Checking, Angle Gauging, High accuracy Gauging, Calibration. Presence Verification: Simple Presence verification, Simple Gauging for assembly verification such as Pin type Verification. Decision making and actuation on visual signals - Case Studies – Currency verification – Pharmaceutical industry.

Reference Books/Learning Resources

1. Christian Demant, Bernd Streicher-Abel, Carsten Garnica "**Industrial Image Processing - Visual Quality Control in Manufacturing**", Second Edition, Springer, 2013.
2. R.C.Gonzalez, Richard E.Woods, "**Digital Image Processing**" Second Edition, Prentice Hall India, 2005.
3. K.S.Fu,R.C.Gonzalez,C.S.G.Lee "**Robotics Control, Sensing, Vision and Intelligence**" Tata McgrawHill, 2008
4. Alexander Hornberg, "**Handbook of Machine Vision**", Wiley VCH, 2006
5. Gerald C. Holst, "**CCD Arrays Cameras and Displays**" Second Edition, SPIE Optical Engineering Press, 1998.
6. Elias N. Malamas, Euripides G.M. Petrakis, Michalis Zervakis, Laurent Petit, Jean-Didier Legat, "**A survey on industrial vision systems, applications and tools**", Image and Vision Computing 21 (2003) 171–188.
7. H. Golnabi, A. Asadpour, "**Design and application of industrial machine vision systems**", Robotics and Computer-Integrated Manufacturing 23 (2007) 630–637.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Image Acquisition**	
1.1	Solid State Sensors – Introduction	1
1.1.1	Operation of Charge Coupled Device (CCD) sensor	1
1.1.2	Operation of Complementary Metal Oxide Semiconductor (CMOS) Sensors	1
1.1.3	Operation of Colour Sensors - Properties of Sensors	1
1.1.4	Digital cameras – control of image capture – Characteristic values – industrial operating conditions.	2
1.1.5	Smart cameras – control of image capture	1
1.1.6	Control of Line Scan and Area scan cameras	2
1.2	Image Data Transfer – Digital Camera Interfaces - Camera Link, Fire Wire, USB and Gigabit Ethernet.	2
2.	**Optics and Illumination**	
2.1	Optical foundations: Depth of field, Field of view and focal point	1
2.1.1	F number, Thin Lens, Imaging Equation	2
2.1.2	Typical Imaging Situations, Aberrations	1
2.1.3	Lens Selection – Mounts, Telecentric lens, Fisheye lenses and endoscopes	2
2.2	Light Sources, Types of Light Filters	1
2.2.1	Types of Lighting: Front lighting – Diffuse, Directed, Polarized, Ring and Structured	2

Module No.	Topic	No. of Lectures
2.2.2	Back lighting – Diffuse, Directional, polarized Telecentric, Structured, Bright field, Dark Field, Incident and Transmitted Lighting.	2
3.	**Image Pre-processing**	
3.1	Gray Scale Transformations - Point operation – brightness modification, Contrast enhancement, negation and thresholding	2
3.1.1	Image Arithmetic: Image Addition, Subtraction and Averaging, Minimum and Maximum of two images.	1
3.2	Global operation – Histogram equalization	1
3.3	Neighbourhood operation – Image smoothing and image sharpening	2
3.3.1	Types of Filters: Linear Filters, Median Filter, Morphological and Non-Linear Filters.	1
3.4	Geometric operation – Display adjustment, image wrapping, magnification and rotation.	1
4.	**Image Processing**	
4.1	Segmentation: Regions of Interests (ROIs) - Threshold Determination from Histogram	1
4.1.1	Contour Tracing: Pixel Correctness, Generating Object Contours, Contour representation	1
4.1.2	Edge based Methods: Edge probing and Edge Detection	2
4.1.3	Template matching: Operation	1
4.2	Feature Extraction: Geometric features – Enclosing rectangle, area, perimeter and centroid.	2
4.3	Classification: Nearest Neighbour classifier	2
5.	**Applications**	
5.1	Dimensional Checking: Simple gauging, Shape Checking, Angle Gauging	2
5.1.1	High accuracy Gauging, Calibration	1
5.2	Presence Verification: Simple Presence verification, Simple Gauging for assembly verification such as Pin type Verification	2
5.2.1	Decision making and actuation on visual signals	1
5.3	Case Studies – Seminars - Currency verification – Pharmaceutical industry	4
	Total	48

Course Designers:

1. Dr. S. Saravana Perumaal sspmech@tce.edu

		Category	L	T	P	Credit
14MCPD0	**VIRTUAL INSTRUMENTATION**	PC	4	0	0	4

Preamble

A virtual instrumentation system consists of an industry-standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-in boards, and driver software, which together perform the functions of traditional instruments. Virtual instruments represent a fundamental shift from traditional hardware-centered instrumentation systems to software-centered systems that exploit the computing power, productivity, display, and connectivity capabilities of popular desktop computers and workstations.

Advanced Modular Instrument hardware use the latest I/O and data processing technologies, including Analog to Digital Converters (ADC), Digital to Analog Converters, Filed Programmable Gate Arrays (FPGAs), and PC busses to provide high resolution and throughput for measurements from 7 1/2-digit DC to 2.7 GHz. In combination with powerful software, engineers can create custom-defined measurements and sophisticated analysis routines.

Virtual instrumentation has been widely adopted in test and measurement areas and is rapidly making headway in control and design areas.

Prerequisite

Course Code: Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Define the terminologies and concepts used in virtual instrumentation	Remember
CO2	Will write graphical programs effectively.	Apply
CO3	Discuss in detail about ADC, DAC and Plug in boards used in Virtual Instrument	Understand
CO4	Choose appropriate Architecture/Template for realizing a given application	Apply
CO5	Develop virtual instrument programs for realizing Mechatronic Application	Apply

Mapping with Programme Outcomes

COS	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	L	L	S						L
CO2	S	S	S	S	S						M
CO3	S	L	L	L	M						L
CO4.	S	M	S	M	S						L
CO5.	S	S	S	S	S						M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	60	20	20
Apply	60	20	60	60
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

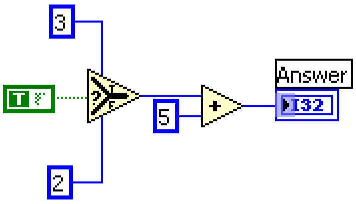
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Virtual Instrument.
2. Define Data Flow Programming.
3. List the advantages of Virtual Instrument over Traditional Instrument.
4. Define Cluster.
5. Write the functions of a Formula node.
6. Write the function of a shift register in a loop.

Course Outcome 2 (CO2):

1. Differentiate Virtual Instrument and Traditional Instrument.
2. Find the output of the given question.



3. Describe the programming Architectures in a Virtual Instrument.
4. Build a VI that displays two random plots on a single chart. These should be Random numbers (0<x<10) and their five-point moving average. The points should appear on your plots as points, while trend line should be a solid line.
5. Build a VI program to calculate the sum of 'n' Numbers.
6. Build a VI program to find the factorial of 'n' number.
7. Build a four-function calculator using Case Structure. Use a Menu ring to select the function required.

Course Outcome 3 (CO3):

1. Explain about functioning of Flash type Analog to Digital Converter.
2. Discuss about weighted resistor Digital to Analog Converter.
3. Explain about successive approximation type Analog to Digital Converter.
4. A weighted Resistor digital to analog converter has n=8 bits, the reference voltage V_R=10V, the most significant bit resistance R=12 Kilo ohm, and the feedback resistance of the operational amplifier R_f=6 kilo ohm.

   Calculate

   (a) The output voltage V_o corresponding to the least significant bit.

   (b) The output voltage V_o corresponding to the least significant bit.

   (c) The resolution.

   (d) The output voltage V_o corresponding to the binary input 10101100.

   (e) The maximum value of the output voltage.

   (f) The nominal full-scale output voltage.

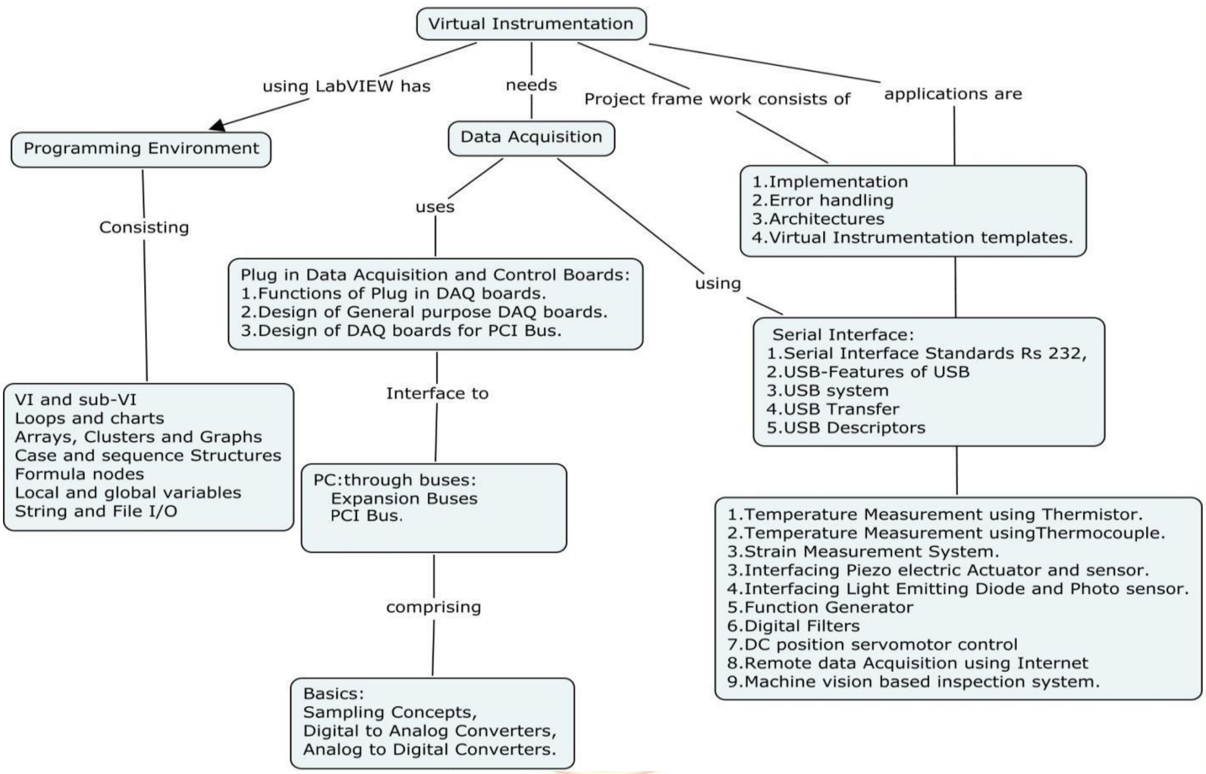
Course Outcome 4 (CO4):

1. State the reason for using state machine architecture for a given application.

Course Outcome 5 (CO5):

1. Develop a Virtual Instrument to realise a function generator to generate Saw tooth waveform with frequency 50Hz.Choose appropriate update rate for realising the above.
2. Develop a Virtual Instrument to acquire Temperature using J type Thermocouple for every one minute and store the data using Excel.
3. Develop a Virtual Instrument to acquire data about level of a tank using internet from a remote place and continuously display it for monitoring purpose.
4. Explain about building a machine vision-based inspection system for inspection of fasteners.

Concept Map



Syllabus

Introduction: Tradition Instrument, Virtual Instrument, Components of a VI, Difference between TI and VI, Advantages of VI.**VI Programming Environment:** Front panel, Block diagram, VI and sub-VI, loops and charts, arrays, clusters and graphs, case and sequence Structures, formula nodes, local and global variables, string and file I/O. **Data Acquisition:** Principles of Data Acquisition: Sampling Concepts, Digital to Analog Converters, Analog to Digital Converters. Interfacing To PC: Expansion Buses-ISA Bus, EISA Bus, PCI Bus. Plug in Data Acquisition and Control Boards: Functions of Plug in DAQ boards, Design of General purpose DAQ boards, Design of DAQ boards for PCI Bus. Data Acquisition using Serial Interface: Serial Interface Standards Rs 232, USB-Features of USB, USB system, USB Transfer, USB Descriptors. **Planning VI Applications:** Implementation, Error handling, architectures, Virtual Instrumentation templates. **Applications:** Temperature Measurement using Thermistor, Thermocouple, Strain Measurement System, Interfacing Piezo electric Actuator and sensor, Interfacing Light Emitting Diode and Photo sensor, Acceleration Measurement, Function Generator, Digital Filters, DC position servomotor control, Remote data Acquisition using Internet, Machine vision-based inspection system. IC engine data acquisition system.

Reference Books

1. N.Mathivanan, "**PC based Instrumentation: Concepts and Practice**" PHI Learning Pvt Ltd, 2007.
2. Jovitha Jerome, "**Virtual Instrumentation Using LabVIEW**", PHI Learning Pvt. Ltd-New Delhi, 2010.
3. Sanjay Gupta, Joseph John "**Virtual Instrumentation Using LabVIEW**", Tata McGraw Hill Education Private Limited, 2010.
4. Dan Necsulescu "**Mechatronics**" Pearson Education, 2002.
5. "**LabVIEW User Manual**"-National Instruments, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Introduction:**	
1.1	Tradition Instrument, Virtual Instrument, Components of a VI.	1
1.2	Difference between TI and VI, Advantages of VI.	1
2.0	**The VI Programming Environment**	
2.1	Front panel, Block diagram, VI and sub-VI	2
2.2	Loops	2
2.3	Arrays and Clusters	2
2.4	Graphs and charts	2
2.5	Case and sequence Structures, Formula nodes	3
2.6	Local and global variables	1
2.7	String and file, I/O	2
3.0	**Data Acquisition**	
3.1	Principles of Data Acquisition: Sampling Concepts, Digital to Analog Converters, Analog to Digital Converters.	3
3.2	Interfacing To PC: Expansion Buses- PCI Bus.	3
3.3	Plug in Data Acquisition and Control Boards: Functions of Plug in DAQ boards.	2
3.4	Design of General purpose DAQ boards.	2
3.5	Design of DAQ boards for PCI Bus.	2

Module No.	Topic	No. of Lectures
3.6	Data Acquisition using Serial Interface: Serial Interface Standards Rs 232,	2
3.7	USB-Features of USB, USB system, USB Transfer, USB Descriptors.	2
4.0	**Planning VI applications**	
4.1	Implementation, Error handling,	2
4.2	Architectures, Virtual Instrumentation templates.	3
5.0	**Applications**	
5.1	Temperature Measurement using Thermistor	1
5.2	Temperature Measurement using Thermocouple	1
5.3	Strain Measurement System	1
5.4	Interfacing Piezo electric Actuator and sensor	1
5.5	Interfacing Light Emitting Diode and Photo sensor	1
5.6	Acceleration Measurement	1
5.7	Function Generator	1
5.8	Digital Filters	1
5.9	DC position servomotor control	1
5.10	Remote Data Acquisition using Internet	1
5.11	Machine vision-based inspection system.	1
	Total	48

Course Designers:

1. Mr. Vivek T tvivek@tce.edu

14MC310	DIGITAL CONTROL USING MICRO CONTROLLERS	Category	L	T	P	Credit
		PC	4	0	0	4

Preamble

A Control system consists of interconnected components to achieve desired objective. Digital control is a branch of control theory that uses digital computers to act as system controllers. This course provides the students with the needed background for analyzing, designing, and implementing digital controllers Modern embedded solutions allow for better performance and lower cost control of dynamic systems such as servomechanisms, chemical processes, and vehicles that move over water, land, air, or space.

Digital control theory is here an enabling factor as it can exploit steadily increasing computational capabilities to shift emphasis from hardware to software and thus to take full advantage of modern embedded solutions. The aim is to provide basic notions required for the design and implementation of a digital control system. This knowledge is necessary for the selection of an appropriate microprocessor for the correct design of a control system

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Develop Transfer function and State space model of Physical system	Apply
CO 2.	System analysis based on root locus, frequency domain and state space methods	Apply
CO 3.	Design controller based on root locus, frequency domain and state space methods	Apply
CO 4.	Implement Digital controller in a Micro controller	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO11	M	S	S	M	L				S		
CO12	M	S	S	S	L		L		M		M
CO13	L	M	S	M	M				M		
CO14	M	S		S	S	M	M		S		S

S- Strong; M-Medium; L-Low

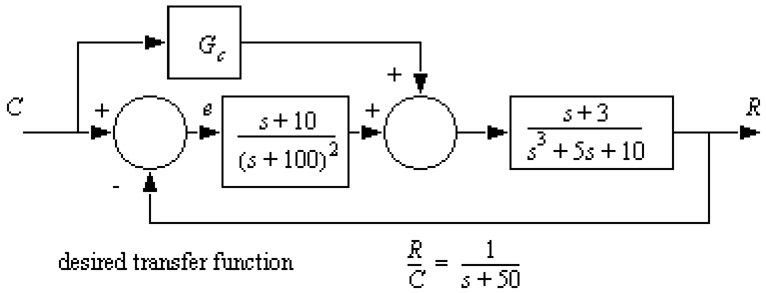
Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	40	20	40
Apply	60	40	60	40
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

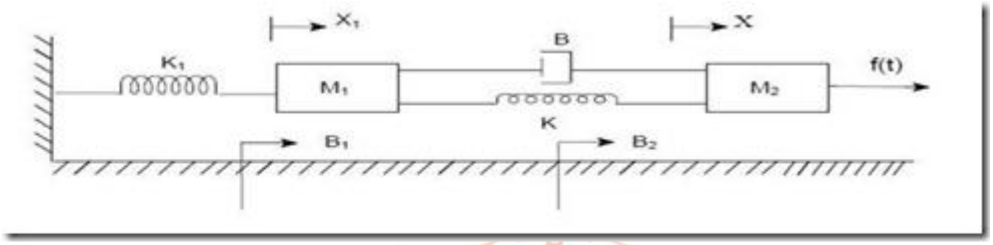
Course Level Assessment Questions

Course Outcome 1 (CO1):

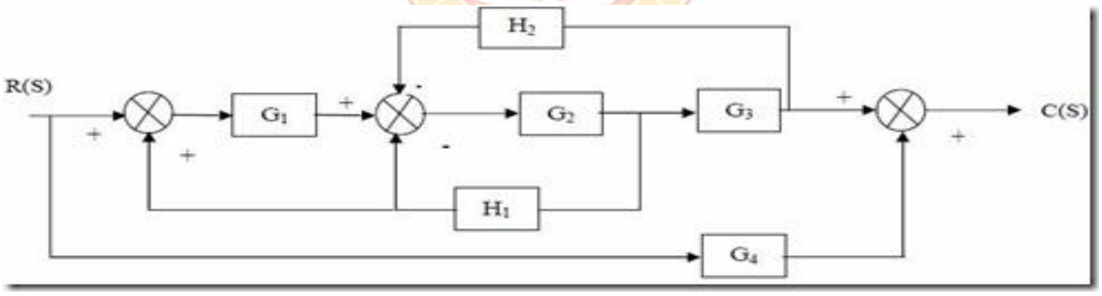
1. State sampling theorem
2. Define Transfer function.
3. Define Aliasing.
4. State the advantages of state space model over transfer function approach.
5. Explain the effect of zero order hold in the pulse transfer function
6. With a neat block diagram explain about various elements of digital control system
7. Derive the transfer function of first order hold.
8. Prove that various state space representations are not unique under similarity transformation.
9. Find the solution of state space equation.
10. A recursive filter is given by its pulse transfer function D(z)=u(z)/e(z)=1+(0.9Z^-1/1+0.6Z^-1)+(1+0.8Z^-1/1+0.95^Z-1). Describe two methods of realization using direct form 1 and parallel form. Include charts using delay elements and computer programs using an assembly language.
11. For the pulse transfer function D(z) = (3+(5/4)z^-1+(5/8)z^-2) / (1+(1/4)z^-1-(1/4)z^-2-(1/16)z^-3). Determine a parallel programming state space representation and draw the diagram and do the same for cascade programming.
12. Determine the overall transfer function for the system shown below.



