CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Mechatronics) PROGRAMME

FIRST to FOURTH SEMESTERS

FOR THE STUDENTS ADMITTED FROM THE
ACADEMIC YEAR 2017-2018 ONWARDS

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

MADURAI – 625 015, TAMILNADU
Phone: 0452 – 2482240, 41
Fax: 0452 2483427
Web: www.tce.edu

Approved in BOS Meeting on 29.04.17 Approved in Academic Council Meeting on 17.06.17

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

M.E MECHATRONICS PROGRAMME

Vision:

"Be a globally renowned school of engineering in Mechanical Sciences"

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
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 Mechatronics
M.E. DEGREE (Mechatronics) PROGRAMME
Scheduling of Courses

Sem.	Theory Courses						Practical/ Project
1st (24)	**17MC110** Linear Algebra (4 credits)	**17MC120** Principles of Mechanical Systems /**17MC180** Principles of Electronics Systems (3 credits)	**17MC130** Sensors and Actuators (4 credits)	**17MC140** Mechatronics System Design (4 credits)	**17MC150** Automotive Mechatronics (4 credits)	**17MC160** Digital Control System (4 credits)	**17MC170** Automation Lab (1 credit)
2nd (24)	**17MC210** Robotics-Concepts and Analysis (4 credits)	**17MC220** Real Time Embedded System (4 credits)	**17MCPX0** Elective -I (3 credits)	**17MCPX0** Elective -II (4 credits)	**17MCPX0** Elective – III (4 credits)	**17MCPX0** Elective - IV (4 credits)	**17MC270** Sensors and Micro controller Lab (1 credit)
3rd (16)	**17MC310** MEMS (4 credits)	**17MCPX0** Elective -V (4 credits)	**17MCPX0** Elective -VI (4 credits)	---	---	---	**17MC 340** Project I (4 credits)
4th (12)	---	---	---	---	---	---	**17MC410** 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

SUBJECTS OF STUDY

(For the candidates admitted from 2017-2018 onwards)

FIRST SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week L	T	P	credits
THEORY						
17MC110	Linear Algebra	DC	3	1	-	4
17MC120	Principles of Mechanical Systems	DC	3	0	-	3
17MC180	Principles of Electronic Systems					
17MC130	Sensors and Actuators	DC	4	0	-	4
17MC140	Mechatronics System Design	DC	4	0	-	4
17MC150	Automotive Mechatronics	DC	4	0	-	4
17MC160	Digital Control System	DC	4	0	-	4
PRACTICAL						
17MC170	Automation Lab	DC	-	-	2	1
Total			**22**	**1**	**2**	**24**

BS : Basic Science

DC : Department Core

DE : Departmental Elective

L : Lecture

T : Tutorial

P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 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 2017-2018 onwards)

FIRST SEMESTER

S.No	Sub. Code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	17MC110	Linear Algebra	3	50	50	100	25	50
2	17MC120 17MC180	Principles of Mechanical Systems / Principles of Electronics Systems.	3	50	50	100	25	50
3	17MC130	Sensors and Actuators	3	50	50	100	25	50
4	17MC140	Mechatronics System Design	3	50	50	100	25	50
5	17MC150	Automotive Mechatrnics	3	50	50	100	25	50
6	17MC160	Digital Control System	3	50	50	100	25	50
PRACTICAL								
7	17MC170	Automation Lab	3	50	50	100	25	50

* CA evaluation pattern will differ from subject to subject and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

** 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

SUBJECTS OF STUDY

(For the candidates admitted from 2017-2018 onwards)

SECOND SEMESTER

Subject code	Name of the subject	Category	No. of Hours / Week			credits
			L	T	P	
THEORY						
17MC210	Robotics Concepts and Analysis	DC	4	0	-	4
17MC220	Real time Embedded system	DC	4	0	-	4
17MCPX0	Elective I	DC	3	0	-	3
17MCPX0	Elective II	DC	4	0	-	4
17MCPX0	Elective III	DE	4	0	-	4
17MCPX0	Elective IV	DE	4	0	-	4
PRACTICAL						
17MC270	Sensors and Micro Controller Laboratory	DC	-	-	2	1
Total						**24**

BS : Basic Science
DC : Department Core
DE : Departmental Elective

L : Lecture
T : Tutorial
P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 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 2017-2018 onwards)

SECOND SEMESTER

S.No	Sub. code	Name of the subject	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam **	Max. Marks	Terminal Exam	Total
THEORY								
1	17MC210	Robotics Concepts and Analysis	3	50	50	100	25	50
2	17MC220	Real time Embedded system	3	50	50	100	25	50
3	17MCPX0	Elective I	3	50	50	100	25	50
4	17MCPX0	Elective II	3	50	50	100	25	50
5	17MCPX0	Elective III	3	50	50	100	25	50
6	17MCPX0	Elective IV	3	50	50	100	25	50
PRACTICAL								
7	17MC270	Sensors and Micro Controller Laboratory	3	50	50	100	25	50

* CA evaluation pattern will differ from subject to subject and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

** 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

SUBJECTS OF STUDY

(For the candidates admitted from 2017-2018 onwards)

THIRD SEMESTER

Course Code	Name of the Course	Category	No. of Hours / Week			Credits
			L	T	P	
THEORY						
17MC310	MEMS	PC	4	0	0	4
17MCPX0	Elective III	PE	4	0	0	4
17MCPX0	Elective IV	PE	4	0	0	4
PRACTICAL						
17MC340	Project I	PC	0	0	8	4
Total			**12**	**0**	**8**	**16**

PC : Program Core

PE : Program Elective

L : Lecture

T : Tutorial

P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 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 2017-2018 onwards)

THIRD SEMESTER

S.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	17MC310	MEMS	3	50	50	100	25	50
2	17MCPX0	Elective III	3	50	50	100	25	50
3	17MCPX0	Elective IV	3	50	50	100	25	50
PRACTICAL								
4	17MC340	Project I	3	50	50	100	25	50

* CA evaluation pattern will differ from subject to subject and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

** 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

SUBJECTS OF STUDY

(For the candidates admitted from 2017-2018 onwards)

FOURTH SEMESTER

Course Code	Name of the Course	Category	No. of Hours / Week			credits
			L	T	P	
PRACTICAL						
17MC410	Project II	PC	0	0	24	12
Total						**12**

BS : Basic Science

PC : Program Core

PE : Program Elective

L : Lecture

T : Tutorial

P : Practical

Note:

1 Hour Lecture/Tutorial is equivalent to 1 credit

2/3 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 2017-2018 onwards)

FOURTH SEMESTER

S.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
PRACTICAL								
1	17MC410	Project II	3	50	50	100	25	50

* CA evaluation pattern will differ from subject to subject and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

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

PROGRAM ELECTIVES						
Course code	**Name of the Course**	**Category**	L	T	P	Credits
17MCPA0	Additive Manufacturing	PE	4	0	0	4
17MCPB0	Internet of Things	PE	4	0	0	4
17MCPC0	Professional Practice	PE	4	0	0	4
17MCPD0	Thermal Packaging of Electronics	PE	4	0	0	4
17MCPE0	CNC Technology	PE	4	0	0	4
17MCPF0	Autonomous Mobile Robots	PE	4	0	0	4
17MCPH0	Modeling and Simulation of Mechatronics Systems	PE	4	0	0	4
17MCPJ0	Intelligent Motion Control Drives	PE	4	0	0	4

		Category	L	T	P	Credit
17MC110	**LINEAR ALGEBRA**	DC	3	1	-	4

Preamble

Mathematicians define Linear Algebra as a branch of mathematics that deals with the study of vectors, vector spaces and linear equations. Modern mathematics also relies upon linear transformations and systems of vector matrix. A PG Mechatronics student needs some basic linear algebra to understand design methodology. It is possible to consider the analysis of rotations in space, selected curve fitting techniques, differential equation solutions, as well as many other problems in science and engineering using techniques of linear algebra. Analytic geometry utilizes the techniques learned during a study of linear algebra, for analytically computing complex geometrical shapes. The main objective of this course is to introduce the basic terminology used in Linear Algebra. Based on this, the course aims at giving adequate exposure in vector spaces, orthogonality, linear transformation, generalized eigen values and vectors, Singular value decomposition and QR algorithm.

Prerequisite

Eigen values, Eigen vectors and types of matrices

Course Outcomes

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

CO1	Verify whether the given set is a vector space or not. If So, determine its dimension.	Apply
CO2	Determine the matrix for the given linear transformation	Understand
CO3	Predict ortho normal basis	Apply
CO4	Perform diagonalization of a given matrix	Apply
CO5	Compute Pseudo inverse for the given matrix and Construct a QR decomposition for the given matrix	Apply
C06	Solve the given system of linear differential equations	Apply

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**S**	**M**	**S**	**S**	**S**	**L**	**L**	**L**	**L**	**L**	**L**
CO2	**S**	**M**	**S**	**S**	**S**	**L**	**L**	**L**	**L**	**L**	**L**
CO3	**S**	**M**	**S**	**S**	**S**	**L**	**L**	**L**	**L**	**L**	**L**
CO4	**S**	**S**	**S**	**S**	**S**	**S**	**-**	**-**	**-**	**-**	**-**
CO5	**S**	**S**	**S**	**S**	**S**	**S**	**-**	**-**	**-**	**-**	**-**
C06	**S**	**S**	**S**	**S**	**S**	**S**	**-**	**-**	**-**	**-**	**-**

S- Strong; M-Medium; L-Low

Assessment Pattern

	Bloom's category	Continuous Assessment Tests			End Semester Examinations
		1	2	3	
1	Remember	10	10	0	0
2	Understand	30	30	30	30
3	Apply	60	60	70	70
4	Analyze	0	0	0	0
5	Evaluate	0	0	0	0
6	Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Let x,y,z be vectors in a vector space V. If $x+y=x+z$, then prove that y = z
2. Prove that $R \times R$ is a vector space over R.
3. Estimate the row space and column space of the matrix $A=\begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\end{pmatrix}$
4. Estimate the dimension of the row space of the matrix $A=\begin{pmatrix}1 & -2 & 3\\ 2 & -5 & 1\\ 1 & -4 & -7\end{pmatrix}$
5. Compute the dimension of the subspace of R^4 spanned by

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

Course Outcome 2 (CO2):

1. Let L: $R^2 \rightarrow R$ be defined by $L(x_1, x_2)^T = \sqrt{x_1^2 + x_2^2}$. Determine whether L is a linear operator or not.

2. Let L: $R^3 \rightarrow R^3$ be defined by $L(x_1, x_2, x_3)^T = (x_1, x_1+x_2, x_1+x_2+x_3)^T$. Check whether L is a linear operator or not. If so, find the corresponding matrix A such that L(x) = Ax

3. Prove that Ker L is a subspace.

4. Let $L: R^3 \rightarrow R^3$ be defined by $L(x_1, x_2, x_3)^T = (2x_1 - x_2 - x_3, 2x_2 - x_1 - x_3, 2x_3 - x_1 - x_2)^T$ Discuss whether or not L is a linear transformation. If so, find the corresponding matrix A such that L(x)=Ax

5. Let $L: R^2 \rightarrow R^2$ be defined by $L(x_1, x_2)^T = (x_1, -x_2)$. Prove that L is a linear transformation.

Course Outcome3 (CO3):

1. Consider the vector space $C[-1, 1]$ with inner product defined by

$< f, g >= \int_{-1}^{1} f(x)g(x)dx$ Calculate orthonormal basis for subspace spanned by $\{ 1, x, x^2 \}$

2. Show that $\left\{ \frac{(1,1,1)^T}{\sqrt{3}}, \frac{(2,1,-3)^T}{\sqrt{14}}, \frac{(4,-5,1)^T}{\sqrt{42}} \right\}$ is an orthonormal set in R^3
3. Estimate the best quadratic least square fit to the data

x	0	3	6
y	1	4	5

4. Given the basis $\{(1,1,1)^T, (1,2,2)^T, (1,1,0)^T\}$ for R^3, construct an orthonormal basis for R^3.
5. Solve the following system of equations in the least –square sense:
   $x_3 + 2x_4 = 1; x_1 + 2x_2 + 2x_3 + 3x_4 = 2.$

Course Outcome 4 (CO4):

1. Diagonaize the matrix $\begin{bmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{bmatrix}$
2. Identify the following matrix are in Jordan canonical form or not,
   where $A = \begin{bmatrix} 3 & 1 & 0 & 0 & 0 \\ 0 & 3 & 1 & 0 & 0 \\ 0 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 4 & 1 \\ 0 & 0 & 0 & 1 & 4 \end{bmatrix}$.
3. Compute the chain that is generated by the generalized eigen vector of rank 3 for the matrix $A = \begin{pmatrix} 7 & 1 & 2 \\ 0 & 7 & 1 \\ 0 & 0 & 7 \end{pmatrix}$
4. Diagonalise the matrix $\begin{pmatrix} 6 & -2 & 2 \\ -2 & 3 & -1 \\ 2 & -1 & 3 \end{pmatrix}$
5. Diagonalise the matrix $A = \begin{pmatrix} 3 & -1 & -2 \\ 2 & 0 & -2 \\ 2 & -1 & -1 \end{pmatrix}$

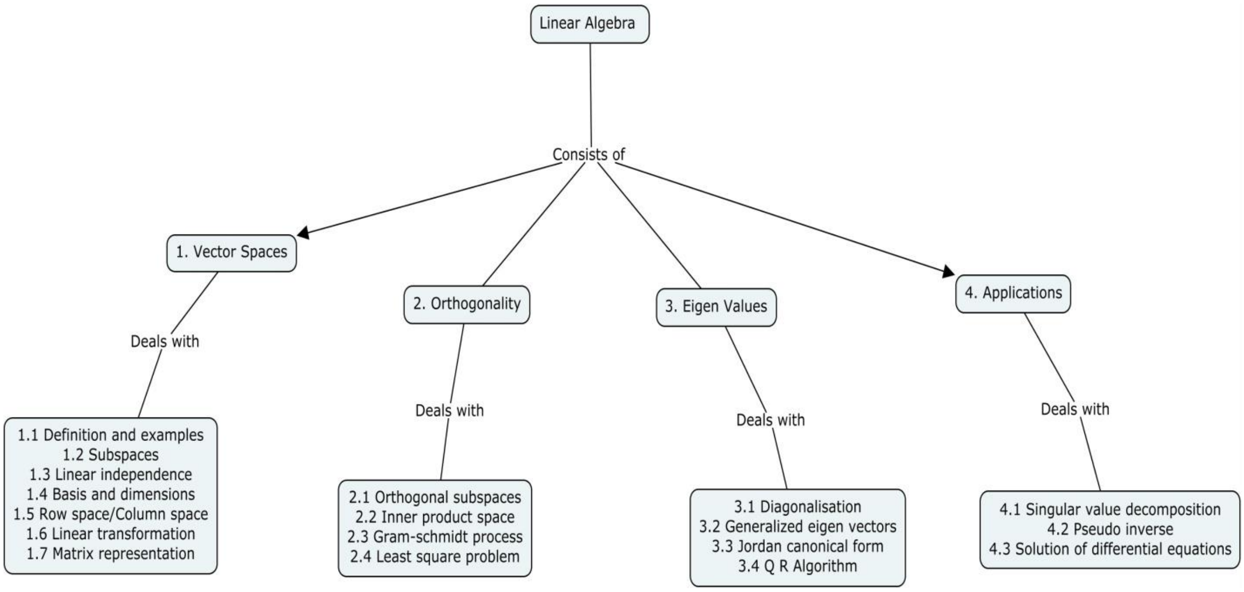
Course Outcome 5 (CO5):

1. Obtain singular value decomposition for the matrix A = $\begin{pmatrix} 1 & 1 \\ 1 & 1 \\ 0 & 0 \end{pmatrix}$ and hence find its pseudo inverse
2. Compute a singular value decomposition for the matrix $\begin{bmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{bmatrix}$
3. Obtain pseudo inverse for the matrix $\begin{pmatrix} 1 & 3 \\ 3 & 1 \\ 0 & 0 \\ 0 & 0 \end{pmatrix}$
4. Construct a QR decomposition for the matrix $\begin{bmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{bmatrix}$

Course Outcome 6(CO6):

1. Solve the system $y_1^{1} = 3y_1 + 4y_2$ and $y_2^{1} = 3y_1 + 3y_2$
2. Solve the initial value problem $y_1^{1} = y_1 - 2y_2$ and $y_2^{1} = 2y_1 + y_2$, $y_1(0)=1$, $y_2(0) = -2$
3. Solve the system $y_1^{1} = -y_1 + 2y_2$ and $y_2^{1} = 2y_1 - y_2$

Concept Map



Syllabus

Vector space and Linear Transformations: Definition and examples, Subspaces, the null space, linear independence, basis and dimension.: Linear transformation, Matrix representation of linear transformation. **Orthogonality:** Orthogonal subspaces, Inner Product spaces, orthogonal bases and Gram Schmidt process, Least square approximations. **Eigen values:** Diagonalization, Generalized Eigen vectors, Jordan Canonical form, QR algorithm. **Applications:** Singular value decomposition and Pseudo inverse, Solving Differential equations, MATLAB- simple problems.

Reference Books

1. Steven J. Leon, "Linear Algebra with Applications", Macmillan publishing company, New York, 1990.
2. Gilbert Strang, "Introduction to Linear Algebra", Third edition, Wellesley, Cambridge Press,2003
3. Seymour Lipschutz , "Theory and Problems of Linear Algebra, Schaum's Outline Series", McGraw Hill, New York, II Edition, 1991
4. David C.Lay , "Linear Algebra and its Applications"Fourth Edition, Addison-Wesley, 2012

Course Contents and Lecture Schedule

Sl No	Topics	No. of Periods
	Vector Spaces and Linear Transformations	
1.1	Vector spaces: axioms; properties examples of vector spaces	3
1.2	Sub-spaces: Null space of matrix examples	2
1.3	Linear combinations; span of a set properties; Examples, Linear independence and dependence-definition	2
1.4	Basis and dimension; properties; examples	2
1.5	The row and column space	2
1.6	Linear transformation: Image and kernel properties; Examples	2
1.7	Matrix representation of linear transformation	1
	Tutorial	1
	Orthogonality	
2.1	Orthogonal subspaces	2
2.2	Inner product space, normed linear space; orthogonal complements-properties	2
2.3	Orthogonal bases: Gram Schmidt orthonormalisation process	3
2.4	Least square approximations.	3
	Tutorial	1

	Eigen values	
3.1	Diagonalisation of matrices	2
3.2	Generalized Eigen vectors	2
3.3	Jordan Canonical form	2
3.4	QR algorithm.	2
	Tutorial	1
	Applications	
4.1	Singular value decomposition	2
4.2	Pseudo inverse	2
4.3	Solving Differential equations	4
	Tutorial	1
	MATLAB (Digital image processing)	4
	TOTAL HOURS	48

Course Designers:

1. Dr.G.Jothilakshmi gjlmat@tce.edu
2. Dr.A.P.Pushpalatha appmat@tce.edu

		Category	L	T	P	Credit
17MC120	**PRINCIPLES OF MECHANICAL SYSTEMS**	DC	3	-	-	3

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.

Course Outcomes

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

CO1	Select suitable mechanism for a given environment.	Apply
CO2	Explain the different types of transmission system.	Understand
CO3	Determine the frequency of free, forced and damped vibrations of machine parts	Apply
CO4	Design the shafts, screws and gears for mechanical systems	Apply
CO5	Explain the working principle of machine tools	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

	Bloom's category	Continuous Assessment Tests			End Semester Examinations
		1	2	3	
1	Remember	20	20	20	20
2	Understand	30	30	30	30
3	Apply	50	50	50	50
4	Analyze	0	0	0	0
5	Evaluate	0	0	0	0
6	Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What do you mean by Vibration Isolation and Transmissibility?
2. What is torsionally equivalent shaft?
3. An engine mechanism is shown in Fig. 1. The crank CB = 100 mm and the connecting rod BA = 300 mm with centre 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.

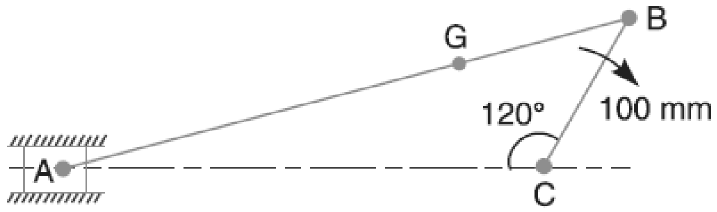


Figure 1

4. 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.

Course Outcome 2 (CO2):

1. Differentiate between machine and structure with examples.
2. Define coefficient of friction and angle of repose.

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.

Course Outcome 2 (CO3):

1. What are the advantages of using clutches in automobiles?
2. Identify the suitable kinematic chains to which the following mechanism belongs to: Elliptical trammel and pantograph
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 diameter. 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.

