OUTCOME BASED EDUCATION

M.Tech. DEGREE (Control and Instrumentation) PROGRAMME

CURRICULUM AND DETAILED SYLLABI FOR

I to IV SEMESTERS

CORE & ELECTIVE COURSES

FOR THE STUDENTS ADMITTED FROM THE ACADEMIC YEAR 2014-2015

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

MADURAI – 625 015, TAMILNADU
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Department of Electrical and Electronics Engineering

VISION

Transforming the individuals into globally competent electrical engineers to fulfil the technological needs of the society.

MISSION

1. Establishing world class infrastructure in Electrical Engineering.
2. Enhancing the knowledge of the faculty in cutting edge technologies through continuous improvement programmes.
3. Providing well balanced curriculum in graduate, postgraduate and doctoral programmes.
4. Adopting innovative content delivery, assessment and continuous improvement methods to achieve desired outcomes.
5. Facilitating industry institution interaction in teaching & learning, consultancy and research activities to accomplish the technological needs of the society.
6. Encouraging the faculty and students to carry out innovative research work
7. Practicing ethical standards by the faculty and students.
8. Motivating the students for active participation in co-curricular and extracurricular activities.

Programme Educational Objectives (PEO's)

PEO 1: Graduates of the programme will have successful career in Instrumentation, automation and inter-disciplinary fields.

PEO 2: Graduates of the programme will have professional competency to address the technological needs of society and industrial problems ethically.

PEO 3: Graduates of the programme will excel in research and contribute to technological development in control and instrumentation.

PEO 4: Graduates of the programme will demonstrate life-long independent and reflective learning skills in their career.

PEO 5: Graduates of the programme will exhibit project management skills and ability to work in collaborative, multidisciplinary tasks in their profession.

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Programme Outcomes (POs)

After the successful completion of the M.Tech. (Control & Instrumentation) programme, students should be able to:

PO1. Scholarship of Knowledge

Acquire state-of-art knowledge in instrumentation, control and automation, with an ability to discriminate, evaluate, analyze and synthesize existing and new knowledge, and integration of the same for enhancement of knowledge.

PO2. Critical Thinking

Analyze complex problems in instrumentation, control and automation engineering critically, apply independent judgement for synthesizing information to make intellectual and/or creative advances for conducting research in a wider theoretical and practical and policy context.

PO3. Problem Solving

Think laterally and originally, conceptualise and solve instrumentation, control and automation problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors.

PO4. Research Skill

Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyse and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in instrumentation, control and automation domains.

PO5. Usage of modern tools

Create, Select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex instrumentation control and automation engineering activities with an understanding of the limitations.

PO6. Collaborative and Multidisciplinary work

Possess knowledge and understanding of group dynamics, recognise opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.

PO7. Project Management and Finance

Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economical and financial factors.

PO8. Communication

Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

PO9. Life-long Learning

Recognise the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

PO10. Ethical Practices and Social Responsibility

Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

PO11. Independent and Reflective Learning

Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

Thiagarajar College of Engineering, Madurai-625015

Department of Electrical and Electronics Engineering

M.Tech. Control and Instrumentation

For the students admitted from 2014-15

Scheduling of Courses

Sem.	Theory Courses						Practical/Project	Total credits
I	14CI110 Applied Mathematics for Electrical Engineers 3:1	14CI120 Systems Theory 3:1	14CI130 Transducer Engineering 3:1	14CI140 Process Control and Instrumentation 3:1	14CI150 Microcontroller based system Design 3:0	14CI160 Advanced Digital Signal Processing 3:1	14CI170 Control and Instrumentation Laboratory 0:1	24
II	14CI210 Industrial Data Communication 3:0	14CI220 Digital Control system 3:1	14CIPx0 Elective I 3:1	14CIPx0 Elective II 3:1	14CIPx0 Elective III 3:1	14CIPx0 Elective IV 3:1	14CI270 Advanced Control and Instrumentation Laboratory 0:1	24
III	14CI310 System Identification and adaptive control 3:1	14CIPx0 Elective V 3:1	14CIPx0 Elective VI 3:1				14CI340 Project - I 0:4	16
IV							14CI410 Project - II 0:12	12
							Total Credits	**76**

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.Tech. DEGREE (Control and Instrumentation) PROGRAMME

COURSES OF STUDY

(For the students admitted from 2014-2015)

FIRST SEMESTER

Course code	Name of the Course	Category	No. of Hours / Week			credits
			L	T	P	
THEORY						
14CI110	Applied Mathematics for Electrical Engineers	BS	3	2	-	4
14CI120	Systems Theory	PC	3	2	-	4
14CI130	Transducer Engineering	PC	3	2	-	4
4CI140	Process Control and Instrumentation	PC	3	2	-	4
14CI150	Microcontroller based system Design	PC	3	-	-	3
14CI160	Advanced Digital Signal Processing	PC	3	2	-	4
PRACTICAL						
14CI170	Control and Instrumentation Laboratory	PC	-	-	**2**	1
		Total	**18**	**10**	**2**	**24**

SECOND SEMESTER

Course code	Name of the Course	Category	No. of Hours / Week			credits
			L	T	P	
THEORY						
14CI210	Industrial Data Communication	PC	3	-	-	3
14CI220	Digital Control System	PC	3	2	-	4
14CIPx0	Elective-I	PE	4/3	0/2	-	4
14CIPx0	Elective-II	PE	4/3	0/2	-	4
14CIPx0	Elective-III	PE	4/3	0/2	-	4
14CIPx0	Elective-IV	PE	4/3	0/2	-	4
PRACTICAL						
14CI270	Advanced Control and Instrumentation Laboratory	PC	-	-	**2**	1
		Total	**22/18**	**2/10**	**2**	**24**

THIRD SEMESTER

Course code	Name of the Course	Category	No. of Hours / Week			credits
			L	T	P	
THEORY						
14CI310	System Identification and adaptive control	PC	3	2	-	4
14CIPx0	Elective-V	PE	4/3	0/2	-	4
14CIPx0	Elective-VI	PE	4/3	0/2	-	4
PRACTICAL						
14CI340	Project - I	PC	-	-	12	4
		Total	**11/9**	**2/6**	**12**	**16**

FOURTH SEMESTER

Course code	Name of the Course	Category	No. of Hours / Week			credits
			L	T	P	
PRACTICAL						
14CI410	Project - II	PC	-	-	36	12
		Total	**-**	**-**	**36**	**12**

Total credits: 76

BS : Basic Science
PC : Program Core
PE : Program Elective

L : Lecture
T : Tutorial
P : Practical

Note:

1 Hour Lecture is equivalent to 1 credit

2 Hours Tutorials/Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.Tech. DEGREE (Control and Instrumentation) PROGRAMME

SCHEME OF EXAMINATIONS
(For the students admitted from 2014-2015)

FIRST 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	14CI110	Applied Mathematics for Electrical Engineers	3	50	50	100	25	50
2	14CI120	Systems Theory	3	50	50	100	25	50
3	4CI130	Transducer Engineering	3	50	50	100	25	50
4	14CI140	Process Control and Instrumentation	3	50	50	100	25	50
5	14CI150	Microcontroller based system Design	3	50	50	100	25	50
6	14CI160	Advanced Digital Signal Processing	3	50	50	100	25	50
PRACTICAL								
7	14CI170	Control and Instrumentation Laboratory	3	50	50	100	25	50

SECOND 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	14CI210	Industrial Data Communication	3	50	50	100	25	50
2	14CI220	Digital Control System	3	50	50	100	25	50
3	14CIPx0	Elective-I	3	50	50	100	25	50
4	14CIPx0	Elective-II	3	50	50	100	25	50
5	14CIPx0	Elective-III	3	50	50	100	25	50
6	14CIPx0	Elective-IV	3	50	50	100	25	50
PRACTICAL								
7	14CI270	Advanced Control and Instrumentation Laboratory	3	50	50	100	25	50

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	14CI310	System Identification and adaptive control	3	50	50	100	25	50
2	14CIPx0	Elective-V	3	50	50	100	25	50
3	14CIPx0	Elective-VI	3	50	50	100	25	50
PRACTICAL								
7	14CI340	Project - I	-	150	150	300	75	150

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	14CI410	Project - II	-	150	150	300	75	150

* 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.

List of Elective Subjects – M.Tech. Control and Instrumentation

Programme Electives			
Course Code 14CIPx0	Course Name	Pre/Co requisites	Credits
14CIPA0/ 14PSPQ0	Control of Electric Drives	DC Machines and transformers AC Machines	4
14CIPB0	Bio-Medical Instrumentation	Transducer Engineering	4
14CIPC0	Digital System Design using FPGA	Digital Systems	4
14CIPD0	Industrial Controllers	Digital Systems	4
14CIPE0	Intelligent Controllers	Control systems Process control	4
14CIPF0	Optimal Control And Filtering	Linear Control System Systems Theory	4
14CIPG0	Robust Control	Control Systems Systems theory	4
14CIPH0/ 14PSPG0	Power Plant Instrumentation and Control	Measurements and Instrumentation	4
14CIPJ0	Analytical Instrumentation	Transducer Engineering	
14CIPK0	MEMS	Transducer Engineering	4
14CIPL0	Multi sensor data fusion	Systems Theory Transducer Engineering	4
14CIPM0	Robotics	Systems theory Transducer Engineering	4
14CIPN0	Embedded System Design	Microcontroller based system Design C Programming	4
14CIPP0/ 14PSPJ0	SCADA	Measurements and Instrumentation	4
14CIPQ0/ 14PSPC0	Real Time Operating System	Microprocessor/ Microcontrollers	4
14CIPR0	Non linear control	Control systems Systems Theory	4
14CIPS0	Digital Image Processing	Advanced Digital Signal Processing	4
14CIPT0	State Estimation	Control Systems Systems Theory	4

14CI110/14PS110	**APPLIED MATHEMATICS FOR ELECTRICAL ENGINEERS**	Category	L	T	P	Credit
		BS	3	1	0	4

Preamble

An engineering PG student needs to have some basic mathematical tools and techniques to apply in diverse applications in Engineering. This emphasizes the development of rigorous logical thinking and analytical skills of the student and appraises him the complete procedure for solving different kinds of problems that occur in engineering. Based on this, the course aims at giving adequate exposure in Linear Algebra to find the singular value decomposition and Pseudo inverse of the matrix, Random Process to deal the Random Experiments with the state space S and parameter set T, stationary Functions, Gaussian Process…, Calculus of Variations to find the maximum or minimum value of a definite integral involving certain functions.

Prerequisite

- Matrix,
- Probability and Statistics,
- Calculus.

Course Outcomes

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

CO1.	Compute the pseudo- inverse of the rectangular matrix and Decompose the non-square matrix by singular value decomposition	Apply
CO2.	Derive the probability density function of a function of random variables.	Apply
CO3.	Estimate the functions of time when the probability measure is associated through random process	Apply
CO4.	Optimize the functional involving several variables and higher derivatives.	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests 1	Continuous Assessment Tests 2	Continuous Assessment Tests 3	Terminal Examination
Remember	10	10	10	10
Understand	10	20	20	20
Apply	80	70	70	70
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Generalized eigen vectors.
2. Determine the singular value decomposition of $\begin{pmatrix} 1 & 2 \\ 1 & 1 \\ 1 & 3 \end{pmatrix}$
3. construct QR decomposition of the matrix$\begin{pmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{pmatrix}$
4. Find the canonical basis for the matrix. $\begin{bmatrix} 2 & 2 & 2 \\ 0 & 4 & 0 \\ 3 & -3 & 1 \end{bmatrix}$.
5. Obtain the generalized inverse of A =$\begin{pmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{pmatrix}$.

Course Outcome 2(CO2)

1. What is meant by independent random variable?
2. If the joint pdf of X and Y is f(x,y)= x+y,0<x<2,0<y<1
   = 0 else where
   Show that X and Y are statistically dependent.
3. The current I and resistance R in a circuit are independent continuous RVs with the following density functions.

   f(i) = 2i, 0≤i≤1
   = 0 else where,
   g(r) = $\frac{r^2}{9}$, 0≤ri≤3
   = 0 else where,
   find the p.d.f of the voltage E in the circuit where E IR.
4. Train A arrives at a station at random in the time interval(0,T) and stops for a minutes. Train A arrives at a station at random in the time interval(0,T) and stops for a minutes independently.
   a. Find the probability that X will arrive before Y
   b. Find the probability that two trains meet.
   c. Assuming that the two trains meet, find the probability that X will arrive before Y

5. The joint pmf of a bivariate random variable (X,Y) is given by
   $P(x_i,y_j) = \begin{cases} k(2x_i + y_j), & x_i = 1,2;\ y_j = 1,2 \\ 0 & otherwise \end{cases}$
   Find the Value of k. Find the marginal probability mass function of x and y. Are they independent?