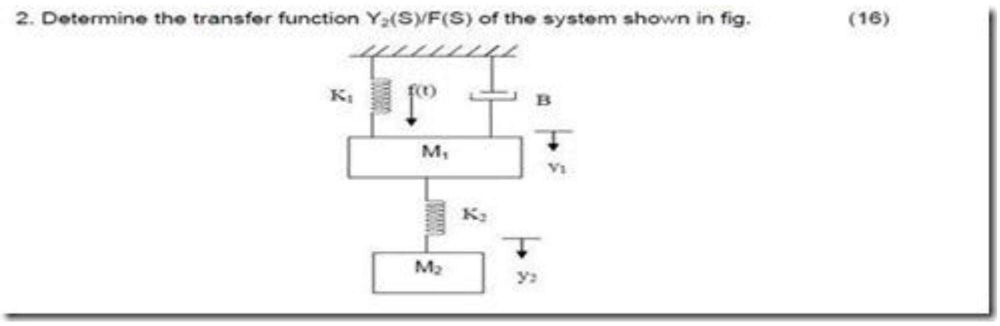
13. Write the differential equations governing the Mechanical system shown in the fig. and determine the transfer function.



14. Determine the overall transfer function for the system shown below.



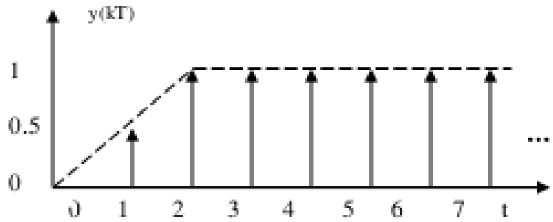
15. Write the differential equations governing the Mechanical system shown in the fig. and determine the transfer function.



Course Outcome 2(CO2)

1. Obtain the z transform of t^2 e^-at.

2. Determine the controllability characteristics of the following system G(z)=z+2/(z+1)(z+3).
3. Determine the controllability characteristics of the following system G(z)=z/(z+1)^2 .
4. A unit step sequence $u(k)$ is applied to a system and the output is obtained as below.
   a. Find the z transform of signal y(kT)
   b. Find the discrete transfer function of the system $G(z) = Y(z)/U(z)$
   c. Rewrite the system in difference equation form and find the first five output sequence (i.e. k= {0,1,2,3,4}) for unit ramp sequence



5. Derive the discrete transfer function from the discrete state model of the system
6. Using Jury's stability criterion determine the stability of the system with characteristic equation $\Delta(z) = z^4 + 1.7z^3 + 0.92z^2 + 0.172z + 0.0096 = 0$
7. Evaluate Z transform of the function
8. Consider a digital control system described by input output relation in form of following difference equation c(k+2) +2c(k+1) +c(k)=u(k+1) +u(k). Check the above system is controllable or not.
9. Find the Inverse z-transform by partial fractions expansion for y(z)=z / z^2 - 4z+3.
10. Solve the following difference equation by use of the z transform method x(k+2) +3x(k+1) +2x(k)=0, x (0) =0, x (1) =1.

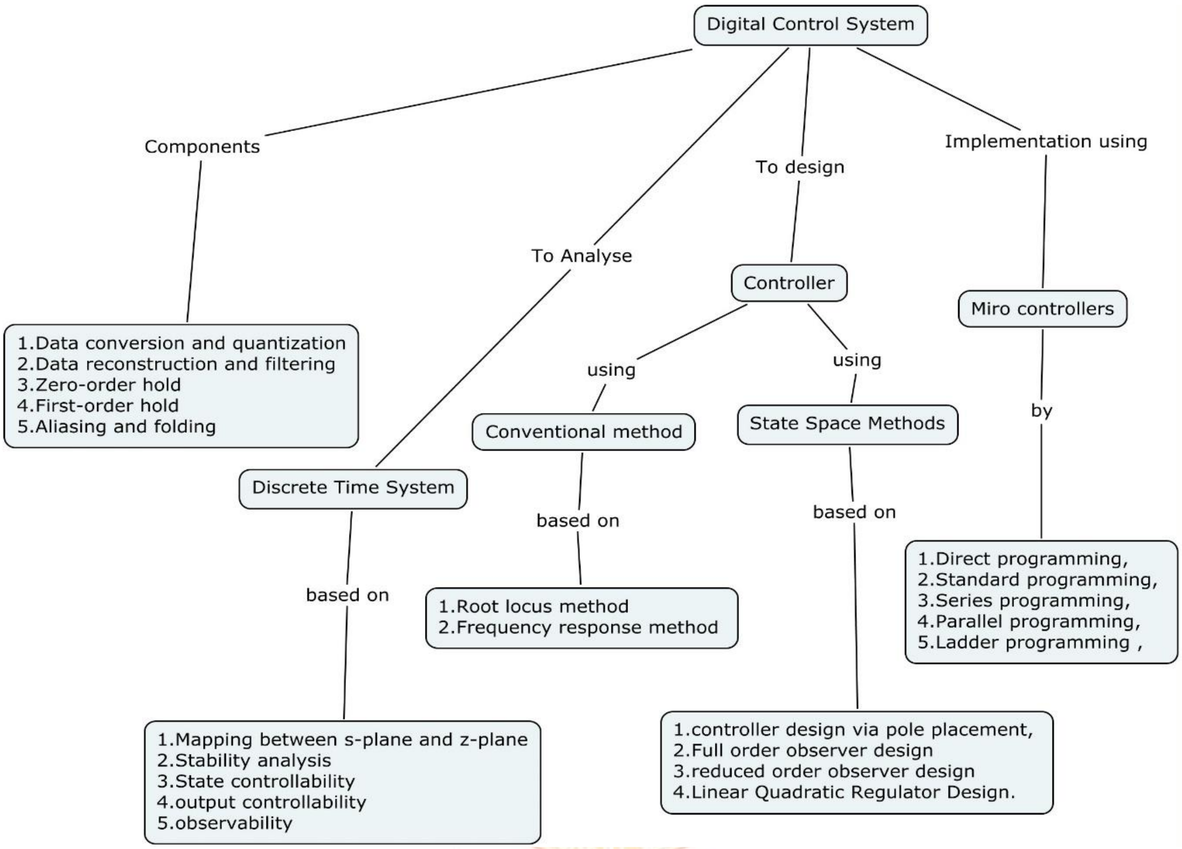
Course Outcome 3 (CO3)

1. Consider the system G(s) =1/s+1. It is to be sampled at the rate of 0.2s through a zero-order hold. Design suitable compensator using discrete root locus to achieve dead beat response.
2. Consider a continuous system G(s) =1/s(s+2). It is to be sampled through a ZOH. Find which of the following sampling period is preferred. T=1s, 0.1s and 1ms
3. Find the Inverse z- transform of a more complex expression for y(z)=4+2.67z^-1+1.56z^-2-1.42z^-3 / 1-0.36z^-1+0.19z^-2-1.03z^-3+0.2z^-4.
4. Find the Inverse z-transform by long division for y(z)=z^-1 / 1-4z^-1+3z^-2.
5. Obtain the solution of the following difference equation in terms of x (0) and x (1): x(k+2) +(abs) x(k+1) +abs(k)=0.

Course Outcome 4 (CO4)

1. Consider the position control of separately exited DC servomotor fed by a buck converter. Assume the armature inductance of DC motor and viscous friction coefficient is negligible. Manipulated variable is duty cycle. Let the sampling time T=1/26 s.
    a. Obtain the discrete state model of the system
    b. Design a state feedback controller such that motor position attains desired reference at 2 sampling instants.
    c. If a constant load torque is to applied check whether the disturbance is eliminated as $k \to \infty$
    d. Assuming position alone is measured, design an output feedback regulator to achieve $\varsigma = 0.5$ and $\omega_n = 4$
2. A continuous plant is described by the equation $\dot{y} = -y + u + w$ is to be controlled by a digital computer. y is the output, u is the input and w is the disturbance signal. Let sampling interval T=1s.
    a. Obtain discrete time state variable model of the plant. Compute K and N such that control law $u(k) = -Ky(t) + Nr$, result in a response y(t) with time constant 0.5s and $y(\infty) = r$ (r is the constant reference)
    b. Show that steady state error to constant disturbance input w, is not zero
    c. Add to the plant equation an integrator equation, $v(k) = v(k-1) + y(k) - r$ and select gains K1 and K2 such that the control law $u = -K_1y(k) - K_2v(k)$ results in a response $\zeta = 0.5\ and\ \omega_n = 4$
    d. Show that steady state error to constant disturbance w is zero for the above control law
3. For the system $X_{k+1} = \begin{bmatrix} 0 & 1 \\ -1 & 1 \end{bmatrix} X_k + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u_k$ and $Y_k = x_1$.
    a. Design full order observer for the system with dead beat response
    b. Design reduced order observer to with eigen value at z=0.1
4. Determine the state space representation of the discrete filter D(z)=1/(z+1)^2 (z+0.1). Use parallel programming and draw the block diagram.

Concept Map



Syllabus

Introduction to digital control systems and Z- Transform Techniques

Basic elements, data conversion and quantization, sample and Hold devices, mathematical modeling of the sampling process, data reconstruction and filtering of sampled signals, zero-order hold, the first-order hold, aliasing and folding, Z-transform, Inverse Z-transform, Pulse Transfer Function, Mathematical modeling of physical system using transfer function and state space, Block diagram reduction technique.

Analysis: Various canonical forms, similarity transformation, Solution of state equation, transfer function to state space conversion, Mapping between s-plane and z-plane, Jury's Stability test, stability analysis by use of bilinear transformation and Routh stability criterion.

Design: Transient response specifications, design based on root locus method, design based on frequency response method, State controllability, output controllability, observability, Effect of discretization on controllability and observability, controller design via pole placement, Full order and reduced order observer design, Effect of addition of observer on closed loop system.

Implementation: Realization of digital controllers and digital filters: direct programming, standard programming, series programming, parallel programming, ladder Programming, Stabilization of an antenna dish. Basics of Optimal control: Performance Indices, Linear Quadratic Regulator Design.

Reference Books

1. Katsuhiko Ogata," Discrete **time control systems**" second edition, Pearson Education Asia Pte Ltd, 2002.
2. George Stephanopoulos, "**Chemical process control: An introduction to theory and practice**", Prentice hall of India private limited,1999.
3. M.Gopal, "**Digital Control and State Variable Methods**", Tata McGraw Hill Publishing Company Limited, Second edition, 2003.
4. Elbert Hendricks, Ole Janner up, Paul Hasse Sorenson, "**Linear systems control**" Springer.2008.
5. Dogan Ibrahim, "**Micro controller based Applied Digital Control** ". First Edition, wiley. 2006.
6. Paul kautz, "**Digital Control using Microprocessors**" First Edition, Prentice Hall International, 1981.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	Introduction to digital control systems and Z- Transform Techniques Basic elements, data conversion and quantization	1
1.1	Sample and Hold devices	1
1.2	Mathematical modeling of the sampling process	1
1.3	Data reconstruction and filtering of sampled signals	1
1.4	Zero-order hold, the first-order hold, Aliasing and folding	1
1.5	Z-transform, Inverse Z-transform	3
1.6	Pulse transfer function	1
1.7	Mathematical modelling of physical system using transfer function	1
1.8	Mathematical modelling of physical system using state space	1

Module No.	Topic	No. of Lectures
1.8	Block diagram reduction technique.	1
2.	Analysis: Various canonical forms, similarity transformation.	3
2.1	Solution of state equation, transfer function to state space conversion	1
2.2	Mapping between s-plane and z-plane	2
2.3	Jury's Stability analysis	2
2.4	Stability analysis by use of bilinear transformation	1
2.5	Routh stability criterion	1
3.	Design: Transient response specifications, design based on root locus method	4
3.1	Design based on frequency response method	3
3.2	State controllability, output controllability, observability	2
3.3	Effect of discretization on controllability and observability	1
3.4	controller design via pole placement	1
3.5	Full order observer design	1
3.6	Reduced order observer design	1
3.7	Effect of addition of observer on closed loop system	1
4.	Implementation: Realization of digital controllers and digital filters:	1
4.1	Direct programming, Standard programming,	2
4.2	Series programming, Parallel programming,	2
4.3	Ladder Programming.	1
4.4	Stabilization of an antenna dish.	3
4.5	Basics of Optimal control: Performance Indices, Linear Quadratic Regulator Design	3
	Total	48

Course Designers:

1. T. Vivek tvivek@tce.edu.
2. N. Anandh anandh_n@tce.edu.

14MCPE0	MODELING AND SIMULATION OF MECHATRONICS SYSTEMS	Category	L	T	P	Credit
		PE	2	0	2	3

Preamble

In the study of Mechatronics systems, the diverse methodologies that exist within different disciplines, their unique terminology, and names for components pose a problem for students and experts whose training is in one but not all disciplines. The need for a more unifying approach was felt a long time ago. Mathematical models and bond graphs provide a very logical and succinct way of dealing with the variety from different disciplines.

Prerequisite

Nil

Course Outcomes

On successful completion of the course, students will be able to

CO 1.	Develop a mathematical model of physical system	Apply
CO 2.	Explain the basic concepts of bond graph	Understand
CO 3.	Develop a model of electrical and Mechanical systems using Bond graph	Apply
CO 4.	Develop a Model of Hydraulic and Electronic System using bond graph	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	S	S	L			M		
CO2.	S	L	L	S	L	L			S		
CO3.	S	S	S	S	S	L			M		
CO4.	S	L	L	S	L	S			S		

S- Strong; M-Medium; L-Low

Assessment Pattern

Theory (70 marks)					Practical (30 marks)		
Bloom's Category	Continuous Assessment Tests (20)			Terminal Examination (50)	Valuation category	Continuous Assessment (10)	Continuous Assessment Test 3 (20)
	1	2					
Remember	20	20		20	Class work	90	90
Understand	60	60		60	Record	10	10
Apply	20	20		20			
Analyse	0	0		0			
Evaluate	0	0		0			
Create	0	0		0			

Theory cum Practical Courses:

There shall be three tests: the first two tests (Maximum 50 marks for each test) will be from theory component and the third test (Maximum 50 Marks) will be for practical component. The sum of marks of first two tests shall be reduced to 20 Marks and the third test mark shall be reduced to 20 marks. Average mark awarded for viva – voce, conduct of experiments, observation & results, record work in regular class works shall be reduced to 10 marks. The sum of these 50 Marks would be rounded to the nearest integer.

Course Level Assessment Questions

Course Outcome 1 (CO1):

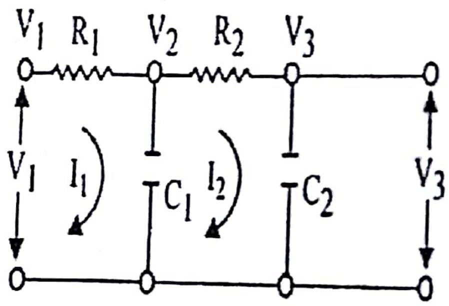
1. Define Transfer Function
2. List the type of mathematical models
3. Define Linearization models

Course Outcome 2 (CO2):

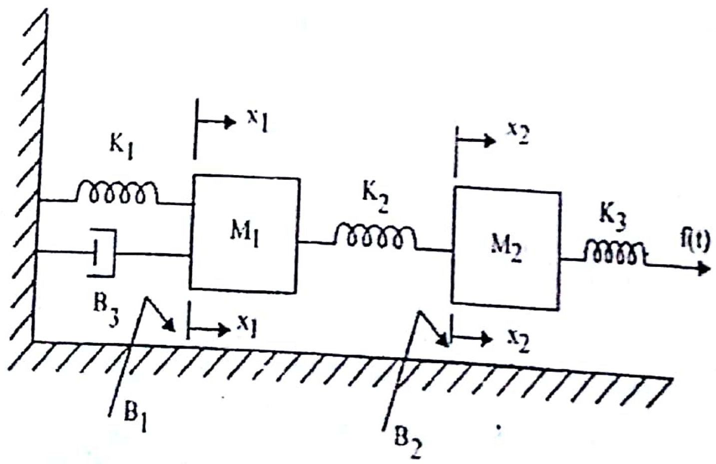
1. Discuss about Power Variables used in bond graph
2. Define components in physical systems
3. Explain about Transformer Element and Gyrator Element

Course Outcome 3 (CO3):

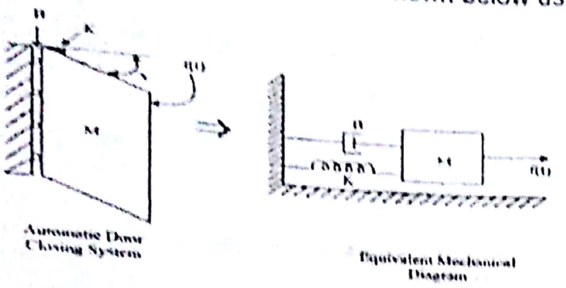
1. Develop a model for the physical system shown below using bond graph



2. Develop a model for the physical system shown below using bond graph

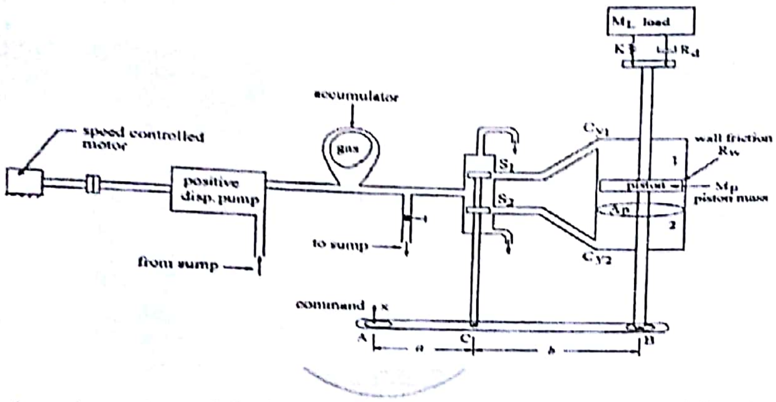


3. Develop a model for the physical system shown below using bond graph

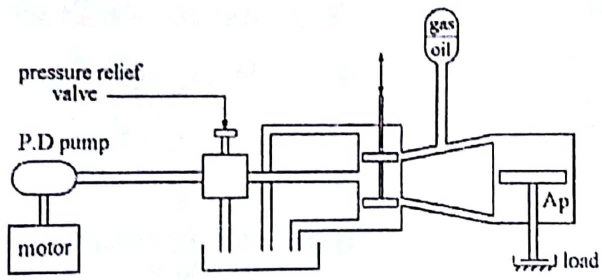


Course Outcome 4 (CO4):