Course Outcome 2 (CO4):

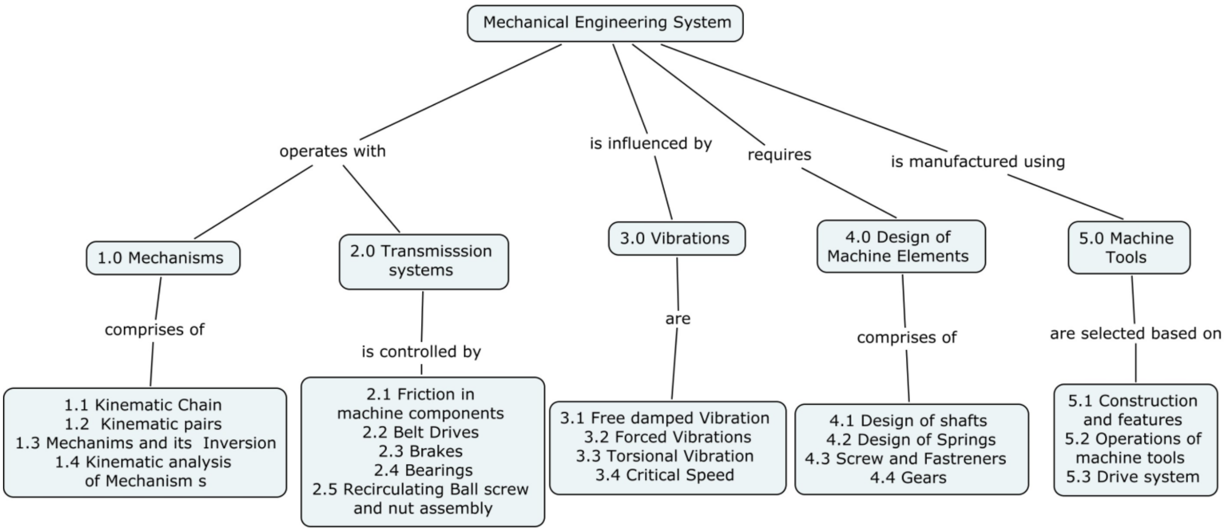
1. A shaft has a number of collars integral with it. The external diameter of the collars is 400 mm and the shaft diameter is 250 mm. If the uniform intensity of pressure is 0.35 N/mm^2 and its coefficient of friction is 0.05, estimate: 1. power absorbed in overcoming friction when the shaft runs at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

Course Outcome 2 (CO5):

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.

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 Kinametic 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
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

No.	Topic	No. of Lectures
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**	
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

No.	Topic	No. of Lectures
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 Kinametic 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

17MC180	PRINCIPLES OF ELECTRONIC SYSTEMS	Category	L	T	P	Credit
		DC	3	-	-	3

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.

Course Outcomes

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

CO1	Explain the working and applications of all Analog and Digital electronic devices.	understand
CO2	Design the analog and Digital electronic circuits.	Apply
CO3	Design the logic circuits.	Apply
CO4	Explain the concept of modulation and demodulation techniques.	understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

	Bloom's category	**Continuous Assessment Tests**			**End Semester Examinations**
		1	**2**	**3**	
1	Remember	20	20	20	20
2	Understand	50	30	30	50
3	Apply	30	50	50	30
4	Analyze	0	0	0	0
5	Evaluate	0	0	0	0
6	Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

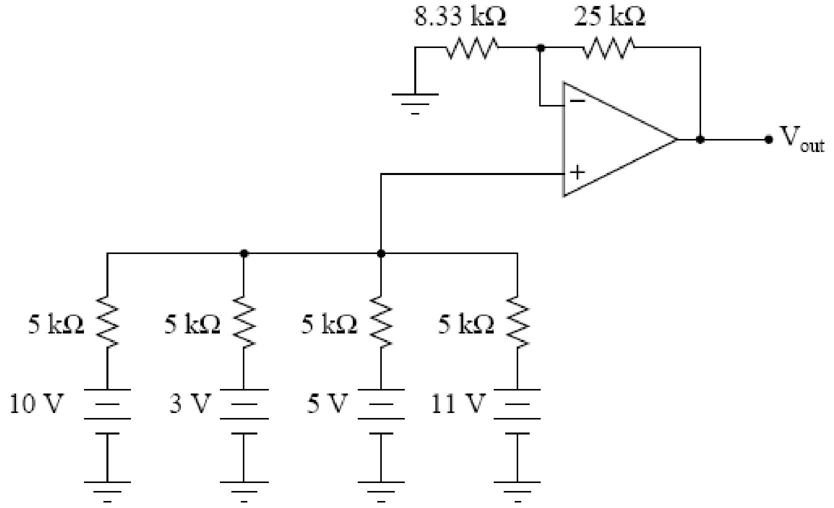
1. Define the static and dynamic resistance of a diode.
2. Give the applications of Zener diode.
3. What are the advantages of IC over discrete component circuits?
4. What is a scale changer?

Course Outcome 2 (CO2):

1. Define the reverse recovery time of a diode.
2. Define off-set current and virtual ground in an op-amp.
3. Mention the different types of DAC.
4. Explain the working of an instrumentation amplifier with neat sketch.

Course Outcome 3 (CO3):

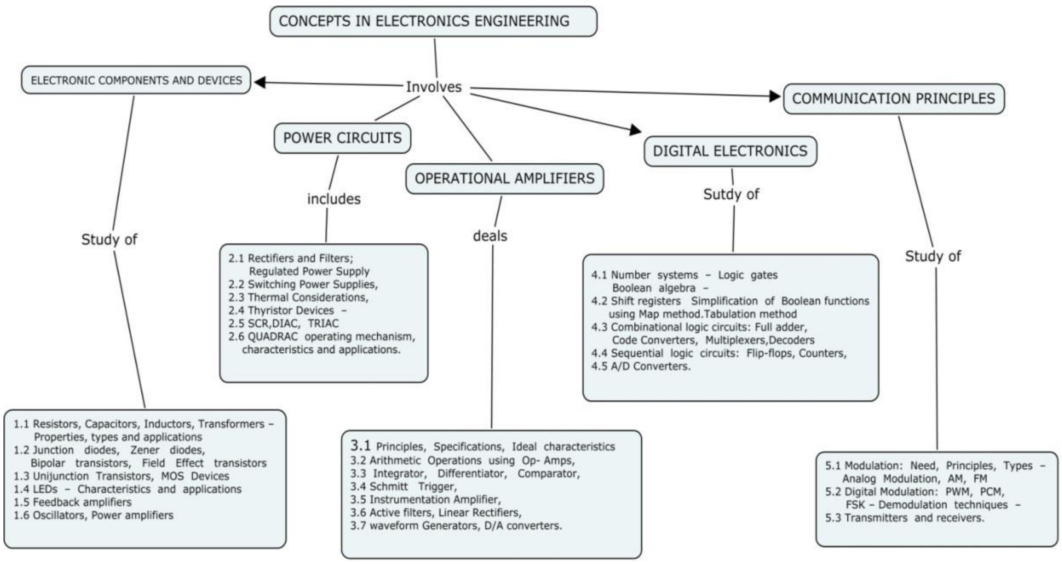
1. With neat sketch explain the 3 input inverting summing amplifier.
2. Design a synchronous decade counter
3. Design a 3 input Multiplexer
4. Discuss the operation of a transmitter and receiver circuit.
5. Determine the output voltage of the circuit shown below.



Course Outcome 4 (CO4):

1. Explain the concept of modulation techniques.
2. Explain the concept of demodulation techniques.

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, "**Micro electronics 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

17MC130	SENSORS AND ACTUATORS	Category	L	T	P	Credit
		DC	4	0	0	4

Preamble

This course provides engineering students with basic understanding of two of the main components of any modern electrical or electromechanical system; sensors as inputs and actuators as outputs. The covered topics include error and uncertainty analysis, also performance specification of sensors: position, speed, stress, strain, temperature, vibration, acceleration, pressure, flow, exhaust gas sensors, engine knock sensors, torque, vision based sensors and GPS sensors. Actuators: Solenoids and relays, electric motors, DC motors, stepper motors, Hydraulic Valves, Hydraulic actuators, Pneumatic actuators. Introduction to interfacing methods: bridge circuits, A/D and D/A converters, microcontrollers. This course is useful for those students interested in control engineering, robotics and systems engineering.

Prerequisite

Nil

Course Outcomes

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

CO 1	Comprehend the static characteristics, standards, errors and uncertainty of measuring instruments	Understand
CO 2	Design suitable signal conditioning circuits for custom application	Apply
CO 3	Select/Design the suitable sensor for following applications: Force, Temperature, Vibration, Proximity, Photonic, Level and special sensors.	Apply
CO 4	Choose appropriate actuators such as solenoids and relays, DC motors, stepper motors, Hydraulic Valves, Hydraulic actuators, Pneumatic actuators for the specified applications	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	L		S	L			S		S
CO2.	S	S	S	M	S	M					S
CO3.	L	M	S	M	M	M	L		M		S
CO4.		L	S	M		M	L		M		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	40	40	40	40
Apply	40	40	40	40
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define international standard for length.
2. Define 'precision and 'accuracy'.
3. Define Resolution.
4. A voltmeter is used to measure the electrical output signal from a pressure transducer. The nominal pressure is expected to be about 3 psi (3 lb/in.2¼0.2 bar). Estimate the design-stage uncertainty in this combination. The following information is available:
1. **Voltmeter**
2. Resolution: 10 mV; Accuracy: within 0.001% of reading
3. **Transducer**
4. Range: ±5 psi (~±0.35 bar); Sensitivity: 1 V/psi; Input power: 10 VDC ±1%; Output: ±5 V
5. Linearity error: within 2.5 mV/psi over range; Sensitivity error: within 2 mV/psi over range
6. Resolution: negligible
7.

Course Outcome 2(CO2):

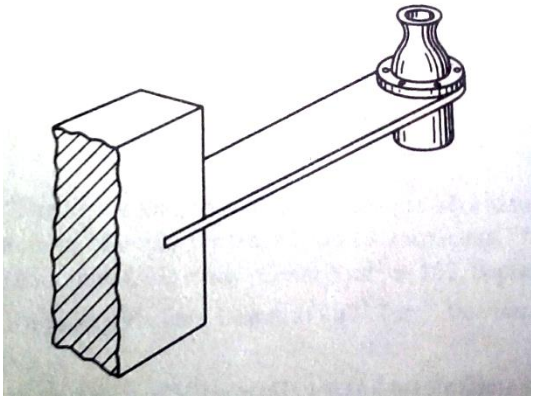
1. The four arms of a wheat stone bridge are as follows: AB=100Ω, BC=1000Ω, CD=4000Ω and DA=400Ω. The galvanometer has a resistance of 100Ω, a sensitivity of 100mm/μA and is connected across AC. A source of 4 V d.c is connected across BD. Calculate the current through the galvanometer and its deflection if the resistance of arm DA is changed from 400Ω to 401Ω.
2. Explain the working of charge amplifier.
3. Brief the construction and working of instrumentation amplifier.
4. Construct 4-bit ADC and DAC.

Course Outcome 3 (CO3):

8. Explain construction, working, merits and demerits of ultrasonic type flow meters.
9. Explain Hall Effect displacement sensor with neat diagram.
10. Discuss the semiconductor's gauge factor.
11. Explain the temperature compensation in strain gauges.
12. A thermometer is initially at room temperature of 23 deg C. it is immersed in an oil bath at 151˚ C. After 3 seconds it shows a reading of 95 deg c. find its time constant. After what time from the start will be thermometer read 150˚ C.
13. Design a strain-gauge thrust transducer for small experimental rocket engines which are roughly in shape of a cylinder 6 inch in diameter by 12 inch long. The following information is given:

i. Weight of motor and mounting bracket, 20lbf.

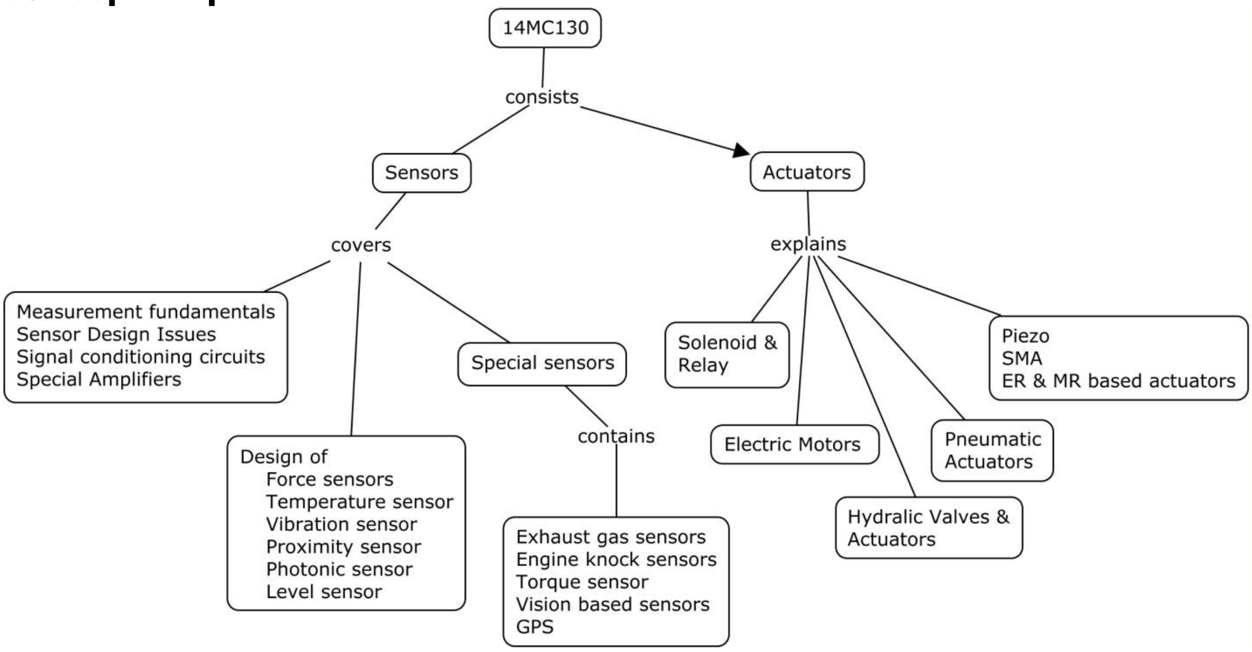
ii. Maximum steady thrust, 50 lbf.
iii. Oscillating component of thrust, ± 10 lbf maximum.
iv. Oscillating components of thrust up to 100 Hz must be measured with a flat amplitude ratio within ±5 %.
v. A recorder with the sensitivity of 0.1V/in, frequency response flat to 120 Hz and input resistance of 10,000 Ω is available.
vi. Thrust changes of 0.5 lbf must be clearly detected.
vii. Gauges with a resistance of 120 Ω and gauge factor of 2.1 are available. They are 0.5×0.1 inch in size.
viii. An amplifier (to be placed between transducer and recorder) is available with a gain up to 1,000.
ix. Design the transducer as so to require a minimum of amplifier gain. If damping is employed, calculated the required damping coefficient B, but do not design the damper. Use the cantilever-beam arrangement below.

14. 

Course Outcome 4 (CO4):

1. Find the specifications for a pneumatic valve capable of handling 100 psi, and draw a schematic showing how you would interface it to a digital system.
2. If a machine requires that a 1 cm inner diameter single-acting hydraulic cylinder produce 2000 N of force, what is the minimum required system pressure in MPa?
3. For each of the following applications, what is a good choice for the type of electric motor used? Justify your choice.
   a. robot arm joint
   b. ceiling fan
   c. electric trolley
   d. circular saw
4. A solenoid can be modeled as an inductor in series with a resistor. Design a circuit to use a digital output to control a 24 V solenoid.

Concept Map



Syllabus

*(*Design case studies are intended to give expertise to students about selection of sensors from available catalog and able to solve practical difficulties in interfacing)*

Measurement: System of units, conversion factors, significant figures, error analysis, probability and statics, Uncertainty analysis

Signal conditioning: resistance bridges, impedance bridges, resonant circuits, op-amps, **Special Amplifiers:** Charge amplifiers, instrumentation amplifier, shielding and grounding, filters, A/D and D/A converters, microcontroller interfacing.

Application of sensors and Actuators: Exhaust gas sensors, engine knock sensors, torque sensor, vision based sensors, GPS, solenoids and relays, electric motors, DC motors, stepper motors, Hydraulic Valves, Hydraulic actuators, Pneumatic actuators, piezo, SMA, ER & MR based actuators.

Force sensors design: Types of force sensors, selection of sensors, signal conditioning, interfacing circuit, Design of force sensors: Determine the stress situation near a pressure vessel nozzle, Determine power transmission through the shaft

Temperature sensor design: types of temperature sensors, selection of sensors, signal conditioning, interfacing circuit, Design of temperature sensors: temperature measurement inside the boiler, design of sensor for quality automatic welding systems, room temperature measurement.

Vibration sensor design: types of vibration sensors, selection of sensors, signal conditioning, interfacing circuit, Design of vibration sensors: Building vibration measurement, beam vibration measurement, modeling of piezo electric accelerometer.

Proximity sensor design: types of proximity sensors, selection of sensors, signal conditioning, interfacing circuit, Design of proximity sensor: obstacle detection, Speed measurement of shaft.

Photonic sensor design: types of photonic sensors, selection of sensors, signal conditioning, interfacing circuit, Design of photonic sensor: optical encoder for speed measurement.

Level sensor design: types of level sensors, selection of sensors, signal conditioning, interfacing circuit, Design of level sensor: water level in boiler, storage level of solid particles.

Reference Books

1. David G.Alciatore *et. al*.,**"Introduction to Mechatronics and Measurement systems",** fourth edition, McGraw-Hill, 2012.
2. Richard S.Figliola et.al.,**"Theory and Design for Mechanical Measurements",** Fifth edition John Wiley & Sons, Inc, 2011.
3. Walt Boyes,**"Instrumentation Reference Book**", Fourth Edition, Elsevier Inc., 2010.
4. John P.Bentley,**"Principles of Measurement Systems"**, Fourth Edition, Prentice Hall, 2004.
5. Ernest O.Dobline et. al.,**"Measurement systems"**, Sixth Edition, McGraw Hill Education, 2011.
6. Gregory K. McMillan, Douglas M.Considine, **"Process/Industrial Instruments and controls Handbook"**, Fifth edition, McGraw Hill, 1999.
7. Sabrie Solomon, "**Sensors and control systems in manufacturing**", McGraw Hill international Editions, 1994.
8. Singh S.K., "**Industrial Instrumentation and Control**", Tata McGraw Hill Edition, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Measurement**	
1.1	System of units, conversion factors, significant figures	1
1.2	Error analysis, probability and statics	1
1.3	Uncertainty analysis	1
2	**Signal conditioning**	
2.1	Resistance bridges, Impedance bridges	1
2.2	Resonant circuits, op-amps	1
2.3	Special Amplifiers: Charge amplifiers, instrumentation amplifier	1
2.4	Shielding and grounding	1
2.5	Filters, A/D and D/A converters	1
2.6	Microcontroller interfacing	1
3	**Application of sensors and Actuators**	
3.1	Exhaust gas sensors, engine knock sensors, torque sensor	1
3.2	Vision based sensors, GPS	1
3.3	Solenoids and relays, electric motors	1
3.4	DC motors, stepper motors	1
3.5	Hydraulic Valves, Hydraulic actuators, Pneumatic actuators	1
3.6	Piezo, SMA, ER & MR based actuators.	1

4	**Force sensors design**	
4.1	Different type of force sensors	1
4.2	selection of sensors, signal conditioning, interfacing circuit	2
4.3	Design of force sensors: Determine the stress situation near a pressure vessel nozzle	2
4.4	Determine power transmission through the shaft	1
5	**Temperature sensor design**	
5.1	Different type of temperature sensors	2
5.2	Selection of sensors, signal conditioning, interfacing circuit	1
5.3	Design of temperature sensors: temperature measurement inside the boiler	1
5.4	design of sensor for quality automatic welding systems, room temperature measurement	1
6	**Vibration sensor design**	
6.1	Different type of vibration sensors	2
6.2	Selection of sensors, signal conditioning, interfacing circuit	2
6.3	Design of vibration sensors: Building vibration measurement	1
6.4	Beam vibration measurement	1
6.5	Modeling of piezo electric accelerometer	1
7	**Proximity sensor design**	
7.1	Different type of proximity sensors	2
7.2	Selection of sensors, signal conditioning, interfacing circuit	1
7.3	Design of proximity sensor: obstacle detection	1
7.4	Shaft speed measurement	1
8	**Photonic sensor design**	
8.1	Different type of photonic sensors	2
8.2	Selection of sensors, signal conditioning, interfacing circuit	1
8.3	Design of photonic sensor: optical encoder for speed measurement	1
9	**Level sensor design**	
9.1	Different type of level sensors	1
9.2	Selection of sensors, signal conditioning, interfacing circuit	1
9.3	Design of level sensor: water level in boiler	1

9.4	Storage level of solid particles	1
	Total	**45**

Course Designers:

1. Dr. L.R. Karlmarx - lrkarlmarx@gmail.com
2. Ms S. Siva Priya - siva2692@hotmail.com

17MC140	**MECHATRONICS SYSTEM DESIGN**	Category	L	T	P	Credit
		PC	4	0	0	4

Preamble

A Mechatronic system design is a design process that is characterized by synergistic integration of mechanisms, sensors, actuators and control to perform complex tasks in a metaphysical environment.

An important characteristic of mechatronic devices and systems is their built-in intelligence, which results through a combination of precision mechanical and electrical engineering and real-time programming integrated with the design process. Mechatronics system design makes possible to understand the basic design process involved in mechatronics, selection of sensors and actuators, the interface issues and communication problems. Design of a mobile robot is introduced in this subject to illustrate the concepts.

Prerequisite

Nil

Course Outcomes

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

CO 1	Discuss about modelling of Mechatronic System	Understand
CO 2	Explain the design process involved in Mechatronics	Understand
CO 3	Select the sensor and Actuator for a Mechatronic application	Apply
CO 4	Develop a Mechatronic product for the given problem	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C	L	M	S	S	-	-	S	-	-	M	L	S
CO2.	L	L	S	S	-	-	-	-	-	M	L	S
CO3.	L	S	L	M	M	-	-	-	-	L	L	M
CO4.	L	S	L	M	L	-	M	-	-	L	L	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	20	40	20	40
Apply	60	40	60	40
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Describe modelling.
2. Explain various modelling methods of a Mechatronic system.
3. Describe the basic components of bond graphs
4. Draw the bond graph model of DC series Motor

Course Outcome 2(CO2):

1. Does Conceptual Design help in real life problems? If yes, how?
2. Choose the sensor and actuator for a fire fighting robot.
3. Write any four graphical-based application software used for DAC system with its description.
4. Explain the simulation methods for a real life problem.