Course Outcome 3(CO3)

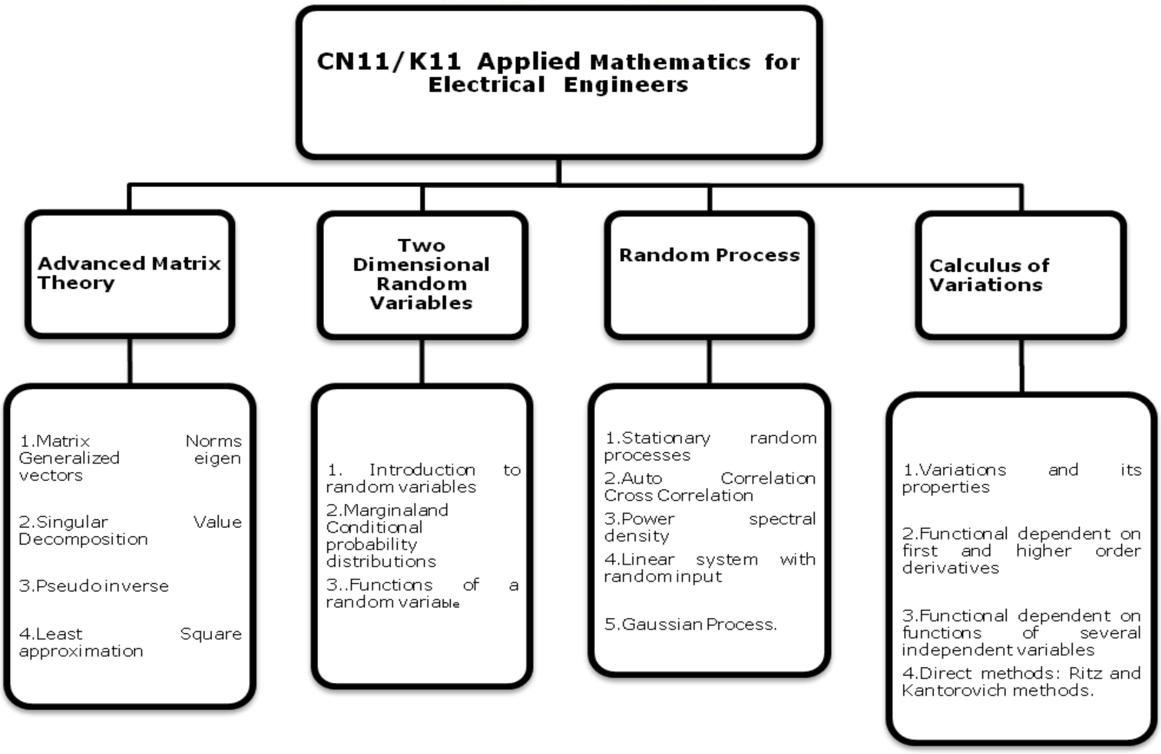
1. What is wide sense stationary process.
2. Check whether the random process X(t) =$Ae^{i\omega t}$ is a WSS if E[A]=0

3. If the random process X(t)= sin$(\omega t + y)$ where y is a random variable uniformly distributed in the interval $(0,2^{\pi})$,prove that for the process X(t), $C(t_1,t_2)$ = $R(t_1,t_2)$= $\frac{\cos\omega(t_1-t_2)}{2}$
4. If the function of Gaussian process are uncorrelated, then P.T. they are Independentant.
5. Calculate the power spectral density of a stationary random process for which the auto correlation is $R_{XX}(\tau) = \sigma^2 e^{-\alpha|\tau|}$

Course Outcome 4(CO4)

1. Write the Solution of the Eulers equation v(y(x))= $\int F(y,\acute{y})$dx.
2. Determine the extremals of $\int_0^{2}(y^{12}+z^{12}+2y^{3})$dx satisfying the conditions y(0)=0,y($\frac{\pi}{2}$)= 1,z(0)=1 and z$(\frac{\pi}{2}) = 0$.
3. Apply Ritz method to find approximate solution of the problem y'' +y+x=0, 0≤x≤1,, y(0) =0= y(1).
4. Prove that the extremal of the isometric problem v(y(x))= $\int_1^4 y'^2$ dx, y(1)=3, y(4)=24 subject to $\int_1^4 y$ dx= 36 is a parabola
5. A curve C joining the points (x $(x_1,y_1),(x_2,y_2)$ is revolved about the x-axis. Find the shape of the curve so that the surface thus generated is a minimum.

Concept Map



Syllabus

Advanced Matrix Theory

Matrix Norms – Jordon canonical form – Generalized eigen vectors – Singular Value Decomposition – Pseudo inverse – Least Square approximation – QR algorithm. (Treatment as per text book 1).

Two Dimensional Random Variables

Introduction to random variables. Marginal and Conditional probability distributions, Independent random Variables, Functions of a random variable, distribution of product and quotient of independent random variables. (Treatment as per text book 2).

Random Process

Classification – Stationary random processes – Auto Correlation – Cross Correlation – Power spectral density – Linear system with random input – Gaussian Process. (Treatment as per text book 3).

Calculus of Variations

Variations and its properties –Euler's equation – Functional dependent on first and higher order derivatives – Functional dependent on functions of several independent variables – Some applications – Direct methods: Ritz and Kantorovich methods. (Treatment as per text book 4).

Reference Books

1. Bronson,R, " Matrix Operations, Schaums Outline Series", McGraw Hill, New York, 1989.
2. Paul L.Meyer, "Introductory Probability and statistical applications", Addison-Wesley,1981.
3. Peebles JR., P.Z., "Probability Random Variables and Random Signal Principles", McGraw Hill inc.,(1993)
4. Gupta .A.S. ,"Calculus of variations and applications", Prentice Hall of India, New Delhi, 1999.
5. Irwin Miller, John E.Freund "Probability and Statistics for Engineers" Prentice Hall of India Pvt. Ltd.; New Delhi, 1977.
6. T.Veerarajan "Probability, Statistics and Random Processes" Tata McGraw-Hill, New Delhi, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Advanced Matrix Theory**	
1.1	Matrix Norms	1
1.2	Jordon canonical form – Generalized eigen vectors	2
1.3	Singular Value Decomposition	2
1.4	Pseudo inverse	2
1.5	Least Square approximation	2
1.6	QR algorithm	1
2.0	**Two Dimensional Random Variables**	
2.1	Introduction to random variables	2
2.2	Marginal and Conditional probability distributions	1
2.3	Independent random Variables	1
2.4	Functions of a random variable	2
2.5	distribution of product and quotient of independent random variables	2
3.0	**Random Process**	
3.1	Classification	2

3.2	Stationary random processes	2
3.3	Auto Correlation, Cross Correlation	2
3.4	Power spectral density	2
3.5	Linear system with random input	2
3.6	Gaussian Process	2
4.0	**Calculus of Variations**	
4.1	Variations and its properties	2
4.2	Euler's equation	2
4.3	Functional dependent on first and higher order derivatives	2
4.4	Functional dependent on functions of several independent variables, Some applications	2
4.5	Direct methods: Ritz and Kantorovich methods	2
	Total	**40**

Course Designers:

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2. Dr.S.Jeyabharathi sjbmat@tce.edu
3. Dr.C.S. Senthil Kumar kumarstays@tce.edu

		Category	L	T	P	Credit
14CI120/14PS120	**SYSTEMS THEORY**	PC	3	1	0	4

Preamble

Modern control theory is a powerful technique for the analysis and design of linear and nonlinear, time-invariant or time varying MIMO systems. The classical design methods suffer from certain limitations due to the fact that the transfer function model is applicable only to linear time invariant systems, and that there too it is generally restricted to single-input, single-output (SISO) systems. This course aims at giving an adequate exposure in state space analysis, state space controller design, MIMO system, Non-linear system, stability analysis.

Prerequisite

Control Systems, Matrix Algebra, Vector calculus,

Course Outcomes

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

CO1	Construct the state space model for the given electrical/electro-mechanical systems	Apply
CO2	Design pole placement controller and/or observer for the given system to achieve desired specifications	Apply
CO3	Explain optimal state regulator and stochastic optimal regulator	Understand
CO4	Explain the frequency domain characteristics of MIMO system	Understand
CO5	Construct the phase plane trajectory of a given nonlinear system	Apply
CO6	Explain describing function for various nonlinearities	Apply
CO7	Identify the existence of limit cycle(s) for the given nonlinear system using describing function method	Apply
CO8	Identify the stability of the given linear and nonlinear system using Lyapunov stability theory	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	M	M							M
CO2	S	M	M	M							M
CO3	M	S	S								
CO4	M	S	S								
CO5	S	M	M	M							M
CO6	S	M	M	M							M
CO7	S	M	M	M							M
CO8	S	M	M	M							M

S- Strong; M-Medium; L-Low

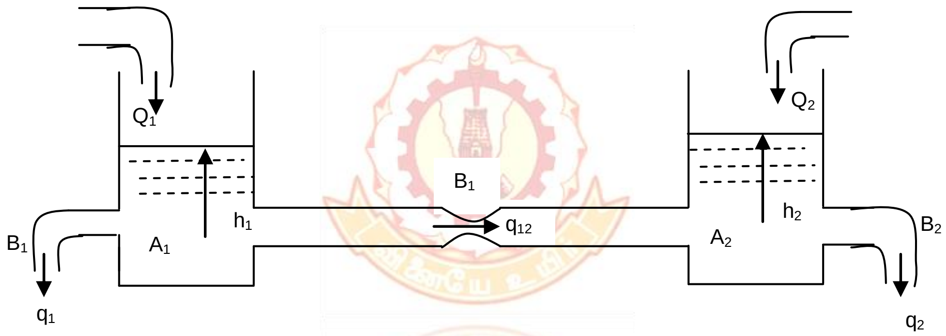
Assessment Pattern

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

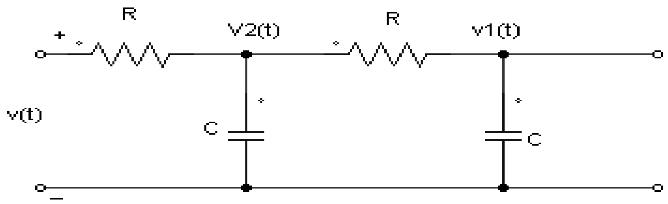
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Consider the hydraulic system shown in fig.1. Derive state space equations for the system with water levels h_1 and h_2 in the two tanks as the state variables x_1 and x_2 respectively and discharges q_1, q_{12} and q_2 as the outputs y_1, y_2 and y_3 respectively.



2. Obtain the state model of the electrical network shown in fig.2 by choosing v1 (t) and v2 (t) as state variables.



3. A feedback system is characterized by the closed loop transfer function:

$$T(S) = \frac{S^2 + 3S + 3}{(S^3 + 2S^2 + 3S + 1)}$$

Draw a suitable signal flow graph and there from construct a state model of the system.

Course Outcome 2 (CO2):

1. A computer system has the double integrator plant

$$\frac{Y(s)}{R(s)} = \frac{1}{s^2}$$

(i) Taking x_1=y and $x_2 = \dot{y}$ as state variables, obtain the state variable model of the plant.

(ii) Find k_1 and k_2 such that $u = -k_1x_1 - k_2x_2$ gives closed-loop characteristic roots with $\omega_n = 1$ and $\xi = 0.707$

(iii) Design a full-order observer that estimates x_1 and x_2 given measurements of x_1. Pick the characteristic roots of the state-error equations with $\omega_n = 5$ and $\xi = 0.5$

2.

A servo system has the plant described by the equation

$$X^o(t) = \begin{bmatrix} -1 & -2 & -2 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix} X(t) + \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix} u(t)$$

$$Y(t) = \begin{bmatrix} 1 & 1 & 0 \end{bmatrix} X(t)$$

Find a suitable pole placement controller to place the closed pole locations at -2, -2,-3.

3. Obtain the error equation for full order and reduced order observer.

Course Outcome 3 (CO3):

1. Consider the system shown below. Determine the optimal feedback gain matrix K such that the following performance index is minimized:
$J = 1/2 \int_0^\infty (x^T Qx + 2u^2)$ dt; Q=$\begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$.

2. Explain the working of stochastic optimal state estimators.

3. Write the expression for performance index (J) of an optimal regulator problem.

Course Outcome 4 (CO4):

1. Define singular values
2. Define transmission zero
3. Explain the frequency domain analysis of MIMO systems

Course Outcome 5 (CO5):

1. A linear second order servo is described by the equation, $\ddot{y} + 2\zeta\omega_n\dot{y} + \omega_n^2 y = \omega_n^2$, where $\omega_n = 1$, y(0)=2, $\dot{y}$(0)=0, ζ=1.5. Determine the singular point and construct the phase trajectory.

2. Determine the kind of singularity for each of the following differential equations. Also locate the singular points on the phase plane:
$\ddot{y}$+3$\dot{y}$+2y=0
$\ddot{y}$+5$\dot{y}$+6y=6
$\ddot{y}$-8$\dot{y}$+17y=34

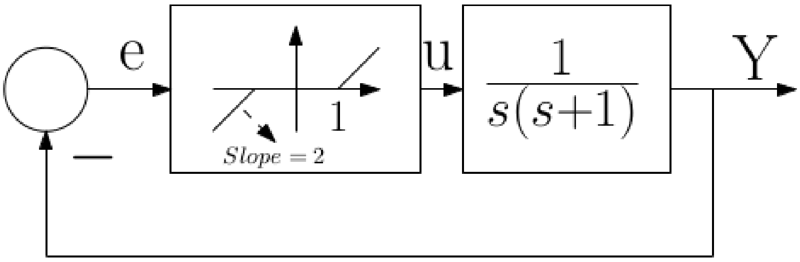
3. Define phase trajectory.

Course Outcome 6 (CO6):

1. Obtain the describing function of dead zone and saturation non linearity.
2. Explain in detail about different non linearity.
3. Obtain the describing function of relay with hysteresis.

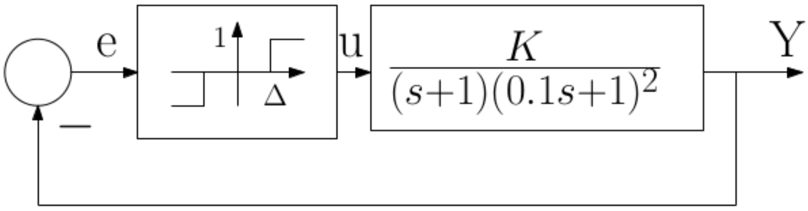
Course Outcome 7 (CO7):

1. Consider the system shown below. Using the describing function analysis, investigate the possibility of a limit cycle. If a limit cycle is predicted, determine its amplitude and frequency and investigate its stability.



2. Explain the stability analysis of non linear system by describing function method.

3. Investigate the stability of a relay controlled system shown in figure.



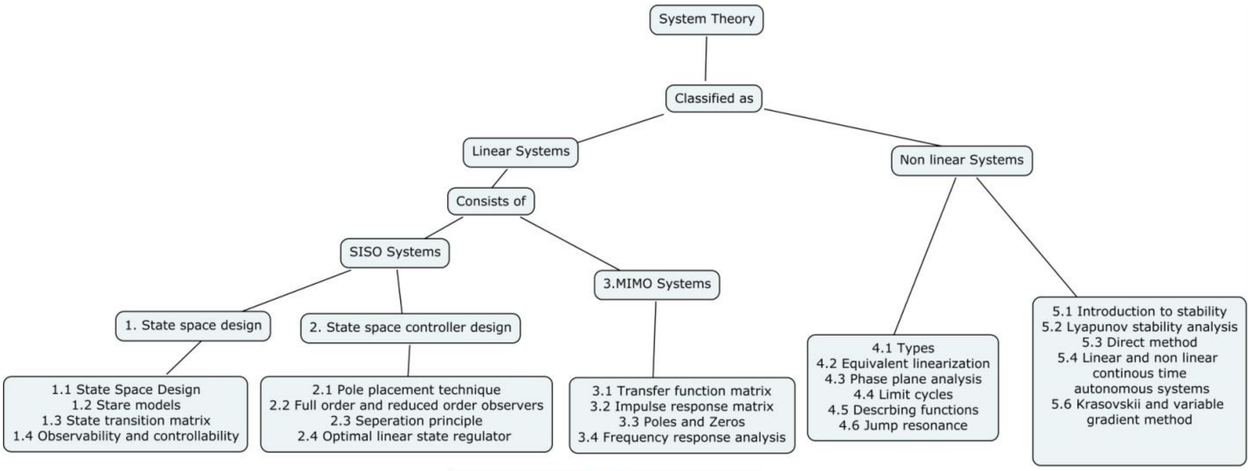
Course Outcome 8 (CO8):

1. Consider the linear autonomous system $\dot{x} = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} x$
   Using direct method of Lyapunov, determine the stability of the equilibrium state.