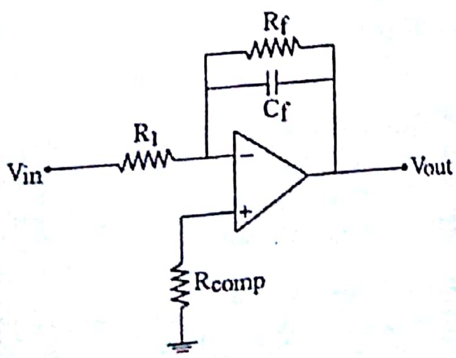
1. Develop a Bond Graph model for the Hydraulic Servo motor

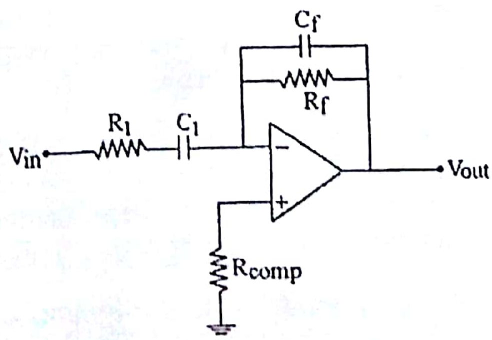


2. Make a bond graph model of the hydraulic system used for metal forming operation

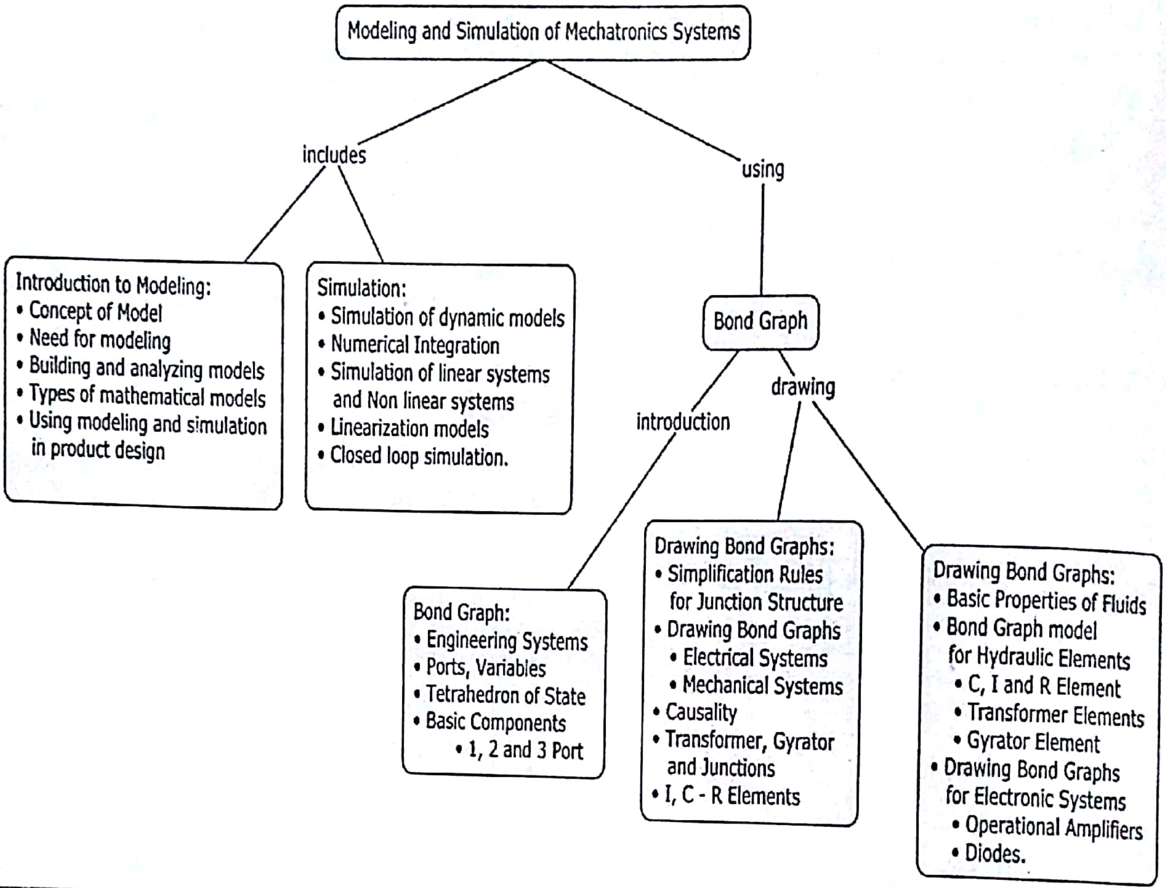


3. Draw a bond graph model for Practical integrator and differentiator circuit shown in below





Concept Map



Syllabus

Introduction to Modeling: Concept of Model, Need for modeling. Building and analyzing models, Using modeling and simulation in product design, Types of mathematical models, Differential equations, Differential Algebraic equations, Transfer functions, State space models

Simulation: Simulation of dynamic models, Numerical Integration, Fixed step and variable step solvers, Simulation of linear systems and Non linear systems, Linearization models, Closed loop simulation.

Introduction to Bond Graph: Engineering Systems - Ports - Generalized Variables - Power Variables - Energy Variables - Tetrahedron of State - Bond Graphs - Word Bond Graphs - Basic Components in Systems – 1 Port Components - 1 Port Resistor - 1 Port Capacitor- 1 Port Inductor/Inertia-2 Port Components - Transformer Element - Gyrator Element – 3 Port Components - 0 Junction, 1 Junction.

Drawing Bond Graphs for Electrical and Mechanical Systems: Simplification Rules for Junction Structure - Drawing Bond Graphs for Electrical Systems - Drawing Bond Graphs for Mechanical Systems in Translation and Rotation - Causality – Transformer – Gyrator – Junctions - Storage Elements: *I*, *C* - *R* for Resistive Elements.

Drawing Bond Graphs for Hydraulic and Electronic Systems: Basic Properties of Fluids – Bond Graph model for Hydraulic Elements – Fluid Compliance, C Element – Fluid Inertia, I

Element – Fluid Resistances, R Element – Transformer Elements – Gyrator Element - Drawing Bond Graphs for Electronic Systems - Operational Amplifiers – Diodes.

Reference Books

1. Shuvra Das., "**Mechatronic Modeling and Simulation Using Bond Graphs**"., CRC Press, 2009.
2. Amalendu Mukherjee, Ranjit Karmakar, Arun kumar samantaray, "**Bond Graph in Modeling, Simulation and Fault Identification**" I.K International Pvt Ltd, Jan 2006.
3. Jacqueline Wilkie., Michael Johnson., Reza Katebi., " **Control Engineering an Introductory course** " Palgrave Publication, 2003.
4. Wayne Bequette. B., "**Process Control: Modeling, Design and Simulation**" ., Prentice Hall PTR, 2002.
5. Peter Fritzson., "**Principles of object oriented modeling and Simulation with Modelica 2.1**"., IEEE Press, 2004.
6. "**Control design with Simulink**" – The Math work tutorial – 2004.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Introduction to Modeling**	
1.1	Concept of Model, Need for modeling, Building and analyzing models,	1
1.2	Types of mathematical models, Differential equations, Differential Algebraic equations,	2
1.3	Transfer functions, State space models	2
1.4	Using modeling and simulation in product design	1
2.0	**Simulation**	
2.1	Simulation of dynamic models, Numerical Integration, Fixed step and variable step solvers	2
2.2	Simulation of linear systems and Non linear systems	2
2.3	Linearization models	1
2.4	Closed loop simulation	1
3.0	**Introduction to Bond Graph**	
3.1	Engineering Systems – Ports - Generalized Variables - Power Variables - Energy Variables	1
3.2	Tetrahedron of State - Bond Graphs - Word Bond Graphs - Basic Components in Systems	1
3.3	1 Port Components - 1 Port Resistor - 1 Port Capacitor- 1 Port Inductor/Inertia	2
3.4	2 Port Components - Transformer Element - Gyrator Element	2
3.5	3 Port Components - 0 Junction, 1 Junction.	2
4.0	**Drawing Bond Graphs for Electrical and Mechanical Systems**	
4.1	Simplification Rules for Junction Structure	1
4.2	Drawing Bond Graphs for Electrical Systems	1
4.3	Drawing Bond Graphs for Mechanical Systems in Translation and Rotation	2
4.4	Causality – Transformer – Gyrator – Junctions	1
4.5	Storage Elements: L, *C* - *R*, for Resistive Elements -	1
5.0	**Drawing Bond Graphs for Hydraulic and Electronic Systems**	

Module No.	Topic	No. of Lectures
5.1	Basic Properties of Fluids	1
5.2	Bond Graph model for Hydraulic Elements	2
5.3	Fluid Compliance, C Element – Fluid Inertia, L Element – Fluid Resistances, R Element	2
5.4	Transformer Elements – Gyrator Element	2
5.5	Drawing Bond Graphs for Electronic Systems	1
5.6	Operational Amplifiers – Diodes	2
	Total	**36 Hours**

Laboratory Experiments

Experiment No.	Topic
1	Develop and simulate a model for the simple speed control system with DC motor.
2	Develop and simulate a model for the simple house heating system
3	Develop and simulate a model that uses PID Controller to control Position of a D.C Motor.
4	Develop and simulate a Bond graph model for integrated circuit that uses operational amplifiers.
5	Develop and simulate a bond graph model for a wien bridge oscillator.
6	Develop and simulate a bond graph model for Position control of mass and spring damper combination - Proportional Control-PID Control.
7	Develop and simulate a bond graph model for Slider crank mechanism.
8	Develop and simulate a bond graph model for four bar mechanism.
9	Develop and simulate a bond graph model for DC Shunt Motor.
10	Develop and simulate a bond graph model for DC Series Motor.
11	Develop and simulate a bond graph model for Servo motor.
12	Develop and simulate a bond graph model for the simple speed control system with DC motor.
	No. of Hours = 12

Course Designers:

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14MCPF0 **AUTONOMOUS VEHICLES**

Category	L	T	P	Credit
PE	4	0	0	4

Preamble

Today's procedural-software-driven computer controllers are limited by the amount of programming and decision-making "intelligence" passed onto it by a human programmer or engineer. The biggest challenge for the 21st century is to make robots and machines "intelligent" enough to learn how to perform tasks automatically and adapt to unforeseen operating conditions or errors in a robust and predictable manner, without the need for human guidance, instructions or programming.

The autonomous vehicle exists to apply, develop and promote technology related to the field of robotics, driverless car, Automated Guided Vehicle (AGV), underwater vehicle and unmanned aerial vehicle (UAV). It is for the students from all disciplines, particularly mechatronics engineering to apply the principles and technology of autonomous vehicle. It concerned with the principles of locomotion, kinematics, sensors, localization and navigation of autonomous vehicles like mobile robot.

Prerequisite

- Microcontroller

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Describe the structure of Automated guided and autonomous Vehicles	Understand
CO2	Explain the mobility requirements of an autonomous vehicle	Understand
CO3	Describe the mechanical system behaviour and motion control through kinematics	Understand
CO4	Select suitable sensors for mobile robot application	Apply
CO5	Implement the concept of localization and navigation for path planning through different algorithms	Apply
CO6	Write an interface code with ATMEL8051 microcontroller for various elements of vehicle system like steeper motor, servo motor and non-contact sensors	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	-	L	-	-	-	-	-	L	-	-
CO2	S	-	L	-	-	-	-	-	L	-	-
CO3	S	-	L	-	-	-	-	-	L	-	-
CO4	S	-	M	L	-	-	-	-	L	-	-
CO5	S	M	M	L	-	-	-	-	L	-	-
CO6	S	-	M	L	L	-	-	-	L	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests 1	2	3	Terminal Examination
Remember	40	20	20	10
Understand	60	40	40	30
Apply	0	40	40	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Describe the structure of automated guided vehicle (AGV) and its monitoring systems.
2. Explain the architecture of unmanned ground vehicle and mention any four of its applications.
3. Discuss the classification of bio-inspired robots in terms of locomotion.

Course Outcome 2 (CO2):

1. Define controllability.
2. Describe four wheel types for mobile robots.
3. Explain various parameters involved in the design of wheeled locomotion.

Course Outcome 3 (CO3):

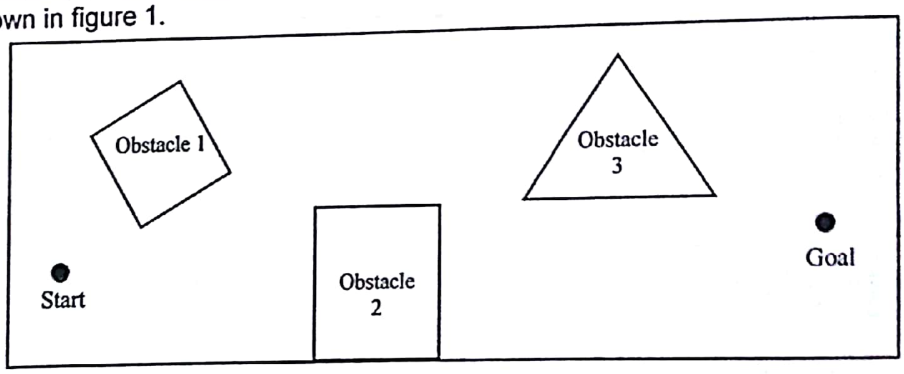
1. Explain the forward kinematic model of a wheeled mobile robot.
2. With use of simple sketches, explain the working of castor wheel for steering.
3. Describe the open loop motion control to follow a trajectory described by its position trajectory profile.

Course Outcome 4 (CO4):

1. Explain how the sensors are classified.
2. Select suitable sensors for pick and place mobile robot to carry one kg of a component which operates within 10 meters.
3. Suggest a suitable sensor for collision avoidance between the moving vehicles in a straight line.

Course Outcome 5 (CO5):

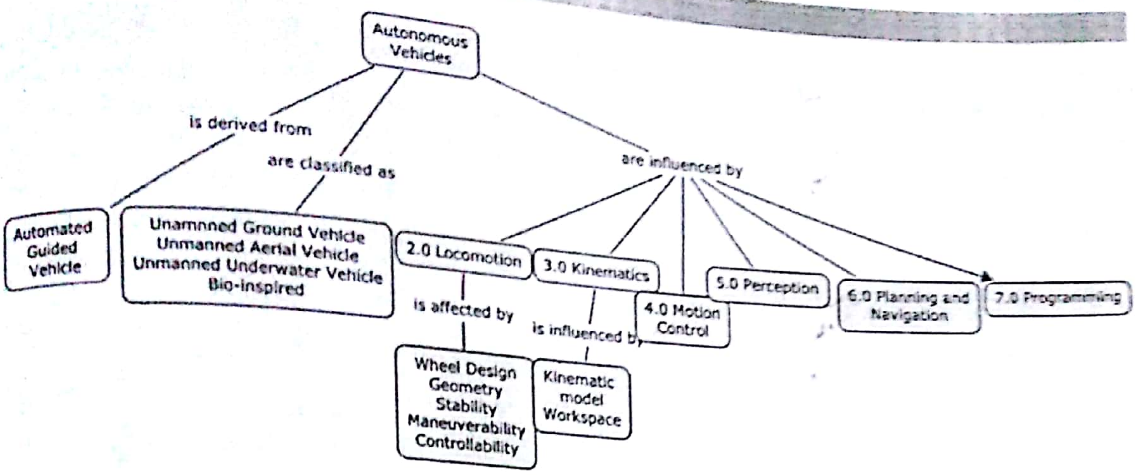
1. Describe the general schematic for mobile robot localization.
2. Explain the architecture for behaviour-based navigation with use of block diagram.
3. Generate Voronoi diagram for determining the feasible path between destination as shown in figure 1.



Course Outcome 6 (CO6):

1. Write a 8051 assembly language program to interface a stepper motor and to run in forward and reverse direction.
2. Write a 8051 assembly language program to interface a IR sensor to count a number of objects entry in a conveyor system.
3. Write a 8051 assembly language program to measure the temperature and operate a limit switch.

Concept Map



Syllabus

Automated Guided Vehicle: Type, structure and safety aspects. Definition of autonomy, Classification- Unmanned Ground Vehicle (UGV), Unmanned Aerial Vehicle (UAV), Unmanned Underwater Vehicle (UUWV) and Bio-inspired robots. **Locomotion**: Introduction, key issues for locomotion, wheeled locomotion-wheel design, geometry, stability, maneuverability and controllability. **Mobile Robot kinematics**: kinematic model and constraints, Mobile robot workspace-motion control. **Perception:** sensors for mobile robots-classification, characterizing sensor performance, wheel or motor sensors, heading sensors, ground-based beacons, active ranging, motion/speed sensors, introduction to vision based sensor, Global Positioning Systems (GPS) – Blue tooth interface. **Mobile robot localization:** challenges, localization based on navigation versus programmed solutions, map representation, probabilistic map-based localization. **Planning and navigation:** planning and reacting- path planning, road map path planning, cell decomposition path planning, potential field path planning, navigation architecture-techniques for decomposition, offline planning. **Micro controller programming using 8051:** Interfacing Limit switch, Hall effect sensor, optical encoder, proximity sensor-capacitive, inductive and Infra-red, Interfacing Servo motor and stepper motor.

Reference Books/Learning Resources

1. Roland Siegwart and Illah R.Nourbakhsh, "Introduction to Autonomous Mobile Robots", Prentice Hall of India (P) Ltd., 2005.
2. George A. Bekey, "Autonomous Robots – From Biological Inspiration to Implementation and control", MIT Press, 2005.
3. Howie Choset, Kevin M. Lynch, Seth Hutchinson, George A. Kantor, Wolfram Burgard, Lydia E. Kavraki and Sebastian Thrun, "Principles of Robot Motion – Theory, Algorithms and Implementation", MIT Press, 2005.
4. Mikell P.Groover, "Automation, Production Systems and Computer Integrated Manufacturing", Prentice Hall of India Learning, Third Edition, 2009.