Course Outcome 3 (CO3):

1. Draw the driver circuit to control four servo motors of a mobile robot.
2. Discuss real time interfacing? Explain briefly the elements of a data acquisition and control system with neat sketch.
3. For a wall painting robot design a control architecture to interface the sensor and actuator and support your choice.

Course Outcome 4 (CO4):

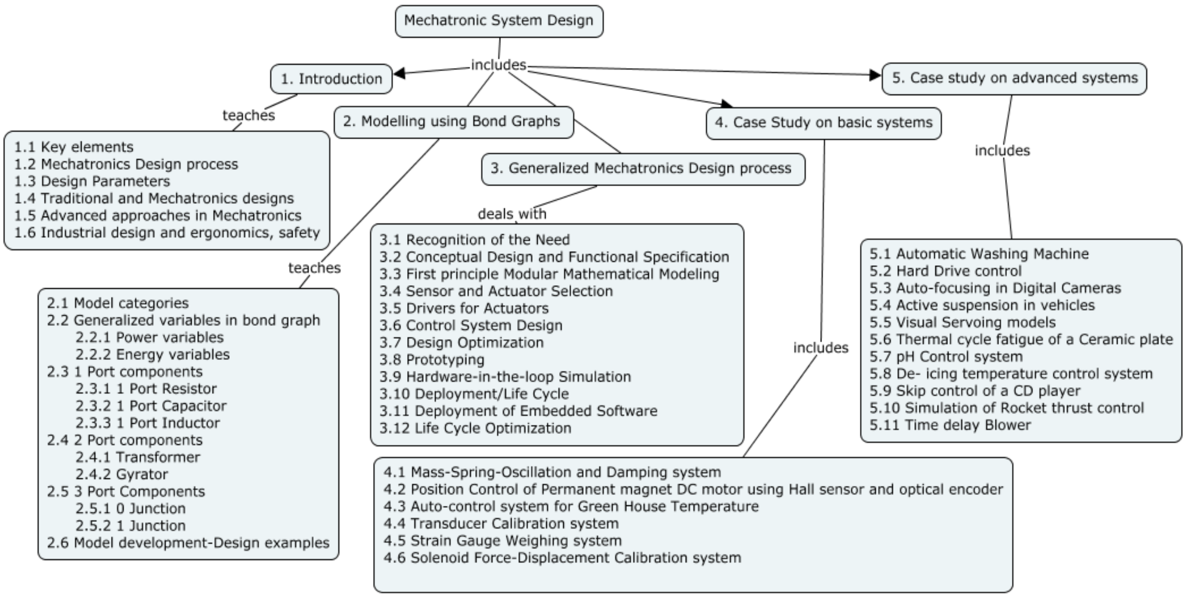
1. Design a mobile robot which moves along a room and paints the wall at a height of 3m from the ground. Consider all the mechanical alternatives and draw all possible designs. Choose sensor, actuator, communication and interface method for all designs. The robot of mass 3 kg should reach the maximum velocity in 1 s, so an acceleration of $0.15 m/s^2$ is desired. The wheel radius is assumed to be 3 cm. Calculate the maximum torque and required power. According to the design considered, choose a differential (gear reduction mechanism) to raise the spray gun to a particular height. Design optimum motor driving circuitry, signal conditioning circuit and algorithm for smooth functioning of the robot.

2. For a beam of length 0.285 m, width 0.0254 m, thickness 0.003 m, modulus 70.3 N/m2, density 2712 kg/m3, Obtain an optimum beam experimental setup. Assume that the beam is divided into 10 finite beams. To measure the vibration levels of the beam, Consider a sensor – actuator is tightly bounded and placed below the beam. The moment generated is proportional to the voltage

of the sensor. Model the sensor and PZT actuator. According to the voltage generated, develop the instrumentation setup (charge amplifier), signal conditioning circuit, Controller and software. Explain the algorithm of working.

3. If a robot of length 31cm, 31cm wide and 27 cm height, mass 3 kg is used to extinguish fire in a room, Explain the mechanical alternatives, types of materials used in the construction of robot. A candle is used to set the flame 15cm to 20 cm above the floor level. The robot should extinguish the flame in 50 secs. The motor is energized by a driver circuit (H Circuit).Select a suitable gear ratio to lift the CO2 spray gun with an acceleration of 0.34 m/s.Calculate the maximum torque and power needed.

Concept Map



Syllabus

Introduction to Mechatronic System Design:

Key elements – Mechatronics Design process –Design Parameters – Traditional and Mechatronics designs – Advanced approaches in Mechatronics - Industrial design and ergonomics, safety.

System Modelling by Bond Graphs:

Introduction-model categories-fields of application, generalized variables in bond graph- Power variables – Energy variables, Basic components in Bond graph-1 Port components- 1 Port Resistor- 1 Port Capacitor – 1 Port Inductor, 2 Port components- Transformer- Gyrator, 3 Port Components – 0 Junction, 1 Junction, Model development-Design examples.

Generalized Mechatronics Design Process:

Recognition of the Need, Conceptual Design and Functional Specification, First principle Modular Mathematical Modeling, Sensor and Actuator Selection, Drivers for Actuators, Control System Design, Design Optimization, Prototyping, Hardware-in-the-loop Simulation, Deployment/Life Cycle, Deployment of Embedded Software, Life Cycle Optimization.

Case Study on basic systems

Mass-Spring-Oscillation and Damping system – Position Control of Permanent magnet DC motor using Hall sensor and optical encoder – Auto-control system for Green House Temperature – Transducer Calibration system – Strain Gauge Weighing system – Solenoid Force-Displacement Calibration system.

Case study on advanced systems

Automatic Washing Machine – Hard Drive control – Auto-focusing in Digital Cameras – Active suspension in vehicles – Visual Servoing models – Thermal cycle fatigue of a Ceramic plate – pH Control system – De- icing temperature control system – Skip control of a CD player – Simulation of Rocket thrust control – Time delay Blower.

Reference Books

1. Shruva Das, “Mechatronic Modelling and Simulation Using Bond Graphs” CRC Press, 2009.
2. W. Bolton, “Mechatronics – Electronic control systems in Mechanical & Electrical Engineering”, Pearson Education Ltd., 2003.
3. Shetty and Kolk , “Mechatronics System Design” , CENGAGE Learning, India, second edition, 2011.
4. Bishop, Robert H, "Mechatronics Hand book", CRC Press, 2002.
5. Kenji Uchino and Jayne R. Giniewicz, “Mechatronics" publication: Marcel Dekker, Inc.
6. A. Smaili and F. Mrad, “Applied Mechatronics”, OXFORD university press published in April 2007.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to Mechatronic System Design**	
1.1	Key elements – Mechatronics Design process	2
1.2	Design Parameters – Traditional and Mechatronics designs	2
1.3	Advanced approaches in Mechatronics - Industrial design and ergonomics, safety.	2
2	**System Modelling by Bond Graphs**	
2.1	Introduction-model categories-fields of application	2
2.2	Variables in bond graph- Power variables – Energy variables	2
2.3	Basic components in Bond graph-1 Port components	2
2.4	2 Port components- Transformer- Gyrator	2
2.5	3 Port Components – 0 Junction, 1 Junction	2
2.6	Design Examples	2
3	**Generalized Mechatronics Design Process**	
3.1	Recognition of the Need, Conceptual Design and Functional Specification	1
3.2	First principle Modular Mathematical Modeling	1
3.3	Sensor Selection	1
3.4	Actuator Selection	1
3.5	Drivers for Actuators	1
3.6	Control System Design	1
3.7	Communication Strategy	1
3.8	Software Development	1
3.9	Design Optimization	1
3.10	Prototyping	1
3.11	Hardware-in-the-loop Simulation	1
3.12	Deployment/Life Cycle, Deployment of Embedded Software, Life Cycle Optimization	1
4	**Case Study on basic systems**	
4.1	Mass-Spring-Oscillation and Damping system	1

Module No.	Topic	No. of Lectures
4.2	Position Control of Permanent magnet DC motor using Hall sensor and optical encoder	2
4.3	Auto-control system for Green House Temperature	1
4.3	Transducer Calibration system	1
4.4	Strain Gauge Weighing system	1
4.5	Solenoid Force-Displacement Calibration system	1
5	**Case Study on advanced systems**	
5.0	Automatic Washing Machine	1
5.1	Hard Drive control – Auto-focusing in Digital Cameras	1
5.2	Active suspension in vehicles	2
5.3	Visual Servoing models	1
5.4	Thermal cycle fatigue of a Ceramic plate	1
5.5	PH Control system	1
5.6	De- icing temperature control system	1
5.7	Skip control of a CD player	1
5.8	Simulation of Rocket thrust control	1
5.9	Time delay Blower	1
	Total Hours	**48**

Course Designers:

1. Mr T Vivek - tvivek@tce.edu
2. Mr M.A Ganesh - ganeshma2015@tce.edu

		Category	L	T	P	Credit
17MC150	**AUTOMOTIVE MECHATRONICS**	DC	4	0	0	4

Preamble

Automotive Mechatronics is a discipline that involves multidisciplinary integration of automotive mechanical and electronic systems. It includes automotive-specific mechanics, electronics, communication, advanced control and modelling. The subject deals with all the aspects of automotive mechatronics, especially in transmission, braking, steering, cruise, traction, suspension and stability. Some of the main applications of mechatronics are introduced. The students would be able to understand the basic dynamics and develop the equations according to the vehicle conditions.

Prerequisite

Nil

Course Outcomes

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

CO1	Identify basic automotive mechatronic systems	Understand
CO2	Explain transmission control, Cruise Control and Engine control system dynamics.	Understand
CO3	Illustrate braking control Traction Control and Suspension Control dynamics.	Apply
CO4	Solve the Stability Control, Steering control dynamics	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	M	S	S			S			M	L
CO2	M	L	S	S		S				M	L
CO3	M	S	L	M	M	M				L	L
CO4	S	S	M	S	M	S	S			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	80	80	80	80
Apply	0	0	0	0
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the function of Air Bags.
2. Describe the working of TPMS.
3. State the basic principle of automatic headlight control
4. Describe the mechanisms of folding roofs.
5. Draw the mechanism of wiper control.

Course Outcome 2(CO2):

1. Explain the components behind Automatic Transmission
2. List the Control Modes and describe the Mechanism of transmission control.
3. Explain the working of Mechatronic Gear Shift
4. Identify the need of Cruise control.
5. Report the effect of engine control affect the performance of the vehicle
6. Discuss the difference between Adaptive and Automatic cruise control.
7. Draw the architecture of cruise controller.
8. Explain the common failsafe circuit of cruise control.

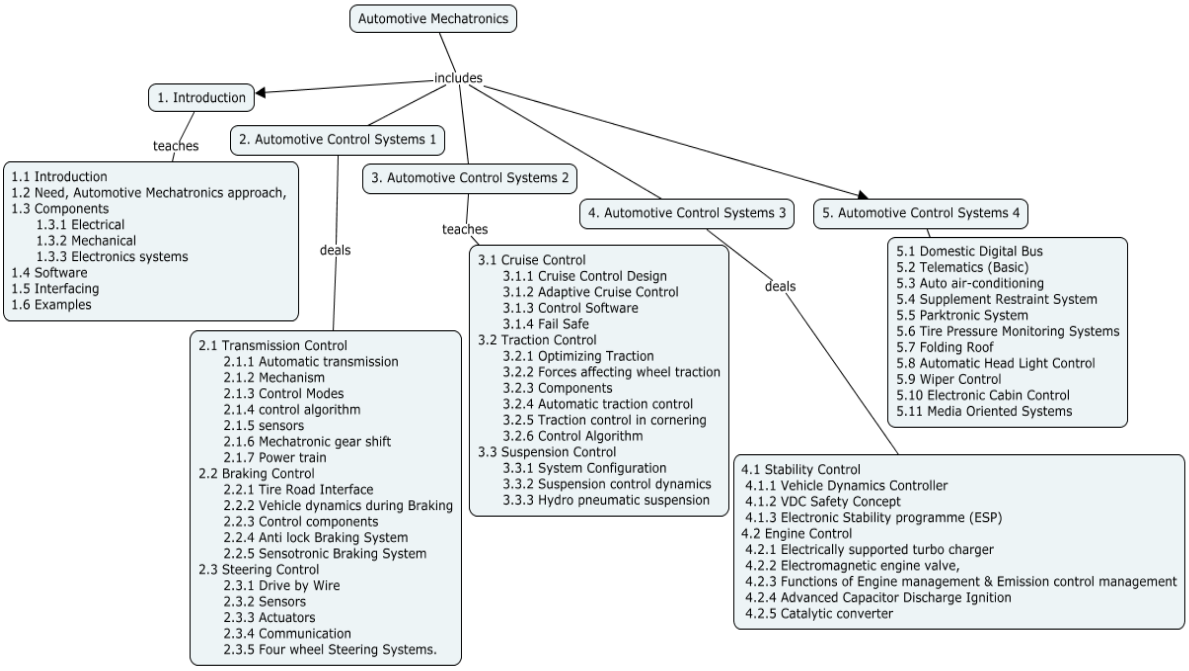
Course Outcome 3 (CO3):

1. Describe the forces affecting wheel traction. Avoid negligible forces and derive an equation.
2. Derive the vehicle dynamics equations during braking
3. Describe the purpose of ABS system. How is it different from conventional braking.
4. Explain the suspension control dynamics for hydro pneumatic suspension system

Course Outcome 4 (CO4):

1. List the different types of stability controllers.
2. Describe the function of Vehicle Dynamics Controller.
3. Explain VDC Safety Concept. Draw the architecture and discuss.
4. Review the function of Four Wheel Steering Systems.

Concept Map



Syllabus

Introduction to Automotive Mechatronics

Introduction, Need, Automotive Mechatronics approach, Components-Electrical, Mechanical, Electronics systems, Software, Interfacing. Examples.

Automotive Systems I

Transmission Control – Automatic transmission – Mechanism – Control Modes - control algorithm – sensors - Mechatronic gear shift – Power train, *Braking Control*– Tire Road Interface – Vehicle dynamics during Braking - Control components – Anti lock Braking System – Sensotronic Braking System, *Steering Control*– Drive by Wire – Sensors – Actuators – Communication – Four wheel Steering Systems.

Automotive Systems II

Cruise Control – Cruise Control Design - Adaptive Cruise Control – Control Software – Fail Safe, *Traction Control* - Optimizing Traction – Forces affecting wheel traction - Components– Automatic traction control - Traction control in cornering - Control Algorithm, *Suspension Control* - System Configuration – suspension control dynamics – Hydro pneumatic suspension control system.

Automotive systems III

Stability Control – Vehicle Dynamics Controller – VDC Safety Concept - Electronic Stability programme (ESP), Engine Control - Electrically supported turbo charger -electromagnetic engine valve, Functions of Engine management & Emission control management - Advanced Capacitor Discharge Ignition, Catalytic converter.

Automotive Systems IV

Domestic Digital Bus, Telematics (Basic), Auto air-conditioning, Supplement Restraint System, Parktronic System, Tire pressure monitoring systems, Automatic head light control, Folding roof, Wiper Control, Electronic Cabin control, Media Oriented Systems.

Reference Books

1. Uwe Kiencke, Lars Nielsen, **"Automotive Control Systems"**, by Springer second edition, 2005.
2. Ronald K Jurgen, **"Automotive Electronics"**, by McGraw Hill, second edition. (Original edition- 1999).
3. Robert K Bishop,**" Mechatronics Handbook"**, CRC Press, 2002.
4. Bosch Professional Automotive Information, **"Automotive Mechatronics: Automotive Networking, Driving Stability Systems, Electronics"** published by Springer in 2014.

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Introduction to Automotive Mechatronics**	
1.1	Introduction, Need	
1.2	Automotive Mechatronics approach, Components-Electrical, Mechanical	1
1.3	Electronics systems, Software, Interfacing	1
1.4	Examples	1
2	**Automotive Systems 1**	
2.1	*Transmission Control* – Automatic transmission – Mechanism	
2.2	Control Modes - control algorithm	1
2.3	Sensors - Mechatronic gear shift— Power train	2
2.4	Braking Control– Tire Road Interface	1
2.5	Vehicle dynamics during Braking	1
2.6	Control components – Anti lock Braking System	1
2.7	Sensotronic Braking System	1
2.8	*Steering Control*– Drive by Wire	1
2.9	Sensors	1
2.10	Actuators	1
2.11	Communication – Four wheel Steering Systems.	1
3	**Automotive Systems 2**	
3.1	*Cruise Control* – Cruise Control Design	
3.2	Adaptive Cruise Control – Control Software	2
3.3	Fail Safe	1
3.4	*Traction Control* - Optimizing Traction – Forces affecting wheel traction	2
3.5	Components– Automatic traction control	2
3.6	Traction control in cornering - Control Algorithm	2
3.7	*Suspension Control* - System Configuration	1
3.8	Suspension control dynamics	1
3.9	Hydro pneumatic suspension control system	1
4	**Automotive Systems 3**	
4.1	*Stability Control* – Vehicle Dynamics Controller	
4.2	VDC Safety Concept	1
4.3	Electronic Stability programme (ESP)	1
4.4	Engine Control - Electrically supported turbo charger - electromagnetic engine valve	1

Sl. No.	Topic	No. of Lectures
1	**Introduction to Automotive Mechatronics**	
4.5	Functions of Engine management & Emission control management	2
4.6	Advanced Capacitor Discharge Ignition, Catalytic converter.	2
5	**Automotive Systems 4**	
5.1	Domestic Digital Bus	
5.2	Telematics (Basic)	1
5.3	Auto air-conditioning	1
5.4	Supplement Restraint System	1
5.5	Parktronic System	1
5.6	Tire pressure monitoring systems	1
5.7	Automatic head light control	1
5.8	Folding roof, Wiper Control	1
5.9	Electronic Cabin control, Media Oriented Systems Transport	2
	Total Hours	**48**

Course Designers:

1. Mr M.A Ganesh ganeshma2015@tce.edu
2. Mr M Manimegalan mmmech@tce.edu

		Category	L	T	P	Credit
17MC160	**DIGITAL CONTROL SYSTEM**	DC	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 controller for the correct design of a control system

Prerequisite

NIL

Course Outcomes

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

CO 1.	Develop Transfer function and State space model for given Physical system	Apply
CO 2.	Implement the time domain specification methods for analysis the performance of systems	Apply
CO 3.	Implement the frequency domain specification methods for analysis the performance of systems	Apply
CO 4.	Understand the system controllability and observability using state space approach	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

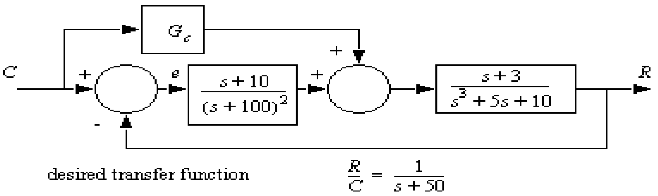
Assessment Pattern

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. Define Transfer Function.
2. Differentiate state space and transfer function approach.
3. Draw the block diagram and signal flow graph for field controlled DC motor.
4. State Mason's gain formula.
5. Determine the overall transfer function for the system shown below.



Course Outcome 2(CO2):

1. Define settling time of a second order system with relevant equation.
2. Define peak overshoot of a second order system with relevant equation.
3. Define rise time and delay time of a second order system with relevant equation
4. Derive the response of under damped and over damped second order system with unit step input.
5. Derive the response of critically damped second order system with unit step input.

Course Outcome 3 (CO3):

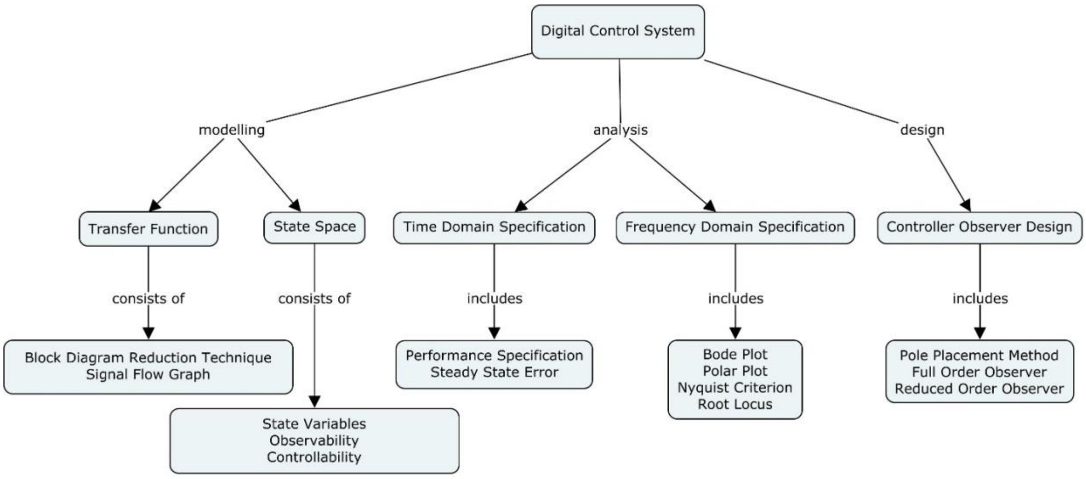
1. Define Phase Margin
2. List the frequency domain specifications.
3. Draw root locus for the following system $G(s)=k/s^2(.5s+1)$.

4. Construct the Routh array and determine the stability of the system whose characteristic equation is $s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0$. Also determine the number of roots lying on right half of s-plane
5. Draw bode plot for the following system. G(s)=100/s(.5s+1)(10s+1).

Course Outcome 4 (CO4):

1. Define State controllability.
2. Determine the controllability characteristics of the following system G(z)=z+2/(z+1)(z+3).
3. Determine the observability of the following system $G(z)=z/(z+1)^2$.