2. Check the stability of the equilibrium state of the system described by

   $\dot{x}_1 = x_2$
   $\dot{x}_2 = -x_1 - x_1^2 x_2$
3. Consider a nonlinear system described by the equations
   $\dot{x}_1 = -3x_1 + x_2$
   $\dot{x}_2 = x_1 - x_2 - x_2^3$
   Using the Krasovskii method for constructing the Lyapunov function with P as identity matrix, investigate the stability of the equilibrium state.

Concept Map



Syllabus

State Space Analysis
Introduction - Concept of state space model for dynamic systems – Time invariance and Linearity- Non-uniqueness - Minimal realization – Canonical state models - Solution of state equations – State transition matrix - Free and forced responses – Controllability and observability- Stabilisability and detectability.

State Space Controller Design
Introduction – State Feedback control – Pole Placement by State Feedback – Full Order and Reduced Order Observers – Separation principle –Optimal linear state regulator – Stochastic optimal linear estimator.

MIMO Systems
Properties of transfer functions Matrix – Impulse response matrices – Poles and zeros of transfer function matrices – Critical frequencies – Resonance – Steady state and dynamic response – Bandwidth- Nyquist plots – Singular value analysis.

Non-Linear Systems
Types of non-linearity – Typical examples – Equivalent linearization – Phase plane analysis – Limit cycles – Describing functions- Analysis using Describing functions – Jump resonance.

Stability
Introduction – Equilibrium Points – Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems – The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems – Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems – Krasovskii and Variable-Gradient Method.

Reference Books

1. M. Gopal, "Modern Control System Theory", New Age International Publications, revised 2nd edition, 2005.
2. K. Ogatta, "Modern Control Engineering", PHI Publications, 2002.
3. I.J.Nagarath , M. Gopal, "Control Systems Engineering", New Age International Publications, 4th edition, New Delhi, 2006.
4. M.Gopal, "Digital Control and state variable methods – conventional and intelligent control systems", Tata Mcgraw Hill 3rd edition, New Delhi, 2008.
5. Stanley M. Shinners, "Modern control system theory and design" Wiley-IEEE 2nd edition, 1998.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**State Space Analysis**	
1.1	Introduction - Concept of state space model for dynamic systems	1
1.2	Time invariance and Linearity, Non-uniqueness, Minimal realization, Canonical state models	2
1.3	Solution of state equations – State transition matrix	2
1.4	Free and forced responses	1
1.5	Controllability and Observability	2
1.6	Stabilisability and Detectability	1
2.0	**State Space Controller Design**	
2.1	Introduction – State Feedback control	1
2.2	Pole Placement by State Feedback	2
2.3	Full Order and Reduced Order Observers	2
2.4	Separation principle	2
2.5	Optimal linear state regulator	2
2.6	Stochastic optimal linear estimator	1
3.0	**MIMO Systems**	
3.1	Properties of transfer functions Matrix	1
3.2	Impulse response matrices	2
3.3	Poles and zeros of transfer function matrices	1
3.4	Critical frequencies, Resonance, Steady state and dynamic response, Bandwidth	1
3.5	Nyquist plots	2
3.6	Singular value analysis	1
4.0	**Non-Linear Systems**	
4.1	Types of non-linearity – Typical examples	2
4.2	Equivalent linearization	1
4.3	Phase plane analysis	2
4.4	Limit cycles	1
4.5	Describing functions- Analysis using Describing functions	2
4.6	Jump resonance	1
5.0	**Stability**	

5.1	Introduction – Equilibrium Points	1
5.2	Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems	2
5.3	Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems	2
5.4	The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems	1
5.5	Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems	1
5.6	Krasovskii and Variable-Gradient Method	2
	Total	**45**

Course Designers:

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2	Mr.V.Mahesh	maheshv@tce.edu

		Category	L	T	P	Credit
14CI130	**TRANSDUCER ENGINEERING**	PC	3	1	0	4

Preamble

Sensor and Transducer are used in automation, in construction, domestic appliances, industries, transport, health services, and other applications. Advances in processing and computation have opened up opportunities for very accurate control of plants, processes, and systems. Sensors/Transducers have helped achieve substantial accuracy and control as automation of any kind begins with the measurement of certain system parameters of which sensors and transducers form and essential and indispensable part. Industrial process monitoring has become possible by appropriate and accurate sensing of the relevant variables. This course deals with different sensors and transducers their characteristics, operation and applications.

Course Outcomes

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

(CO)	Course Outcome	Bloom's Level
(CO1)	Explain the static and dynamic characteristics of transducers and final control elements	Understand
(CO2)	Illustrate the mathematical model for resistive, inductive, capacitive, Piezo-electric, thermo-emf, magneto-resistive, hall effect	Understand
(CO3)	Choose suitable sensors/transducers for pressure, flow, temperature, magnetic field, displacement, torque, shock, vibration, liquid level, Ph, viscosity, conductivity, humidity and illumination measurement applications	Apply
(CO4)	Choose suitable signal conditioning methods for a specific application	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define the term Resolution
2. Distinguish between Accuracy and Precision.
3. List the causes for hysteresis in transducers.

Course Outcome 2 (CO2):

1. Write the relationship between temperature and resistance of conductors in RTD.
2. A piezo electric transducer has a capacitance of 1000 pF and a charge sensitivity of 4 X 10^{-6} Coulomb/cm. The connecting cable has a capacitance of 400 pF. The display device has an input impedance of 1 M ohm resistance and 50 pF capacitance connected in parallel. What is the lowest frequency that can be measured with 2 percent error?
3. A Hall element made out of Sn-Ge with co-efficient of 8 X 10^{-6}V-m^3/ (Wb-Amp) is subjected to a magnetic flux density of 0.75 Wb/sq.m. The thickness of this element is 2 mm. When a current of 1.5 A is flowing through the element, what is the voltage output.

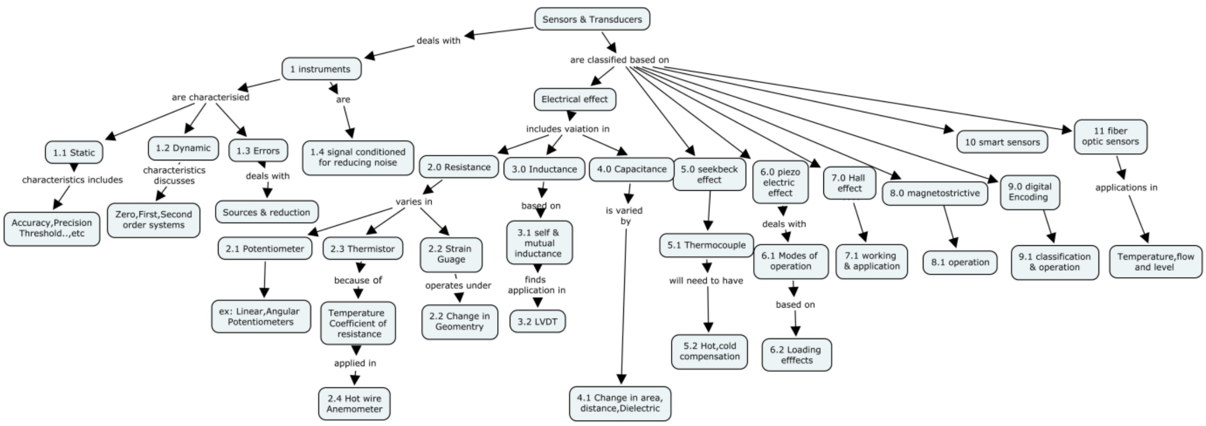
Course Outcome 3 (CO3):

1. Classify the different methods of measuring temperature
2. Write some Natural and artificial piezoelectric crystals
3. State the limitations of contact type shaft encoders.

Course Outcome (CO4):

1. To avoid self-lead error while using an wheatstone bridge for measurement of temperature using RTD, what should be the type of RTD to be used?
2. Of the two instruments, viz. Voltmeter and Oscilloscope, which of the meters will you use to find out the displacement from a LVDT, whose manufacturer data you have. Why?
3. Substantiate the necessity for going in for ac supply when using a Differential pressure transmitter.

Concept Map



Syllabus

Introduction to measurement systems: Elements of a measurement system – Definition of Sensor/ Transducer

Performance Characteristics of Transducers

Static characteristics: Meaning of static calibration, Accuracy, Precision, bias, Linearity, Threshold, Resolution, Hysteresis and Dead space, Scale readability and span
Dynamic characteristics: Sinusoidal transfer function, zero order transducer, First order transducer, Step, Ramp, Frequency and Impulse response, Second order transducer, Step, Ramp Frequency and Impulse response - **Errors in measurement process:** Sources and reduction of systematic error, Random error

Variable Resistance Transducers

Potentiometers: Loading effect, Power rating of potentiometers, Linearity and Sensitivity, Construction of potentiometers, Non-linear potentiometers - **Strain gauges**
Theory of Strain gauges, Types of strain gauges, Characteristics of strain gauges - **Resistance thermometers:** Characteristics, Linear approximation, Quadratic approximation, 2 wire RTD, 3 wire RTD – **Thermistors:** Resistance vs. Temperature characteristics - **Hot wire anemometers:** Constant current mode and Constant temperature mode

Variable Inductance transducers

Variable Inductance sensor - Linear Variable Differential Transformer Construction, Working principle, Auxiliary circuits

Variable capacitance transducers

Change in area of plates, Change in distance between the plates, Differential arrangement, Variation of dielectric constant, Frequency response.

Thermocouples - Construction, Measurement of thermocouple output, Law of Thermocouples, Compensating circuits, Reference junction compensation, Lead Compensation

Piezoelectric transducers -Modes of operation of piezoelectric crystals, Properties, Equivalent circuit of piezoelectric transducers, Loading effects and frequency response

Hall effect transducers- working principle, application, **Magnetostrictive transducers-** principle of operation

Digital encoding transducers – Classification of encoders, Construction of encoders – Signal generation - Brush type, Optical type, Magnetic type, Eddy current type

Fibre optic sensors – Liquid level sensing, Pressure sensing.

Smart sensors: Introduction, primary sensors, Excitation, Amplification, Filters, Convertors, Compensation, Information coding process, Data communication

Transmitters - Standards and Calibration: Instrumentation current Standards, Instrumentation Pressure Standards, Calibrators

Reference Books

1. E.O.Doubelin, Measurement Systems, McGraw Hill Book Company, 2008
2. Tony R. Kuphaldt , Lessons In Industrial Instrumentation ,Version 1.0 – Released September 28, 2009
3. D. Patranabis, Sensors and Transducers, Wheeler Publishing, 2006
4. Hermann, K.P. Neubert, Instrument Transducers, Oxford University Press, 1988
5. D.V.S. Murthy, Transducers and Instrumentation, Prentice Hall of India Pvt. Ltd., 2008

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.1	**Introduction to measurement systems:** Elements of a measurement system – Definition of Sensor/ Transducer	1
1.2	**Performance Characteristics of Transducers** **Static characteristics:** Meaning of static calibration, Accuracy, Precision, bias, Linearity, Threshold, Resolution, Hysteresis and Dead space, Scale readability and span **Dynamic characteristics:** Sinusoidal transfer function, zero order transducer, First order transducer, Step, Ramp, Frequency and Impulse response, Second order transducer, Step, Ramp Frequency and Impulse response	2
1.3	**Errors in measurement process:** Sources and reduction of systematic error, Random error	2
2.0	**Variable Resistance transducers**	
2.1	**Potentiometers:** Loading effect, Power rating of potentiometers, Linearity and Sensitivity, Construction of potentiometers, Non-linear potentiometers	2
2.2	**Strain gauges** Theory of Strain gauges, Types of strain gauges, Characteristics of strain gauges	2
2.3	**Resistance thermometers:** Characteristics, Linear approximation, Quadratic approximation, 2 wire RTD, 3 wire RTD **Thermistors:** Resistance vs. Temperature characteristics	2
2.4	**Hot wire anemometers:** Constant current mode and Constant temperature mode	2
3.0	**Variable Inductance transducers**	
3.1	Variable Inductance sensor -	1
3.2	Linear Variable Differential Transformer Construction, Working principle, Auxiliary circuits	2
4.0	**Variable capacitance transducers**	
4.1	Change in area of plates, Change in distance between the plates, Differential arrangement, Variation of dielectric constant, Frequency response.	2
5.0	**Thermocouples** Compensating circuits, Reference junction compensation, Lead Compensation	
5.1	Construction, Measurement of thermocouple output	2
5.2	Law of Thermocouples, Compensating circuits, Reference junction compensation, Lead compensation	2
6.0	**Piezoelectric transducers**	
6.1	Modes of operation of piezoelectric crystals, Properties, Equivalent	2

	circuit of piezoelectric transducers	
6.2	Loading effects and frequency response	2
7.0.	**Hall effect transducers**	
7.1	working principle, application	2
8.0	**Magnetostrictive transducers**	
8.1	Principle of operation	1
9.0	**Digital encoding transducers**	
9.1	Classification of encoders, Construction of encoders – Signal generation - Brush type, Optical type, Magnetic type, Eddy current type	3
10.	**Smart sensors**	
10.1	Introduction, primary sensors, Excitation, Amplification, Filters, Convertors, Compensation, Information coding process, Data communication	3
11.	**Fibre optic sensors**	
	Liquid level sensing, Pressure sensing	3
12.	**Transmitters**	1
13.	**Standards and Calibration:** Instrumentation current Standards, Instrumentation Pressure Standards, Calibrators	1
	Total	**40**

Course Designers:

1. Dr.V.Prakash vpeee@tce.edu
2. Mr.B.Ashok kumar ashokudt@tce.edu

14CI140	PROCESS CONTROL AND INSTRUMENTATION	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Process control is an important area of control theory. It enables mass production with desired quality, safe operation of many industries. Objective of the course is to introduce the concepts of modelling, analysis & control of SISO/MIMO processes and recent trends in process instrumentation.