Course Contents and Lecture Schedule

S.No	Topics	No. of Lectures
1	**Automated Vehicles**	
1.1	**Automated Guided Vehicle (AGV)** - Type, structure safety aspects	1
1.2	**Autonomous Vehicles:** Definition of autonomy	1
1.2.1	Classification- Unmanned Ground Vehicle (UGV), Unmanned Aerial Vehicle (UAV), Unmanned Underwater Vehicle (UUWV) and Bio-	1

S.No	Topics	No. of Lectures
	inspired robots	
2	**Locomotion**	
2.1	Introduction, Key issues for locomotion	1
2.2	Wheeled locomotion-wheel design	2
2.3	Geometry, stability, maneuverability and controllability	2
3	**Mobile Robot kinematics**	
3.1	Kinematic model and constraints	2
3.2	Mobile robot workspace-motion control	2
4	**Perception**	
4.1	Classification of Sensors for mobile robots	1
4.1.1	Characterizing sensor performance	1
4.2	Wheel or motor sensors, heading sensors	1
4.2	Ground-based beacons, active ranging	1
4.3	Motion/speed sensors, introduction to vision based sensor	1
5	**Mobile robot localization**	
5.1	Introduction - challenges	1
5.2	Localization based on navigation versus programmed solutions	1
5.3	Map representation	1
5.3.1	Probabilistic map-based localization	2
6	**Planning and navigation**	
6.1	Planning and reacting - path planning	1
6.2	Road map path planning, cell decomposition path planning	2
6.3	Potential field path planning	2
6.4	Navigation architecture	1
6.4.1	Techniques for decomposition, offline planning	2
7	**Micro controller programming using 8051**	
7.1	Interfacing Code – Introduction	1
7.1.1	Limit switch Hall effect sensor and optical encoder,	2
7.1.2	Proximity sensor: capacitive, inductive and Infra-red	2
7.1.3	Interfacing Servo motor and stepper motor	2
	Total	**37 Hours**

Course Designers:

1. Dr. C. Paramasivam cpmech@tce.edu
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4. Mr. T.Vivek tvivek@tce.edu

14MCPG0 **INDUSTRIAL ROBOTICS**

Category	L	T	P	Credit
PE	4	0	0	4

Preamble

Robotics is the applied science of motion control for multi-axis manipulators and is a large subset of the field of "mechatronics" (Mechanical, Electronic and Software engineering for product or systems development, particularly for motion control applications). Robotics, sensors, actuators and controller technologies are continuously improving and evolving synergistically. In the 20th century, engineers have mastered almost all forms of motion control and have proven that robots and machines can perform almost any job that is considered too heavy, too tiring, too boring or too dangerous and harmful for human beings. This course supports the students to design and develop multi-Degrees of Freedom (DOF) manipulators.

Prerequisite

- Matrix manipulations
-

Course Outcomes

On the successful completion of the course, students will be able to

CO1 :	Describe the working of the subsystems of robotic manipulator	Understand
CO2:	Develop the forward kinematic model of multi-degree of freedom (DOF) manipulator and inverse kinematic model and dynamic model of two degrees of freedom robot arm	Apply
CO3:	Develop a cubic polynomial trajectory in joint space with given kinematic constraints of multi-degree of freedom (DOF) manipulator	Apply
CO4:	Explain various types of control schemes, sensors and interfaces used in the operation of robot/ with the robot controller	Understand
CO5:	Develop a offline robot program for point-to-point applications such as pick and place, palletizing, sorting and inspection of work-parts	Apply
CO6:	Explain the importance of decision making systems/ Heuristics and Artificial intelligence in robot execution	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO5.	M	-	L	-	-	-	-	-	L	-	-
CO6.	S	-	S	M	-	-	-	-	L	-	-
CO7.	S	-	S	L	-	-	-	-	L	-	-
CO8.	S	-	L	-	-	-	-	-	L	-	-
CO9.	S	M	M	-	-	-	-	-	L	-	-
CO10.	M	-	L	-	-	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	10
Understand	40	40	40	30
Apply	40	40	40	60
Analyse				
Evaluate				
Create				

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define industrial robot.
2. Explain the classification of actuators used in robotic manipulators and indicate their advantages and limitations.
3. Describe the construction features of an industrial robot.

Course Outcome 2 (CO2):

1. Write the coordinate transformation matrices for all PUMA joints as shown in figure 1 using DH parameters.

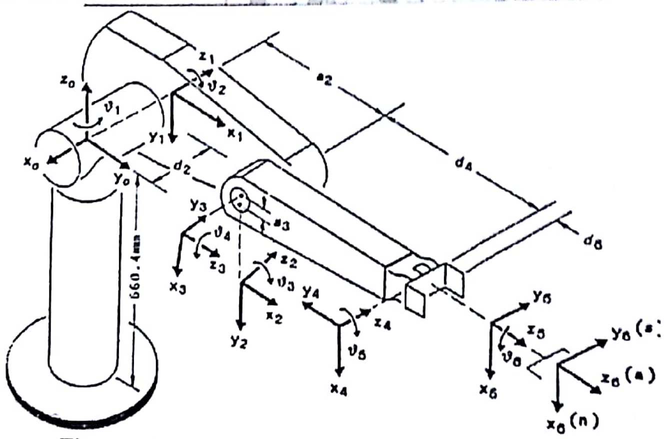


Figure 1

2. Consider the two-link planar arm of Figure 2. The joint axes z_0 and z_1 are normal to the page. The established base frame $x_0 y_0 z_0$ is as shown. The origin is chosen at the point of intersection of the z_0 axis with the page and the direction of the x_0 axis is completely arbitrary. Once the base frame is established, the $x_1 y_1 z_1$ frame is fixed as shown by the DH convention, where the origin, o_1 has been located at the intersection of z_1 and the page. The final frame $x_2 y_2 z_2$ is fixed by choosing the origin, o_2 at the end of link 2 as shown. Write the DH parameters and its corresponding transformation matrices.

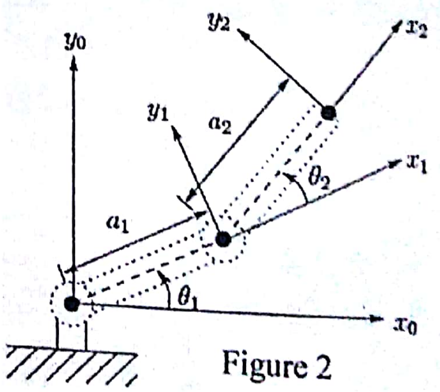


Figure 2

3. Develop a dynamic model for two degree of freedom manipulator as shown in figure 2.

Course Outcome 3 (CO3):

1. Explain step by step procedure for the generation a cubic polynomial trajectory for a joint with specified kinematic constraints.

2. The initial and final joint positions of a robot joint are $\theta_i = 15^\circ$ and $\theta_f = 75^\circ$ with time period of 3 sec. The following expressions are governing equations for position, velocity and acceleration. Develop a trajectory for the above conditions.

   $\theta(t) = 15 + 20t^2 - 4.44t^3$

   $\dot{\theta}(t) = 40t - 13.32t^2$

   $\ddot{\theta}(t) = 40 - 26.64t$

3. Develop a trajectory for a robot whose initial and final position are given as $\theta_i = -45^\circ$ and $\theta_f = 15^\circ$ and governing equation is $\theta(t) = -45 + 24t + 4t^2$. Determine the time period for this trajectory.

Course Outcome 4 (CO4):

1. Name any four sensors used in robot as internal sensor.
2. Explain the classification of the sensors used in robotic applications.
3. Explain the general control architecture of robotic system with suitable block diagram.

Course Outcome 5 (CO5):

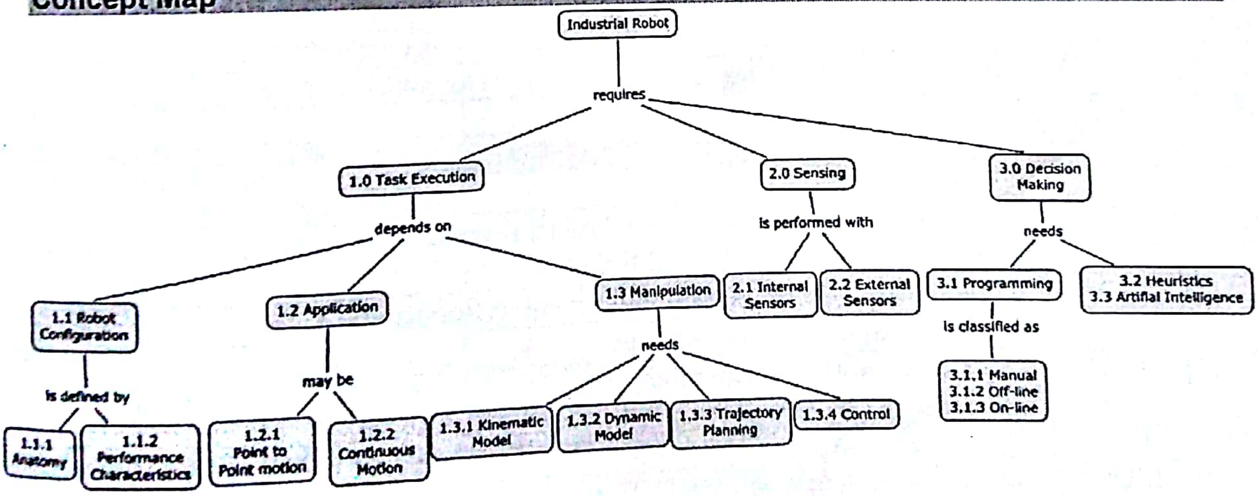
1. Write a robot programming for a palletizing operation. The robot must pick up the parts from an incoming chute and deposit them onto a pallet. The pallet has four rows that are 50 mm apart and six columns that are 40 mm apart. The plane of the pallet is assumed to be parallel to XY plane. The rows of the pallet are parallel to the x-axis and the columns of the pallet are parallel to the Y-axis. The objects are to be picked up are about 25 mm tall.
2. Write a VAL statements for defining coordinate frame *'Grasp – Point 1'* which can be obtained by rotating coordinate frame *'Block – Point 2'* through an angle 65° about Y-axis and then translate it by 100 and 150 mm in X and Y axes respectively.
3. Two MS plates of size 50x100x10 mm which are vertically oriented need to be joined through robot welding. Draw suitable diagram of the situation and write the offline VAL program.

Course Outcome 6 (CO6):

1. Define Artificial Intelligence.
2. Explain the significance of artificial intelligence in robotic applications.

   Explain the rule-based expert system with suitable examples.

Concept Map



Syllabus

Introduction to Robotics - **Task Execution:** Robot Configuration - Robot Anatomy, Sub-systems/Elements of Industrial Robot - Performance characteristics of industrial Robots. Applications - Progressive advancement in Robots – Point to point and continuous motion applications - Mobile manipulators and its applications. Manipulation: Kinematic model -

Forward Kinematics for two DOF manipulator – Algebraic method, Mechanical structure and notations, Coordinate frames, Description of objects in space, Transformation of vectors, Fundamental rotation matrices (principal axes and fixed angle rotation) Description of links and joints, Denavit-Hartenberg (DH) notation, Forward Kinematics for multi-Degrees of Freedom (DOF) manipulator. Inverse kinematics of two DOF manipulator - Manipulator workspace. Dynamic model: Lagrangian method - Forward and inverse dynamic model for two DOF manipulator. Trajectory planning: Definitions and planning tasks, Joint space techniques – Motion profiles – Cubic polynomial motion. Cartesian space techniques. Control of manipulators: Manipulator control problem, Linear second-order model of manipulator, Functions of controller, Joint actuators- stepper motor, servo motor, Control Schemes - PID control scheme, Position and force control schemes. **Sensors:** Robotic sensors and its classification, Internal sensors – Position, velocity, acceleration and force information, External Sensors – Contact sensors-Limit switches, piezoelectric, pressure pads, Non-contact sensors - Architecture of robotic vision system - Description of components of vision system. **Decision Making:** Robot Programming: Manual Programming – Teach Pendant, Offline programming - VAL programming, Online Programming. Expert Systems, Artificial intelligence - Importance of artificial intelligence. Case Studies.

Reference Books/Learning Resources

1. K.S. Fu, R.C Gonzalez and C.S. Lee, Robotics- Control, Sensing, Vision and Intelligence, Tata McGraw-Hill Editions, 2008.
2. S.K.Saha, "Introduction to Robotics", Second Edition, Mc Graw Hill Education (India) Private Limited, New Delhi, 2014.
3. Saeed B. Niku, "Introduction to Robotics, Analysis, System, Applications", Second Edition, John Wiley, 2010.
4. John J.Craig, Introduction to Robotics, Mechanics and control, Third edition, Pearson education, 2005.
5. Mark W.Spong, M.Vidyasagar, "Robot dynamics and control", Wiley India, 2009.
6. Mikell P. Groover, Mitchell Weiss, Roger N.Nagel and Nicholas G. Odrey, "Industrial Robotics" – Technology, Programming and Applications" Tata McGraw-Hill Edition, 2008.
7. Robert J. Schiling, "Fundamentals of Robotics: Analysis and Control", Indian Reprint, Prentice Hall of India Private Limited, 1990.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
	Introduction to Robotics	
1.0	**Task Execution**	1
1.1	Robot Configurations	
1.1.1	Robot Anatomy	1
1.1.2	Performance characteristics of industrial Robots - Sub-systems/Elements of Industrial Robot	2
1.2	Applications - Progressive advancement in Robots	
1.2.1	Point to point motion applications	1
1.2.2	Continuous motion applications	1
1.3	Manipulation	
1.3.1	Kinematic model	
1.3.1.1	Forward Kinematics for two DOF manipulator – Algebraic method	1
1.3.1.2	Mechanical structure and notations	1
1.3.1.3	Coordinate frames, Description of objects in space, Transformation of vectors, Fundamental rotation matrices	2
1.3.1.4	Description of links and joints, Denavit-Hartenberg (DH) notation.	2

Module No.	Topic	No. of Lectures
1.3.1.5	Forward Kinematics for multi DOF manipulator	2
1.3.1.6	Inverse kinematics of two DOF manipulator - Manipulator workspace.	2
1.3.2	Dynamic model: Lagrangian method - Forward and inverse dynamic model for two DOF manipulator	1
1.3.2.1	Lagrangian method - Forward and inverse dynamic model for two DOF manipulator	2
1.3.3	Trajectory planning	
1.3.3.1	Definitions and planning tasks	1
1.3.3.2	Joint space techniques – Motion profiles – Cubic polynomial motion	2
1.3.3.3	Cartesian space techniques	1
1.3.4	Control of manipulators	
1.3.4.1	The manipulator control problem, Linear second-order model of manipulator.	1
1.3.4.2	Functions of controller	1
1.3.4.3	Joint actuators- stepper motor, servo motor	1
1.3.4.4	Control Schemes: PID control scheme	1
1.3.4.5	Position and force control schemes.	1
2.0	**Sensors**	
	Robotic sensors and its classification.	1
2.1	Internal sensors – Position, velocity, acceleration and force information	1
2.2	External Sensors – Contact sensors-Limit switches, piezoelectric, pressure pads	1
2.2.1	Non-contact sensors - Architecture of robotic vision system, Description of components of vision system	2
3.0	**Decision Making**	
3.1	Robot Programming: Manual Programming – Teach Pendant, robot offline programming languages	1
3.1.1	Offline programming VAL programming	1
3.1.2	Online Programming	1
3.2	Expert Systems	1
3.3	Artificial Intelligence - Importance	
	Case Studies: Material Handling, Welding, Mining	2
	Total	38

Course Designers:

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2. Dr. S.Saravana Perumaal sspmech@tce.edu

14MCPH0	ELEMENTS AND PROGRAMMING OF CNC MACHINES	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

Manufacturing remains an important engine for economic growth. Efficient operation of conventional machine tools such as lathes, milling machines, drilling machine is dependent on operator skill, training and time consuming. Thus conventional machining is slow and expensive to meet the challenges of frequently changing product/part shape and size. Mechatronics has a variety of applications as products and systems in the area of manufacturing automation. Computer numerical control (CNC) machine is the best and basic example of application of Mechatronics in manufacturing automation. CNC machines are now widely used in small to large scale industries to overcome the above. With the increased automation of manufacturing processes with CNC machining, considerable improvements in consistency and quality have been achieved with no strain on the operator. CNC reduces the frequency of errors and provided the operators with more time to perform additional tasks. CNC also allows for more flexibility in the way parts are held in the manufacturing process and the time required changing the machine to produce different components.

Prerequisite

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Course Outcomes

On the successful completion of the course, students will be able to:

CO1:	Classify and distinguish NC, CNC and DNC systems	Understand
CO2:	Develop CNC machine systems and select appropriate system drives and feedback devices	Apply
CO3:	Select element for CNC measuring system and tooling	Apply
CO4:	Develop CNC Program word address format and APT part programs and test the programs through simulation	Apply
CO5:	Schedule the maintenance and testing procedure for CNC machine	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO11.	L	L	L	M	M	-	-	-	-	-	-
CO12.	M	L	S	M	S	-	-	-	-	-	-
CO13.	M	S	S	M	S	-	-	-	-	-	-
CO14.	M	M	S	M	S	-	-	-	-	-	-
CO15.	S	L	L	M	M	-	-	-	-	-	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	60	60	60	60

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the different NC and CNC control system.
2. List the important specifications of adaptive control.
3. Identify the uses of PLC.
4. Explain the functions of NC, CNC, DNC systems.
5. List the types of loads on CNC Machines.

Course Outcome 2 (CO2):

1. Illustrate adaptive control system with suitable diagram.
2. Demonstrate feedback devices in CNC system of your choice.
3. Solve the different issues on CNC machine during assembly of electrical drives.

Course Outcome 3 (CO3):

1. Execute the process of identifying the problems in ball screw assembly.
2. Sketch the ball screw and nut assembly.
3. Apply the precautions to be followed while assembly of LM guides way.
4. Execute the process of identifying the problems in Roller screw assembly

Course Outcome 4 (CO4):

1. Illustrate the concept of writing CNC program for turning and milling with suitable diagram.
2. Implement a CNC program for milling operation to machine a component of your choice and give detailed description with necessary calculation.
3. Illustrate the concept of writing APT Program.
4. Implement a CNC part program to turn a machine component as shown in the figure 1. Figure shows the dimensions of required contour. Size of raw stock is Dia. 90 x 140 mm. Both the end faces are turned. Prepare the process plan. Draw the sketch of workpiece and show the tool path. Highlight the important functions used in the CNC code.

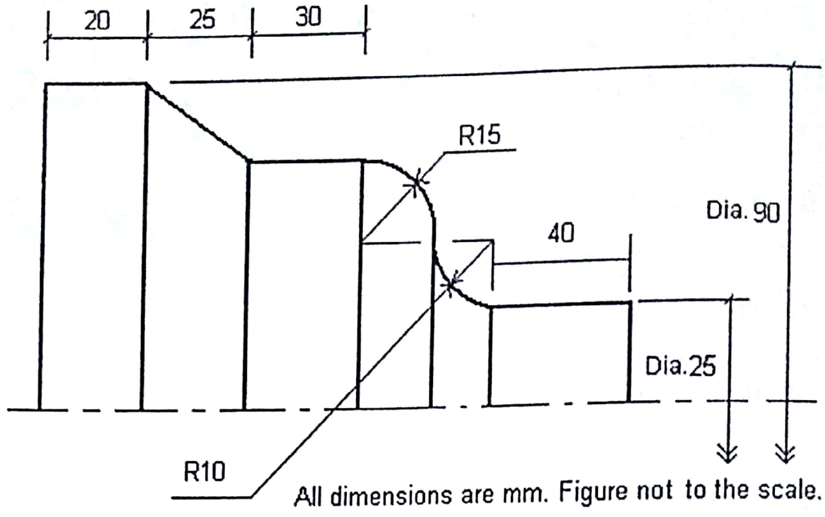


Figure 1

5. Figure 2 shows a component to be contour finished on Vertical Machining Center. Write the CNC part program. Show the tool path and explain the important preparatory functions.