Concept Map



Syllabus

Introduction and Mathematical Models of system:

Introduction, Examples of control system, Differential equations of physical system, linear approximation, transfer function of linear systems, block diagram reduction technique, Signal flow graph method, developing transfer function from physical system.

Time and Frequency Domain Analysis:

Types of input, Performance specifications, Step response of first order and second order system, steady state error: static and dynamic error coefficients. Routh-Hurwitz stability criterion, Root locus method, Design examples, and Frequency response methods: Bode plot and polar plot, Nyquist criterion. Design Examples.

State space Methods: sampling and data hold circuit, State variables of a dynamic system, 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, State controllability, output controllability, observability, Effect of discretization on controllability and observability.

Controller and Observer Design. Controller design-Pole placement. **Observer Design:** Full order and reduced order, Realization of digital Controller, Stabilization of an antenna dish. Introduction to Matlab and Simulink.

Reference Books

1. Richard C.Bishop, Robert H. Bishop, "**Modern Control Systems**" Twelfth Edition, Pearson Education, 2014.
2. Katsuhiko Ogata,"**Discrete time control systems**" second edition, Pearson Education Asia Pte Ltd, 2002.
3. George Stephanopoulos, "**Chemical process control: An introduction to theory and practice**", Prentice hall of India private limited,1999.
4. Elbert Hendricks, Ole Janner up, Paul Hasse Sorenson, "**Linear systems control**" Springer.2008.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
	Introduction and Mathematical Models of system.	
1.1	Introduction, Examples of control system.	1
1.2	Differential equations of physical system, linear approximation.	1
1.3	Transfer function of linear systems.	1
1.4	Block diagram reduction technique.	2
1.5	Signal flow graph method.	2
1.6	Developing transfer function from physical system	3
2.	**Time and Frequency Domain Analysis**	
2.1	Types of input, Performance specifications.	2
2.2	Step response of first order and second order system.	3
2.3	Steady state error: static and dynamic error coefficients	2
2.4	Routh-Hurwitz stability criterion.	2
2.5	Root locus method -Design examples.	2
2.6	Frequency response methods: Bode plot and polar plot.	4
2.7	Nyquist criterion-Design Examples.	2
3.	**State space Methods:**	
3.1	State variables of a dynamic system	1
3.2	Various canonical forms, similarity transformation	1
3.3	Solution of state equation, Transfer function to state space	1

Module No.	Topic	No. of Lectures
	conversion.	
3.4	Mapping between s-plane and z-plane.	1
3.5	Jury's Stability test.	1
3.6	State controllability, output controllability.	2
3.7	Observability.	1
3.8	Effect of discretization on controllability and observability.	1
4.	**Controller and Observer Design.**	
4.1	**Controller design-** Pole placement.	2
4.2	**Observer Design:** Full order and reduced order.	3
4.3	Realization of digital PID Controller.	2
4.4	**Example:** Stabilization of an antenna dish.	2
4.5	Introduction to Matlab and Simulink.	3
Total		**48 Hours**

Course Designers:

1. T.Vivek tvivek@tce.edu.
2. A.Prakash apmech@tce.edu.

		Category	L	T	P	Credit
17MC170	**AUTOMATION LABORATORY**	DC	-	-	2	1

Preamble

This course provides engineering students with basic understanding of simulating and building automation system;Students simulate automation circuits using software then implement it using pneumatic hardware ,and also by plc. They also build automation system using Personal computer.

Prerequisite

17MC140-Industrial Automation.

Course Outcomes

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

CO1	Simulate pneumatic and hydraulic systems using software	Apply
CO2	Implement pneumatic systems using hardware	Apply
CO3	Implement pneumatic systems using PLC	Apply
CO4	Design and implement PC based Automation	Apply

Mapping with Program Outcomes

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

S- Strong; M-Medium; L-Low

Syllabus

List of experiments		
Ex.No	**Experiments/Exercise**	**Hours**
1	Simulation of Hydraulic / Pneumatic circuits using Automation Studio.	2
2	Simulation of Hydraulic / Pneumatic circuits using Fluid sim/Hydro sim.	2
3	Design and implementation of Cascading circuit A+B+B-A- using Pneumatic Components.	2
4	Design and implementation of Sequential circuit A+B+A-B- using Pneumatic Components.	2
5	Design and implementation of Sequential circuit A+B+A-B- using electro Pneumatic Components and PLC.	2
6	PLC-based Experiment-Car Park Barrier	2
7	Level control system using PLC.	2
8	Edge detection using Machine vision.	2
9	DC servo motor Control System.	2
10	Strain gauge data acquisition system using Lab VIEW.	2
11	Pick and place / path tracking using Robot.	2
12	PC based Temperature Measurement and Data logging.	2
13	LVDT based displacement measurement using LabVIEW.	2
	Total	24

Minimum of 12 experiments are to be given

Course Designers:

1.	T.Vivek	tvivek@tce.edu.
2.	Ramesh.H	rameshh@tce.edu.

17MC210	ROBOTICS :CONCEPTS AND ANALYSIS	Category	L	T	P	Credit
		PC	4	0	0	4

Preamble

Robotics is the interdisciplinary branch of engineering and science that includes mechanical engineering, electrical engineering, computer science, and others. Robotics deals with the design, construction, operation, and use of robots, as well as computer systems for their control, sensory feedback, and information processing. 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 made by humans. This course supports students to design and develop both multi DOF manipulators and wheeled mobile robots.

Prerequisite

Nil

Course Outcomes

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

CO 1	Describe the working of subsystems of robotic manipulator	Understand
CO 2	Develop the forward and inverse kinematic model of multi DOF manipulator	Apply
CO 3	Develop forward and inverse dynamic model of two DOF manipulator	Apply
CO 4	Elucidate kinematic and dynamic analysis of wheeled mobile robot	Apply
CO5	Develop offline robot program for a given application	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M	L	L	-	-	L	-	-	M	S
CO2.	S	S	L	L	-	-	-	-	-	M	S
CO3.	S	L	S	M	M	-	-	-	-	S	S
CO4.	S	L	S	M	S	-	M	-	-	S	S
CO5.	S	L	S	M	S	-	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	20	20	20
Apply	60	60	60	60
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

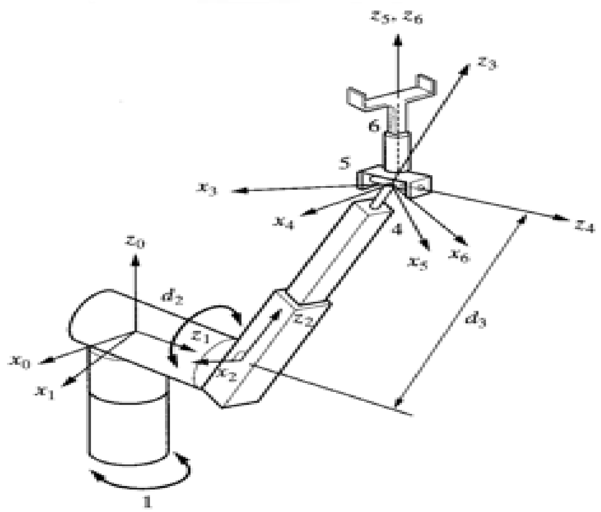
1. Define Robot

2. Explain the classification and the performance of Robots.
3. Describe the constructional features of a mobile robot.
4. Brief the applications of industrial and mobile robot.

Course Outcome 2(CO2):

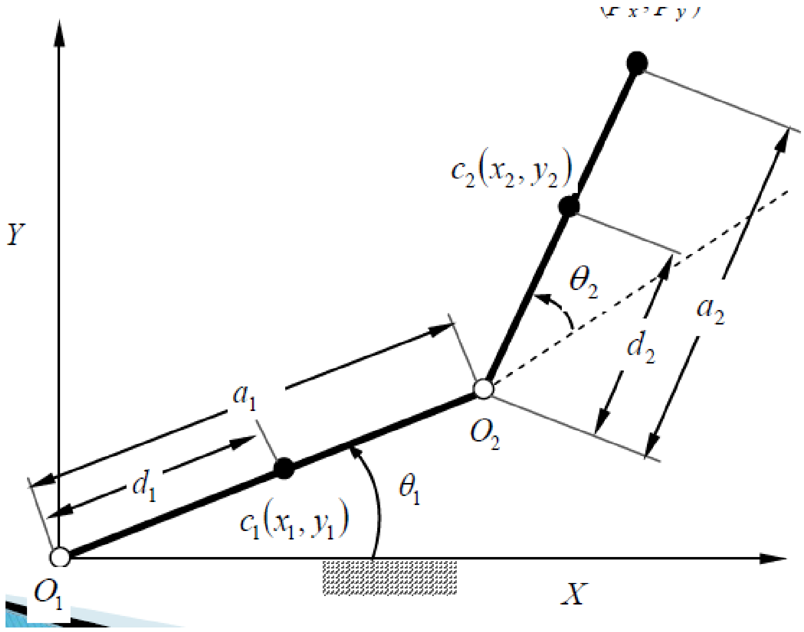
1. Write the coordinate transformation matrices for all PUMA joints as shown in the fig using DH parameters.

2. Find the DH parameters for the robot given in the following fig and derive the forward kinematics



Course Outcome 3 (CO3):

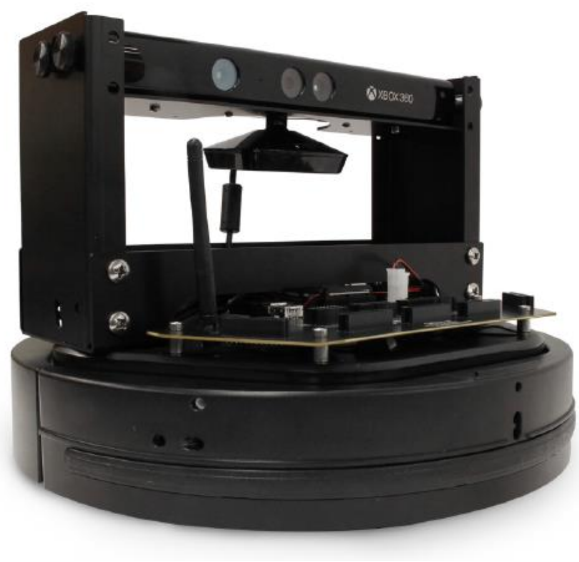
1. Derive the dynamic model of two link manipulator



2. Explain the lagrangian dynamic model. Compute the kinetic energy and potential energy and hence derive the torque.

Course Outcome 4 (CO4):

1. Derive the kinematic model of a two wheeled robot shown below. The diameter, distance between the left and right wheels, height, maximum speed mass of the QBot is 0.35 m, 0.235 m, 0.27 m, 0.7 m/s, 3.79 kg respectively. Consider flat surface, indoor environment, no frictional coefficient.



2. Assume the characteristics of a three wheeled robot and model the slip and analyze the static stability. Develop the equations of motion and verify whether the design is feasible or not.

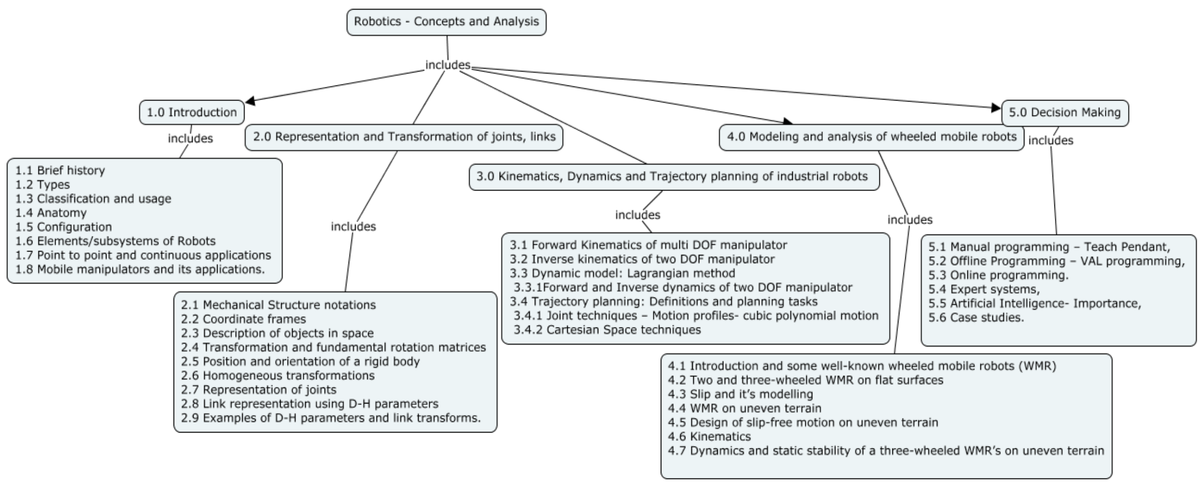
Course Outcome 5 (CO5):

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 pellet. 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 the 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 25mm tall.

2. 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.
3. 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.

Concept Map



Syllabus

Introduction to Robotics

Introduction – brief history, Robot - types, classification and usage, configuration, Anatomy, Elements/subsystems of Robots, Point to point and continuous applications, Mobile manipulators and its applications.

Representation and Transformation of joints, links

Mechanical Structure notations, Coordinate frames, Description of objects in space, Transformation and fundamental rotation matrices, Position and orientation of a rigid body, Homogeneous transformations, Representation of joints, link representation using D-H parameters, Examples of D-H parameters and link transforms.

Kinematics, Dynamics and Trajectory planning of industrial robots

Forward Kinematics of multi DOF manipulator, Inverse kinematics of two DOF manipulator, Dynamic model: Lagrangian method – Forward and Inverse dynamics of two DOF manipulator. Trajectory planning: Definitions and planning tasks, Joint techniques – Motion profiles- cubic polynomial motion, Cartesian Space techniques.

Modeling and analysis of wheeled mobile robots

Introduction and some well-known wheeled mobile robots (WMR), two and three-wheeled WMR on flat surfaces, Slip and it's modelling, WMR on uneven terrain,

Design of slip-free motion on uneven terrain, Kinematics, dynamics and static stability of a three-wheeled WMR's on uneven terrain.

Decision Making

Robot Programming: Manual programming – Teach Pendant, Offline Programming – VAL programming, Online programming. Expert systems, Artificial Intelligence- Importance, Case studies.

Reference Books

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, 2004.

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. Mikell P Groover, Mitchell Weiss, Roger N Nagel and Nicholas G Odrey, “Industrial Robotics – Technology , Programming and Applications”, Tata McGraw Hill Edition, 2008.
6. 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
1	**Introduction to Robotics**	
1.1	Introduction – brief history	1
1.2	Robot - types	1
1.3	Classification and usage	1
1.4	Configuration, Anatomy, Elements/subsystems of Robots	1
1.5	Point to point and continuous applications, Mobile manipulators and its applications.	1
2.0	**Representation and Transformation of joints, links**	
2.1	Mechanical Structure notations, Coordinate frames, Description of objects in space	1
2.2	Transformation and fundamental rotation matrices, Position and orientation of a rigid body	1
	Homogeneous transformations	2
2.3	Representation of joints, link representation using D-H parameters	1
2.4	Examples of D-H parameters and link transforms.	2
3	**Kinematics, Dynamics and Trajectory planning of industrial robots**	
3.1	Forward Kinematics of multi DOF manipulator	2
3.2	Inverse kinematics of two DOF manipulator	2
3.3	Lagrangian method – Forward dynamics of two DOF manipulator	2
	Inverse dynamics of two DOF manipulator	2
3.4	Trajectory planning: Definitions and planning tasks	1
3.5	Joint techniques – Motion profiles	2
	cubic polynomial motion	1
3.6	Cartesian Space techniques	2
4	**Modeling and analysis of wheeled mobile robots**	
4.1	Introduction and some well-known wheeled mobile robots (WMR), two and three-wheeled WMR on flat surfaces	2
4.2	Slip and it’s modelling	2
4.3	WMR on uneven terrain	1
4.3	Design of slip-free motion on uneven terrain	2

Module No.	Topic	No. of Lectures
4.4	Kinematics of a three-wheeled WMR's on uneven terrain	1
4.5	Dynamics of a three-wheeled WMR's on uneven terrain	2
	static stability of a three-wheeled WMR's on uneven terrain	2
5	**Decision Making**	
5.0	Robot Programming: Manual programming	1
	Teach Pendant	1
5.1	Offline Programming – VAL programming	2
5.2	Online programming	1
5.3	Expert systems	2
5.4	Artificial Intelligence- Importance	1
5.5	Case studies.	2
	Total Hours	**48**

Course Designers:

1. Dr G Kanagaraj - gkmech@tce.edu
2. Mr M.A Ganesh - ganeshma2015@tce.edu

17MC220	REAL TIME EMBEDDED SYSTEM	Category	L	T	P	Credit
		PC	4	0	0	4

Preamble

Necessity is the mother of invention and embedded systems are the inventions that were fuelled by the idea of making pre-programs to perform a dedicated narrow range of functions as a 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 response 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 with real time embedded systems concepts, design and implementation.

Prerequisite

NIL

Course Outcomes

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

CO1	Understand the various concepts of 8051 microcontroller such as architecture, instruction set, programming, interrupts and timer	Understand
CO2	Understand the various types of embedded systems, concept of concept of design and development of embedded systems and real time systems concepts	Understand
CO3	Explain the various real time operating system concepts used in the design of embedded system	Understand
CO4	Select suitable real time software model and design procedure to solve engineering issues	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	-	L	M	M	S	M	-	-	M	-	-
CO2	S	S	S	L	-	L	-	M	M	-	S
CO3	-	L	-	L	M	M	S	S	M	-	S
CO4	-	-	M	-	-	M	-	-	-	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	50	50
Apply	0	30	30	30
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the architecture of 8051 microcontroller
2. List the various interrupts in 8051
3. Explain the various addressing modes in 8051

Course Outcome 2 (CO2):

1. Explain the various types of embedded systems
2. Describe the various embedded hardware units and devices in embedded system
3. Explain the concept of real time system
4. Explain the design process in embedded system

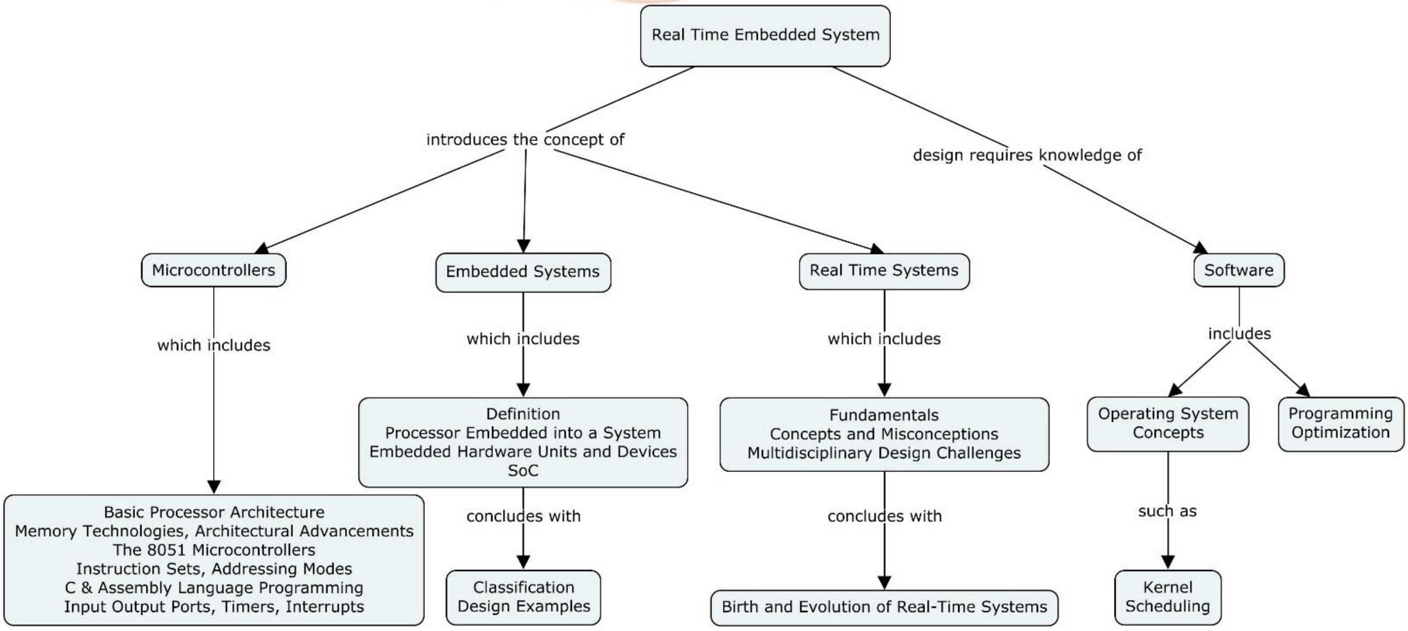
Course Outcome 3 (CO3):

1. Briefly explain the various scheduling schemes used in embedded system
2. Discuss about the various memory related issues in the design of a embedded system

Course Outcome 4 (CO4):

1. Develop a kernel model with the hardware / software requirements for an Automatic Cruise Control System in a Car
2. Develop a kernel model with the hardware / software requirements for a Machine Vision based Conveyer System

Concept Map



Syllabus

Introduction to Microcontrollers: Basic Processor Architecture, Memory Technologies, Architectural Advancements. The 8051 Microcontrollers, Instruction Sets, Addressing Modes, C & Assembly Language Programming, Input Output Ports, Timers, Interrupts.

Introduction to Embedded System: Definition, Processor Embedded into a System, Embedded Hardware Units and Devices, System on Chip (SoC), Classification of Embedded System, Design Examples.

Introduction to Real-Time Systems: Fundamentals, Concepts and Misconceptions, Multidisciplinary Design Challenges, Birth and Evolution of Real-Time Systems.