Prerequisite

- Ordinary differential equations
- Laplace Transforms
- Control System

Course Outcomes

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

CO1	Construct the state space and transfer function model of chemical processes	Apply
CO2	Analyze the time domain and frequency domain characteristics and stability of a given chemical process	Analyze
CO3	Use PID tuning methods to achieve the desired specifications for a given process	Apply
CO4	Explain the working principle of dead time compensation, inverse response compensation, Cascade, Ratio, Feed forward, adaptive and selective control scheme	Understand
CO5	Design decentralized PID controller and Dynamic matrix controller for a given multivariable process	Analyze
CO6	Explain the characteristics of HART & field bus protocols	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	25	30	20	20
Apply	15	30	20	40
Analyse	0	30	50	40

Evaluate	0	0	0	0
Create	0	0	0	0

(CO4 for CAT III shall be evaluated from case studies/simulations)

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Construct the mathematical model of Continuously stirred tank reactor
2. Construct the mathematical model of Continuously stirred tank heater
3. Develop the mathematical model of Quadruple tank process

Course Outcome 2(CO2)

1. Sketch the unit step response of the process with transfer function $G(s)=\frac{1}{s^2+8s+25}.e^{-3s}$
2. Using Nyquist stability criterion comment on the closed stability of the process $G(s)=\frac{1}{s^2}e^{-s}$
3. Consider a liquid level control process with transfer function $G(s)=\frac{0.1}{0.1s+1}e^{-2s}$. Water flows in to the tank at the rate of 100lph. Linear velocity of water is 2m/s. Because of some constraint, the control valve has to be moved far away from the tank. Find the maximum distance at which the control valve can be placed without affecting the closed loop stability of the process

Course Outcome 3 (CO3)

1. Calculate the PID controller parameters for the process $G(s)=\frac{0.1}{0.1s+1}e^{-2s}$ using Ziegler Nichols method
2. Illustrate the effects of integral windup and the methods to overcome it.
3. Explain the relay feedback method of PID tuning

Course Outcome 4 (CO4)

1. With suitable diagram explain the working principle of Smidth Predictor
2. Explain the principle of operation of various adaptive control schemes.
3. Describe cascade control with an example

Course Outcome 5 (CO5)

1. Consider the MIMO Process given below. Design decentralized P controller to increase the speed of the process by 10 times

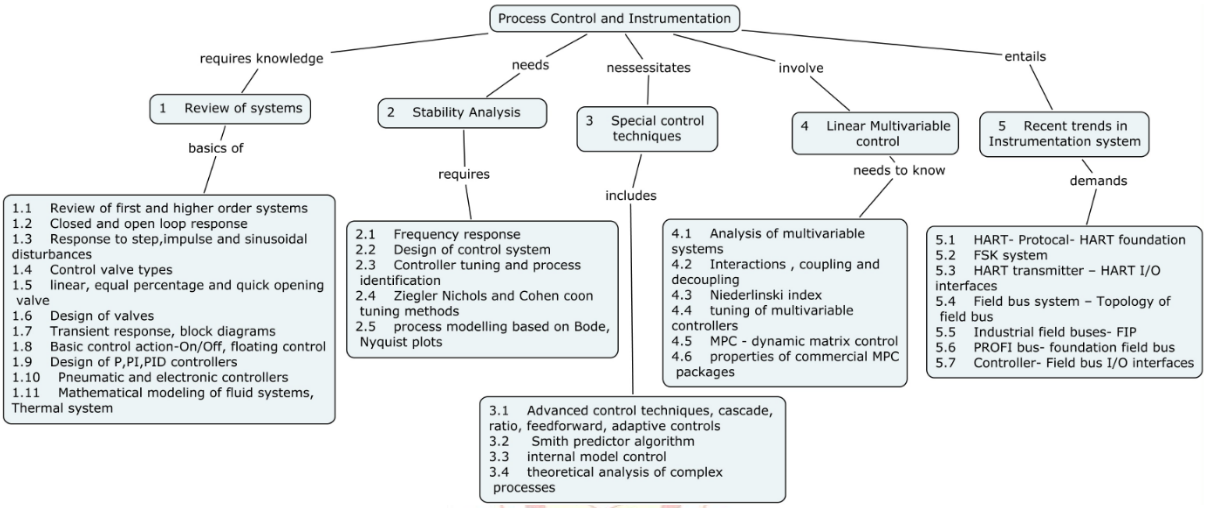
$$G_p(s)=\begin{bmatrix} \frac{2.6}{62s+1} & \frac{1.5}{(62s+1)(23s+1)} \\ \frac{1.4}{(30s+1)(90s+1)} & \frac{2.8}{90s+1} \end{bmatrix}$$

2. Design simplified and static decoupler for the process shown above. Compare their performance at the frequencies 0.01rad/s, 1 rad/s and 100 rad/s
3. Compare the features of various MPC packages.

Course Outcome 6 (CO6)

1. Illustrate the role of HART as a bridge in analog and digital instrumentation
2. With suitable diagram explain HART I/O Interfaces
3. Compare the features of various Industrial field buses

Concept Map



Syllabus

Review of systems

Review of first and higher order systems – Closed and open loop response-Response to step, impulse and sinusoidal disturbances- Control valve types- linear, equal percentage and quick opening valve- Design of valves- Transient response- block diagrams-Basic control action-On/Off, floating control- Design of P,PI,PID controllers, Pneumatic and electronic controllers, Mathematical modelling of Thermal system

Stability Analysis

Frequency response- Design of control system-Controller tuning and process identification-Ziegler Nichols and Cohen coon tuning methods- Bode, Nyquist plots-process modelling

Special control techniques

Advanced control techniques- cascade, ratio, feed forward, adaptive controls- selective control- Smith predictor algorithm- internal model control- theoretical analysis of complex processes

Linear Multivariable control

Analysis of multivariable systems- interactions- coupling and decoupling – Niederlinski index- tuning of multivariable controllers- MPC - dynamic matrix control- properties of commercial MPC packages

Recent trends in Instrumentation system

HART- Protocol- HART foundation- FSK system- HART transmitter – HART I/O interfaces- Field bus system – Topology of field bus- Industrial field buses- FIP- PROFI bus- foundation field bus – Controller- Field bus I/O interfaces

Reference Books

1. B.Wayne Bequette, “Process Control: Modeling, Design, and Simulation”, Prentice Hall of India, 2004
2. Dale E. Seborg , Duncan A. Mellichamp , Thomas F. Edgar, and Francis J. Doyle, III “Process Dynamics and Control”, John Wiley and Sons, 3rd Edition, 2010
3. George Stephanopolus, "Chemical Process Control", Prentice Hall India,2000
4. Instrumentation symbols and identification ANSI/ISA-S5.1-1984 (R 1992), Instrument Society of America, 1992
5. Wade, H.L., “Regulatory and advanced regulatory control: system development”, Research Triangle Park, NC, Instrument Society of America, 1994.
6. Qin, S. Joe, and Thomas A. Badgwell. "A survey of industrial model predictive control technology." *Control engineering practice* 11, no. 7 (2003): 733-764**.**

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture hours
1	**Review of systems**	
1.1	Review of first and higher order systems	1
1.2	Closed and open loop response	1
1.3	Response to step, impulse and sinusoidal disturbances	1
1.4	Control valve types	1
1.5	linear, equal percentage and quick opening valve	1
1.6	Design of valves	1
1.7	Transient response, block diagrams	1
1.8	Basic control action-On/Off, floating control	1
1.9	Design of P,PI,PID controllers	1
1.10	Pneumatic and electronic controllers	4
1.11	Mathematical modelling of Thermal system	2
2	**Stability Analysis**	
2.1	Frequency response	1
2.2	Design of control system	1
2.3	Controller tuning and process identification	2
2.4	Ziegler Nichols and Cohen coon tuning methods	1
2.5	Process modelling based on Bode, Nyquist plots	2
3	**Special control techniques**	
3.1	Advanced control techniques, cascade, ratio, feed forward, adaptive controls	3
3.2	Smith predictor algorithm	1
3.3	Internal model control	2
3.4	Theoretical analysis of complex processes	1
4	**Linear Multivariable control**	
4.1	Analysis of multivariable systems	1
4.2	Interactions , coupling and decoupling	2
4.3	Niederlinski index	1
4.4	tuning of multivariable controllers	1
4.5	MPC - dynamic matrix control	1
4.6	Properties of commercial MPC packages	1
5	**Recent trends in Instrumentation system**	

5.1	HART- Protocol- HART foundation	1
5.2	FSK system	1
5.3	HART transmitter – HART I/O interfaces	1
5.4	Field bus system – Topology of field bus	1
5.5	Industrial field buses- FIP	1
5.6	PROFI bus- foundation field bus	1
5.7	Controller- Field bus I/O interfaces	1
	Total	**45**

Course Designers:

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2. Dr.D.Kavitha dkeee@tce.edu

14CI150	**MICROCONTROLLER BASED SYSTEM DESIGN**	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

This course provides a broad and systematic introduction to microcontroller based system design. It explores the hardware architecture, programming and applications of C8051F040. Both assembly and C languages are used in programming. The details about hardware and software development tools (SiLab IDE) are discussed.

Prerequisite

Digital systems

Micro Processors and Microcontrollers.

Course Outcomes

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

CO1	Explain about the architecture and peripherals of C8051F040	Understand
CO2	DescribeAssembly and C programming of C8051F040	Understand
CO3	WriteC8051F040 programs for various applications.	Apply
CO4	Design a suitable interface to control a given system using µC.	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	40	20	0	20
Understand	40	40	0	20
Apply	20	40	100*	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CAT3 MAY BE CONDUCTED IN MICROCONTROLLER LABORATORY TO TEST CO3 AND CO4

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the registers associated with the operation of the AD module? What is the function of ADON bit? What is right and left justification of AD results?

2. Compare SPI, I^2C, and USART stating the possible application areas.
3. What is an interrupt?
4. What is a function prototype?
5. Why it is more efficient to use interrupts to handle inputs and outputs.
6. What is pre scaling and post scaling in timer 2? What is the advantage in using post scaling?

Course Outcome 2 (CO2):

1. Write assembler directives to reserve 20 bytes starting from the program-memory Location 0x1200 and initialize them to 0x20.
2. State the advantages of C programming over assembly language programming.
3. What is the instruction sequence to output the value of input port P4? And write the value to P5 of the C8051F040.
4. Write assembler directives to construct a table of the ASCII code of uppercase letters starting from the program-memory location at 0x40.
5. Write an instruction sequence to output the value of input Port P5 of the C8051F040.

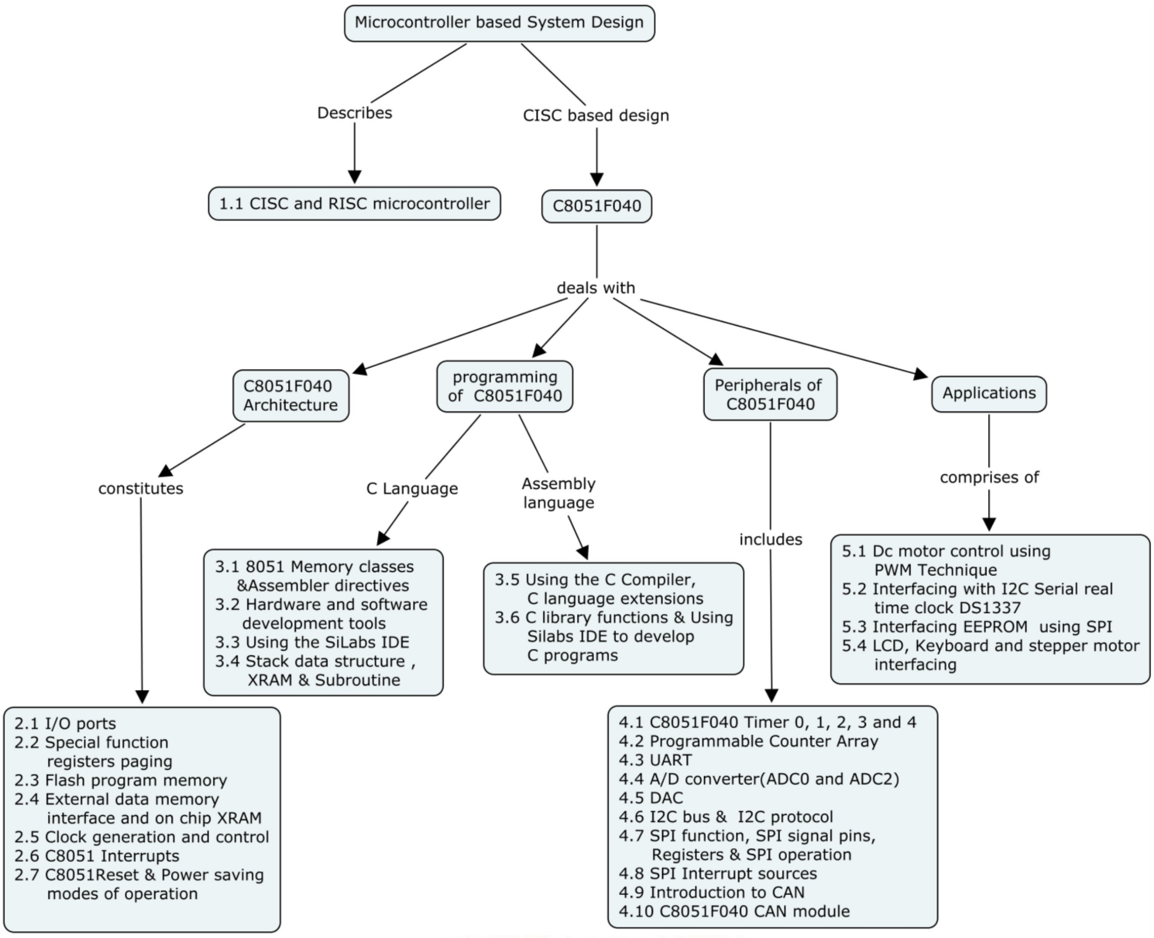
Course Outcome 3 (CO3):

1. Write a program to generate a square waveform with a 50 percent duty cycle and a frequency that alternates between 1 kHz and 2 kHz every four seconds.
2. Write a program to add the 16-bit numbers stored at internal data-memory locations 0x34 ~ 0x35 and 0x36 ~ 0x37, respectively, and save the sum at 0x40~0x41.
3. Write a C program to swap the first column of a matrix to last column.