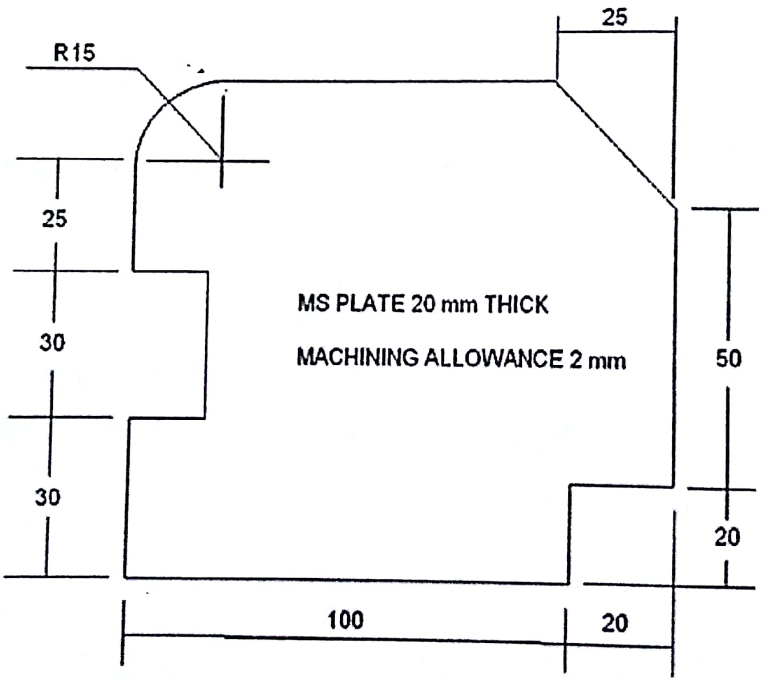


Figure 2

6. Develop an APT code for 12 mm diameter drill at centre of a MS plate of size 20 x 40 mm with 3 mm thickness.

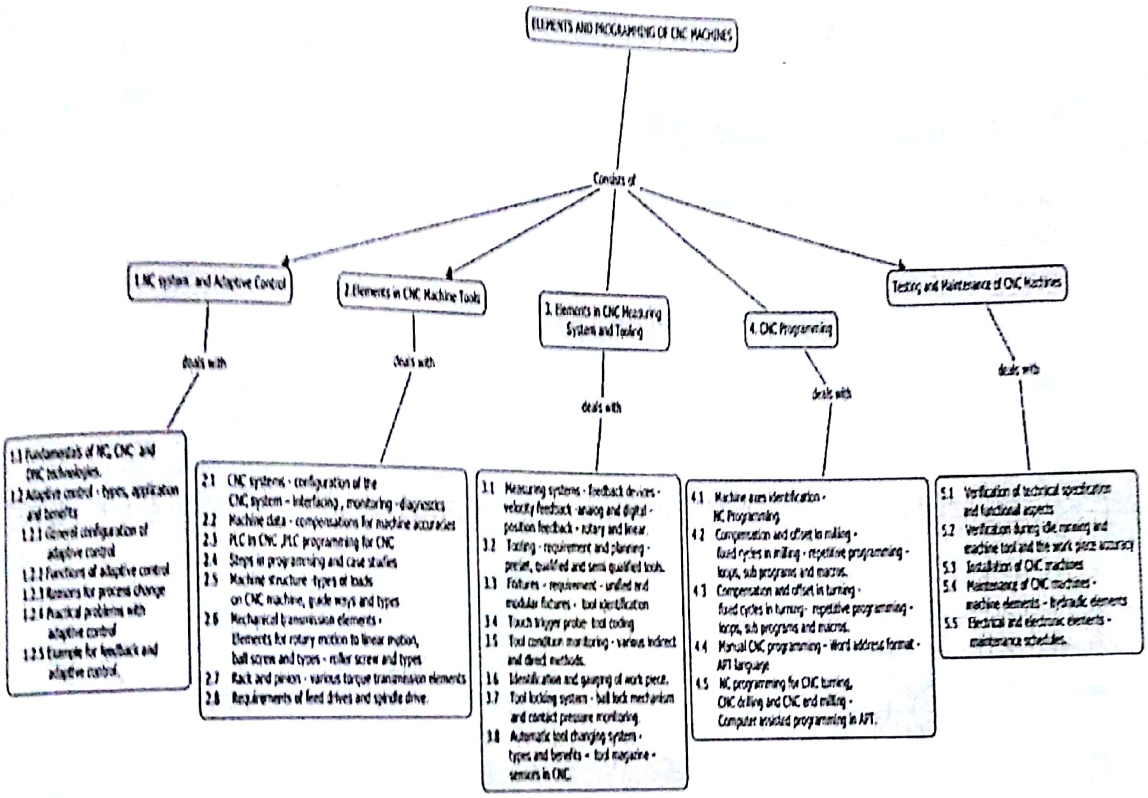
Course Outcome 5 (CO5):

1. Schedule the maintenance for a CNC machine.
2. Put into the method of verification to ensure the accuracy of the machine tool and the

work piece.

3. Illustrate the general procedure to be followed for verifying technical and functional specifications of a CNC machine.
4. Describe the different safety aspects of a CNC turning and machine centers.

Concept Map



Syllabus

Introduction of NC system and Adaptive Control: Fundamentals of NC, CNC and DNC technologies. Adaptive control - types, application and benefits - general configuration of adaptive control and function – reasons for process change - practical problems with adaptive control - example for feedback and adaptive control.

Elements in CNC Machine Tools: CNC systems - configuration of the CNC system – interfacing – monitoring –diagnostics - machine data - compensations for machine accuracies - PLC in CNC –PLC programming for CNC, steps in programming and case studies – machine structure -types of loads on CNC machine - guide ways and types – mechanical transmission elements - elements for rotary motion to linear motion - ball screw and types - roller screw and types - rack and pinion - various torque transmission elements - requirements of feed drives and spindle drive.

Elements in CNC Measuring System and Tooling: Measuring systems - feedback devices - velocity feedback - analog and digital - position feedback - rotary and linear. Tooling - requirement and planning - preset, qualified and semi qualified tools. Fixtures – requirement - unified and modular fixtures - tool identification - touch trigger probe- tool coding. Tool condition monitoring - various indirect and direct methods. Identification and gauging of work

piece. Tool locking system - ball lock mechanism and contact pressure monitoring. Automatic tool changing system - types and benefits – tool magazine –sensors in CNC.
CNC Programming: Machine axes identification - NC Programming - compensation and offset in milling -fixed cycles in milling - repetitive programming - loops, sub programs and macros. Compensation and offset in turning - fixed cycles in turning- repetitive programming - loops, sub programs and macros. manual CNC programming - Word address format - APT language - NC programming for CNC Turning center, CNC drilling and end milling - Computer assisted programming in APT.
Testing and Maintenance of CNC Machines: Verification of technical specification and functional aspects, Verification during idle running and machine tool and the work piece accuracy - Installation of CNC machines - Maintenance of CNC machines - machine elements – hydraulic elements – electrical and electronic elements – maintenance schedules.

Reference Books

1. Jonathan Lin,S.C., "Computer Numerical Control (From Programming to Networking)", Delmar Publishers Inc., 2000.
2. HMT Limited, "Mechatronics", Tata Mcgraw-Hill Publishing Co Ltd, 2002.
3. Groover,M.P., "Automation, Production System and CIM", Prentice Hall of India Pvt. Ltd, 2003.
4. Grahamt.Smith, "Advanced Machining: The Handbook of Cutting Technology", IFS Publications Ltd., 1989.
5. Sehrawatt,M.S., and Narang,J.S., "CNC Machine", Dhanpat Rai And Co, 2002
6. N. Mathivanan, "Micro processors, PC Hardware and Interfacing", Prentice Hall of India, 2003.
7. Yusuf Altintas, "Manufacturing Automation", Cambridge universal Press, 2012
8. Peter Smid, "CNC Programming Handbook", Industrial Press Inc., 2008
9. Newton C. Braga, "Mechatronics Source Book", Eswar Press, 2003.
10. Ken Evans, "Programming of CNC Machines", Industrial Press Inc., 2007
11. P N. Rao, "CAD/CAM Principles and Applications", Tata McGraw Hill, 2010.

Course Contents and Lecture Schedule

Module Number	Topic	No. of Lectures
1.0	**Introduction of NC system and Adaptive Control**	
1.1	Fundamentals of NC, CNC and DNC technologies.	1
1.2	Adaptive control - types, application and benefits	1
1.2.1	General configuration of adaptive control	1
1.2.2	Functions of adaptive control	1
1.2.3	Reasons for process change	1
1.2.4	Practical problems with adaptive control	1
1.2.5	Example for feedback and adaptive control.	1
2.0	**Elements in CNC Machine Tools**	
2.1	CNC systems - configuration of the CNC system – interfacing , monitoring –diagnostics	1
2.2	Machine data - compensations for machine accuracies	1
2.3	PLC in CNC ,PLC programming for CNC	1
2.4	Steps in programming and case studies	1
2.5	Machine structure -types of loads on CNC machine, guide ways and types	1
2.6	Mechanical transmission elements - Elements for rotary motion to	1

Module Number	Topic	No. of Lectures
	linear motion, ball screw and types - roller screw and types	
2.7	Rack and pinion - various torque transmission elements	1
2.8	Requirements of feed drives and spindle drive.	1
3.0	**Elements in CNC Measuring System and Tooling**	
3.1	Measuring systems - feedback devices - velocity feedback - analog and digital - position feedback - rotary and linear.	2
3.2	Tooling - requirement and planning - preset, qualified and semi qualified tools.	1
3.3	Fixtures – requirement - unified and modular fixtures - tool identification	1
3.4	Touch trigger probe- tool coding	1
3.5	Tool condition monitoring - various indirect and direct methods.	1
3.6	Identification and gauging of work piece.	1
3.7	Tool locking system - ball lock mechanism and contact pressure monitoring.	1
3.8	Automatic tool changing system - types and benefits – tool magazine –sensors in CNC.	1
4.0	**CNC Programming**	
4.1	Machine axes identification - NC Programming	1
4.2	Compensation and offset in milling -fixed cycles in milling - repetitive programming - loops, sub programs and macros.	2
4.3	Compensation and offset in turning - fixed cycles in turning-repetitive programming - loops, sub programs and macros.	1
4.4	Manual CNC programming - Word address format - APT language	2
4.5	NC programming for CNC turning, CNC drilling and CNC end milling - Computer assisted programming in APT.	1
5.0	**Testing and Maintenance of CNC Machines**	
5.1	Verification of technical specification and functional aspects	1
5.2	Verification during idle running and machine tool and the work piece accuracy	1
5.3	Installation of CNC machines	1
5.4	Maintenance of CNC machines - machine elements – hydraulic elements	1
5.5	Electrical and electronic elements – maintenance schedules.	1
	Total	36

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14MCPJ0	COMPUTER INTEGRATED MANUFACTURING	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

Computer Integrated Manufacturing (CIM) is a manufacturing approach using computers to control the entire production process. The integration of all elements of CIM allows individual processes to exchange information with each other and initiate actions. These activities encompass all functions necessary to translate customer needs into a final product. It includes computer aided design (CAD), computer aided manufacturing (CAM), computer aided process planning (CAPP), computer numerical control machine tools, computer integrated production management system and a business system integrated by a common data base.

Prerequisite

- NIL

Course Outcomes

On successful completion of the course, students will be able to

CO1	Develop solid models using different solid modeling approaches	Apply
CO2	Explain the concept of FMS and write an APT code for milling operation	Apply
CO3	Explain the concept of computer data communication and graphics standards	Understand
CO4	Explain the formulation of computer aided process planning	Understand
CO5	Illustrate the working of MRP and methods of factory data collection system	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	S	L	-	S	-	-	M	L	-	M
CO2	S	S	S	-	S	-	-	M	L	-	S
CO3	S	M	M	-	S	M	-	M	L	-	M
CO4	S	M	M	-	S	-	-	M	L	-	M
CO5	S	S	M	-	S	-	-	M	L	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	10
Understand	40	70	60	40
Apply	40	10	20	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

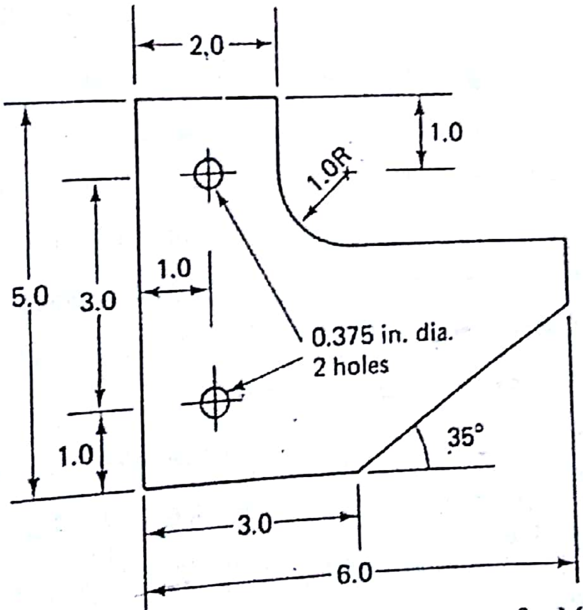
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Develop a solid model of hollow cylinder of 15 mm thickness with inner diameter of 20 mm using sweep representation technique.
2. Suggest a suitable manipulation technique for joining two different solids.
3. Illustrate the Boundary representation and CSG technique with suitable solid model and compare the complexity of the two techniques used.

Course Outcome 2 (CO2):

1. Write an APT program for milling the part as shown in the following figure.



2. Develop an APT code for 12 mm diameter drill at centre of a MS plate of size 20 x 40 mm with 3 mm thickness.
3. Describe the different layouts of flexible manufacturing system.

Course Outcome 3 (CO3):

1. Develop IGES neutral format for circle of radius 20 mm with centre (10, 5, 0) and a straight line with two ends (0, 0) and (15, 25).
2. Develop DXF neutral format for a point located at (10, 2, 8) and circle of diameter 40 mm with (0, 0, 0) as centre.
3. Explain the general procedure for framing of data along with the types of data error.

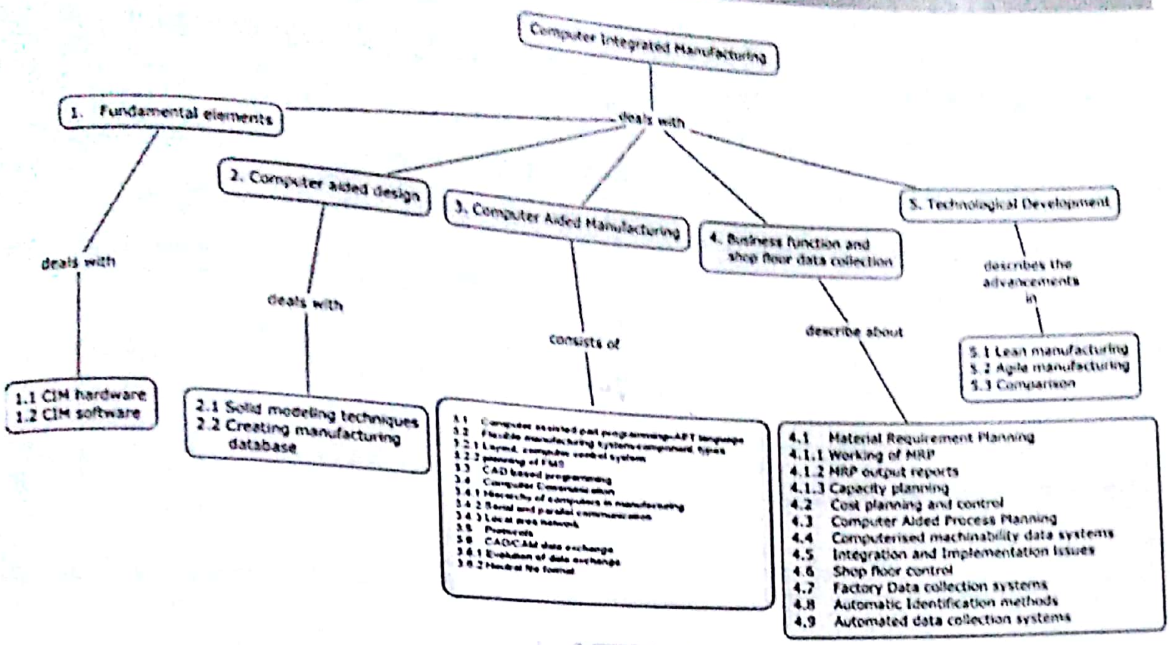
Course Outcome 4 (CO4):

1. Explain the concept of Generative type CAPP.
2. Describe about the computerised machinability data systems.
3. Discuss about the integration and implementation issues of CAPP and its advantage and limitation.

Course Outcome 5 (CO5):

1. Illustrate the principle of MRP functioning with suitable master scheduling data.
2. Suggest a suitable data collection method for mass production of oil seal and explain.
3. Discuss about any two automatic identification methods generally followed in a job shop production environment.

Concept Map



Syllabus

Fundamentals Elements: Nature of CIM, Evolution of CIM, CIM hardware and software. **Computer Aided Design:** Design process, solid modeling techniques, creating manufacturing database. **Computer Aided Manufacturing:** Elements of CNC machine tools, Computer assisted part programming–APT language, CAD based programming, Flexible manufacturing system-component, types, layout, computer control system and planning of FMS. Computer Communication: Hierarchy of computers in manufacturing, Serial and parallel communication, Local area network, Protocols: Manufacturing Automation Protocol and Technical Office Protocol, CAD/CAM data exchange-Method of data exchange, Evolution of data exchange, Neutral file format: DXF, IGES and PDES. **Business function and shop floor data collection:** Material Requirement Planning, Inputs to MRP, Working of MRP, MRP output reports, Capacity Planning, Cost planning and control, **Computer Aided Process Planning:** Retrieval type and Generative type CAPP, Benefits, Computerised machinability data systems, Integration and Implementation issues, **Shop floor control:** Functions, information flow, Factory Data collection systems, Automatic Identification methods, automated data collection systems, **Technological Development:** Agile manufacturing, Lean manufacturing, Comparison of Agile and Lean manufacturing.