Real-Time Operating Systems: Pseudo kernels, Interrupt-Only Systems, Pre-emptive Priority Systems, Hybrid Scheduling Systems, the Task Control Block Model. Scheduling Framework, Round-Robin Scheduling, Cyclic Code Scheduling, Fixed Priority Scheduling: Rate-Monotonic Approach, Dynamic Priority Scheduling: Earliest Deadline First Approach.

Programming Languages for Real-Time Systems: Coding of Real-Time Software, Assembly Language, Procedural Languages, and Object-Oriented Languages, Overview of Programming Languages, Automatic Code Generation, and Compiler Optimizations of Code.

.

Reference Books

1. Muhammad Ali Maxidi, Janice Gillispie Mazidi, Rolin D.McKinlay, “The 8051 Mirocontroller and Embedded Systems”, Pearson Publication, II edition, 2016
2. Phillip A. Laplante, Seppo J. Ovaska, “Real-Time Systems Design and Analysis”, IEEE Press, A John Wiley & Sons, Inc. Publication, IV edition, 2013
3. Frank Vahid, Tony Givargis, “Embedded System Design: A Unified Hardware/Software Approach”, A John Wiley & Sons, Inc. Publication, IV edition, 2013
4. Raj Kamal, “Embedded Systems : Architecture, Programming and Design”, Mcgraw Hill Education, III Edition, 2014

Course Designers: Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Introduction to Microcontrollers**	
1.1	Basic Processor Architecture, Memory Technologies, Architectural Advancements	2
1.2	The 8051 Microcontrollers,	2
1.3	Instruction Sets	3
1.4	Addressing Modes	1
1.5	C Language Programming	2
1.6	Assembly Language Programming	2
1.7	Input Output Ports	1
1.8	Timers	2
1.9	Interrupts	2
2	**Introduction to Embedded System**	
2.1	Definition, Processor Embedded into a System	2
2.2	Embedded Hardware Units and Devices	1
2.3	System on Chip, Classification of Embedded System	2
2.4	Design Examples	2
3	**Introduction to Real-Time Systems**	
3.1	Fundamentals, Concepts and Misconceptions	1
3.2	Multidisciplinary Design Challenges	2
3.3	Birth and Evolution of Real-Time Systems	1
4	**Real-Time Operating Systems I**	
4.1	Pseudo kernels, Interrupt-Only Systems, Pre-emptive Priority Systems	3
4.2	Hybrid Scheduling Systems, Task Control Block Model	2
4.3	Scheduling Framework, Round-Robin Scheduling, Cyclic Code Scheduling,	2
4.4	Fixed Priority Scheduling: Rate-Monotonic Approach	2
4.5	Dynamic Priority Scheduling: Earliest Deadline First Approach	2
5	**Programming Languages for Real-Time Systems**	
5.1	Coding of Real-Time Software, Assembly Language	2
5.2	Procedural Languages, and Object-Oriented Languages	2
5.3	Overview of Programming Languages	2
5.4	Automatic Code Generation, and Compiler Optimizations of Code	3
	Total	**48**

Course Designers:

1. Sheik Masthan S.A.R sarsmech@tce.edu
2. Parthasarathi S parthasarathi_s@tce.edu

		Category	L	T	P	Credit
17MCPA0	**ADDITIVE MANUFACTURING**	PE	4	0	0	4

Preamble

Additive Manufacturing is a process of joining materials to make objects from 3D model data, usual layer up on layer, as opposed to subtractive manufacturing methodologies, such as traditional machining. The basic principle of AM is that a model, initially generated using a three-dimensional Computer Aided Design (3DCAD) system, can be fabricated directly. The course aims to provide knowledge about AM technologies, design and its relating to specific additive manufacturing applications.

Prerequisite

Nil

Course Outcomes

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

CO1.	Explain the concepts of AM process and Importance of AM.	**Understand**
CO2.	Select the suitable AM Technologies based on different parts and process parameters	**Apply**
CO3.	Identify the different methods for Post-processing of AM parts	**Apply**
CO4.	Explain the Design for manufacture and synthesis method for AM.	**Understand**
CO5.	Applications of AM for creation of different Products in Automobile, Aerospace, Medical Industry etc.	**Apply**

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	S	L	M	M	M	M	M	M	M	M
CO2	M	S	M	M	M	M	S	S	S	S	M
CO3	M	S	L	L	L	M	M	M	L	M	M
CO4	S	M	L	S	M	M	S	M	M	S	S
CO5	M	M	L	M	M	M	M	M	S	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	50	50	50	50
Apply	30	30	30	30

Analyse	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Additive Manufacturing?
2. Explain the process chain of additive manufacturing process
3. Explain the STL file manipulation in Additive manufacturing.

Course Outcome 2 (CO2):

1. Explain the classification of AM process.
2. Define polymerization Process
3. Explain the process parameters of Solid Ground Curing (SGC).
4. Explain the principle of Stereo lithography (SLA) processes.
5. Discuss the solid ground process steps in details with suitable diagrams.

Course Outcome 3 (CO3):

1. Discuss the Machining strategy for finishing the AM parts and tools.
2. Suggest the few methods for Property Enhancements Using Thermal Techniques.
3. Explain the different methods of support material removal in AM process,

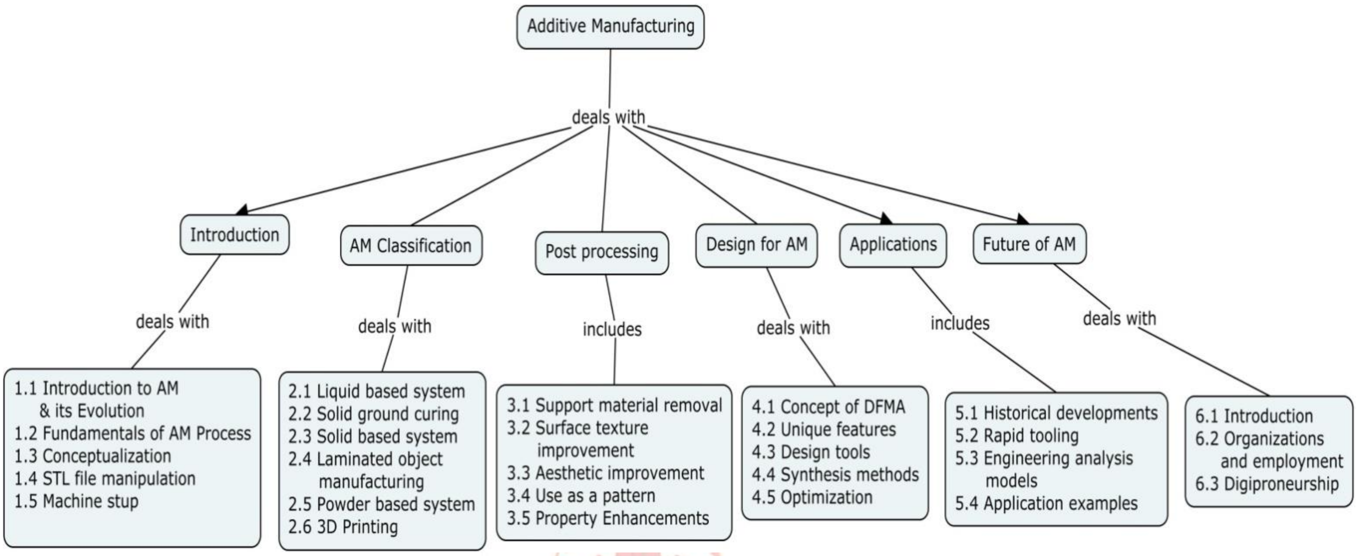
Course Outcome 4 (CO4):

1. Explain three ways that current designers are trained that are at odds with theconcept of DFAM?
2. Explain the four AM unique design capabilities
3. Explain the different optimization methods to improve the design in AM.

Course Outcome 5 (CO5):

1. Select the suitable AM process for the development of Pattern for jewellery application
2. Select the suitable AM process for the development of Fixture for measurement purpose
3. Selectthe suitable AM Process be particularly useful for military applications?
4. Explain how digiproneurship involves the creation of a business enterprise.

Concept Map



Syllabus

Introduction to Additive Manufacturing and AM process chain: Introduction to AM, AM evolution, Distinction between AM & CNC machining, Fundamentals of AM, Benefits of AM, Conceptualization, CAD, conversion to STL, Transfer to AM, STL file manipulation, Machine setup, build , removal and clean up, post processing.

Classification of AM processes: Liquid based system - Stereo lithography systems & Solid Ground curing, Solid Based system - Fused Deposition Modelling & Laminated Object Manufacturing, Powder based system - Selective Laser Sintering &Three Dimensional printing.

Post processing of AM parts: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques.

Design for AM: Motivation, DFMA concepts and objectives, AM unique capabilities, Exploring design freedoms, Design tools for AM - Solid-Modeling CAD Systems, Promising CAD Technologies, Synthesis Methods - Theoretically Optimal Lightweight Structures, Optimization Methods, Topology Optimization.

AM Applications: Historical developments - Functional models, Rapid tooling - Pattern for investment and vacuum casting, Medical Application, Engineering analysis models, Bi-metallic parts, Re-manufacturing. Application examples for Aerospace, Defence, automobile, and general engineering industries.

Future Directions of AM: Introduction, new types of products, organizations, employment and digiproneurship.

Reference Books

1. Ian Gibson, David W. Rosen, Brent Stucker, **"Additive manufacturing technologies: rapid prototyping to direct digital manufacturing"** Springer, 2010.
2. C.K. Chua, K.F. Leong and C.S. Lim, "**Rapid prototyping: principles and applications**", 3rd Edition, World Scientific, 2010.

3. Pham D T and Dimov S S, "**Rapid Manufacturing**", The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer 2001.
4. Ali K. Kamrani, Emand Abouel Nasr, **"Rapid Prototyping: Theory & Practice",** Springer, 2006.
5. Peter D. Hiltonand Jacobs, Paul F "**Rapid Tooling: Technologies And Industrial Applications"** Marcel Dekker Inc, 2000.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to Additive Manufacturing and AM process chain**	
1.1	Introduction to AM, AM evolution	1
1.2	Distinction between AM & CNC machining, Fundamentals of AM, Benefits of AM	2
1.3	Conceptualization, CAD, conversion to STL,	2
1.4	Transfer to AM, STL file manipulation,	2
1.5	Machine setup, build, and removal and clean up, post processing.	2
2	**Classification of AM processes:**	
2.1	Liquid based system - Stereo lithography systems Principle – process	2
2.2	Solid Ground curing, Principle – process	2
2.3	Solid Based system - Fused Deposition Modelling Principle – process	2
2.4	Laminated Object Manufacturing, Principle – process	2
2.5	Powder based system - Selective Laser Sintering Principle – process	2
2.6	Three Dimensional printing (3DP) Principle – process	2
3	**Post processing of AM parts:**	
3.1	Support material removal	1
3.2	Surface texture improvement, Accuracy improvement,	1
3.3	Aesthetic improvement,	1
3.4	Preparation for use as a pattern,	2
3.5	Property enhancements using non-thermal and thermal techniques.	2
4	**Design for AM:**	
4.1	Motivation, DFMA concepts and objectives,	1
4.2	AM unique capabilities, Exploring design freedoms,	2
4.3	Design tools for AM - Solid-Modeling CAD Systems, Promising CAD Technologies,	2
4.4	Synthesis Methods - Theoretically Optimal Lightweight Structures,	2
4.5	Optimization Methods, Topology Optimization.	2
5	**AM Applications:**	
5.1	Historical developments - Functional models,	1
5.2	Rapid tooling - Pattern for investment and vacuum casting,	1
5.3	Engineering analysis models, Bi-metallic parts, Re-manufacturing.	1
5.4	Application examples for Aerospace, Defence, automobile, and general engineering industries.	2
6	**Future Directions of AM:**	
6.1	Introduction, new types of products	1
6.2	Organizations , employment	1
6.3	Digiproneurship	2
	Total	46

Course Designers:

1. Mr. M. Karthic mkmect@tce.edu
2. Ms. T.R.Viveki trvmect@tce.edu

		Category	L	T	P	Credit
17MCPB0	**INTERNET OF THINGS**	PE	4	0	0	4

Preamble

The IoT is receiving a large amount of interest on the part of researchers, with thousands of papers published on this topic in the recent past. While specific applications have existed for several years, perhaps supported on private enterprise networks, Internet-based systems along with system supporting a broader application scope are now beginning to be deployed. The capabilities offered by IP Version 6 (IPv6) are critical to the wide-spread deployment of the technology. This course aims at exploring these evolving trends and offering practical suggestions of how these technologies can be implemented in the service provider networks to support cost-effective applications, and how new revenue-generating services could be brought to the market. All the latest physical layer, MAC layer, and upper layer IoT and Machine to Machine (M2M) protocols are discussed.

Prerequisite

Nil

Course Outcomes

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

CO1	Developing knowledge on Fundamentals of internet of things	Understand
CO2	To ensure, develop different wireless technologies and to learn about the IPv6 over 6LoWPAN	Apply
CO3	Developing software packages using python for internet of things	Apply
CO4	Analysing most of IoT projects using open source hardware	Analyse

Mapping with programme outcomes

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

S- Strong; M-Medium; L-Low

Assessment pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compare IoT frameworks.
2. Describe the architecture of CoAP protocol
3. Define Scalability and Interoperability

Course Outcome 2 (CO2):

1. Explain about IEEE 802.15.6 protocol and architecture of Frames

2. Illustrate IPv6 tunnelling
3. Describe IPv6 over 6LoWPAN

Course Outcome 3 (CO3):

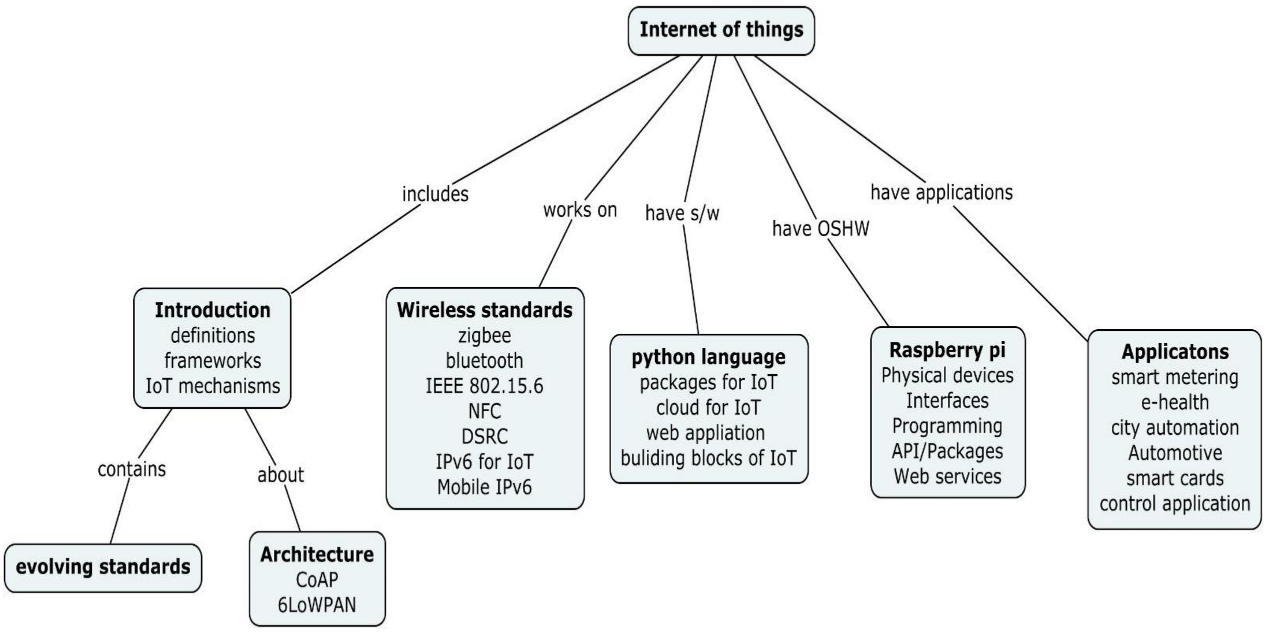
1. What are the packages used in IoT frame work
2. Can machine learning theories and algorithms help explain human learning?
3. What are the basic building blocks of IoT device?

Write a simple python program for the Http request from Raspbeerypi to server

Course Outcome 4 (CO4):

1. Elaborate the design and working of city automation
2. Design an smart metering system for the IoT
3. Design a system to monitor your health using body area networks.
4. Write about an automotive IoT system

Concept Map



Syllabus

Introduction to IoT: Overview, IPv6 role, Development and Standardization, IoT Definitions, IoT Frameworks.
Fundamental IoT mechanisms: Characteristics, scalability, interoperability, Key IoT mechanisms, sensor technology, Evolving IoT standards, Architectural reference model, CoAP, 6LoWAPAN.
Wireless technologies for the IoT: ZIGBEE, BLUETOOTH, IEEE 802.15.6, NFC, DSRC, IPv6 FOR IoT, IPv6 address space, protocol, tunnelling, QoS.
Mobile IPV6 for IoT: New IPv6 protocol, requirements for IPv6 nodes, IPv6 over 6LoWPAN
Logical design& physical devices: Python packages of interest for loT, Cloud for loT, python web application framework. Basic building blocks of a loT Device.
Open source hardware: Raspberry PI physical devices, Raspberry Pi Interfaces, Programming, APIs / Packages. Web services
Applications: Smart Metering/Advanced Metering Infrastructure , e-Health/Body Area Networks ,City Automation , Automotive Applications ,Home Automation Smart Cards , Control Application

Reference books

1. Arshdeep Bahga, Vijay Madisetti, **"Internet of Things – A hands-on approach"**, Universities Press,2015
2. Peter Waher, **"Learning Internet of Things"**, Packt Publishing,UK, 2015.
3. Marco Schwartz, **"Internet of Things with the Arduino Yun"**, Packt Publishing, 2014
4. Adrian McEwen, Hakim Cassimally, **"Designing the Internet of Things"**,Wiley Publishing, 2015

Course Contents and Lecture Schedule

Module no	Topic	No.of.lectures
1	**INTRODUCTION TO IoT**	
1.1	Overview, IPv6 role	1
1.2	Development and Standardization	1
1.3	IoT Definitions	1
1.4	IoT Frameworks.	1
2	**FUNDAMENTAL IoT MECHANISMS**	
2.1	Characteristics	2
2.2	scalability, interoperability	1
2.3	Key IoT mechanisms	1
2.4	sensor technology	1
2.5	Evolving IoT standards	1
2.6	CoAP, 6LoWAPAN	2
3	**WIRELESS TECHNOLOGIES FOR THE IOT**	
3.1	ZIGBEE	1
3.2	BLUETOOTH	1
3.3	IEEE 802.15.6	1
3.4	NFC, DSRC,	1
3.5	IPv6 FOR IoT	1
3.6	IPv6 address space, protocol, tunnelling, QoS	1
4	**MOBILE IPV6 FOR IoT**:	
4.1	New IPv6 protocol	2
4.2	requirements for IPv6 nodes	2
4.3	IPv6 over 6LoWPAN	2
5	**LOGICAL DESIGN& PHYSICAL Devices**	
5.1	Python packages of interest for IoT,	2
5.2	Cloud for IoT,	2
5.3	python web application framework..	2
5.4	Basic building blocks of a IoT Device	2
6	**OPEN SOURCE HARDWARE**	
6.1	Raspberry PI physical devices	2
6.2	Raspberry Pi Interfaces	2
6.3	Programming, APIs / Packages	2
6.4	Web services	2
7	**APPLICATIONS**	
7.1	Smart Metering/Advanced Metering Infrastructure	1
7.2	e-Health/Body Area Networks	1
7.3	City Automation	1
7.4	Automotive Applications	1
7.5	Home Automation Smart Cards	1
7.6	Control Application	1
	Total hours	46

Course Designers

1. Mr.S. Parthasarathi parthasarathi_s@tce.edu
2. Mr.S.A.R.Sheik masthan sarsmech@tce.edu

		Category	L	T	P	Credit
17MCPC0	**PROFESSIONAL PRACTICE**	PE	0	0	4	3

Preamble

This course will aim to achieve a professional development of the student in the context of the overall goal of his/her programme. Depending upon his professional interest, this course will be conducted in terms of actual participation in professional activities such as teaching, laboratory organization, course development, organizational development, R&D work, design, production, data organization, data preparation or management of institution etc. The course will also deal with communication aspects such as teaching a course, presenting a paper in the seminar/conference, articulating ideas and concepts to professional audience/customers, etc. This course will also deal with the laws and ethics concerned with the profession of an individual.

Prerequisite

NIL

Course Outcomes

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

CO1.	Participate in the professional activities	Understand
CO2.	Teach the interested subjects of Mechatronics engineering	Understand
CO3.	Handle the laboratory experiments for Under Graduate Students	Understand
CO4.	Develop the learning materials in the form of lecture notes and laboratory manuals	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Valuation category	Assessment (100)
Class work/ Lab classes	50
Professional Values & Ethics - Assignments/Test/Quiz	10
Industrial visit and Report	20
Viva-voce	10

Note:

Each student will get assigned /attached to the faculty member of the Department. The student will be assisting on Professional activities assigned by the concerned faculty. A technical report will be prepared by the individual student on a relevant industry visit made during the semester of study. All the assessments will be carried out by the assigned faculty and submit the marks at the end of the semester. Viva-voce will be conducted by a team of 4 faculty members constituted by the Head of the Department.

Course Designer

1. Dr. M.Palaninatha Raja hodmect@tce.edu

17MCPD0	THERMAL PACKAGING OF ELECTRONICS	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Appropriate thermal design has become one of the enabling factors for the realization of high power density electronic equipment. In addition to preventing failures that may result from high temperature, smart and innovative thermal designs will increase the life expectancy. In addition, design and manufacture of microelectronic devices and systems are multidisciplinary engineering activities. With the continuous trend toward miniaturization and high power density systems, the dependency between different design disciplines becomes more pronounced. Mechatronics being interdisciplinary branch, thermal packaging becomes more suitable subject.