Course Outcome 4 (CO4):

1. Write a program to use Timer 2 of the C8051F040 to create a time delay of 20 ms, assuming that the C8051F040 is running with a 24-MHz external oscillator.
2. Write a program to generate a 500-kHz digital wave form with a 50 percentage duty cycle from the T2 pin of a C8051F040 running with a 24-MHz crystal oscillator.
3. Interface C8051F040 with DC motor and write a program to control the speed of the motor.
4. With suitable interfacing diagram, develop a C- program to interface matrix keyboard with C8051F040.

Concept Map



Syllabus

Introduction: CISC and RISC microcontroller.

C8051F040 Architecture: I/O ports- Special function registers paging- Flash program memory- External data memory interface and on chip XRAM- Clock generation and control- C8051 Interrupts- C8051Reset- Power saving modes of operation.

Assembly and C programming of C8051F040: 8051 memory classes- 8051 assembly directives- Hardware and software development tools- Using the SiLabs IDE- Stack data structure- XRAM- Subroutine- Using the C Compiler- C language extensions- C library functions -Using SiLabs IDE to develop C programs.

Peripherals of C8051F040: C8051F040 Timer 0, 1, 2, 3 and 4- Programmable Counter Array-UART-A/D converter(ADC0 and ADC2)- DAC- I2C bus- I^2C protocol- SPI function – SPI signal pins – Registers- SPI operation –Interrupt sources-Introduction to CAN-C8051F040 CAN module.

Applications of C8051F040: Dc motor control using PWM Technique- Interfacing with I^2C Serial real time clock DS1337- Interfacing EEPROM using SPI-LCD, Keyboard and stepper motor interfacing

Reference Books

1. Han-Way Huang – Embedded System Design using C8051-Cengage Learning India Private Limited, New Delhi, 2009.
2. Ajay V Deshmukh-Microcontrollers-Theory and Applications-Tata McGraw-Hill Publishing Company Limited, New Delhi, 2005.
3. WWW.Silabs.com

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Introduction**	
1.1	CISC and RISC microcontroller	1
2.0	**C8051F040 Architecture**	
2.1	I/O ports	1
2.2	Special function registers paging	1
2.3	Flash program memory	2
2.4	External data memory interface and on chip XRAM	1
2.5	Clock generation and control	1
2.6	C8051 Interrupts	2
2.7	C8051 Reset & Power saving modes of operation	1
3.0	**Assembly and C programming of C8051F040**	
3.1	8051 Memory classes & Assembler directives	2
3.2	Hardware and software development tools	2
3.3	Using the SiLabs IDE	1
3.4	Stack data structure ,XRAM & Subroutine	1
3.5	Using the C Compiler, C language extensions	2
3.6	C library functions & Using Silabs IDE to develop C programs	2
4.0	**Peripherals of C8051F040**	
4.1	C8051F040 Timer 0, 1, 2, 3 and 4	2
4.2	Programmable Counter Array	2
4.3	UART	2
4.4	A/D converter(ADC0 and ADC2)	2
4.5	DAC	1
4.6	I^2C bus & I^2C protocol	2
4.7	SPI function, SPI signal pins, Registers & SPI operation	2
4.8	SPI Interrupt sources	1
4.9	Introduction to CAN	2
4.10	C8051F040 CAN module	2
5.0	**Applications of C8051F040**	
5.1	Dc motor control using PWM Technique	1
5.2	Interfacing with I^2C Serial real time clock DS1337	2
5.3	Interfacing EEPROM using SPI	1
5.4	LCD, Keyboard and stepper motor interfacing	2
	Total	**45**

Course Designers:

1. Dr.M.Saravanan mseee@tce.edu
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14CI160	ADVANCED DIGITAL SIGNAL PROCESSING	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Signals play major role in our life. In general, a signal can be a function of time, distance, position, temperature, pressure etc., and represents some variable of interest associated with system. A signal carries information and objective of signal processing is to extract this information. Signal processing is concerned with representing the signal in mathematical terms and extracting the information by carrying out the algorithmic operations on the signal. Digital processing of a signal has major advantage over analog techniques. With digital filters, linear phase characteristics can be achieved; filters can be made to work over a wide range of frequencies. Storage of digital data is very easy. Digital processing is more suited for low frequency signals like seismic signals, bio-signals.

Prerequisite

- Signals and Systems

Course Outcomes

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

CO1	Identity properties of discrete-time systems such as time-invariance, stability, causality, and linearity.	Apply
CO2	Determine the DTFT, DFT and FFT of a sequence.	Apply
CO3	Design and Realize the IIR and FIR filters for a given specification	Apply
CO4	Employ Multirate Signal Processing in digital signals	Apply
CO5	Apply wavelet transforms in signals	Apply
CO6	Describe the architecture and features of TMS320f240 digital signal processor	Understand
CO7	Describe the role of DSP in PID controller, Position control, power meter etc.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L								L
CO2	S	M	L								L
CO3	S	M	L								L
CO4	S	M	L								L
CO5	S	M	L								L
CO6	M	L									
CO7	M	L									

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	20	20	10
Understand	30	30	40	40
Apply	60	50	40	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Find circular convolution of the given sequences and compare with linear convolution.

   $x_1(n) = \{2, 3,-1,2\}$ & $x_2(n)=\{-1,2,-1,2\}$.
2. Define odd and even signal.
3. Check whether the system y(n) = x(n) – x(n-1) is LTI and stable.

Course Outcome 2 (CO2):

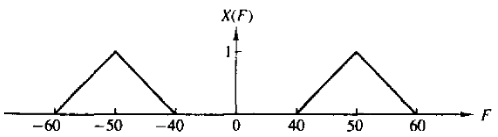
1. State and prove circular frequency shift property of DFT.
2. Determine 8 point DFT of the sequence x(n) = {1,1,1,1,1,1,0,0}.
3. An 8- point sequence is given by x(n) = {2,2,2,2,1,1,1,1} compute DFT of x(n) using radix 2 DIT FFT.

Course Outcome 3(CO3):

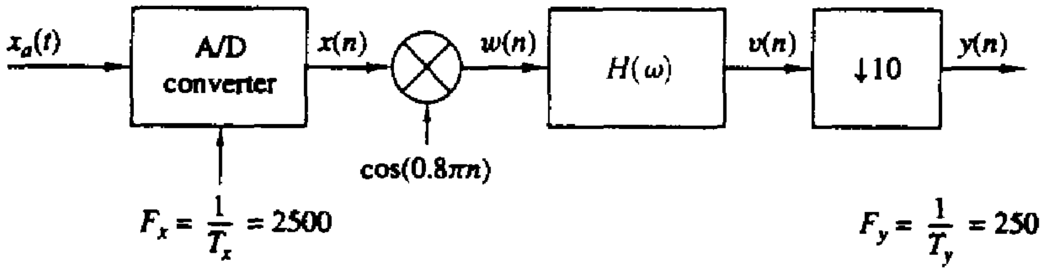
1. Using a rectangular window technique design a LPF with pass band gain of unity, cutoff frequency of 1000Hz and working sampling frequency of 5kHz. The length of impulse be 7.
2. Design and also realize a high pass FIR filter with a cutoff frequency of 1.3 rad/sec and N=9.
3. Design an analog BPF to satisfy the following specifications:
   i) 3dB upper and lower cut-off frequencies are 100 Hz and 3.8kHz
   ii) Stop attenuation of 20dB at 20Hz and 8Hz
   iii) No ripple with pass band and stop band

Course Outcome 4(CO4):

1. Consider the sampling of band pass signal whose spectrum is given in the figure. Determine minimum sampling rate to avoid aliasing.



2. Explain the effects due to upsampling.
3. An analog signal Xa(t)is band limited to the range 900≤F≤1100Hz. It is used as an input to the system shown in the figure. In this system H(w) is an ideal LPF with cutoff frequency Fc= 125Hz.



a) Determine and sketch the spectra for the signals x(n),w(n),v(n)and y(n).

b) Show that it is possible to obtain y(n) by sampling Xa(t) with period T= 4msecs.

Course Outcome 5 (CO5):

1. Define and give the properties of DWT.
2. Explain impulse and magnitude responses of the four level trees of Haar Wavelets.
3. Discuss how the data compression can be obtained as an application of Wavelet transform.

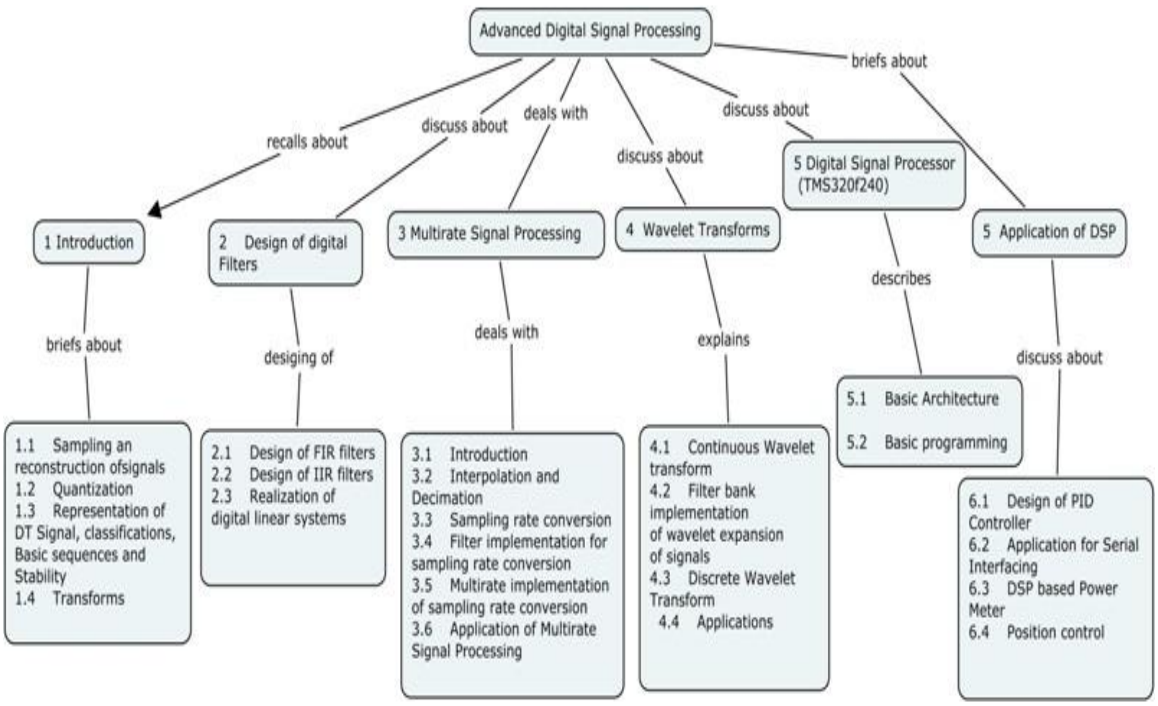
Course Outcome 6 (CO6):

1. Write assembly language program to generate Pulse Width modulated signal with fixed duty cycle for TMS320f240 Digital signal processor.
2. With block diagram explain the architecture of TMS320f240 Digital signal processor.
3. Describe the integrated peripherals of the TMS320F240.

Course Outcome 6 (CO6):

1. With block diagram explain DSP based Power meter.
2. Explain DSP based PID controller.
3. Explain the concept of multi-rate signal processing with spectral interpretation of decimation of a signal from 6 KHz to 2 KHz and spectral interpretation of interpretation of signal from 2 KHz to 6 KHz.

Concept Map



Syllabus

Introduction

Sampling and reconstruction of signals, Quantization. Representation of DT Signal, classifications, Basic sequences and Stability, Transforms-DTFT & its properties, Discrete Fourier Transform and its properties, Convolution and correlation, efficient computation of DFT by Fast Fourier Transform. Design of digital Filters- Design of FIR filters - design of linear phase FIR filters using Windows, Design of IIR Filters- Design of IIR Filters using Impulse Invariant method and Bilinear transformation method, Butterworth filters and Chebychev filters, Realization of digital linear systems - realization of FIR systems realization of IIR systems.

Multirate Signal Processing

Introduction, Interpolation and Decimation, sampling rate conversion, Filter implementation for sampling rate conversion, multirate implementation of sampling rate conversion, Application of Multirate Signal Processing.

Wavelet Transforms: Continuous Wavelet transform, filter bank implementation of wavelet expansion of signals, Discrete Wavelet Transform -Wavelets, orthogonal Wavelets and biorthogonal Wavelets, Applications.

Digital Signal Processor (TMS320f240)

Basic Architecture – Computational building blocks, MAC, Bus Architecture and memory, Data Addressing, Parallelism and pipelining, Parallel I/O interface, Memory Interface, Interrupt, DMA. Basic programming – Arithmetic Operations, Convolution and Correlation, Filter Design, PWM generation

Application of DSP

Design of Decimation and Interpolation Filter, FFT Algorithm, PID Controller, Application for Serial Interfacing, DSP based Power Meter, Position control.