Reference Books

1. Vajpayee S. Kant, "Principles of Computer Integrated Manufacturing", Prentice Hall of India Learning, 2009.
2. Ibrahim Zeid, "Mastering CAD/CAM", Tata McGraw Hill Education (P) Ltd., Special Indian Edition, 2008.
3. Mikell P.Groover, "Automation, Production Systems and Computer Integrated Manufacturing", Prentice Hall of India Learning, Third Edition, 2009.
4. Yorem Koren and Joseph Ben-Uri, "Numerical Control of Machine tools", Khanna Publishers, 1988.
5. David Bedworth, "Computer Integrated Design and Manufacturing", Tata Mc Graw Hill publishing company Ltd, 1998.
6. Sureder Kumar and A.K.Jha, "Technology of Computer Aided Design and manufacturing" Dhanpat rai and sons, Delhi, 1993.
7. P.Radhakrishnan, S.Subramanyan and V.Raju, CAD/CAM/CIM, New Age International (P) Ltd., New Delhi, 2008.

Course Contents and Lecture Schedule

S.No	Topics	No. of Lectures
1.	**Fundamentals Elements:** Nature of CIM, Evolution of CIM	2
1.1	CIM hardware	1
1.2	CIM software	
2.	**Computer Aided Design:** Design process	2
2.1	Solid modeling techniques	2
2.2	Creating manufacturing database	1
3.	**Computer Aided Manufacturing:** Elements of CNC machine tools	1
3.1	Computer assisted part programming–APT language	2
3.2	Flexible manufacturing system-component, types	2
3.2.1	Layout, computer control system	2
3.2.2	planning of FMS	1
3.3	CAD based programming	1
3.4	Computer Communication	1
3.4.1	Hierarchy of computers in manufacturing	1
3.4.2	Serial and parallel communication	2
3.4.3	Local area network	

3.5	Protocols-Manufacturing Automation Protocol Technical Office Protocol	1
3.6	CAD/CAM data exchange-Method of data exchange	2
3.6.1	Evolution of data exchange	2
3.6.2	Neutral file format-DXF IGES and PDES	
4.	**Business function and shop floor data collection**	
4.1	Material Requirement Planning-Inputs to MRP	1
4.1.1	Working of MRP	2
4.1.2	MRP output reports	2
4.1.3	Capacity Planning	
4.2	Cost planning and control	1
4.3	Computer Aided Process Planning-Retrieval type	1
	Generative type CAPP, Benefits of CAPP	1
4.4	Computerised machinability data systems	1
4.5	Integration and Implementation issues	2
4.6	Shop floor control-functions, information flow	1
4.7	Factory Data collection systems	2
4.8	Automatic Identification methods	2
4.9	Automated data collection systems	2
5.	**Technological Development**	
5.1	Agile manufacturing	1
5.2	Lean manufacturing	
5.3	Comparison of Agile and Lean manufacturing	1
	Total	46 Hours

Course Designers:

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14MCPK0	**MEDICAL ELECTRONICS AND INSTRUMENTATION**	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

Medical instruments are the application of electronics and measurement techniques to develop devices used in diagnosis and treatment of disease. The Electronics in hospital plays a vital role to serve many human being lives. The engineers interfaced with medical professions are encouraged to learn as much as possible about medical and hospital practice and in particular about the physiology about human being. It is only by gaining such an understanding that they are communicating intelligently with the members of medical professions. Some knowledge on psychology is essential for further improvement in the design and development of the medical instrumentation.

Computers are an essential part of bio medical instrumentation, where the microcomputer needed to process the large amount of information in a medical imaging system. These devices range in complexity from the simple, such as nerve stimulators, infusion pumps and electronic thermometers, to the very complex, such as CT and MRI imaging systems, cardiac cauterization suites, ICU and CCU monitoring and telemetry systems, surgical lasers, heart lung bypass machines, dialysis machines and many others. This course aims to provide knowledge on construction and working principle, recording, monitoring, controlling, data acquisition, advantages, limitations and applications of various Medical Instruments.

Prerequisite

- NIL

Course Outcomes

On successful completion of the course, students will be able to

CO 1.	Discuss the principle and operations of various medical equipments.	Understand
CO 2.	Explain various recording and monitoring process for a given bio medical instrumentation using block diagrams and flow charts.	Understand
CO 3.	Explain various measurements and controlling technique using sensors and electrodes.	Understand
CO 4.	Select a suitable method and monitoring process for given patient condition.	Apply
CO 5.	Select a suitable medical instrument, electrode, processing system for given application.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	L	-	-	-	-	-	-	-	-	-	-
CO2.	-	-	-	S	-	-	-	-	L	-	-
CO3.	-	-	-	S	-	-	-	-	M	-	-
CO4.	L	M	S	-	M	-	-	-	M	-	-
CO5.	M	S	S	-	M	-	M	-	M	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	60	50	60	60
Apply	20	30	20	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Describe different modes of Operation of cardiac pacemakers
2. Discuss the operation of combined telemetry system for ECG signal respiration rate.
3. Explain the working principle of DC defibrillator with neat sketch.

Course Outcome 2 (CO2):

1. Describe the recording method of unipolar and bipolar EEG with schematic diagram.
2. Discuss the principle behind electrochemical pH determination with neat sketch.
3. Explain the current amplifier in medical instrumentation with neat circuit diagram.

Course Outcome (CO3):

1. Discuss the different types of Surface electrodes and its applications.
2. Explain briefly the action of piezo electric transducer as pressure sensor.
3. Explain how the glucose rate in blood is measured using Gluco sensor.

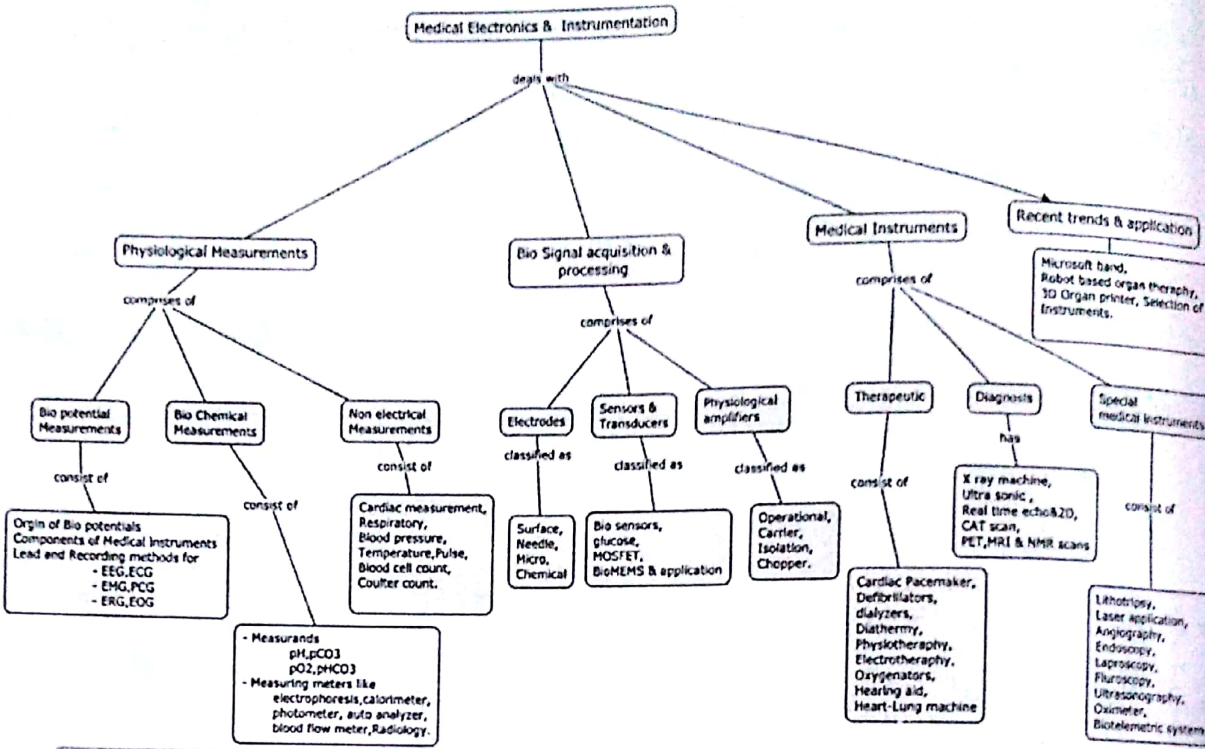
Course Outcome (CO4):

1. Suggest the suitable instrument to monitor the patient and record its biosignal for long period.
2. Suggest the suitable system that will analyze the pulmonary function in patient.
3. Select a suitable process to achieve a bloodless surgery using laser.

Course Outcome (CO5):

1. Calculate the cardiac output for given data: spirometer O2 consumption 250ml/min, arterial O2 content 0.20ml/ml, venous O2 content 0.15ml/ml.
2. Construct the instrumentation amplifier with the gain of 10 and CMRR is 10dB.
3. Select the electrode of the smallest area that has an impedance of 10Ω at 100Hz.

Concept Map



Syllabus

Introduction: Basicconceptsof Medicalelectronicsandinstrumentation–Differentsystemsin Humanbody – Terminology– Generalizedmedicalinstrumentationsystem–Measurements constrainsandClassification–Interfacingandmodifyinginputs&biostatistics. Regulationof medical devices-electrical safety inmedical environment-telemedicine.

Electro-Physiology&Biopotential measurements: Originofbiopotentials-Components of Medical instruments system – Electroencephalogram(EEG), Electrocardiogram(ECG), Electromyogram (EMG),Electroretinogram (ERG), Electro-Oculogram (EOG)lead systems and recording methods.

Biochemical&Non-ElectricalParameter measurements:pH,pC02,p02, pHCO3 and electrophoresis,calorimeter,photometer,auto analyzer,bloodflowmeter,cardiacoutput measurement, respiratorymeasurement, blood pressure measurement, temperature measurement, pulsemeasurement-Bloodcell counters:coultercounters

BiopotentialElectrodes,sensors&signalacquisition: Types : surface – micro - needle electrodes-Chemical electrodes -Biosensors - Glucose sensor – Immune sensor – MOSFET sensor – BioMEMS and its applications.Specialfeaturesofpsychologicalsignalamplifiers– OperationalAmplifier– carrieramplifier-Isolationamplifier-Chopperamplifiers.

Therapeuticequipment: CardiacPacemakers-Defibrillators– Dialyzers-Diathermy-Physiotherapyandelectrotherapyequipment- oxygenators - heartlungmachine - hearingaid.

Diagnosisequipment: X-raymachines-ultrasonicfrequencyformedicalapplication-Real timeechoand2D - CATscan - PET-MRIand NMRscan.

Special medical instruments: Lithotripsy –lasersin biomedicalfield–Angiography-diagnostic Radiology-Endoscopy–Laparoscopy –Fluoroscopy–Gasanalyzer–Oximeter– Bio telemetricsystems.

RecentTrendsandApplications: StudyofMicrosoftband,CasestudyofRobotbased organtransplantation,Application based selection of Instruments, Casestudyof3Dorganprinters.

Reference Books

1 Khandpur R.S, "**Hand Book of Biomedical Instrumentation**", Tata Mc Graw Hill publication New Delhi 2nd edition 2003

2 Leslie Cromwell, Fred J.Weibell, Erich A. Pfeiffer, "**Biomedical Instrumentation & Measurement**", Prentice Hall, India, 2ndEdn. 2003

3 Joseph J Carr and John m Brown – "**Introduction to Biomedical equipment Technology**", Pearson Education 4th edition New Delhi 2001.

4 Gillian Pocock & Christopher D.Richards, "**The Human Body**", Oxford University Press, 2009.

5 Arumugam.M, "**Bio-Medical Instrumentation**", Anuradha Agencies, 2003.

6 Rajarao.C and Guha.S.K, "**Principles of Medical Electronics and Bio-medical Instrumentation**", Universities press (India) Ltd, Orient Longman ltd, 2000

7 D. L. Wise, "**Biosensors: Theory and Applications**", CRC Press, 1993, 2001.

8 Webster.J, "**Medical Instrumentation**", John Wiley & Sons, 1995.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Basic concepts of Medical electronics and instrumentation – Different systems in Human body – Terminology – Generalized medical instrumentation system	1
1.2	Measurements constrains and Classification – Interfacing and modifying inputs & bio statistics. Regulation of medical devices-electrical safety in medical environment-telemedicine.	2
2	**Electro-Physiology & Bio potential measurements**	
2.1	Origin of bio potentials-Components of Medical instruments system	1
2.1	EEG, ECG, EMG, ERG, EOG lead systems and recording methods.	2
3	**Biochemical & Non-Electrical Parameter measurements**	
3.1	pH, pC02, p02, pHCO3 and electrophoresis	2
3.2	Calorimeter, photometer, auto analyzer, blood flow meter	2
3.3	Cardiac output measurement, respiratory measurement, blood pressure measurement	2
3.4	Temperature measurement, pulse measurement-Blood cell counters: coulter counters	2
4	**Bio potential Electrodes, sensors & signal acquisition :**	

4.1	Types :surface-micro-needle electrodes- Chemical electrodes	2
4.2	Bio sensors– Glucose sensor – Immune sensor – MOSFET sensor – BioMEMS and its applications	2
4.3	Special features of psychological signal amplifiers – Operational Amplifier –carrier amplifier- Isolation amplifier -Chopper amplifiers	2
5	**Therapeutic equipment:**	
5.1	Cardiac Pacemakers – Defibrillators	1
5.2	Dialyzers- Diathermy-Physiotherapy and electrotherapy equipment	2
5.3	Oxygenators-heart lung machine-hearing aid.	1
6	**Diagnosis equipment:**	
6.1	X-ray machines- ultrasonic frequency for medical application	2
6.2	Real time echo and 2D-CAT scan	2
6.3	PET- MRI and NMR scan.	2
7	**Special medical instruments:**	
7.1	Infant Incubators, Lithotripsy	1
7.2	lasers in biomedical field	2
7.3	Patient monitoring system	1
7.4	EEG controlled Aesthetic monitor	1
7.5	Angiography-diagnostic Radiology	1
7.6	Endoscopy – Laparoscopy	2
7.7	Radiography – Fluoroscopy	2
7.8	Blood flow meter	1
7.9	Gas analyzer – Oximeter	1
7.10	Bio telemetric systems	1
8	**Recent Trends and Application software:**	
8.1	Study of Microsoft band	1
8.2	Case study of Robot based organ transplantation	1
8.3	Case study of 3D organ printers, Selection of Instruments	1
	Total	**46 Hours**

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14MCPL0 **MATERIAL HANDLING, STORAGE AND ASSEMBLY AUTOMATION**

Category	L	T	P	Credit
PE	4	0	0	4

Preamble

The importance of material handling function is greater in those industries where the ratio of handling cost to the processing cost is large. The function of a material storage system is to store materials for a period of time and to permit access to those materials when required. Materials stored by manufacturing firms includes Raw materials, Purchased Parts, Work-in-process, Finished Product, rework and scrap, Tooling, spare parts etc. Automation is defined as the technology by which a process or procedure is accomplished without human assistance. An automated production line consists of multiple workstations that are automated and linked together by a work handling system that transfers parts from one station to another. The line includes inspection station, manual stations. An automated assembly system performs a sequence of automated assembly operations to combine multiple components into a single entity. Automatic identification and data capture (AIDC) refers to the technologies that provide entry of data into computer or other microprocessor controlled system without using a keyboard. It is being used increasingly to collect data in material handling and manufacturing applications. A flexible manufacturing system (FMS) is a manufacturing system in which there is some amount of flexibility (machine/routing) that allows the system to react in case of changes, whether predicted or unpredicted.

Prerequisite

NIL

Course Outcomes

On successful completion of the course, students will be able to

CO 1.	Select and Analyse the Material Transport Systems and Storage Systems	Analyse
CO 2.	Explain various Automatic Identification and Data capture Methods	Understand
CO 3.	Explain the Principle, configuration and applications of Automated Production Lines and Automated Assembly Systems	Understand
CO 4.	Explain the types, components and applications of and Flexible Manufacturing Systems	Understand
CO 5.	Determine line efficiency of Transfer line and Assembly Systems.	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	S	S	S	M	M	L	L	L	L	L	-	-
CO2.	L	M	L	M	L	-	-	L	L	L	M	-
CO3.	L	M	L	M	L	-	-	L	L	L	L	-
CO4.	L	M	L	M	L	-	-	L	L	M	L	-
CO5.	S	S	S	M	M	-	-	L	L	M	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	30	30	30	30
Analyse	20	20	20	20
Evaluate	--	--	--	--
Create	--	--	--	--

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compare the features of Automated Guided Vehicle system with Rail-Guided Vehicle system?
2. Compare the performance of Automated Storage /Retrieval systems with Carousel storage Systems?
3. A single carousel storage system is located in a factory making small assemblies. It is 20m long and 1.0m wide .The pick up-and –deposit time is 0.25 min. The speed at which the carousel operates is 0.5 m/s. The storage system has 90% utilization. Determine the hourly throughput rate, and compare if the storage system utilisation rate is of 80% for the same factors considered?

Course Outcome 2 (CO2):

1. Explain in detail about Automated Identification and Data Capture?
2. Discuss the various drawbacks of Automated Identification and Data Capture?
3. Explain the Principal applications of Machine Vision in Automated Inspection Tasks?

Course Outcome 3 (CO3):

1. Explain the importance and role of Automated Production Lines?
2. Vivid the applications of Automated Production Lines?
3. Enumerate the design considerations made in Automated Production lines?