Prerequisite

Nil

Course Outcome

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

CO 1.	Calculate the rate of conduction heat transfer	Apply
CO 2.	Determine the rate of convection heat transfer	Apply
CO 3.	Calculate the rate of convection heat transfer	Apply
CO 4.	Determine the heat dissipation in electronic equipment	Apply
CO 5.	Choose the microchannel heat sink for given application	Analysis

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO6.	S	S	M	M	L	L	L	L	L	L	L	L
CO7.	S	S	M	M	L	L	L	L	L	L	L	L
CO3	S	S	M	M	L	L	L	L	L	L	L	L
CO4	S	S	M	M	L	L	L	L	L	L	L	L
CO5.	S	S	S	M	L	L	L	L	L	L	L	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	50	50	30	30
Analyse	-	-	20	20
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is the temperature boundary condition at a symmetry plane
2. Two similar copper balls are heated inside an oven. Then one of them is left in still air while the other one is inside still water. Which copper ball is more likely to be considered a lumped system? Why?

3. Consider a 10 mm × 10 mm in size and 2 mm thick silicon die attached to a ceramic substrate. The heat dissipated uniformly in the die is 2 W. The side of the die attached to the substrate is kept at 1100C, and the other side is exposed to convection heat transfer to air at 250C. The convection heat transfer coefficient is h = 12 W/m2°C. Obtain the temperature distribution in the die and the heat transfer rate to the substrate and to the air. The thermal conductivity of silicon is 148 W/moC
4. If the length of a fin is doubled, will the heat transfer rate from the fin double as well? Why?

Course Outcome 2 (CO2)

1. What is the physical significance of the Reynolds number? How is it defined for a flat plate of length L?
2. Explain how natural convection flow is created around a hot object?
3. Consider a house that is maintained at 22°C at all times. The thickness and thermal conductivity of the walls are 0.15 m and 0.04 W/m°C. During a cold winter night, the outside air temperature is 4°C and wind at 50 km/h is blowing parallel to a 3 m high and 8 m long wall of the house. If the heat transfer coefficient on the interior surface of the wall is 8 W/m°C, determine the rate of heat loss from that wall of the house. Disregard any radiation heat transfer.
4. Consider an electronic package mounted on a horizontal printed circuit board. The package dissipates 3 W and its dimensions are 60 mm × 60 mm. The junction-to-case thermal resistance of this package is Rjc = 5°C/ W.
    a. Calculate the case-to-air thermal resistance, R, of this package in natural convection.
    b. What will be the junction temperature of this package if the air temperature is 25°C?
5. Consider water flow inside two similar pipes. The Reynolds number in one pipe is 550 and in the other pipe is 15,000. A small amount of a colored fluid is injected into each of these pipes. Explain what happens to the colored fluid in each pipe.

Course Outcome 3 (CO3)

1. Define the term Spectral intensity.
2. Define surface emissivity**.**
3. The emissivity of an opaque surface is 0.35. What are its absorptivity and reflectivity?
4. If the view factor between surfaces 1 and 2, F_{12}, is 0.3, and the absorptivity of surface 2 is 0.8, what fraction of the radiation energy emitted by surface 1 is absorbed by surface 2?
5. Consider a 0.6 m × 0.45 m printed circuit board dissipating 200 W and sitting on the base of a 0.6 m × 0.45 m × 0.15 m enclosure as shown below. If the emissivity and temperature of the top and side surfaces are 30°C and 0.7, and the emissivity of the printed circuit board is 0.8, what is the temperature of the printed circuit board? Neglect any conduction and convection heat transfer.

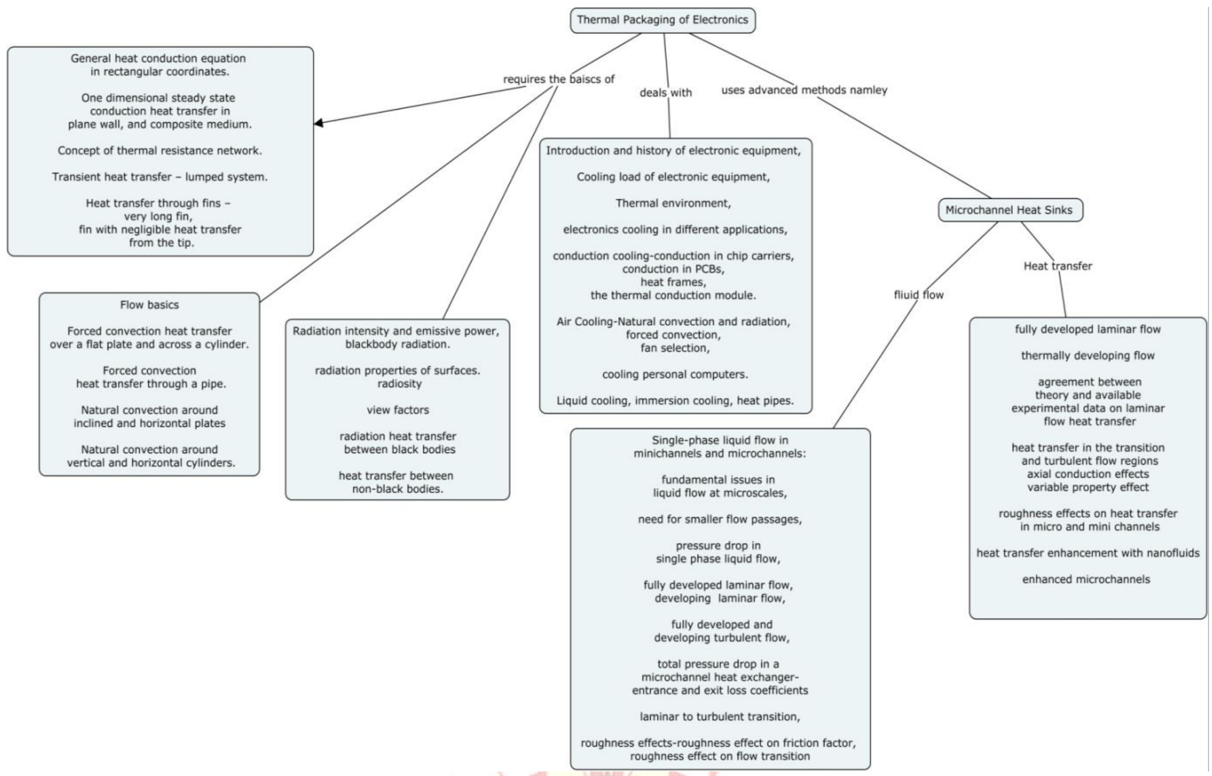
Course Outcome 4 (CO4)

1. A logic chip used in a computer dissipates 4 W of power and has a heat transfer surface area of 0.3 cm^2. If the surface of the chip is to be maintained at 70°C while being cooled by immersion in a dielectric fluid at 20°C, determine the necessary heat transfer coefficient and the type of cooling mechanism that needs to be used to achieve that heat transfer coefficient.
2. The temperature of the case of a power transistor that is dissipating 3 W is measured to be 50°C. If the junction-to-case resistance of this transistor is specified by the manufacturer to be 15°C/W, determine the temperature at the junction of the transistor.
3. A fan blows air at 30°C at a velocity of 200 m/min over a 1.2-W plastic DIP with 16 leads mounted on a PCB, determine the junction temperature of the electronic device. What would the junction temperature be if the fan were to fail?
4. Heat is to be conducted along a PCB with copper cladding on one side. The PCB is 10 cm long and 10 cm wide, and the thickness of the copper and epoxy layers are 0.04 mm and 0.16 mm, respectively. Disregarding heat transfer from side surfaces, determine the percentages of heat conduction along the copper (k = 386 W/m · °C) and epoxy (k = 0.26 W/m°C) layers. Also, determine the effective thermal conductivity of the PCB.
5. Consider a thermal conduction module with 100 chips, each dissipating 3 W of power. The module is cooled by water at 25°C flowing through the cold plate on top of the module. The thermal resistances in the path of heat flow are R_{chip} = 1°C/ W between the junction and the surface of the chip, R_{int} = 8°C/ W between the surface of the chip and the outer surface of the thermal conduction module, and R_{ext} = 6°C/ W between the outer surface of the module and the cooling water. Determine the junction temperature of the chip.

Course Outcome 5 (CO5)

1. Microchannels are directly etched into silicon in order to dissipate 100 W from a computer chip over an active surface area of 10 mm X 10 mm. Each of the parallel microchannels has a width a = 50 μm, depth b = 350 μm, and a spacing s = 40 μm. The silicon thermal conductivity may be assumed to be k5180 W/m K. Assume a uniform heat load over the chip base surface and a water inlet temperature of 35^0C. Assume one-dimensional steady state conduction in the chip substrate.
   a. Calculate the number of flow channels available for cooling.
   b. Assuming the temperature rise of the water to be limited to 10^0C, calculate the required mass flow rate of the water.
   c. Calculate the flow Reynolds number using the mean water temperature for fluid properties.
   d. Check whether the fully developed flow assumption is valid.
   e. Calculate the average heat transfer coefficient in the channels.
   f. Calculate fin efficiency.
   g. Assuming the heat transfer coefficient to be uniform over the microchannel surface, calculate the surface temperature at the base of the fin at the fluid inlet and fluid outlet sections.
   h. Calculate the pressure drop in the core of the microchannel.
   i. If two large reservoirs are used as the inlet and outlet manifolds, calculate the total pressure drop between the inlet and the outlet manifolds.
2. A microchannel is etched in silicon. The microchannel surface is intentionally etched to provide an average roughness of 12 μm. The microchannel dimensions measured from the root of the roughness elements are: width = 200 μm, height = 200 μm, length = 10 mm. Water flows through the microchannels at a temperature of 300 K. Calculate the core frictional pressure drop when (i) m = 90×10^{-6} kg/s, and (ii) m = 180×10^{-6} kg/s.
3. Consider a copper minichannel heat sink with an area of 30 mm X 30 mm and with Channel width = 1 mm, Channel height = 3 mm, and Fin thickness = 1.5 mm. The heat dissipation is 100 W and the water inlet temperature is 30^0C. The maximum surface temperature in the heat sink is limited to 80^0C. Calculate the water flow rate under these conditions. Also calculate the frictional pressure drop in the core. Assume a constant heat transfer coefficient corresponding to fully developed conditions and take the thermal conductivity of copper to be 400 W/m K.
4. Design a microchannel heat exchanger to dissipate 800 watts from a copper heat sink of 20 mm X 20 mm heated surface area. The inlet water temperature is 40^0C, and the maximum surface temperature in the heat sink is desired to be below 60^0C. Check your channel dimensions from a manufacturing standpoint (provide the manufacturing technique you will be implementing). Do not neglect the temperature drop occurring in the copper between the base of the channels and the bottom surface of the heat sink receiving heat. Show the details of the manifold design.

Concept Map



Syllabus

Basics of heat transfer

Conduction Heat Transfer: General heat conduction equation in rectangular coordinates. One dimensional steady state conduction heat transfer in plane wall, and composite medium. Concept of thermal resistance network. Transient heat transfer – lumped system. Heat transfer through fins – very long fin, fin with negligible heat transfer from the tip.

Convection Heat transfer: Flow basics, Forced convection heat transfer over a flat plate and across a cylinder. Forced convection heat transfer through a pipe. Natural convection around inclined and horizontal plates, Natural convection around vertical and horizontal cylinders.

Radiation Heat Transfer: Radiation intensity and emissive power, blackbody radiation, radiation properties of surfaces, radiosity, view factors, radiation heat transfer between black bodies, heat transfer between non-black bodies.

Cooling of electronic equipment – Introduction and history of electronic equipment, Cooling load of electronic equipment, Thermal environment, electronics cooling in different applications, conduction cooling-conduction in chip carriers, conduction in PCBs, heat frames, the thermal conduction module. Air Cooling-Natural convection and radiation, forced convection, fan selection, cooling personal computers. Liquid cooling, immersion cooling, heat pipes.

Microchannel heat sinks: Single-phase liquid flow in minichannels and microchannels: fundamental issues in liquid flow at microscales, need for smaller flow passages, pressure drop in single phase liquid flow, fully developed laminar flow, developing laminar flow, fully developed and developing turbulent flow, total pressure drop in a microchannel heat exchanger-entrance and exit loss coefficients, laminar to turbulent transition, roughness effects-roughness effect on friction factor, roughness effect on flow transition,

Heat transfer in microchannels-fully developed laminar flow, thermally developing flow, agreement between theory and available experimental data on laminar flow heat transfer, heat transfer in the transition and turbulent flow regions, axial conduction effects, variable property effect, roughness effects on heat transfer in micro and mini channels, heat transfer enhancement with nanofluids, enhanced microchannels

Reference Books

1. **Yunus A. Çengel and Afshin J. Ghajar, “**Heat and Mass Transfer – Fundamental & Applications**”, McGraw-Hill Education, Fifth Edition, 2015.**
2. **Incropera, F. P., D. P. DeWitt, T. L. Bergman, and A. S. Lavine, “**Fundamentals of heat and mass transfer**”, Hoboken, NJ: John Wiley & Sons, Inc., Sixth Edition, 2007.**
3. **Holman, J. P., “**Heat transfer**”, New York, NY: McGraw-Hill, 2010.**
4. **Sathis Kandlikar, Srinivas Garimella, Dongqing Li, Stephen Colin and Michael King, “**Heat transfer and fluid flow in minichannels and microchannels**” Butterworth-Heinemann, 2nd Edition, 2014.**
5. **C. B. Sobhan and G. P. Peterson,** “Microscale and Nanoscale Heat Transfer Fundamentals and Engineering Applications”, **CRS Press- New York, 2008**
6. **Ali Jamnia, "**Practical Guide to the packaging of electronics**", 2003,New York, Marcel Dekker,**
7. **Gordon N.Ellison, "**Thermal Computation for electronics**",2011, Boca Raton, CRC Press.**

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Conduction Heat Transfer**	
1.1	General heat conduction equation in rectangular coordinates	**1**
1.2	One dimensional steady state conduction heat transfer in plane wall, and composite medium.	**2**
1.3	Concept of thermal resistance network.	**1**
1.4	Transient heat transfer – lumped system.	**1**
1.5	Heat transfer through fins – very long fin, fin with negligible heat transfer from the tip.	**2**
2	**Convection Heat transfer**	
2.1	Flow basics, Forced convection heat transfer over a flat plate and across a cylinder.	**2**
2.2	Forced convection heat transfer through a pipe.	**1**
2.3	Natural convection around inclined and horizontal plates,	**2**
2.4	Natural convection around vertical and horizontal cylinders.	**2**
3	**Radiation Heat Transfer**	
3.1	Radiation intensity and emissive power	**1**
3.2	Blackbody radiation, Radiation properties of surfaces	**1**
3.3	Radiosity, View factors	**1**
3.4	Radiation heat transfer between black bodies	**2**
3.5	Heat transfer between non-black bodies	**2**
4	**Cooling of electronic equipment**	
4.1	Introduction and history of electronic equipment	**1**
4.2	Cooling load of electronic equipment	**1**
4.3	Thermal environment, electronics cooling in different applications	**2**
4.4	Conduction cooling-conduction in chip carriers	**1**
4.5	Conduction in PCBs, heat frames, the thermal conduction module.	**1**
4.6	Air Cooling-Natural convection and radiation	**1**
4.7	Forced convection, fan selection, cooling personal computers	**1**

Module No.	Topic	No. of Lectures
4.8	Liquid cooling, immersion cooling, heat pipes	**1**
5	**Microchannel Heat Sinks**	
5.1	Single-phase liquid flow in minichannels and microchannels	1
5.2	Fundamental issues in liquid flow at microscales	1
5.3	Need for smaller flow passages	1
5.4	Pressure drop in single phase liquid flow	1
5.5	Fully developed laminar flow, developing laminar flow, fully developed and developing turbulent flow	2
5.6	Total pressure drop in a microchannel heat exchanger-entrance and exit loss coefficients, laminar to turbulent transition	2
5.7	Roughness effects-roughness effect on friction factor, roughness effect on flow transition	1
	Heat transfer in microchannels	
5.8	Fully developed laminar flow, Thermally developing flow	2
5.9	Agreement between theory and available experimental data on laminar flow heat transfer	1
5.10	Heat transfer in the transition and turbulent flow regions	1
5.11	Axial conduction effects, Variable property effect	2
5.12	Roughness effects on heat transfer in micro and mini channels	1
5.13	Heat transfer enhancement with nanofluids	1
5.14	Enhanced microchannels	1
	Total	**48**

Course Designers:

1. G.Kumaraguruparan gkgmech@tce.edu

17MC270	**SENSORS AND MICRO CONTROLLER LABORATORY**	Category	L	T	P	Credit
		PC	-	-	2	1

Preamble

This course provides engineering students with basic understanding of two of the main components of any modern electrical or electromechanical system; sensors as inputs and its interfacing. This course is useful for those students interested in control engineering, robotics and systems engineering.

Prerequisite

17MC130- Sensors and Actuators
17MC220- Real Time Embedded System.

Course Outcomes

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

CO1	Apply the knowledge gained in sensors and microcontrollers to real system.	Apply
CO2	Design and implement interrupts and wave generations in practical/simulation environment	Apply
CO3	Design and implement interfacing of DAQ in practical/simulation environment	Apply
CO4	Design and implement traffic light controller and stepper motor in practical/simulation environment	Apply

Mapping with Program Outcomes

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

S- Strong; M-Medium; L-Low

Syllabus

List of experiments		
Ex.No	**Experiments/Exercise**	**Hours**
1	To perform 8 bit arithmetic operation with 8051 microcontroller and verify through simulation	2
2	To perform code conversion with 8051 microcontroller and verify through simulation	2
3	Sorting of 8 bit and 16 bit valves with 8051 microcontroller and verify through simulation	2
4	To perform timer operations and to generate square waveforms with 8051 microcontroller and verify through simulation	2
5	To perform Interrupt operation and to generate interrupt vector execution with 8051 microcontroller and verify through simulation and hardware test	2
6	To perform interfacing of traffic light controller with 8051 microcontroller and verify through simulation and hardware interface to show a pre defined sequence	2
7	To perform the interface of stepper motor, run forward, reverse, defined angle position	2
8	To perform the interface of AD convertor to convert analog signal to digital using hardware kit	2

9	To perform the interface of DAC, predefined square wave and trapezoidal and sine wave	2
10	To interface a logic controller with 8051 controller to show the execution of Boolean function	2
11	To perform the interface of matrix code and dhow the defined pattern of hardware interface	2
12	To perform the interface of temperature sensor to 8051 microcontroller and to linearise the temperature read out.	2
	Total	24

Minimum of 12 experiments are to be given

Course Designers:

1. Dr. L.R. Karlmarx - lrkarlmarx@gmail.com
2. Ms. S. Siva Priya - siva2692@hotmail.com

17MC310	MEMS	Category	L	T	P	Credit(s)
		PC	4	0	0	4

Preamble

Micro Electro Mechanical System (MEMS) contains components of sizes less than 1 millimeter. MEMS achieve some engineering functions by electro mechanical or electro chemical means. In general a sensor, an actuator and a signal transduction unit forms 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

Nil

Course Outcomes

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

CO1	Explain the characteristics and application of MEMS and Microsystems	Understand
CO2	Solve problems in scaling laws applicable to miniaturization.	Apply
CO3	Explain the working principle of MEMS sensors	Understand
CO4	Describe the working principle of MEMS actuators	Understand
CO5	Select appropriate micromachining process for fabricating MEMS devices and model MEMS device	Apply

Mapping with Program Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	L	L	L	-	-	-	-	-	-
CO2	S	S	S	M	L	-	-	-	-	-	-
CO3	S	M	L	M	M	-	-	-	-	-	-
CO4	S	M	L	M	M	-	-	-	-	-	-
CO5	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	20	20	20	20
Understand	60	60	60	60
Apply	20	20	20	20
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Define the term MEMS.
2. Define shape memory alloys.
3. Write note on the Characteristics of MEMS.
4. Explain in detail the application of MEMS in aerospace industry.
5. With neat diagram explain the functioning of micro pressure sensor.

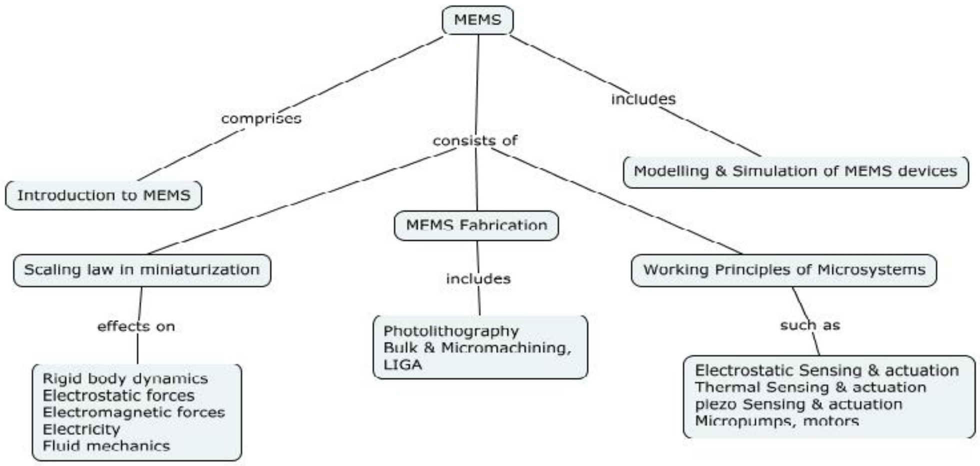
Course Outcome 2 (CO2):
1. Record two types of scaling laws used in micro-systems.
2. Write the scaling formula for a simple rectangular block.
3. Explain in detail, the Trimmer matrix to represent force scaling with related acceleration, time and power density required for scaling of systems in motion.
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 micro meter level?