Reference Books

1. John G.Proakis, Dimitris G.Manolakis, "Digital Signal Processing: Principles, Algorithms and Applications", PHI.
2. A.V. Oppenheim and R.W.Schafer, Englewood "Digital Signal Processing", Prentice Hall, Inc, 1975.
4. P.Ramesh Babu – Digital signal processing, Scitech publications of India, 2001.
5. Lonnie C.Ludeman, 'Fundamentals of DSP' John Wiley & Sons, Singapore.
6. S.Mallet, 'A Wavelet tour of signal processing', Academic Press 1998
7. Raguveer m Rao & Ajith S. Bopardikar, 'Wavelet transforms – Introduction to theory and applications', Addison Wesley, 1998

Course Contents and Lecture Schedule

Module No.	Topic	No of lecture Hours
1	**Introduction**	
1.1	Sampling and reconstruction of signals	1
1.2	Quantization	1
1.3	Representation of DT Signal, classifications, Basic sequences and Stability	1
1.4	Transforms	
1.4.1	DTFT & its properties	1
1.4.2	Discrete Fourier Transform and its properties	1

1.4.3	Convolution and correlation	1
1.4.4	Efficient computation of DFT by Fast Fourier Transform	1
2	**Design of digital Filters**	
2.1	Design of FIR filters	1
2.1.1	Design of linear-phase FIR filters using Windows	1
2.2	Design of IIR Filters	1
2.2.1	Design of IIR Filters using Impulse Invariant method,	1
2.2.2	Bilinear transformation method	1
2.2.3	Butterworth filters, Chebychev filters	1
2.3	Realization of digital linear systems	1
2.3.1	Realization of IIR systems	1
2.3.2	Realization of FIR systems	1
3	**Multirate Signal Processing**	
3.1	Introduction	1
3.2	Interpolation and Decimation	1
3.3	Sampling rate conversion	1
3.4	Filter implementation for sampling rate conversion	2
3.5	Multirate implementation of sampling rate conversion	2
3.6	Application of Multirate Signal Processing	1
4	**Wavelet Transforms**	
4.1	Continuous Wavelet transform	1
4.2	Filter bank implementation of wavelet expansion of signals	2
4.3	Discrete Wavelet Transform	1
4.3.1	Wavelets	1
4.3.2	Orthogonal Wavelets	1
4.3.3	Biorthogonal Wavelets	1
4.4	Applications	1
5	**Digital Signal Processor (TMS320f240)**	
5.1	Basic Architecture	1
5.1.1	Computational building blocks	1
5.1.2	MAC, Bus Architecture and memory	1
5.1.3	Data Addressing, Parallelism and pipelining	1
5.1.4	Parallel I/O interface, Memory Interface	1
5.1.5	Interrupt, DMA	1
5.2	Basic programming	
5.2.1	Arithmetic Operations	1
5.2.2	Convolution and Correlation	1
5.2.3	Filter Design	1
5.2.4	PWM generation	1
6	**Application of DSP**	
6.1	Design of PID Controller	1
6.2	Application for Serial Interfacing	1
6.3	DSP based Power Meter	1
6.4	Position control	1
	Total	**45**

Course Designers:

1. Dr.R.Helen rheee@tce.edu

14CI170	CONTROL AND INSTRUMENTATION LABORATORY	Category	L	T	P	Credit
		PC	0	0	1	1

Preamble

Hands-on experience of the components present in any control system is a must for a control and instrumentation engineer. This helps to develop precise control systems. In this context, this laboratory course aims at providing hands-on training to the students in the fields of instrumentation and control.

Prerequisite

None

Course Outcomes

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

CO1	Use software tools to simulate and control a given system	Precision
CO2	Calibrate given transducer with reference to a standard instrument.	Precision
CO3	Distinguish various control valves by finding out their characteristics	Precision
CO4	Develop VI programs for applications involving controls, indicators, arrays, cluster, bundle, loops, case structures, math script, graph & charts, sub-VI, digital i/o, analog i/o	Precision
CO5	Develop PLC programs for applications involving sequential process and processes (involving digital i/o, counter & timer operations)	Precision

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

List of Experiments

Course Outcome 1(CO1):

1. Simulation of MIMO process using MATLAB/SciLab
2. Tank Level control using digital P,PI and PID controllers
3. Cascade control loop using digital controller
4. Pressure control using digital P,PI and PID controllers
5. Study the effects of compensator (lag/lead) networks.
6. Design and Simulation of state feedback controller with deterministic and stochastic observers for using MATLAB/Scilab

Course Outcome 2(CO2):

1. Calibration of LVDT, Strain gauge and Thermocouple.
2. Characteristics of I/P and P/I converters
3. Design of Current to voltage converter and voltage to current converter
4. Cold junction compensation of thermocouple
5. Microprocessor based measurement control system (temperature, position)

Course Outcome 3(CO3):

1. Characteristics of Control valves

Course Outcome 4(CO4):

1. Data acquisition through virtual instrumentation
2. Verification of Nyquist theorem using LABVIEW software.

Course Outcome 5(CO5):

1. PLC based automation of industrial processes

Course Designers:

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14CI210	**INDUSTRIAL DATA COMMUNICATION**	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

PC has become the most widely used platform for data acquisition and control. The main reasons for the popularity of PC-based technology are low costs, flexibility and ease of use. Data acquisition with a PC enables one to display, log and control a wide variety of real world signals such as pressure, flow, and temperature. This ability coupled with that of easy interface with various stand-alone instruments makes the systems ever more desirable. Today's sophisticated software-based operator interfaces make the PC an increasingly attractive option typical applications like Laboratory data acquisition and control, Automatic test equipment (ATE) for inspection of components , Medical instrumentation and monitoring , Process control of plants and factories, Environmental monitoring and control , Machine vision and inspection . The key to the effective application of PC-based data acquisition is the careful matching of real world requirements with appropriate hardware and software.

In any given plant, factory or installation there are a myriad of different industrial communications standards used and the key to successful implementation is the degree to which the entire system integrates and works together. With so many different standards on the market today, the debate is not about what is the best – be it Foundation Fieldbus, Profibus, Devicenet or Industrial Ethernet – but rather about selecting the most appropriate technologies and standards for a given application and then ensuring that best practice is followed in designing, installing and commissioning the data communications links to ensure they run fault-free. The industrial data communications systems in a plant underpin the entire operation. It is critical that one may apply the best practice in designing, installing and fixing any problems that may occur. The important point to make is that with today's wide range of protocols available, one has to know how to select, install and maintain them in the most cost-effective manner for the plant or factory.

This course gives solid grasp of the principles and practical implementation of interfacing the PC and stand-alone instruments with real world signals. In addition, this course also highlights the various technologies and standards in Industrial communication enabling suitable choice from among a wide range of protocols available.

Prerequisite

CN13 Transducer Engineering

Course Outcomes

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

(CO)	**Course Outcome**	**Bloom's Level**
CO1	Develop a Data Acquisition systems (PC, Microcontroller based DAQ)	Apply
CO2	Categorise the various Fieldbus systems and Device net systems available as Bit oriented communication link, Byte oriented Device level instruments and Message oriented networks	Understand
CO3	Design the overall system by selecting the correct communication technology and standards for a given application / plant based on the requirements from among the potential solutions and design the overall system including choice of cabling and compare with the existing system for analysis	Analyze
CO4	Explain various trace-ability of standards pertaining to calibration of instruments	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	S	S						
CO2.	S	L			M						
CO3.		S	S	M	S		S				
CO4.	S	S	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	10
Understand	60	60	10	60
Apply	20	20	-	30
Analyse	0	0	60*	0
Evaluate	0	0	0	0
Create	0	0	0	0

*** -** ASSIGNMENT WORK/PROJECT PRESENTATION

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is aliasing?
2. Mention the types of popular ADCs.
3. Describe PC based data acquisition system with associated circuitry for measurement of strain using a full bridge.

Course Outcome 2 (CO2):

1. Mention a few Message oriented Networks
2. State the importance of categorising systems used for plants as bit, byte and message oriented.
3. Under which category, would you classify CAN bus system? Why?

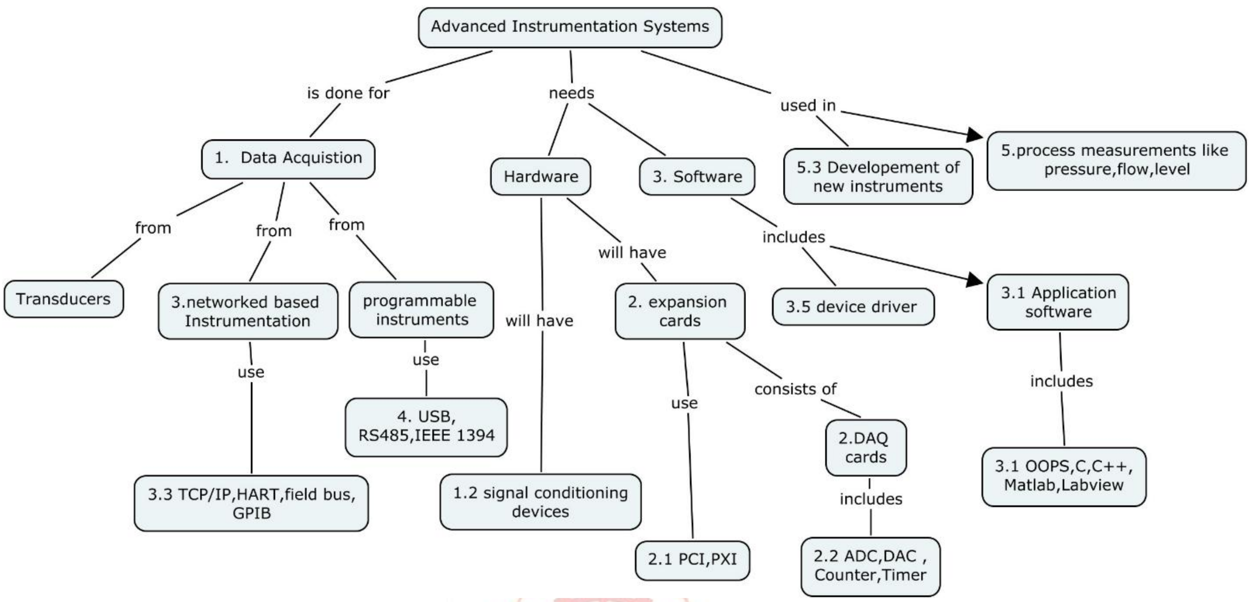
Course Outcome (CO3):

1. With necessary diagrams, describe the general purpose interface bus architecture and explain how multiple devices can be connected to it?
2. Decipher the difficulty with regard to 4-20mA system compared to other recent developments.
3. Which, of the various technologies for Industrial data communication, supports interoperability of Smart instruments?

Course Outcome (CO4)

1. Define: NIST
2. Define: True value
3. What is a Class 1 accuracy instrument / meter?

Concept Map



Syllabus

Data Acquisition and Control: Definition of data acquisition and control, Introduction to Analog controller, Digital Controller - Fundamentals of data acquisition

Network based Instrumentation & **Distributed and stand-alone loggers/controllers**: Methods of operation, Stand-alone logger/controller hardware, Communications hardware interface, Host software, Application Software, Considerations in using standalone logger/controllers – Introduction to DCS, PLCs, Smart Instruments
Signal Conditioning: Types of signal conditioning, Classes of signal conditioning, Cabling basics – Electrical Noise and Interference
PC Expansion Bus Standards : Operation of interrupts, Operation of direct memory access (DMA) Expansion bus standards (PCI and PXI bus)
Plug-in data acquisition boards: A/D Boards, Nyquist criterion of sampling, Aliasing, Anti-aliasing filter, Multiplexers – Block sampling, Interleaved, Simultaneous sampling - Speed vs throughput - Single ended vs differential signals, Resolution, dynamic range and accuracy of A/D boards, D/A boards, Digital I/O boards – Calibration of Instruments – Traceability to international standards.
Generations of Transmission Technology – Pneumatic, 4-20mA, Hybrid, Fieldbus
Serial communication Standards - 20 mA Current loop - RS232 – Nyquist Bandwidth – Shanon's capacity – Signal, Line driver, speed, Settings, Distance – DCE, DTE – Null Modem –RS 422 - RS485 Signal, Line driver, speed, Settings, Distance, modes of operation – Current Loop and RS485 converters, USB, Firewire
Parallel communication Standard – GPIB: Electrical and mechanical characteristics, Physical connection configurations, Device types, Bus structure, Device communication
Introduction to Protocols – OSI model – Industrial protocol —HART Communication protocol -Communication modes , HART networks , control system interface , HART commands – MODBUS

Digital communication Networks:
Open industrial fieldbus and DeviceNet systems -Categorization of Fieldbus systems and Device net systems - Bit oriented – Sensor level devices – Actuator Sensor Interface - Byte oriented - Device level instruments - CANbus, DeviceNet – Message oriented - Field level

devices - Interbus-S- Profibus - Foundation Fieldbus - Fieldbus architecture – H1 overview – HSE overview – Advantages of Foundation Fieldbus - ProfiBUS - Discrete control- Factory automation – Process automation - Difference between Profibus and Fieldbus. Local Area Network

Reference Books

1. John Park, Steve Mackay, “Practical Data Acquisition for Instrumentation and Control Systems” ELSEVIER , 2005
   John Park, Steve Mackay, Edwin Wright, “Practical Data Communication for Instrumentation and Control Systems” ELSEVIER , 2003
2. Howard Austerlitz, “Data acquisition techniques using PC” ACADEMIC PRESS, second edition 2003
3. Mike Tooley, ”PC Based Instrumentation and Control,” ELSEVIER , 2005
4. Deon Reynders , Steve Mackay, Edwin Wright “Practical Industrial Data Communications Best Practice Techniques”, ELSEVIER , 2005
5. N.Mathivanan,”PC Based Instrumentation Concepts and Practice”, PHI ,2007
6. Kevin James,”PC Interfacing and Data Acquisition :Techniques for measurement, Instrumentation and Control “,Newnes 2000

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.	**Data Acquisition:** Definition of data acquisition and control, Introduction to Analog controller, Digital Controller	2
2.	Fundamentals of data acquisition	1
3.	**Network based Instrumentation** & **Distributed and stand-alone loggers/controllers**: Methods of operation, Stand-alone logger/controller hardware, Communications hardware interface, Host software, Application Software, Considerations in using standalone logger/controllers	2
4.	Introduction to DCS, PLCs, Smart Instruments	2
6.	**Signal Conditioning**: Types of signal conditioning, Classes of signal conditioning, Cabling basics – Electrical Noise and Interference	2
7.	Cabling basics – Electrical Noise and Interference	2
8.	**PC Expansion Bus Standards** : Operation of interrupts, Operation of direct memory access (DMA) Expansion bus standards (PCI and PXI bus)	2
9.	**Plug-in data acquisition boards**: A/D Boards, Nyquist criterion of sampling,	1
10.	Aliasing, Anti-aliasing filter	1
11.	Multiplexers – Block sampling, Interleaved, Simultaneous sampling - Speed vs throughput	1
12.	Single ended vs differential signals,	1
13.	Resolution, dynamic range and accuracy of A/D boards	1
14.	D/A boards, Digital I/O boards	2
15.	Calibration of Instruments – Traceability to international standards.	1
16.	Generations of Transmission Technology – Pneumatic, 4-20mA, Hybrid, Fieldbus	1
17.	**Serial communication Standards** - 20 mA Current loop - RS232 – Nyquist Bandwidth – Shanon’s capacity – Signal, Line driver, speed,	4

Module No.	Topic	No. of Lecture Hours
	Settings, Distance – DCE, DTE – Null Modem –RS 422 - RS485 Signal, Line driver, speed, Settings, Distance, modes of operation – Current Loop and RS485 converters, USB, Firewire	
18.	**Parallel communicationStandard – GPIB**: Electrical and mechanical characteristics, Physical connection configurations, Device types, Bus structure, Device communication	2
19.	Introduction to Protocols – OSI model	2
20.	Industrial protocol —-HART Communication protocol -Communication modes , HART networks , control system interface , HART commands - MODBUS	2
21.	**Digital communication Networks:** Open industrial fieldbus and Devicenet systems -Categorization of Fieldbus systems and Device net systems - Bit oriented – Sensor level devices – Actuator Sensor Interface - Byte oriented - Device level instruments - CANbus, DeviceNet	2
22.	Message oriented - Field level devices - Interbus-S- Profibus - Foundation Fieldbus - Fieldbus architecture – H1 overview – HSE overview – Advantages of Foundation Fieldbus	2
23.	ProfiBUS - Discrete control- Factory automation	2
24.	Difference between Profibus and Fieldbus.	1
25.	Local Area Network	1
	Total	40