Course Outcome 4 (CO4):

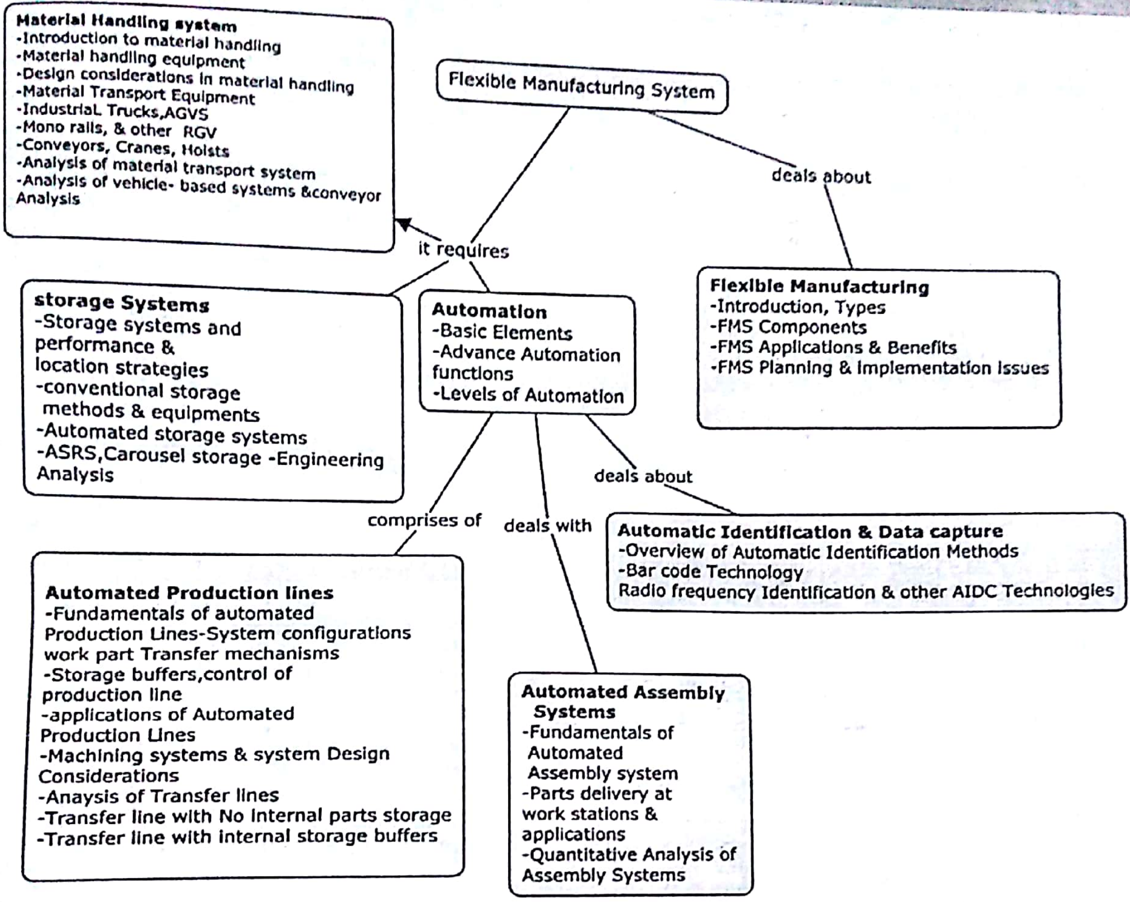
1. Explain the features of Parts classification and coding systems?
2. Explain the Basic structure of Opitz system of parts classification and coding?
3. Explain in detail about Flexible Manufacturing Systems types and its component along with applications?

Course Outcome 5 (CO5):

1. Compare the Transfer lines with No Internal Parts Storage and internal Storage Buffers.
2. A 22- station in-line transfer machine has an ideal cycle time of 0.35 min. Station break down occur with a probability of 0.01. assume that station breakdowns are the only reason for line stops. Average down time = 8.0 min per line stop. Determine a) ideal production rate b) frequency of line stops c) average actual production rate and d) line efficiency. And compare the results if the cycle time is 0.48?
3. An eight-station assembly machine has an ideal cycle time of 6 sec. The fraction defect rate at each of the eight stations q= 0.015 and a defect always jam the affected station. When a breakdown occurs, it takes 1 minute, on average, for the

system to be put back into operation. Determine the production rate for the assembly machine, the yield of good product and proportion uptime of the system.

Concept Map



Syllabus

Material Handling systems: Introduction to Material Handling - Material handling equipment, Design considerations in Material handling, Material Transport Equipment – Industrial Trucks, Automated Guided Vehicles, Monorails and other Rail-Guided Vehicles, Conveyors, Cranes and Hoists, Analysis of Material Transport Systems – Analysis of Vehicle-Based Systems and Conveyor Analysis.

Storage Systems: Storage Systems Perfomance and Location Strategies, Conventional Storage methods and equipments, Automated Storage systems - ASRS and Carousel Storage Systems, Engineering Analysis of Storage Systems - ASRS and Carousel Storage Systems.

Automation: Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automation

Automated Production Lines: Fundamentals of Automated Production Lines – System Configurations, Work part Transfer Mechanisms, Storage Buffers, Control of the Production line, Applications of Automated Production Lines – Machining Systems and System Design Considerations , Analysis of Transfer Lines – Transfer Line with No internal Parts Storage and Transfer Line with internal Storage buffers.

Automated Assembly Systems: Fundamentals of automated Assembly system, system Configurations, Parts Delivery at workstations and applications, Quantitative Analysis of Assembly Systems.

Automatic Identification & Data capture: Overview of Automatic Identification Methods, Bar code Technology, Radio Frequency Identification and other AIDC Technologies

Flexible Manufacturing Systems: Introduction, Types, FMS Components, FMS application and Benefits, FMS Planning and Implementation issues.

Reference Books

1. Mickell P.Groove, **"Automation, Production Systems and Computer-Integrated Manufacturing"**, Third Edition, Prentice Hall of India Private Limited Geoffrey 2008.
2. Boothroyd, **"Assembly Automation & Product Design"**, CRC Press, 1991.
3. Apple, James M, **"Plant Layout and Material Handling"**, John Wiley and Sons, New York, 3rd, edition, 1977.
4. Hasle Hurst, **"Manufacturing Technology"**, viva Books Publications, 1998

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Material Transport systems**	
1.1	Introduction to Material Handling - Material handling equipment	2
1.2	Design considerations in Material handling	2
1.3	Material Transport Equipment – Industrial Trucks, Automated Guided Vehicles, Monorails	2
1.4	and other Rail-Guided Vehicles, Conveyors, Cranes and Hoists	2
1.5	Analysis of Material Transport Systems – Analysis of Vehicle-Based Systems and Conveyor Analysis.	3
2	**Storage Systems**	
2.1	Storage Systems Performance and Location Strategies, Conventional Storage methods and equipments,	3
2.2	Automated Storage systems - ASRS and Carousel Storage Systems,	2
2.3	Engineering Analysis of Storage Systems - ASRS and Carousel Storage Systems.	2
3	**Automation**	
3.1	Basic Elements of an Automated System,	2
3.2	Advanced Automation Functions, Levels of Automation	2
4	**Automated Production Lines**	
4.1	Fundamentals of Automated Production Lines – System Configurations,	3

4.2	Work part Transfer Mechanisms, Storage Buffers,	2
4.3	Control of the Production line, Applications of Automated Production Lines – Machining Systems and System Design Considerations ,	3
4.4	Analysis of Transfer Lines – Transfer Line with No internal Parts Storage and Transfer Line with internal Storage buffers.	3
5	**Automated Assembly Systems**	
5.1	Fundamentals of automated Assembly systems-system Configurations,	2
5.2	Parts Delivery at workstations and applications, Quantitative Analysis of Assembly Systems.	3
6	**Automatic Identification & Data capture**	
6.1	Overview of Automatic Identification Methods, Bar code Technology	2
6.2	Radio Frequency Identification and other AIDC Technologies	2
7	**Flexible Manufacturing Systems**	
7.1	Introduction, Types, FMS Components	2
7.2	FMS application and Benefits, FMS Planning and Implementation issues	3
	Total	**47 hours**

Course Designers:

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14MCPM0	SOFT COMPUTING TECHNIQUES	Category	L	T	P	Credit
		PE	3	1	0	4

Common to 14PSP0 - Soft Computing Techniques

Preamble

The objective of this course is to introduce basic concepts and applications of soft computing tools such as neural networks, fuzzy logic systems, and genetic algorithms. Also it covers soft computing based solutions for real-world power system problems.

Prerequisite

- Prior knowledge of MATLAB software is required.
- 14PS120 Power system modelling and Analysis.

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Identify and describe soft computing techniques and their roles in building intelligent systems	Understand
CO2.	Recognize the feasibility of applying a soft computing methodology for a particular problem	Apply
CO3.	Apply fuzzy logic and reasoning to handle uncertainty and solve power system control problems	Apply
CO4.	Apply neural networks to load forecasting and modelling of power system	Apply
CO5.	Apply genetic algorithm to power system economic load dispatch(ELD) problem	Apply
CO6.	Use MATLAB Fuzzy logic, Neural network and GA toolboxes effectively to solve a given power system problem	Evaluate

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	L										
CO2.	M	S									
CO3.	S	S	S	M							
CO4.	S	S	S	M							
CO5.	S	S	S	M							
CO6.	S	S	S	S	S				M		S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3*	
Remember	10	10	0	10
Understand	10	10	0	40
Apply	30	30	20	50
Analyse	0	0	30	0
Evaluate	0	0	0	0
Create	0	0	0	0

*CAT 3 should be conducted as a practical examination for evaluating the attainment of CO6

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the role of soft computing tools in building intelligent systems.
2. Contrast between conventional logic and fuzzy logic
3. Compare the performance of conventional optimization technique and GA in solving real-world optimization problem.

Course Outcome 2 (CO2):

1. Explain where fuzzy logic can be used with a suitable example.
2. Choose the appropriate soft computing tool to solve the following problem : In a washing machine it is desired to determine wash cycle, wash time, temperature and water based on dirtyness of the clothes, type of clothes and number of clothes.
3. Select the appropriate soft computing tool for computer recognition of handwritten document

Course Outcome 3 (CO3):

1. Define fuzzification and defuzzification
2. The relationship between temperature and maximum operating frequency R depends on various factors for a given electronic circuit. Let $\tilde{T}$ be a fuzzy set (in degrees Fahrenheit) and $\tilde{F}$represent a frequency fuzzy set (in MHz) on the following universes of discourse:

$$\underset{\sim}{T} = \{-100, -50, 0, 50, 100\} \quad \text{and} \quad \underset{\sim}{F} = \{8, 16, 25, 33\}$$

$$\underset{\sim}{R} = \begin{array}{c c} & \begin{array}{ccccc} -100 & -50 & 0 & 50 & 100 \end{array} \\ \begin{array}{c} 8 \\ 16 \\ 25 \\ 33 \end{array} & \begin{bmatrix} 0.2 & 0.5 & 0.7 & 1 & 0.9 \\ 0.3 & 0.5 & 0.7 & 1 & 0.8 \\ 0.4 & 0.6 & 0.8 & 0.9 & 0.4 \\ 0.9 & 1 & 0.8 & 0.6 & 0.4 \end{bmatrix} \end{array} \qquad \underset{\sim}{S} = \begin{array}{c c} & \begin{array}{ccccc} 1 & 2 & 4 & 8 & 16 \end{array} \\ \begin{array}{c} -100 \\ -50 \\ 0 \\ 50 \\ 100 \end{array} & \begin{bmatrix} 1 & 0.8 & 0.6 & 0.3 & 0.1 \\ 0.7 & 1 & 0.7 & 0.5 & 0.4 \\ 0.5 & 0.6 & 1 & 0.8 & 0.8 \\ 0.3 & 0.4 & 0.6 & 1 & 0.9 \\ 0.9 & 0.3 & 0.5 & 0.7 & 1 \end{bmatrix} \end{array}$$

Suppose a Cartesian product between $\tilde{T}$ and $\tilde{F}$ is formed that results in the following relation$\tilde{R}$ The reliability of the electronic circuit is related to the maximum operating temperature. Such a relation $\tilde{S}$ can be expressed as a Cartesian product between the reliability index, $\tilde{M}$ = {1, 2, 4, 8, 16} (in dimensionless units), and the temperature: Find a relationship between frequency and the reliability index, use (a) max–min composition (b) max–product composition.

3. Design a fuzzy logic based power system stabilizer (FPSS) with the generator speed deviation and its derivative, the acceleration, as the inputs and output of the controller as output gain. Take input range as [-1.2 to 1.2] and output as [-0.1 to 0.1]. Convert each input variables into seven linguistic variables of symmetrical and 50% overlap. Represent output as constant. Write all the 49 rules with the use of sample rules shown in Table 6.

Table 6. Sample fuzzy rules for FPSS

	NB	NM	NS	Z	PS	PM	PB
NB				NM			
NM				NM			
NS				NS			
Z				Z			
PS				PS			
PM				PM			
PB				PM			

Course Outcome 4 (CO4):

1. Describe BPN architecture with a neat sketch and explain the steps involved in the training of the network
2. Develop a suitable perceptron neural network model to perform the following classification problem. The vectors (1,1,1,1) and (-1,1,-1,-1) for belonging to the class (target value 1) vectors (1,1,1,-1) and (1,-1,-1,1) for not belonging to the class (target value -1).
3. Develop a BPN architecture for the following short-term load forecasting problem A 12 hour load pattern on a particular day is given below and predict the remaining 12 hour load on that day

Hour	1	2	3	4	5	6	7	8	9	10	11	1
Load (MW)	11178	10695	12097	12161	12210	12260	12215	10427	11405	12488	12527	12

Course Outcome 5 (CO5):

1. List the various operators used in GA
2. Perform two generations of simple binary coded genetic algorithm to solve the following optimization problem. Maximize $f(x) = x^2$ $0 \le x \le 31$, x is an integer. Use proportionate selection, single point crossover, binary mutation and population size of six.
3. Solve the given ELD problem using GA for one generation. Three generators are having the following cost functions and power limits:

Fuel Cost($/h)	Minimum (MW)	Maximum (MW)
$F_1(P_1) = 0.0020P_1^2 + 8.72P_1 + 180$	45	350
$F_2(P_2) = 0.0082P_2^2 + 6.40P_2 + 743$	45	350
$F_3(P_3) = 0.0022P_3^2 + 6.75P_3 + 360$	47.5	450

Total load in the system is 500 MW. Assume that each of the three units is running all the time.

Course Outcome 6 (CO6):

(For evaluating the attainment of CO6 , practical examination should be conducted)

1. Evaluate the performance of the fuzzy logic controller over PI controller for the given power system problem
2. Evaluate the performance of the Perceptron neural network for the given power system problem

   The system data for a load flow solution are given in following tables 1 and 2

Table 1 Line admittance
s

BUS Code	Admittance (p.u)
1-2	2-j8
1-3	1-j4
2-3	0.666-j2.664
2-4	1-j4
3-4	2-j8

Table 2 schedule of active and reactive powers

Bus code	P in p.u	Q in p.u	V in p.u	Remarks
1	-	-	1.06	Slack
2	0.5	0.2	1+j0	PQ
3	0.4	0.3	1+j0	PQ
4	0.3	0.1	1+J0	PQ

Determine the voltages at the end of first iteration using Gauss Seidal method. Take α=1.6. Train the neural network for the load pattern suitably and obtain the load voltages

3. Evaluate the performance of the GA for solving the given power system economic dispatch problem as compared to the gradient methods. Three generators are having the following cost functions and power limits:

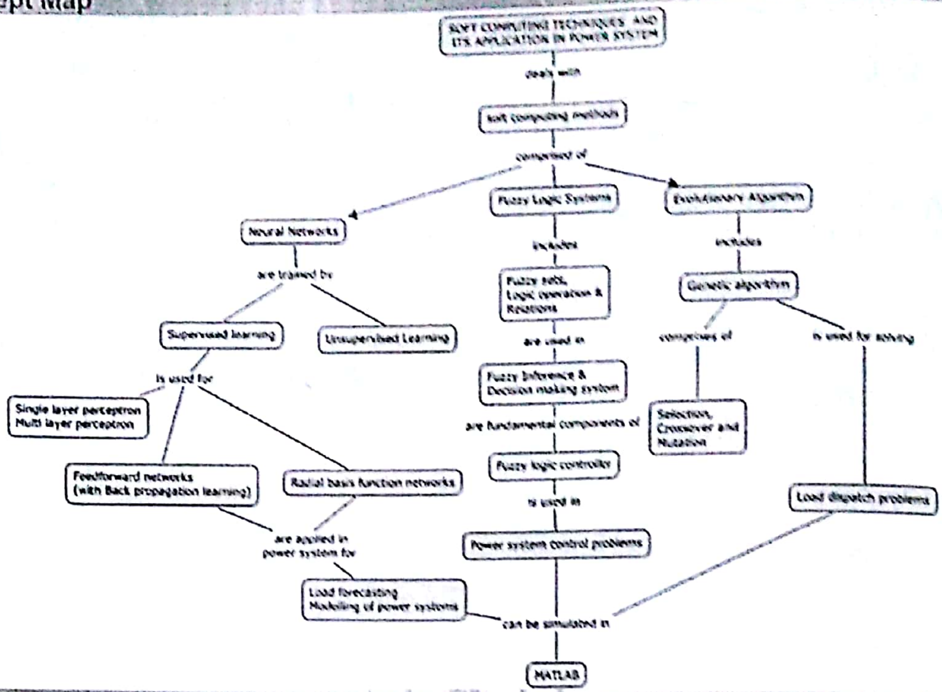
Fuel Cost($/h)	Minimum (MW)	Maximum (MW)
$F_1(P_1) = 0.00525P_1^2 + 8.66P_1 + 328$	50	250
$F_2(P_2) = 0.00608P_2^2 + 10.04P_2 + 137$	5	150
$F_3(P_3) = 0.00591P_3^2 + 9.76P_3 + 59$	15	100

The B-coefficients are given by,

$$B=\begin{bmatrix} 1.36255\,x10^{-4} & 1.753x10^{-5} & 1.8394x10^{-4} \\ 1.753\,x10^{-5} & 1.5448\,x10^{-4} & 2.82765\,x10^{-4} \\ 1.8394\,x10^{-4} & 2.82765\,x10^{-4} & 1.6147\,x10^{-3} \end{bmatrix}$$

Neglect B_0 and B_{00}. The total load in the system is 190 MW. Assume that each of the three units is running all the time.

Concept Map



Syllabus

Introduction to soft computing and its role in building intelligent systems-Need of soft computing tools-Merits and demerits-Fuzzy logic, Neural network, and Genetic algorithms

Fuzzy sets, logic operations, and relations; Fuzzy decision-making; fuzzy inference systems; design steps in fuzzy logic controller; application of fuzzy logic controller in power system

Neural networks: Basic concepts and major classes of neural networks, supervised and unsupervised learning, Single-layer perceptron, Multi-layer perceptron, Back Propagation Neural network, Radial-basis function networks; Application of neural network to load forecasting and modelling of power system

Introduction to genetic algorithms; genetic algorithm steps-Selection, Crossover and Mutation; Application of GA to power system economic dispatch problem

Use of MATLAB Fuzzy logic, Neural network and GA toolboxes to solve power system problems.

Reference Books

1. George J.Klir and, Bo Yuan, **Fuzzy sets and Fuzzy Logic**, Second Edition, PHI,2006
2. J.M.Zurada, **Introduction to artificial neural systems**, Jaico Publishing House, 2006
3. D.E. Goldberg, **Genetic algorithms in search, optimization, and machine learning, Addison**-Wesley.1989.
4. S.N.Sivanandam, and S.N.Deepa, **Principles of Soft computing**, Second Edition, Wiley India Pvt. Ltd,2013

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	Introduction to soft computing and its role in building intelligent systems	1
2	Need of soft computing tools	1
3	Merits and demerits	1
4	Basics of Fuzzy logic, Neural network, and Genetic algorithms	3
5	Fuzzy sets, logic operations, and relations	2
6	Fuzzy decision-making	1
7	fuzzy inference systems	1
8	design steps in fuzzy logic controller;	1
	89	
9	application of fuzzy logic controller in power system	2
10	Neural networks: Basic concepts and major classes of neural networks,	2
11	supervised and unsupervised learning,	1
12	Single-layer perceptron, Multi-layer perceptron	2
13	Back Propagation Neural network,	2
14	Radial-basis function networks	1
15	Application of neural network to load forecasting and modelling of power system	2
16	Introduction to genetic algorithms;	1
17	genetic algorithm steps-Selection,Crossover and Mutation;	2
18	Application of GA to power system economic dispatch problem	2
19	Use of MATLAB Fuzzy logic, Neural network and GA toolboxes to solve power system problems	8
	Total	**36**

Course Designers:

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		Category	L	T	P	Credit
14MCPN0	ROBUST CONTROL	PE	3	1	0	4

Common to 14CIPG0 – Robust Control

Preamble

Robust control deals with system analysis and control design for such imperfectly known process models. One of the main goals of feedback control is to maintain overall stability and system performance despite uncertainties in the plant. One of the most useful qualities of a properly designed feedback control system is robustness, i.e., the ability of the closed-loop system to continue performing satisfactorily despite large variations in the (open-loop) plant dynamics. This course will provide an introduction to the analysis and design of robust feedback control systems. The course enables the control engineer to be pioneered in designing control system. It also gives an attempt to thoroughly analyze the system for performance & stability and design robust controller for various applications.