Course Outcome 4 (CO4):
1. Discuss how the Comb-drive accelerometer works.
2. Describe the working principle of resitive pressure sensor.
3. Explain Thermal Bimorph.
4. Illustrate the working principle of piezo electric force sensor.

Course Outcome 4 (CO4):
1. Discuss how the piezoelectric actuator works.
2. Illustrate the working principle of micro motor.
3. Explain about microgripper.
4. Describe about the working of Magnetic actuators.

Course Outcome 5 (CO5):
1. Explain the general procedure of photolithography. Use neat diagrams.
2. Explain the LIGA process for MEMS fabrication.
3. Discuss about bulk-micromachining process.
4. Illustrate the fabrication process for Micro channel heat sink

Concept Map



Syllabus

Introduction to MEMS: Micro-Electro-Mechanical Systems (MEMS) and Microsystems, Intrinsic Characteristics of MEMS, Applications: Healthcare, Aerospace, Industrial & Consumer Products, Market for MEMS, Micro mechatronics, Overview of Micro fabrication, MEMS materials: Silicon, Silicon Dioxide, Silicon Nitride, Polysilicon, Silicon Carbide, Polymers, shape memory alloys - Clean rooms- Introduction to MOEMS & NEMS.

Scaling law in miniaturization: Introduction to scaling, scaling in rigid body dynamics, electrostatic forces, electromagnetic forces, electricity, fluid mechanics, heat transfer

Working Principles of Microsystems: Electrostatic Sensing & actuation – Resistive/Capacitive Pressure sensor, Comb-drive accelerometer, Comb-drive actuator. Thermal Sensing & actuation- Thermal Bimorph, Thermal actuator. Piezo Sensing & actuation- Force sensor, acoustic sensor, cantilever piezo electric actuator. Magnetic actuators- micro gripper- micro motor- micro valves- micro pumps

MEMS Fabrication: Photolithography, bulk micromachining, surface micromachining, LIGA process **Modelling & simulation of MEMS Devices:** cantilever beam, Micro pressure sensor, Micro channel heat sink, and accelerometer

Reference Book(s)

1. Chang Liu , “Foundation of MEMS”, 2nd Edition, Pearson education, 2012.
2. Tai –Ran Hsu, “MEMS and Microsystem: Design and Manufacture”, Tata McGraw Hill, First Edition, 2002.
3. Thomas M. Adams, Richard A. Layton “Introductory MEMS: Fabrication and Applications”, Springer, 2010
4. 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
5. Gad El Hak (Editor), “The MEMS Hand Book”, Three volume set, 2nd revised Edition, CRC press, 2005
6. Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim “Microsensors, MEMS, and smart devices”, 1st edition, John Wiley & Sons, Ltd, 2001

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to MEMS**	
1.1	Micro-Electro-Mechanical Systems (MEMS) and Microsystems	2
1.2	Intrinsic Characteristics of MEMS, Applications: Healthcare, Aerospace, Industrial & Consumer Products	2
1.3	Market for MEMS,	1
1.4	Micro mechatronics	2
1.5	Overview of Micro fabrication	2
1.6	MEMS materials: Silicon, Silicon Dioxide, Silicon Nitride, Polysilicon, Silicon Carbide, Polymers, shape memory alloys- Clean rooms	3
1.7	Introduction to MOEMS & NEMS.	2
2	**Scaling law in miniaturization**	
2.1	Introduction to scaling,	1
2.2	scaling in rigid body dynamics,	1
2.3	electrostatic forces,	1
2.4	Electromagnetic forces, electricity	2
2.5	fluid mechanics and	2
2.6	heat transfer	2
3	**Working Principles of Microsystems**	
3.1	**Electrostatic Sensing & actuation** – Resistive/Capacitive Pressure sensor, Combdrive accelerometer, Combdrive actuator.	3
3.2	**Thermal Sensing & actuation**- Thermal Bimorph, Thermal actuator.	2
3.3	**piezo Sensing & actuation**- Force sensor, acoustic sensor, cantilever piezo electric actuator.	3
3.4	Magnetic actuators	2
3.5	Microgripper	1
3.6	micro motors- micro valves- micro pumps	3
4	**MEMS Fabrication**	
4.1	Photolithography**,** bulk micromachining, surface micromachining, LIGA process	3
4.2	**Modelling & simulation of MEMS Devices:** Cantilever beam	2
4.3	Micro pressure sensor	2
4.4	Micro channel heat sink	2
4.5	Accelerometer	2
	Total	48

Course Designers:

Sl. No.	Name	E-mail Id
1	Dr.G. Kumaraguruparan	gkgmech@tce.edu
2	Mr.B. Praveen Kumar	bpkmech@tce.edu

17MCPF0	**AUTONOMOUS MOBILE ROBOTS**	Category	L	T	P	Credit(s)
		PE	4	0	0	4

Preamble

Autonomous Vehicles are self-governing vehicle, capable of sensing and navigate its own path for destination. Autonomous vehicles are broad scope of area which integrate computer vision, control system and sensory networks that driven the electrical drivers. Currently this field create a broad resources for surveillance and oppression.

Prerequisite

Nil

Course Outcomes

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

CO1	Derive the kinematics model and wheel kinematics model for different mobile robots.	Understand
CO2	Explain the classifications and operation of mobile robots locomotion.	Understand
CO3	Select appropriate sensors and implementation in mobile robots for given application.	Apply
CO4	Illustrate various localization and mapping techniques for mobile robots.	Apply
CO5	Implement path planning and navigation techniques for various case study conditions.	Apply

Mapping with Programme Outcomes

Cos	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	S	S	L	-	M	-	M	-	-	-	M
CO2	L	M	L	L	M	-	-	-	-	-	M
CO3	M	S	M	M	M	L	-	-	-	-	-
CO4	M	S	M	-	-	L	-	-	-	-	-
CO5	L	M	S	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
Understand	40	40	-	40
Apply	40	40	100	40
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Note: CAT 3 will conduct as Product based assessment pattern technique where students individually submit application prototype and defend the application through presentation.

Course Level Assessment Questions.

Course Outcome 1(CO1):

1. Describe robot motion on terms of component motion by mapping motion along the axes of the global reference frame to motion along the axes of the robot's local reference frame.
2. Explain forward kinematic models.
3. Consider the situation shown in figure 1, with an arbitrary position and orientation of the robot and a predefined goal position and orientation. The actual pose error vector given in the robot reference frame is with, and being the goal coordinates of the robot.

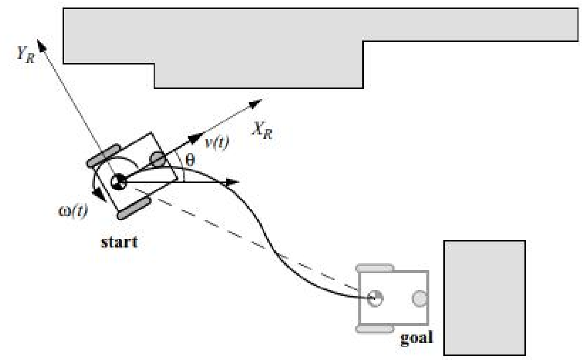


Fig-1

Course Outcome 2 (CO2):

1. With use of simple sketches, explain the working of castor wheel for steering a mobile robot.
2. Explain the classification of the sensors used in robotic applications.
3. List some Key issues of locomotion.

Course Outcome 3 (CO3):

1. Select suitable sensors to identify the obstacles and overcome the obstacles by controlling the robot actuators for following environment shown in Fig-2. Also every 1m distance the robot will generate signal to the remote area operator.

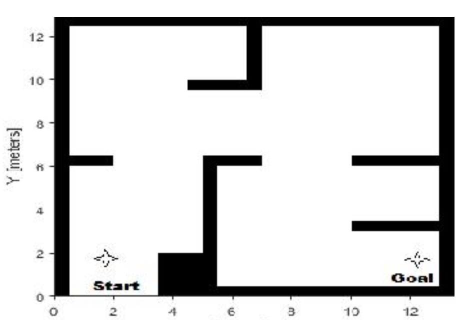


Fig-2

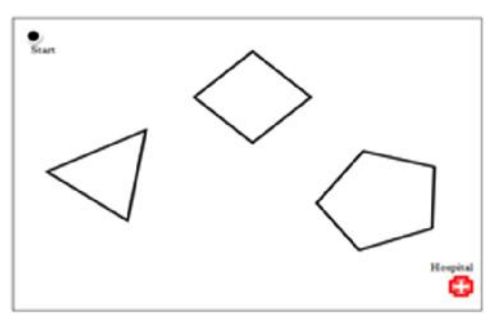


Fig-3

2. Calculate the dynamic range of current sensor which measures motor current and register values from a minimum of 1mA to 20Amps.
3. Select suitable sensor to measure the internal state and dynamics of a mobile robot.

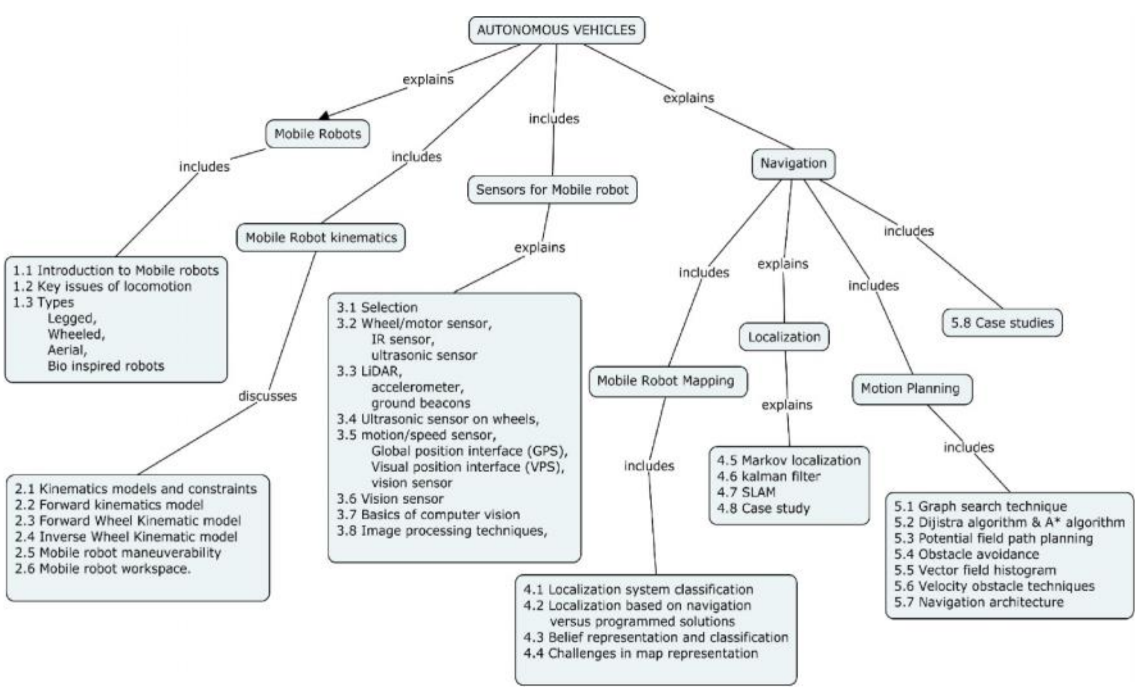
Course Outcome 4 (CO4):

1. A two axis robot is to be used to carry the patient from home location to hospital as shown in the below figure 3. Select a suitable graph search and Cell decomposition technique along with algorithm to overcome the obstacles and find the best path to reach the hospital at short time.
2. Select the suitable mapping technique for map building and maintenance into the standard localization loop using kalman filter localization.
3. Choose the appropriate technique used to correct the error produced in global map because of significant local error.

Course Outcome 5 (CO5):

1. A robot has three IR range sensor, four controlled front and rear wheel motors. Develop a pseudo code of algorithm for keep moving the robot to reach destination. Also explain the control of motors using flow chart. (Select your own environment with static and dynamic obstacles)
2. Illustrate the working for bug algorithm.
3. Apply potential field path planning for the given environment in fig-3.

Concept Map



Syllabus

Introduction: Introduction to Mobile robots – key issues of locomotion – Types- Legged, Wheeled, Aerial, Bio inspired robots. **Mobile Robot kinematics:** Kinematics models and constraints – Forward kinematics model- Wheel Kinematic model- Classification- Forward Wheel Kinematic model, Inverse Wheel Kinematic- Mobile robot maneuverability- Mobile robot workspace.

Sensors for Mobile robot: Sensor classification on perception- wheel/motor sensor, IR sensor, ultrasonic sensor, LiDAR, accelerometer, ground beacons, motion/speed sensor, Global position interface (GPS), Visual position interface (VPS), vision sensor- Fundamentals of computer vision-Image processing.

Mobile Robot Mapping and Localization: localization system –Localization based on navigation versus programmed solutions-Belief representation and classification- challenges in map representation- classifications of probabilistic map-based localization-Markov localization, kalman filter localization-Autonomous Map building SLAM and classifications- case study about mapping.

Motion Planning and Navigation: Path and Motion Planning- Path Planning – graph search, A* algorithm, Dijistra algorithm, Potential field path planning. Obstacle avoidance – bug algorithm, vector field histogram, velocity obstacle techniques. Navigation architecture, Case studies on navigation architecture

Reference Books

1. Ronald siegwart, Illah R.nourbakhsh, Davide scaramuzza," Introduction to Autonomous Mobile Robots",MIT Press Publication,2nd edition,2011.
2. S. M. LaValle. "Planning Algorithms". Cambridge University Press, Cambridge, UK, 2004.
3. Andon Venelinov Topalov, "Recent Advances in Mobile Robotics", published by InTech, Chapters published December 14, 2011
4. https://www.edx.org/course/autonomous-mobile-robots

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to Mobile Robots**	
1.1	Introduction to Mobile robots	1
1.2	Key issues of locomotion –	1
1.3	Types- Legged, Wheeled, Aerial, Bio inspired robots.	1
2	**Mobile Robot kinematics**	
2.1	Kinematics models and constraints	2
2.2	Forward kinematics model	1
2.3	Forward Wheel Kinematic model	1
2.4	Inverse Wheel Kinematic model	1
2.5	Mobile robot maneuverability	2
2.6	Mobile robot workspace.	2
3	**Sensors for Mobile robot**	

Module No.	Topic	No. of Lectures
3.1	Selection of sensors for mobile robots – Classification, performance	1
3.2	Wheel/motor sensor, IR sensor, ultrasonic sensor	1
3.3	LiDAR, accelerometer, ground beacons	1
3.4	Ultrasonic sensor on wheels,	1
3.5	motion/speed sensor, Global position interface (GPS), Visual position interface (VPS), vision sensor	2
3.6	Vision sensor	2
3.7	Basics of computer vision	2
3.8	Image processing techniques,	2
4	**Mobile Robot Mapping and Localization**.	
4.1	Localization system classification	1
4.2	Localization based on navigation versus programmed solutions	1
4.3	Belief representation and classification	2
4.4	Challenges in map representation	1
4.5	Markov localization	2
4.6	kalman filter localization	2
4.7	Autonomous Map building SLAM and classifications	2
4.8	Case study about localization systems	2
5	**Motion Planning and Navigation**	
5.1	Path Planning – Graph search technique	1
5.2	Dijistra algorithm & A* algorithm	2
5.3	Potential field path planning	1
5.4	Obstacle avoidance – bug algorithm	2
5.5	Vector field histogram	1
5.6	Velocity obstacle techniques	1
5.7	Navigation architecture	1
5.8	Case studies on navigation architecture.	2
	Total Hours	**48**

Course Designers:

Sl. No.	Name	E-mail Id
1	Mr S Julius Fusic	sjf@tce.edu
2	Mr M.Manimegalan	mmmech@tce.edu

17MCPH0	MODELING AND SIMULATION OF MECHATRONICS SYSTEMS	Category	L	T	P	Credit(s)
		PE	4	0	0	4

Preamble

A Mechatronic system design is a design process that is characterized by synergistic integration of mechanisms, sensors, actuators and control to perform complex tasks in a metaphysical environment.An important characteristic of mechatronic devices and systems is their built-in intelligence, which results through a combination of precision mechanical and electrical engineering and real-time programming integrated with the design process. Mechatronics system design makes possible to understand the basic design process involved in mechatronics, selection of sensors and actuators, the interface issues and communication problems. The design process includes modelling and simulation. This course teaches the basic concepts of modelling and simulation of Electrical, Electronics, Mechanical and Hydraulic systems combining to Mechatronic Systems. Design of a mobile robot is introduced in this subject to illustrate the concepts.

Prerequisite

Nil

Course Outcomes

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

CO1	Explain various methods modeling and simulation of Mechatronic system	Understand
CO2	Describe the basics of modelling using bond graph	Understand
CO3	Model and Simulate Electrical and Mechanical systems using Bond graph	Apply
CO4	Model and Simulate Hydraulic and Electronic systems using Bond graph	Apply
CO5	Derive the system equation from the bond graphs	Apply

Mapping with Programme Outcomes

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

S - Strong M - Medium L - Low

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.

Assessment Pattern

Theory (70 marks)						Practical (30 marks)		
Bloom's Category	Continuous Assessment Tests (20) 1	2		Terminal Examination (50)		Valuation category	Continuous Assessment (10)	Continuous Assessment Test 3 (20)
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):

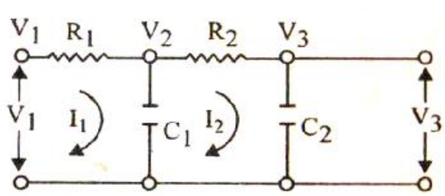
1. Define Transfer Function
2. List the type of mathematical models
3. Define Linearization models

Course Outcome 2 (CO2):

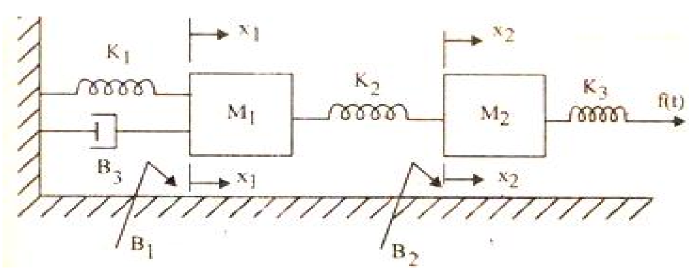
1. Discuss about Power Variables used in bond graph
2. Define components in physical systems
3. Explain about Transformer Element and Gyrator Element

Course Outcome 3 (CO3):

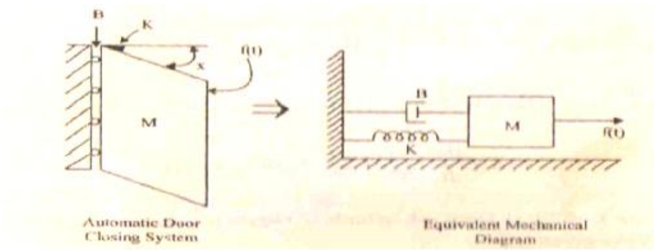
1. Develop a model for the physical system shown below using bond graph



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

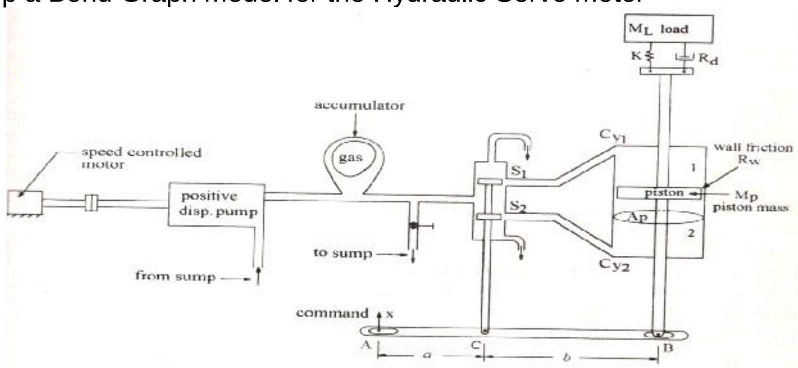


3. Develop a model for the physical system shown below using bond graph

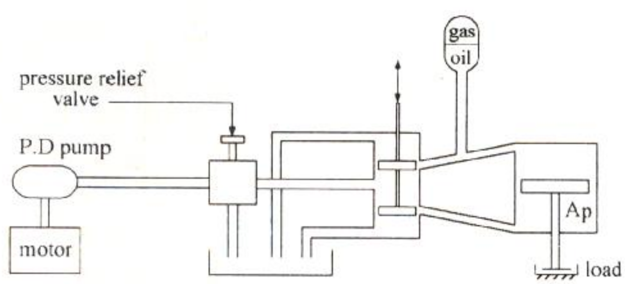


Course Outcome 4 (CO4):

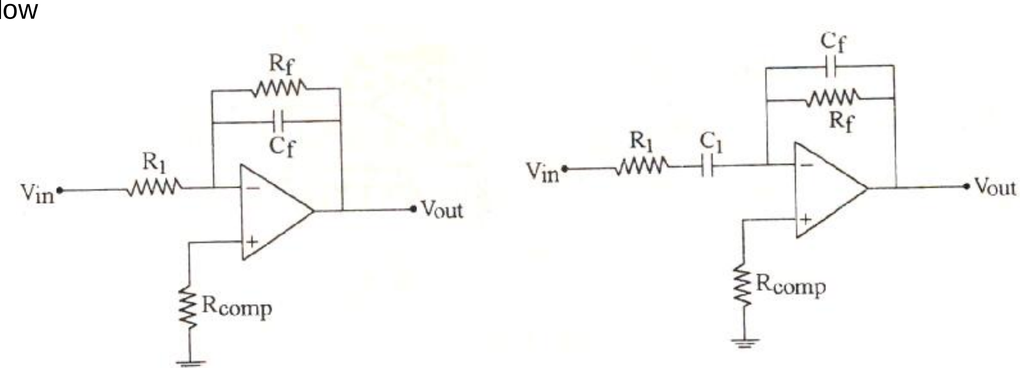
1. Develop a Bond Graph model for the Hydraulic Servo motor