Course Designers:

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2. Mr.B. Ashok Kumar ashokudt@tce.edu

14CI220	DIGITAL CONTROL SYSTEM	Category	L	T	P	Credit
		PC	3	1	0	4

Preamble

Modern embedded solutions allow for better performance and lower costs 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. This course illustrates the main issues related to digital control theory. The aim is to provide basic notions required for the design and implementation of a digital control system. This knowledge is necessary for the selection of an appropriate microprocessor/DSP or for the correct design of a dedicated component

Prerequisite

- Difference Equations
- Z Transforms
- Laplace Transforms
- Linear Control System Analysis
- System Theory

Course Outcomes

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

CO1	Explain the process of sampling and the effect of sampling period in the performance of digital control system	Understand
CO2	Calculate the performance of a given pulse transfer function in time domain and frequency domain	Apply
CO3	Analyze the effect of controllers/compensators in the closed loop performance of a given Linear Time Invariant sampled data system	Analyze
CO4	Construct state feedback controller with full order or reduced order observers for a given Linear Time Invariant sampled data system	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**L**										
CO2	**S**	**M**	**L**		**L**						**L**
CO3	**S**	**M**	**L**		**L**						**L**
CO4	**S**	**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	40	20	20	20
Apply	40	20	60	60
Analyse	0	40	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

(Analyze level of CO3 shall be evaluated through assignments/case studies)

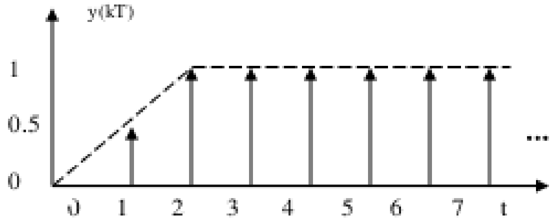
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State sampling theorem
2. Explain the effect of zero order hold in the pulse transfer function
3. With a neat block diagram explain about various elements of digital control system

Course Outcome 2(CO2)

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



2. Derive the discrete transfer function from the discrete state model of the system
3. Using Jury's stability criterion determine the stability of the system with characteristic equation $\boldsymbol{\Delta(z) = z^4 + 1.7z^3 + 0.92z^2 + 0.172z + 0.0096 = 0}$

Course Outcome 3 (CO3)

1. Derive the control law for discrete PID controller.
2. Consider the system G(s)=1/s+1. It is to be sampled at the rate of 0.2s through a zero order hold. Design suitable compensator using discrete root locus to achieve dead beat response.
3. Consider a continuous system G(s)=1/s(s+2). It is to be sampled through a ZOH. Find which of the following sampling period is preferred.
    T=1s, 0.1s and 1ms

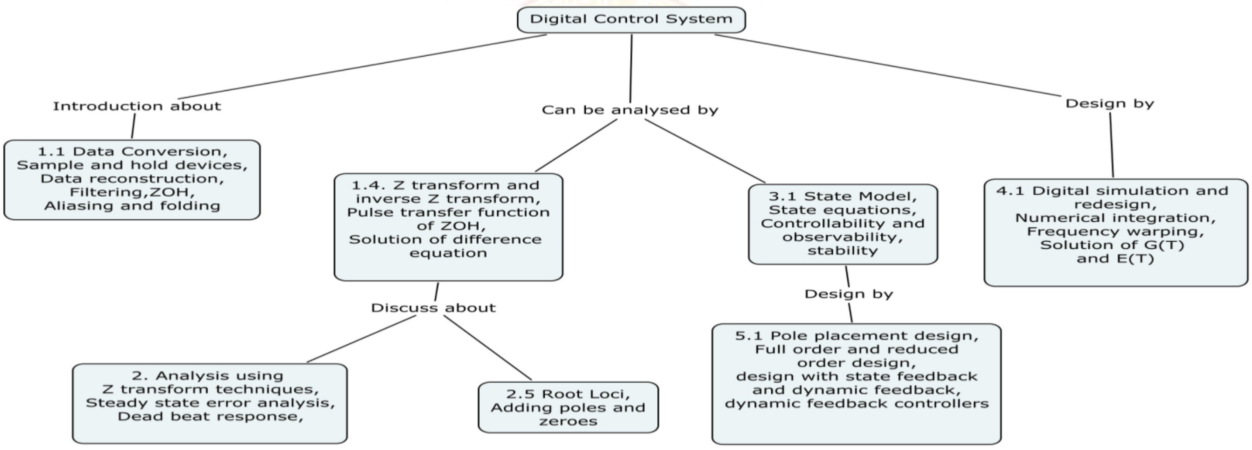
Course Outcome 4 (CO4)

1. Consider the position control of separately exited DC servomotor fed by a buck converter. Assume the armature inductance of DC motor and viscous friction coefficient are negligible. Manipulated variable is duty cycle. Let the sampling time T=1/26 s.

a. Obtain the discrete state model of the system
b. Design a state feedback controller such that motor position attains desired reference at 2 sampling instants.
c. If a constant load torque is to applied check whether the disturbance is eliminated as $k \to \infty$
d. Assuming position alone is measured, design an output feedback regulator to achieve $\varsigma = 0.5$ and $\omega_n = 4$

2. A continuous plant is described by the equation $\dot{y} = -y + u + w$ is to be controlled by a digital computer. y is the output, u is the input and w is the disturbance signal. Let sampling interval T=1s.
   a. Obtain discrete time state variable model of the plant. Compute K and N such that control law $u(k) = -Ky(t) + Nr$, result in a response y(t) with time constant 0.5s and $y(\infty) = r$ (r is the constant reference)
   b. Show that steady state error to constant disturbance input w, is not zero
   c. Add to the plant equation an integrator equation, $v(k) = v(k-1) + y(k) - r$ and select gains K1 and K2 such that the control law $u = -K_1 y(k) - K_2 v(k)$ results in a response $\zeta = 0.5 \; and \; \omega_n = 4$
   d. Show that steady state error to constant disturbance w is zero for the above control law
3. For the system $X_{k+1} = \begin{bmatrix} 0 & 1 \\ -1 & 1 \end{bmatrix} X_k + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u_k$ and $Y_k = x_1$.
   a. Design full order observer for the system with dead beat response
   b. Design reduced order observer to with eigen value at z=0.1

Concept Map



Syllabus

Introduction to digital control systems and Z- Transform Techniques

Basic elements, data conversion and quantization, sample and Hold devices, mathematical modeling of the sampling process, data reconstruction and filtering of sampled signals, zero-order hold, the first-order hold, aliasing and folding, choice of the sampling period - Z-transform, Inverse Z-transform, pulse transfer and z-transfer function, pulse transfer function of the ZOH, solution of difference equation, response of discrete-data control system.

Analysis using Z- Transform Techniques

Comparison of time responses of continuous data and discrete data systems, steady state error analysis of digital control systems, correlation between time response and root locations in the s-plane and the z-plane, constant damping factor and constant damping ratio loci, dead beat response at the sampling instants, root loci for digital control systems, effect of adding poles and zeroes to the open-loop transfer function, Bilinear transformation, compensator design in frequency domain

Discrete-time state model

State equations of discrete-data systems with sample and hold devices, state equations of digital systems with all digital elements, different state variable models, digital simulation and approximation, state transition equations, state diagrams of digital systems, Decomposition of discrete data transfer functions, Controllability and observability of discrete data systems, relation between observability, controllability and transfer functions, Controllability and observability versus sampling period, stability.

Digital simulation and Digital redesign

Digital modeling of sample and Hold devices, Digital simulation of state variable model, Digital simulation- Numerical integration, Frequency warping and pre-warping, Digital redesign- closed form solution for G(T), Partial matching of states, solution of feedback matrix by series expansion, Exact solution of E(T),solution of E(T) by series expansion.

Controller Design using Discrete-time state model

Pole placement design by state feedback: single input and multiple input, Full order and reduced order observer design, design of digital control systems with state feedback and dynamic output feedback, realization of state feedback by dynamic controllers.

Reference Books

1. Benjamin C. Kuo, Digital control systems, Second edition (Indian),2007, Oxford University Press.
2. Ogata, Discrete-time Control Systems, Prentice hall, Second edition, 2005.
3. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill Publication Limited, 2008
4. R. J. Vacaro, Digital Control: A State Space Approach, McGraw-Hill Higher Education, 1995
5. M. Gopal,Digital Control Engineering New Age International,2006.
6. Franklin, Powell, Workman, Digital Control of Dynamic Systems, Pearson Educati Third edition, 2006.

Course Contents and Lecture Schedule

Module No.	Topic	No of Lecture Hours
1	**Introduction to digital control systems and Z- Transform Techniques**	
1.1	Basic elements, data conversion and quantization, sample and Hold devices	1
1.2	Mathematical modelling of the sampling process, data reconstruction and filtering of sampled signals	2
1.3	Zero-order hold, the first-order hold, aliasing and folding, choice of the	2

	sampling period	
1.4	Z-transform, Inverse Z-transform, pulse transfer and z-transfer function	2
1.5	Pulse transfer function of the ZOH, solution of difference equation	2
1.6	Response of discrete-data control system.	1
2	**Analysis using Z- Transform Techniques**	
2.1	Comparison of time responses of continuous data and discrete data systems	1
2.2	Steady state error analysis of digital control systems	2
2.3	Correlation between time response and root locations in the s-plane and the z-plane, constant damping factor and constant damping ratio loci.	1
2.4	Dead beat response at the sampling instants	1
2.5	Root loci for digital control systems	1
2.6	Effect of adding poles and zeroes to the open-loop transfer function.	1
3	**Discrete-time state model**	
3.1	State equations of discrete-data systems with sample and hold devices, state equations of digital systems with all digital elements	2
3.2	Different state variable models, digital simulation and approximation	1
3.3	State transition equations, state diagrams of digital systems	1
3.4	Decomposition of discrete data transfer functions	1
3.5	Controllability and observability of discrete data systems, relation between observability, controllability and transfer functions	1
3.6	Controllability and observability versus sampling period, stability.	2
4	**Digital simulation and Digital redesign**	
4.1	Digital modeling of sample and Hold devices	1
4.2	Digital simulation of state variable model	1
4.3	Digital simulation- Numerical integration	1
4.4	Frequency warping and prewarping	1
4.5	Digital redesign- closed form solution for G(T), Partial matching of states	1
4.6	Solution of feedback matrix by series expansion, Exact solution of E(T)	2
4.7	Solution of E(T) by series expansion.	1
5	**Controller Design using Discrete-time state model**	
5.1	Pole placement design by state feedback: single input and multiple input	2
5.2	Full order and reduced order observer design	2
5.3	Design of digital control systems with state feedback and dynamic output feedback	2
5.4	Realization of state feedback by dynamic controllers	1
	Total	**40**

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mr.V.Mahesh vmeee@tce.edu

14CI270	ADVANCED CONTROL AND INSTRUMENTATION LABORATORY	Category	L	T	P	Credit
		PC	0	0	1	1

Preamble

Hands-on experience of the components present in any control system is a must for a control and instrumentation engineer. This helps to develop precise control systems. In this context, this laboratory course aims at providing hands-on training to the students in the fields of instrumentation and control.

Prerequisite

None

Course Outcomes

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

CO1	Use soft computing tools in modelling and control of a given system	Precision
CO2	Develop virtual instrumentation based data acquisition and control system	Precision
CO3	Develop PLC based process automation system	Precision

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

List of Experiments

CO1:

1. Modelling and control of a nonlinear system using fuzzy logic
2. Modelling and control of a nonlinear system using neural networks
3. PID tuning using Genetic Algorithm

CO2:

1. Virtual Instrumentation based measurement of strain using strain gauge module
2. Virtual Instrumentation based digital IC tester
3. dSPACE based control of Rotary Inverted Pendulum
4. PC based Control of 2DOF helicopter.

CO3:

1. PLC based process automation

Project based on control and instrumentation (Belongs to all Cos) *

* Internal marks will be allocated based on the performance in project

Course Designers:

1. Dr.V.Prakash vpeee@tce.edu
2. Mr.M.Varatharajan varatharajan@tce.edu

14CI310	SYSTEM IDENTIFICATION & ADAPTIVE CONTROL	Category	L	T	P	Credit
		PC	2	1	0	3

Preamble

The area of adaptive control has grown to be one of the richest in terms of algorithms, design techniques, analytical tools, and modifications. The purpose of this course is to alleviate some of the confusion and difficulty in understanding the design, analysis, and robustness of a wide class of adaptive control for continuous-time plants. The system identification methods and several adaptive control techniques are discussed with mathematical models. The course also gives exposure to implementation of adaptive controller for industrial applications.

Prerequisite

Time domain and frequency domain analysis of Linear and nonlinear continuous/digital control systems

Course Outcomes

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

CO1	Explain the need for system identification methods and several adaptive control techniques.	Understand
CO2	Identify the model of a system from given input/output data using parametric estimation methods	Apply
CO3	Use Kalman filter and Extended Kalman filters to estimate the states of a given system	Apply
CO4	Analyze the performance of adaptive control schemes for a given system	Analyze

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the least square technique in detail.
2. What are drawbacks of Gain scheduling technique?
3. State the necessity of an observer.
4. What is the purpose of state and parameter estimation?
5. Explain about gain scheduling control.
6. Explain about Self tuning control technique.
7. Find some pattern in the publications concerning uses of different methods, emphasis on theory and applications.

Course Outcome 2 (CO2):

1. With a suitable example explain about MRAC.
2. Describe the control algorithm for closed loop pole assignment.
3. Find descriptions of adaptive controller from some manufacturers and write a note about them.

Course Outcome 2 & 3 (CO2& CO3):

1. Consider the system $G(s) = G_1(s)G_2(s)$,Where $G_1(s) = \dfrac{b}{(s+a)}$ & $G_2(s) = \dfrac{c}{(s+a)}$. Discuss how to make an MRAS based on the gradient approach.
2. Design an adaptive fuzzy logic for process control to improve the stability of the system.
3. For an automotive application apply adaptive neural control for improvement of efficiency.