Prerequisite

1. Ordinary differential Equations
2. Laplace Transforms
3. Linear Control System Analysis
4. System Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain various types of uncertainties	Understand
CO2	Explain various measures of robustness	Understand
CO3	Develop robust controllers for a given unconstrained uncertain system using LQG, H2 & H Infinity, Mu analysis and synthesis	Apply
CO4	Develop robust controller for a given constrained uncertain system	Apply
CO5	Demonstrate the effect of robust controllers in the closed loop performance using simulation tools	Apply, Precision

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L									
CO2	M	L									
CO3	S	M	L								L
CO4	S	M	L								L
CO5	S	M	L		M						L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	60	20	20	20
Apply	20	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

(CO5 may be evaluated through assignments /case studies)

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define robustness in stability.
2. List the types of uncertainties that affect the closed loop system.
3. Illustrate the role of LFT mapping in controller synthesis

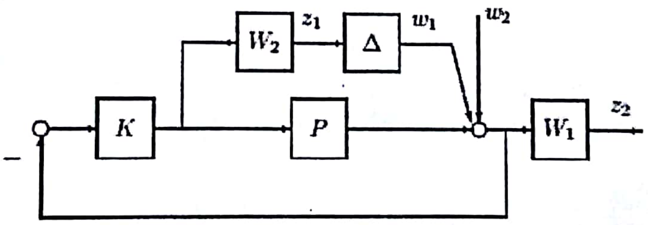
Course Outcome 2(CO2):

1. Draw and explain H2 energy space.
2. Draw and explain H∞ energy space.
3. Explain the role of root locus in performance and stability analysis

Course Outcome 3(CO3):

1. Outline various robust control methods for parametric families.
2. Interpret between the loop shaping design procedure and LQG control scheme.
3. Consider the system shown below. Design a controller K such that

$$P = \frac{0.5(1-s)}{(s+2)(s+0.5)}, \quad W_1 = 50\frac{s/1.245+1}{s/0.007+1}, \quad W_2 = 0.1256\frac{s/0.502+1}{s/2+1}.$$



a. $\underset{K \ stabilizing}{Infinity} \|M\|_\infty$

b. $\underset{K \ stabilizing}{Infinity} \ \underset{\omega}{\sup} \mu_\Delta(M), \qquad \Delta = \begin{bmatrix} \Delta_1 & \\ & \Delta_2 \end{bmatrix}$

Course Outcome 4(CO4):

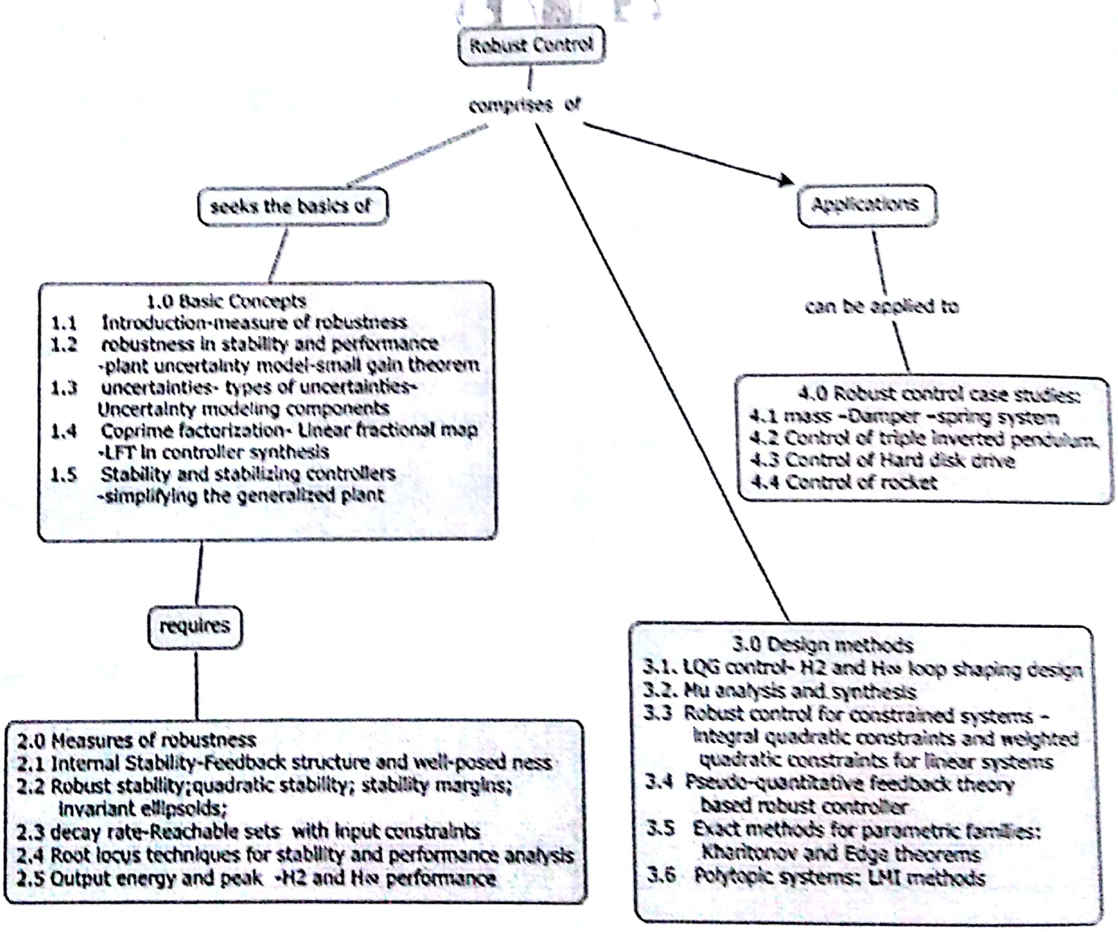
1. Explain edge theorem
2. Consider the system in state space representation shown below. Find the state feedback control law that robustly stabilizes the closed loop system

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ a_0 & a_1 & a_2 & a_3 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

Where, $a_0 \in [0, 1.5]$, $a_1 \in [-1.5, 2]$, $a_2 \in [0, 1]$, $a_3 \in [1, 2]$

3. Consider the plant G(s) with controller C(s).
   a. Choose controller parameters $\{a^0, b^0, c^0\}$ such that closed loop system has its characteristic roots at $-1 \pm j1$ & -10
   b. Now for $a \in \left[a^0 - \frac{\varepsilon}{2}, a^0 + \frac{\varepsilon}{2}\right]$, $b \in \left[b^0 - \frac{\varepsilon}{2}, b^0 + \frac{\varepsilon}{2}\right]$, $c \in \left[c^0 - \frac{\varepsilon}{2}, c^0 + \frac{\varepsilon}{2}\right]$, calculate maximum value of ε that robustly maintains the closed loop stability.
   c. Find the root set of the system when the parameters range over box with sides $\frac{\varepsilon_{max}}{2}$

Concept Map



Syllabus

Basic Concepts
Introduction-measure of robustness –robustness in stability and performance-plant uncertainty model-small gain theorem- uncertainties- types of uncertainties-Uncertainty modelling components- Co-prime factorization- Linear fractional map- Stability and stabilizing controllers -LFT in controller synthesis –simplifying the generalized plant.

Measures of robustness
Internal Stability- Feedback structure and well-posedness - Robust stability; quadratic stability; stability margins; invariant ellipsoids; decay rate-Reachable sets with input constraints-Output energy and peak -H_2 and H_∞ performance.

Various approaches of robust control design
LQG control- H_2 and H_∞ loop shaping design-Mu analysis and synthesis. Robust control for constrained systems –integral quadratic constraints and weighted quadratic constraints for linear systems. Pseudo-quantitative feedback theory based robust controller- Exact methods for parametric families: Kharitonov and Edge theorems -Polytopic systems: LMI methods

Applications using MATLAB
Robust control case studies: mass-Damper-spring system, control of triple inverted pendulum, control of Hard disk drive, control of rocket.

Reference Books

1. Min Wu, Yong He, Jin-Hua She, **Stability Analysis and Robust Control of Time-Delay Systems**, Springer Press Beijing-2010.
2. Sigurd Skogestad, Ian Postlethwaite, **Multivariable Feedback Control: Analysis and Design,** Wiley-Interscience.2005.
3. Kemin Zhou, John C. Doyle, **Essentials Of Robust Control**, Published September, Prentice Hall 1998- ISBN 0-13-525833-2
4. Gu, Da-Wei, Petkov, Petko Hr., Konstantinov, Mihail M, ***Robust Control Design with MATLAB*** Springer-Verlag 2005.
5. S.P.Bhattacharyya, H.Chapellat and L.H.Keel, **Robust Control (The Parametric approach)**, Prentice Hall, New Jersy, 1995.
6. J.Ackerman, **Robust control systems with uncertain physical parameters**, Springer –Verlag, London, 1993.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Basic Concepts**	
1.1	Introduction-measure of robustness	1
1.2	robustness in stability and performance-plant uncertainty model-small gain theorem	2
1.3	uncertainties- types of uncertainties-Uncertainty modeling components	3
1.4	Co-prime factorization- Linear fractional map -LFT in controller	3

	synthesis	
1.5	Stability and stabilizing controllers -simplifying the generalized plant	3
2.0	**Measures of robustness**	
2.1	Internal Stability- Feedback structure and well-posedness	2
2.2	Robust stability; quadratic stability; stability margins; invariant ellipsoids;	3
2.3	Decay rate-Reachable sets with input constraints	2
2.4	Root locus techniques for stability and performance analysis	3
2.5	Output energy and peak -H2 and H∞ performance	2
3.0	**Various approaches of robust control design**	
3.1.	LQG control- H2 and H∞ loop shaping design	3
3.2.	Mu analysis and synthesis	2
3.3	Robust control for constrained systems –integral quadratic constraints and weighted quadratic constraints for linear systems	4
3.4	Pseudo-quantitative feedback theory based robust controller	2
3.5	Exact methods for parametric families: Kharitonov and Edge theorems	2
3.6	Polytopic systems: LMI methods	2
4.	**Applications using MATLAB**	
4.1	Robust control case studies: mass –Damper –spring system	2
4.2	Control of triple inverted pendulum.	1
4.3	Control of Hard disk drive	1
4.4	Control of rocket	2
	Total	**45**

Course Designers:

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14MCPQ0	CONTROL OF ELECTRIC DRIVES	Category	L	T	P	Credit
		PE	3	1	0	4

Common to 14PSPQ0/14CIPA0 – Control of Electric Drives

Preamble

Electrical drives play an important role as electromechanical energy converters in transportation, material handling and most production processes. The ease of controlling electrical drives is an important aspect for meeting the increasing demands by the user with respect to flexibility and precision, needed by technological progress in industry as well as the need for energy conservation. A drive may require a control of torque, acceleration, speed or Position. The field of controlled electrical drives has undergone a rapid expansion mainly due to the advances of semiconductors in the form of power electronics as well as analogue and digital signal electronics. The introduction of electronically switched solid-state power converters has created new and difficult control problems to the electric drives.

Prerequisite

- DC Machines and transformers
- AC Machines
- Electric Drives & control

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	know the operations of different types of DC, AC motors and special machines	Understand
CO2.	Explain the different speed control and braking methods of motors	Understand
CO3.	Find out the torque and speed for different loading conditions	Apply
CO4.	Explain the different converters operation with motor loads	Understand
CO5.	Explain the different digital control methods for the DC, AC motors and special machines	Understand

Mapping with Programme Outcomes

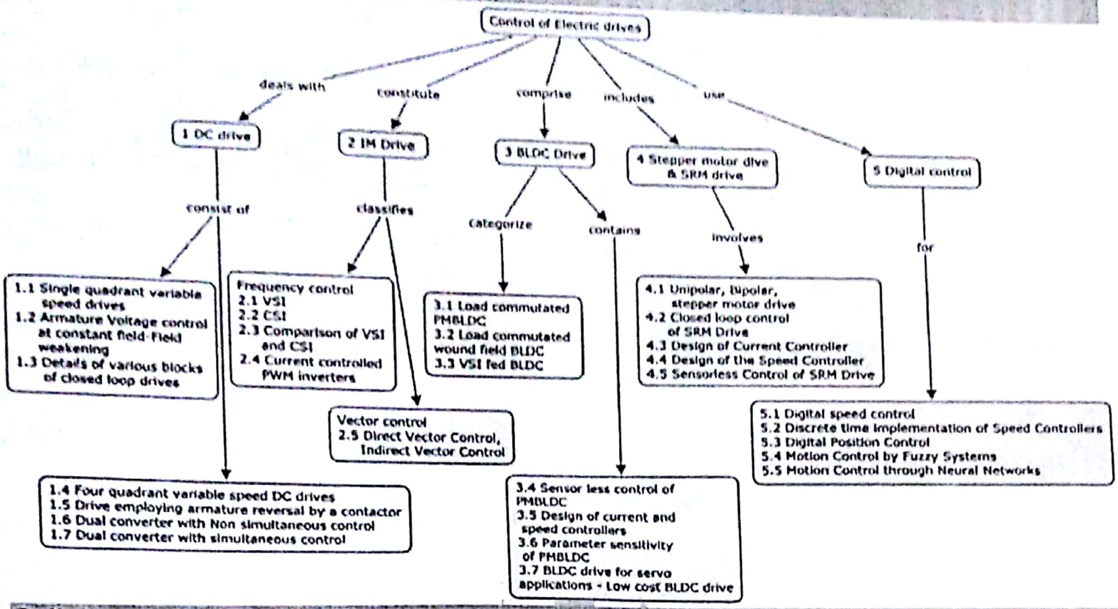
COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M									
CO2.	S										
CO3.	M		S	S							
CO4.	S										
CO5.	S	M			M						

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	30	30
Understand	40	40	40	40
Apply	30	30	30	30
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Concept Map



Syllabus

CONTROL OF DC DRIVES

Single quadrant variable speed drives-Armature Voltage control at constant field- Field weakening- Details of various blocks of closed-loop drives - Four quadrant variable speed DC drives- Drive employing armature reversal by a contactor, Drive employing a Dual converter with Non simultaneous control, Drive employing a Dual converter with simultaneous control.

CONTROL OF INDUCTION MOTOR DRIVES

Voltage Source Inverter fed Variable frequency drives - Current Source Inverter fed Variable frequency drives – Comparison of Voltage source and Current source inverter drives-Closed loop variable frequency drive using Current controlled PWM inverters - Vector controlled Induction Motor drives- Direct Vector Control, Indirect Vector Control.

CONTROL OF BLDC DRIVES

Load commutated Permanent Magnet brushless dc motor drive- Load commutated wound field brushless dc motor drive - Voltage source inverter fed BLDC motor drive- Sensor less control of PMBLDC drive- Design of current and speed controllers - Parameter sensitivity of PMBLDC drive – BLDC drive for servo applications - Low cost BLDC drive.

STEPPER MOTOR DRIVE AND SRM DRIVE

Stepper Motor Drive- Unipolar drive, Bipolar drive - Control of SRM Drive - Closed-Loop, Speed Controlled SRM Drive - Design of Current Controller - Design of the Speed Controller- Sensorless Control of SRM Drive.

DIGITAL CONTROL OF DRIVES

Digital Speed Control- Discrete time implementation of Speed Controllers- Digital Position Control- Motion Control by Fuzzy Systems- Motion Control through Neural Networks.

Reference Books

1. G.K. Dubey, '**Power Semiconductor Controlled Drives**', Prentice Hall, N. Jersey, 1989.
2. R.Krishnan, '**Electric Motor Drives**', PHI Learning Pvt. Ltd., 2001.
3. G.K. Dubey, '**Fundamentals of Electrical Drives**', Narosa Publishing House, Second Edition, 2001.
4. Slobodan N. Vukosavic, '**Digital Control of Electrical Drives**', Springer, 2007.
5. Ion Boldea, Syed A. Nasar, '**Electric Drives**', Second Edition, CRC Press, 1999
6. R. Krishnan '**Switched Reluctance Motor drives**', CRC Press , 2001.
7. Jacek F Gieras , '**Permanent Magnet Motor Technology Design and Applications**', Third Edition, CRC Press, 2010.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**CONTROL OF DC DRIVES**	
1.1	Single quadrant variable speed drives	2
1.2	Armature Voltage control at constant field-Field weakening	2
1.3	Details of various blocks of closed-loop drives	2
1.4	Four quadrant variable speed DC drives	1
1.5	Drive employing armature reversal by a contactor	1
1.6	Drive employing a Dual converter with Non simultaneous control	1
1.7	Drive employing a Dual converter with simultaneous control	1
2	**CONTROL OF INDUCTION MOTOR DRIVES**	
2.1	Voltage Source Inverter fed Variable frequency drives	1
2.2	Current Source Inverter fed Variable frequency drives	1
2.3	Comparison of Voltage source and Current source inverter drives	1
2.4	Closed loop variable frequency drive using Current controlled PWM inverters	2
2.5	Vector controlled Induction Motor drives- Direct Vector Control, Indirect Vector Control	2
3	**CONTROL OF BLDC DRIVES**	
3.1	Load commutated Permanent Magnet brushless dc motor drive	1
3.2	Load commutated wound field brushless dc motor drive	1
3.3	Voltage source inverter fed BLDC motor drive	1
3.4	Sensor less control of PMBLDC drive	2
3.5	Design of current and speed controllers	1
3.6	Parameter sensitivity of PMBLDC drive	1

3.7	BLDC drive for servo applications - Low cost BLDC drive	2
4	STEPPER MOTOR DRIVE AND SRM DRIVE	
4.1	Stepper Motor Drive- Unipolar drive, Bipolar drive	2
4.2	Control of SRM Drive - Closed-Loop, Speed Controlled SRM Drive	2
4.3	Design of Current Controller	1
4.4	Design of the Speed Controller	1
4.5	Sensorless Control of SRM Drive	1
5	DIGITAL CONTROL OF DRIVES	
5.1	Digital Speed Control	1
5.2	Discrete time implementation of Speed Controllers	1
5.3	Digital Position Control	1
5.4	Motion Control by Fuzzy Systems	2
5.5	Motion Control through Neural Networks	2
	Total	**40 Hours**

Course Designer:

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