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

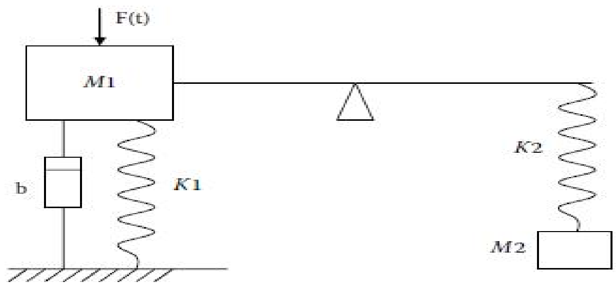


3. Draw a bond graph model for Practical integrator and differentiator circuit shown in below

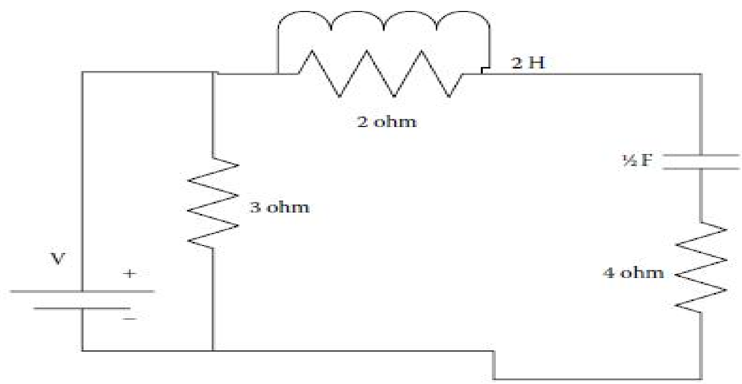


Course Outcome 5 (CO5):

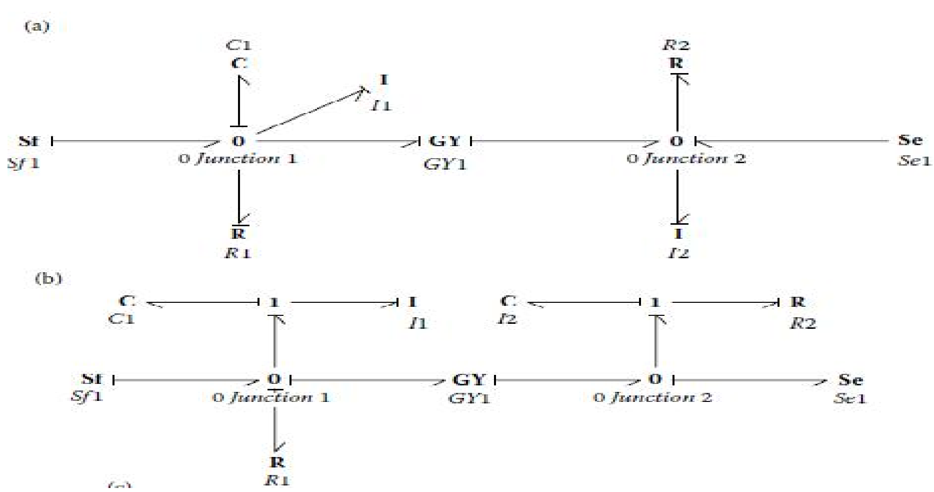
1. Derive the system equation for the following system. Follow the procedure and obtain the equations.



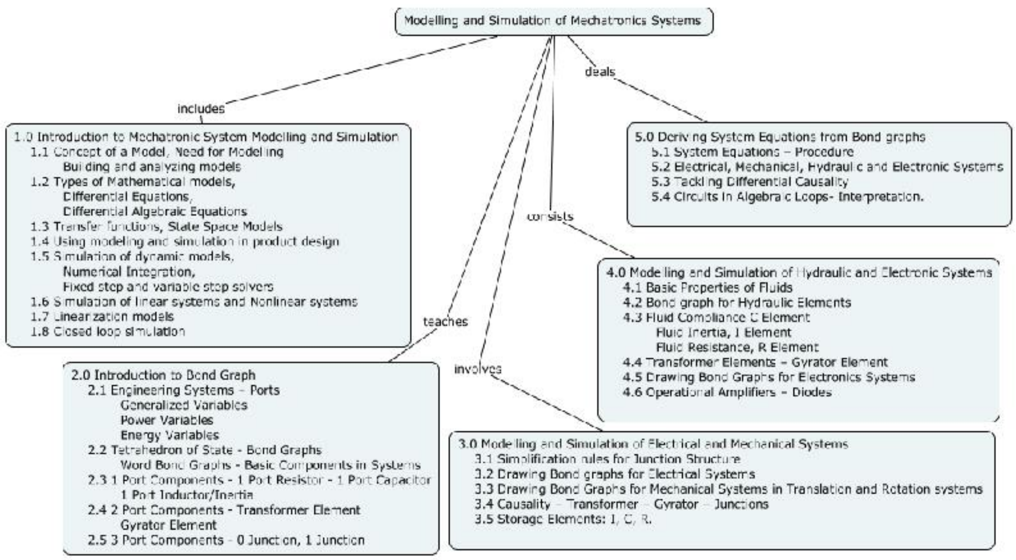
2. Consider the differential causality and derive the system equation for the following system.



3. Derive the governing equations for the bond graphs below:



Concept Map



Syllabus

Introduction to Mechatronic System Modelling and Simulation:

Concept of a Model, Need for Modelling, Building and analyzing models, Using modelling and simulation in product design, Types of Mathematical models, Differential Equations, Transfer functions, State Space Models. **Simulation:** Simulation of dynamic models, Numerical Integration, Fixed step and variable step solvers, Simulation of linear systems and nonlinear systems, Linearization models, Closed Loop simulation.

System Modelling by Bond Graphs:

Introduction-model categories-fields of application, generalized variables in bond graph-Power variables – Energy variables, Basic components in Bond graph-1 Port components- 1 Port Resistor- 1 Port Capacitor – 1 Port Inductor, 2 Port components- Transformer- Gyrator, 3 Port Components – 0 Junction, 1 Junction, Model development-Design examples.

Modelling and Simulation of 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 systems – Causality – Transformer – Gyrator – Junctions – Storage Elements: I, C, R.

Modelling and Simulation of Hydraulic and Electronic Systems

Basic Properties of Fluids – Bond graph for Hydraulic Elements – Fluid Compliance C Element – Fluid Inertia, I Element – Fluid Resistance, R Element – Transformer Elements – Gyrator Element – Drawing Bond Graphs for Electronics Systems – Operational Amplifiers – Diodes.

Deriving System Equations from Bond graphs

System Equations – Procedure – Electrical, Mechanical, Hydraulic and Electronic Systems, Tackling Differential Causality - Circuits in Algebraic Loops- Interpretation.

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. Dean C Karnopp, Donal L Morgolis, Ronald C Rosenberg "System Dynamics; Modeling, Simulation and Control of Mechatronic systems", John Wiley & Sons, Inc, 5th Edition, 2012.
4. Jacqueline Wilkie., Michael Johnson., Reza Katebi., " Control Engineering an Introductory course " Palgrave Publication, 2003.
5. Wayne Bequette. B., "Process Control: Modeling, Design and Simulation" ., Prentice Hall PTR, 2002.
6. Peter Fritzson., "Principles of object oriented modeling and Simulation with Modelica 2.1"., IEEE Press, 2004.
7. "Control design with Simulink" – The Math work tutorial – 2004.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to Mechatronic System Modelling and Simulation**	
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
1.5	Simulation of dynamic models, Numerical Integration, Fixed step and variable step solvers	2
1.6	Simulation of linear systems and Nonlinear systems	2
1.7	Linearization models	1
1.8	Closed loop simulation	1
2	**Introduction to Bond Graph**	
2.1	Engineering Systems – Ports - Generalized Variables - Power Variables - Energy Variables	1
2.2	Tetrahedron of State - Bond Graphs - Word Bond Graphs - Basic Components in Systems	1
2.3	1 Port Components - 1 Port Resistor - 1 Port Capacitor- 1 Port Inductor/Inertia	2
2.4	2 Port Components - Transformer Element - Gyrator Element	2
2.5	3 Port Components - 0 Junction, 1 Junction.	2
3	**Modelling and Simulation of Electrical and Mechanical Systems**	
3.1	Simplification Rules for Junction Structure	1
3.2	Drawing Bond Graphs for Electrical Systems	1
3.3	Drawing Bond Graphs for Mechanical Systems in Translation and Rotation	2
3.4	Causality – Transformer – Gyrator – Junctions	1
3.5	Storage Elements: L, *C* - *R*, for Resistive Elements -	1
4	**Modelling and Simulation of Hydraulic and Electronic Systems**	

Module No.	Topic	No. of Lectures
4.1	Basic Properties of Fluids	1
4.2	Bond Graph model for Hydraulic Elements	2
4.3	Fluid Compliance, C Element – Fluid Inertia, L Element – Fluid Resistances, R Element	2
4.4	Transformer Elements – Gyrator Element	2
4.5	Drawing Bond Graphs for Electronic Systems	1
4.6	Operational Amplifiers – Diodes	2
5	**Deriving System Equations from Bond graphs**	
5.1	System Equations – Procedure	1
5.2	Electrical, Mechanical, Hydraulic and Electronic Systems	2
5.3	Tackling Differential Causality	1
5.4	Circuits in Algebraic Loops- Interpretation.	1
Total		**41 Hours**

Laboratory Experiments

Sl No	Title
1	Modelling and Simulation of DC Motor control using MATLAB/Simulink
2	Modelling and Simulation of a House heating system using MATLAB/ Simulink
3	Modelling and Simulation of a DC (i) Series (ii) Shunt Motor by P, PI,PD and PID controller using 20 SIM
4	Modelling and Simulate the position of a Servo Motor by P, PI,PD and PID controller using 20 SIM
5	Modelling and Simulation of Operational Amplifier
6	Modelling and Simulation of a Mass, Spring, Damper combination by P, PI,PD and PID controller using 20 SIM
7	Modelling and Simulation of an Active Suspension System using 20 SIM
8	Modelling and Simulation of a Robot Grasping an object using 20 SIM
9	Modelling and Simulation of a Walking Robot using 20 SIM
10	Modelling and Simulation of a Hydraulic lift using 20 SIM
11	Modelling and Simulation of a Linear Compressor using 20 SIM
12	Modeling and simulation of Vehicle Dynamics using 20 SIM

Course Designers:

Sl. No.	Name	E-mail Id
1	Dr G Kumaraguruparan	gurupara@gmail.com
2	Mr M.A Ganesh	ganeshma2015@tce.edu

17MCPJ0 INTELLIGENT MOTION CONTROL DRIVES

Category	L	T	P	Credit(s)
PE	4	0	0	4

Preamble

Today, Industries are increasingly demanding process automation in all sectors. Automation results into better quality, increased production and reduced costs. Machine tools and Robots are become fundamental components of any automated Manufacturing work cell. The controlling parameters like motion, Speed, Position and torque are paramount in raising productivity and quality and reducing energy and equipment costs in all industries. Electric drives share most of industrial machine control applications. The heart of the modern machine tool are the motion control elements, which includes a numerical controller and a number of servo drives. The servo drives which drives machine tools need to achieve a high precision and accuracy.

Prerequisite

- 17MC120 - Principles of Mechanical systems
- 17MC130 - Sensors and actuators

Course Outcomes

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

CO1	Explain the basic structure of the position, speed and torque control in drives.	Understand
CO2	Design and evaluate the digital position control of drives.	Apply
CO3	Design and evaluate the digital speed control of drives	Apply
CO4	Develop the Torque control algorithms for the given application	Apply
CO5	Develop the trajectory generation and tracking algorithms.	Apply
CO6	Illustrate the effect of Torsional oscillations in drives and methods to suppress.	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	S	S	S	L	M	M	S	S	M	L
CO2	S	S	S	S	M	S	M	S	S	M	L
CO3	S	S	S	S	M	S	M	S	S	M	L
CO4	S	S	S	S	M	S	M	S	S	M	L
CO5	S	S	S	S	M	M	M	S	S	M	L
CO6	M	M	M	S	S	M	M	M	M	L	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	20	20	20	20
Apply	60	60	60	60
Analyse	-	-	-	-

Course Level Assessment Questions.

Course Outcome 1(CO1):

1. Explain the basic elements of Position control system
2. Explain the basic elements of speed control system.
3. Describe the structure of Torque control in Servo Drive.
4. Write the important specifications of servo drive.
5. Describe the features of servo drive.

Course Outcome 2 (CO2):

1. Explain the derivative action in position controller.
2. Design the non linear position controller for CNC applications.
3. The mechanical sub system of a position controlled system is described by J=0.01 kgm^2 and B=0.01 Nm/(rad/s).The torque actuator gain is K_M=1.Assuming the sampling time of 10 ms, obtain the pulse transfer function $W_P(z)$ of the control object.
4. Develop a simulink model of nonlinear position controller.
5. Discuss the step response and banwidth of the PD and PID controller.

Course Outcome 3 (CO3):

1. Select a drive and program servo drive using PLC for a robotic application with a payload of 10 Kg.
2. Develop servo drive program for driving axis motor of CNC turning Machine.
3. Explain the step response of a integral speed controller.
4. Explain the Feed forward compensation of Integral speed controller.

Course Outcome 4 (CO4):

1. Explain the vector control methods in detail
2. Discuss the direct torque and flux control methods in drives.
3. Explain the structure of closed loop torque control in electric drives.
4. Brief the components of Sliding mode motion control system

Course Outcome 5 (CO5):

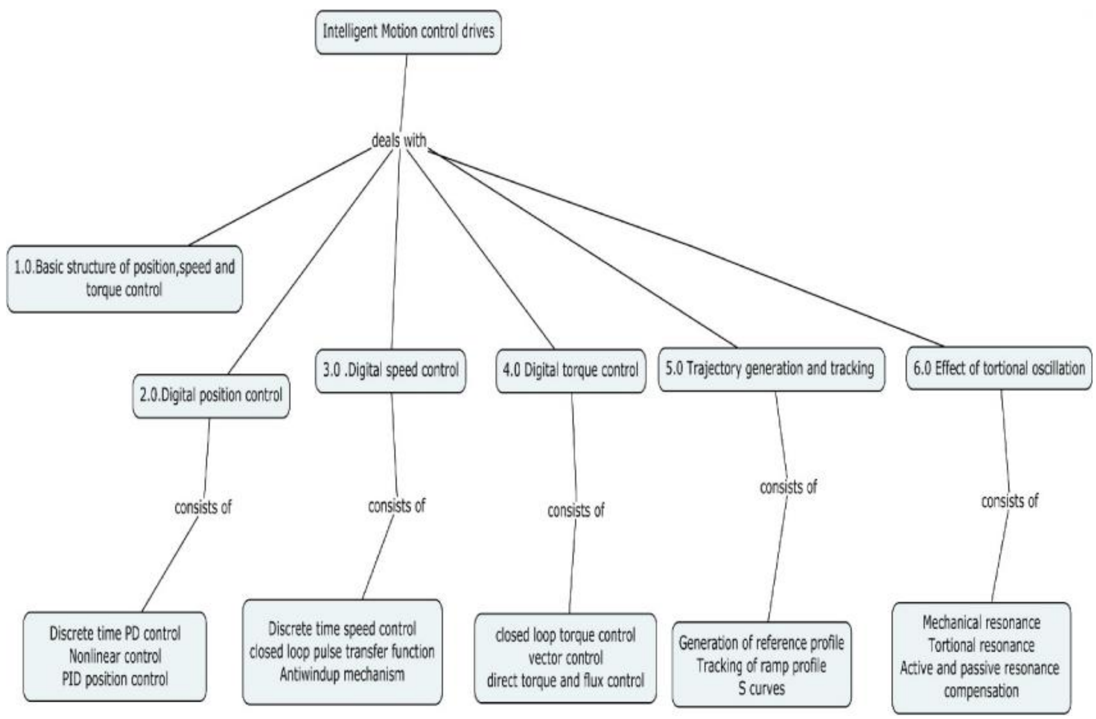
1. Develop a experimental setup for the ramp tracking of PID controller.
2. Discuss the coordinated motion in multiaxis systems
3. Explain the spline interpolation of course reference profiles.
4. Consider the linear PID position controller with proportional and derivative actions replaced in to the feedback path. Assume that the reference profile has a ramp shape ,with the position reference samples $\Theta^*k=kR^*$.Calculate the steady state position error $\Delta\Theta$.calculate the error for the case when the integral and proportional gains are in the direct path ,when the derivative gain resides in the feedback path.

Course Outcome 6 (CO6):

1. Discuss the importance of anti-resonant compensators.

2. Explain the closed loop response of a system with tortional oscillation.
3. Discuss the difference between active and passive resonance compensation methods.
4. A mechanical resonator consists of two rigid bodies, each one having inertia J=0. 0001kgm2.They are coupled by means of a flexible shaft, with stiffness K_k=500Nm/(rad/s). The internal friction of the shaft is K_v=0.01 Nm/(rad/s). Calculate the resonant and ant resonant natural frequency and relevant damping factors.

Concept Map



Syllabus

Structure of Motion control drives-Basic structure of position controllers-structure of speed controller-structure of torque controller-structure of cascaded control.

Digital position control-Performance of a single axis positioners -pulse transfer function-discrete time PD position controller-Evaluation of a system with PD controller-Operation in linear and pulse transfer functions-Nonlinear position controller-Simulation of a system with nonlinear position controller-step response and band width of PD and PID controller-parameter setting of PID position controllers-simulation of input step and load step response-nonlinear PID position controller

Digital speed control: Discrete time implementation of speed controllers-analysis of the system with a PI discrete time speed controller-high frequency disturbances and sampling processes-closed loop system pulse transfer function-parameter setting of discrete time speed controller-performance evaluation-response to large disturbances and the wind-up phenomenon-anti windup mechanism.

Digital torque control: closed loop torque control-torque perturbation observer-vector control-direct torque and flux control methods-multivariable force control-sliding mode motion control system for robot arm- -state space motion control-motion control by fuzzy systems, neural networks.

Trajectory generation and tracking: Tracking of ramp profiles with the PID position controller-steady state error in ramp profile tracking-generation of reference profiles-coordinated motion in multi axis systems-trajectories with trapezoidal speed change-abrupt torque changes and mechanical resonance problems.

Torsional oscillations and its compensation: control object with mechanical resonance-closed loop response of the system with torsional oscillation-ratio between motor and load inertia-Active and passive resonance compensation methods-sustained torsional oscillations-antiresonant compensators.

Reference Books

1. Ion Boldea, S.A Naser “Electric Drives” CRC Taylor & Francis group edition,2009
2. Slobodan N.Vukosavic “Digital control of electric drives”Springer international edition,2012.
3. M.N. Cirstea, A. Dinu, J.G. Khor,M. McCormick, “Neural and fuzzy logic control of drives and power systems” newness publications,2002
4. Frederick F. Ling,Servo motors and industrial control theory, springer,2009.
5. Gopal k.dubey, “Power semiconductor controlled drives”,prentice hall,1988.
6. Fundamenals of Servo motion control ,Parker Hannifin – Electromechanical Automation Div.
7. Indra Motion Logic Drives ,Indra works Software User Manual Bosch Rexroth.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Structure of Motion control drives**	
1.1	Structure of position controller	1
1.2	Structure of speed controller	1
1.3	Structure of torque controller	1
1.4	Structure of cascaded control	2
2	**Digital position control**	
2.1	Performance of a single axis positioners , pulse transfer function	1
2.2	Discrete time PD position controller-Evaluation of a system with PD controller	2
2.3	Operation in linear and pulse transfer functions	1
2.4	Non linear position controller-Simulation of a system with non linear position controller	2

Module No.	Topic	No. of Lectures
2.5	Step response and band width of PD and PID controller-	1
2.6	Parameter setting of PID position controllers	2
2.7	Simulation of input step and load step response-non linear PID position controller	2
3	**Digital speed control**	
3.1	Discrete time implementation of speed controllers	1
3.2	Analysis of the system with a PI discrete time speed controller	1
3.3	High frequency disturbances and sampling processes	1
3.4	Closed loop system pulse transfer function-	1
3.5	Parameter setting of discrete time speed controller-performance evaluation	2
3.6	Response to large disturbances and the wind up phenomenon-anti windup mechanism.	2
4	**Digital torque control**:	
4.1	Closed loop torque control-torque perturbation observer	1
4.2	Vector control-direct torque and flux control methods	2
4.3	multivariable force control	1
4.4	Sliding mode motion control system for robot arm-	2
4.5	State space motion control-motion control by fuzzy systems, neural networks.	2
5	**Trajectory generation and tracking**	
5.1	Tracking of ramp profiles with the PID position controller	2
5.2	Steady state error in ramp profile tracking	1
5.3	Generation of reference profiles-coordinated motion in multi axis systems-	2
5.4	Trajectories with trapezoidal speed change	1
5.5	Abrupt torque changes and mechanical resonance problems.	1
6	**Torsional oscillations and its compensation**	
6.1	Control object with mechanical resonance	2
6.2	Closed loop response of the system with torsional oscillation	2
6.3	Ratio between motor and load inertia-	1
6.4	Active and passive resonance compensation methods	1
6.5	Sustained torsional oscillations-antiresonant compensators.	1
	Total	**48 Hours**

Course Designers:

Sl. No.	Name	E-mail Id
1	Dr.S.Arockia Edwin Xavier	saexeee@tce.edu
2	Mr H.Ramesh	rameshh@tce.edu