Course Outcome 4 (CO4):

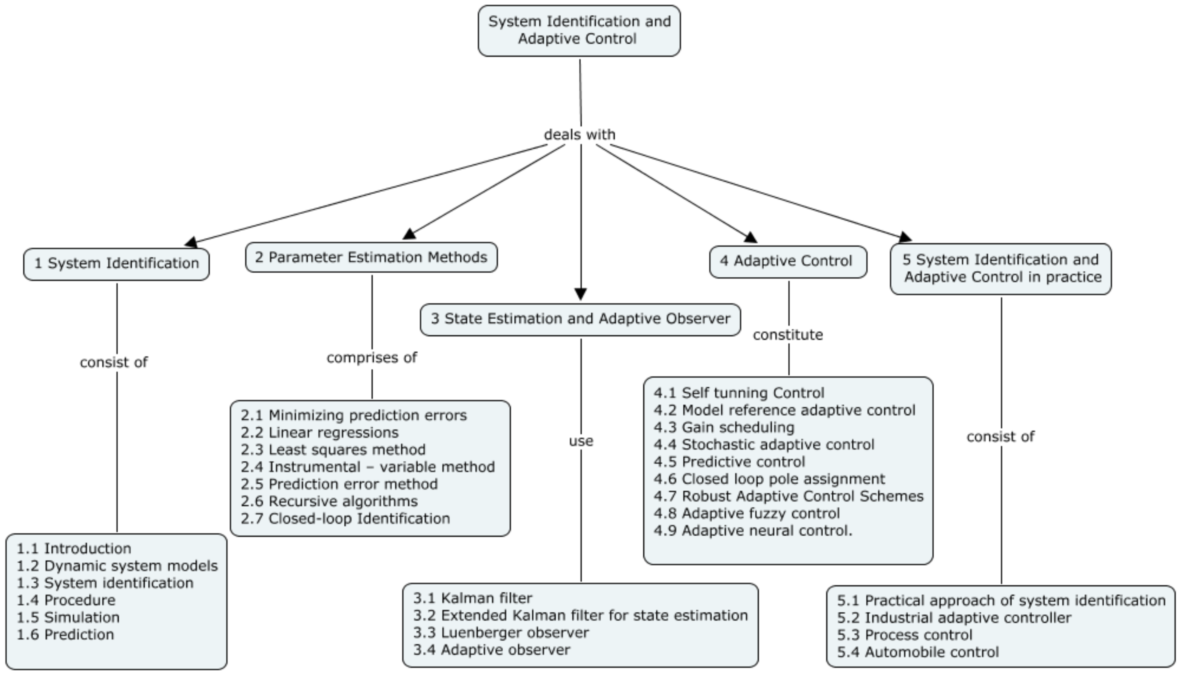
1. Make an assessment of the field of adaptive control by making a literature search.
2. Determine a state observer for the continuous-time system in state-space form

$$\begin{cases} \dot{x}(t) &= \begin{bmatrix} -1 & 0 \\ 1 & -1 \end{bmatrix} x(t) + \begin{bmatrix} 2 \\ 0 \end{bmatrix} u(t) \\ y(t) &= \begin{bmatrix} 0 & \frac{1}{2} \end{bmatrix} x(t) \end{cases}$$

   The desired Eigen values are -5, -5.
3. Consider data generated by the discrete-time system
4. $y(t) = b_0u(t) + b_1u(t-1) + e(t)$
5. Where $e(t)$ is a sequence of independent N(0,1) random variables. Assume that the parameter b of the model $y(t) = bu(t)$is determined by least squares. Determine the estimates obtained for large observation sets when the input u is a step.
6. Consider the system $\frac{dx_1}{dt} = x_2 + \theta f(x_1)$ & $\frac{dx_2}{dt} = u$, where θ is an unknown parameter and f is a known differential function. Find the control law using the certainty equivalence principle.

7. For a system given below determine model reference adaptive controllers based on gradient and stability theory. $G(s) = \frac{k}{s(s+a)}$. Analyse discrete-time direct and indirect self-tuning parameters for the partially know system.
8. Determine the performance parameters of the given system using continuous time parameter estimation. $\frac{k}{s(s+a)}$

Concept Map



Syllabus

System Identification:
Introduction, dynamic system models, system identification procedure, simulation and prediction.

Parameter estimation methods:
Minimizing prediction errors, linear regressions and Least squares method, Instrumental – variable method, prediction error method. Recursive algorithms, Closed-loop Identification.

State Estimation and adaptive observer:

Kalman filter and extended Kalman filter for state estimation, Luenberger observer and adaptive observer.

Adaptive control:
Self tuning Control, model reference adaptive control, Gain scheduling, stochastic adaptive control, Predictive control, Adaptive control algorithms for closed loop pole assignment, Robust Adaptive Control Schemes, adaptive fuzzy control, adaptive neural control.

System Identification and adaptive control in practice:
Practical approach of system identification, Industrial adaptive controller, process control and automobile control

Reference Books

1. Ljung.L,System Identification:Theory for the user, Prentice Hall, EnglewoodCliffs,1987.
2. Astrom .K, Adaptive Control, Second Edition, Pearson Education Asia Pte Ltd, 2002.
3. Chang C. Hong, Tong H. Lee and Weng K. Ho, Adaptive Control, ISA press, Research Triangle Park, 1993.
4. Nelles. O, Nonlinear System Identification, Springer Verlag, Berlin, 2001.

Course Contents and Lecture Schedule

Module. No.	Topic	No. of Lecture Hours
1	**System Identification**	
1.2	Introduction	1
1.3	Dynamic system models	2
1.4	System identification procedure	1
1.5	Simulation and	1
1.6	prediction	1
2	**Parameter estimation methods**	
2.1	Minimizing prediction errors	1
2.2	Linear regressions	1
2.3	Least squares method	1
2.4	Instrumental – variable method	1
2.5	Prediction error method	1
2.6	Recursive algorithms	1
2.7	Closed-loop Identification	1
3	**State Estimation and adaptive observer**	
3.1	Kalman filter	2
3.2	Extended Kalman filter for state estimation	1
3.3	Luenberger observer	2
3.4	Adaptive observer	1
4	**Adaptive control**	
4.1	Self tuning Control	2
4.2	Model reference adaptive control	1
4.3	Gain scheduling	1
4.4	Stochastic adaptive control	2
4.5	Predictive control	2
4.6	Adaptive control algorithms for closed loop pole assignment,	2
4.7	Robust Adaptive Control Schemes	1
4.8	Adaptive fuzzy control	2
4.9	Adaptive neural control	2
5	**System Identification and adaptive control in practice**	
5.1	Practical approach of system identification	2
5.2	Industrial adaptive controller	2
5.3	Process control and	1
5.4	Automobile control	1
	Total	**40**

Course Designers:

1. Mr.G.Sivasankar qsiva@tce.edu

14CIPA0/ 14PSPQ0	CONTROL OF ELECTRIC DRIVES	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

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

Prerequisite

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

Course Outcomes

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

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

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the advantages of variable frequency drives.
2. Name the types of stepper motor drive.
3. List the advantages of load commutated inverter fed BLDC drive.
4. Explain the different methods of speed control of DC motor

Course outcome2 (CO2)

1. Name the various blocks in closed loop drives.
2. What is meant by v/f control?
3. Draw a simple circuit of speed control by current limit control to illustrate the closed loop performance of dc drive.
4. Explain the different types of braking of DC and AC motor.

Course Outcome3 (CO3)

1. A 3-phase, 50KW, 1470rpm, 400V, 50Hz, 4 pole Y-connected induction motor has the following data : R_s =0.42 Ω, R_r =0.23Ω, X_s =0.95 Ω, X_r =0.85 Ω and X_m =28Ω, all the quantities being referred to the stator side. The motor is operated with frequency control. If the slip for maximum torque at the given supply frequency 0.12, determine a) supply frequency b) breakdown torque c) The speed at maximum torque.
2. A 460 V, 60Hz, 6 pole, 1180 rpm, Y-connected squirrel cage induction motor has the following parameters per phase referred to the stator: R_s =0.19 Ω, R_r' =0.07Ω, X_s =0.75 Ω, X_r' =0.67 Ω and X_m =20Ω. The motor is fed by a 6-step inverter, which in turn is fed by a 6-pulse fully controlled rectifier and the motor is operated at constant v/f ratio , calculate the inverter frequency and the stator current at half the rated torque and 500 rpm. Neglect derating due to harmonics.

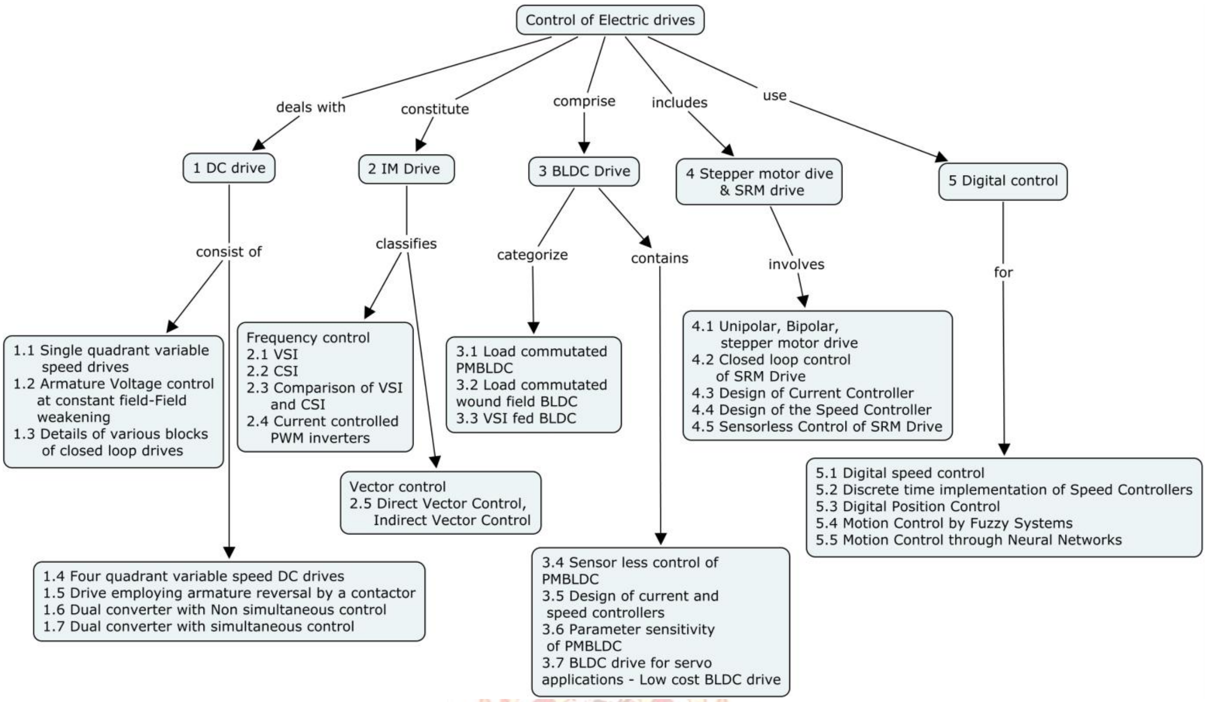
Course Outcome 4 (CO4):

1. With the neat block diagram explain the operation of closed loop speed control with inner current loop and field weakening.
2. Explain how four quadrant operation is achieved by dual converters, each of 3-phase full wave configuration, for a dc motor.
3. With neat block diagram explain the operation of closed loop variable frequency drive using current controlled PWM inverter.
4. Describe the operation of wound field BLDC motor drive with constant margin angle control.
5. Explain the operation of speed controlled PMBLDCM drive scheme.
6. Discuss limits of analog implementation on the closed-loop performance.
7. Construct a current controller for a BLDC motor drive system.
8. Illustrate the effects of slip speed controlled PWM inverter drive with regenerative braking.

Course outcome 5 (CO5)

1. Implement the digital speed controllers in a closed loop operation of drive system.
2. Identify the blocks in digital position control.
3. Explain the different digital control methods for motor control.

Concept Map



Syllabus

CONTROL OF DC DRIVES

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

CONTROL OF INDUCTION MOTOR DRIVES

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

CONTROL OF BLDC DRIVES

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

STEPPER MOTOR DRIVE AND SRM DRIVE

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

DIGITAL CONTROL OF DRIVES

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

REFERENCE BOOKS

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

Course content and lecture schedule

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

5	**DIGITAL CONTROL OF DRIVES**	
5.1	Digital Speed Control	1
5.2	Discrete time implementation of Speed Controllers	1
5.3	Digital Position Control	1
5.4	Motion Control by Fuzzy Systems	2
5.5	Motion Control through Neural Networks	2
	Total	**40**

Course Designer

1. Dr.S.Arockia Edwin Xavier saexeee@tce.edu

14CIPB0	BIO-MEDICAL INSTRUMENTATION	Category	L	T	P	Credit
		PE	2	1	1	4

Preamble

Biomedical instrumentation is the application of engineering principles and design concepts to medicine and biology. This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to improve healthcare diagnosis, monitoring and therapy. Recent advances in medical field have been fuelled by the instruments developed by the Electronics and Instrumentation Engineers. Pacemakers, Ultrasound Machine CAT, Medical diagnostic systems are few names which have been contributed by engineers. Now health care industry uses many instruments which are to be looked after by instrumentation engineers. This subject will enable the students to learn the basic principles of different instruments/equipment used in the health care industry.

Prerequisite

Measurements and Instrumentation

Course Outcomes

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

CO1	Explain the principles of biomedical measurement systems and its characteristics.	K2
CO2	Describe the medical standards, safety and regulation	K2
CO3	Design the bio signal amplifiers for given specification.	K3
CO4	Describe principles of sensors like glucose sensors, immune-sensors.	K2
CO5	Discuss the origin and acquisition of bio potentials and bioelectric signals. Like ECG, EEG..	K2
CO6	Explain the construction and operation principles of Blood Flow, Blood Pressure, Heart sound, and Blood cell counters measurement systems.	K2
CO7	Explain the construction and operation of therapeutic devices.	K2

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**									**M**
CO2	**M**	**L**									**M**
CO3	**S**	**M**	**L**								**M**
C04	**M**	**L**									**M**
C05	**M**	**L**									**M**
C06	**M**	**L**									**M**
CO7	**M**	**L**									**M**

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	80	80	60
Apply	40	0	0	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Discuss various constraints in design of medical instrumentation systems.
2. Explain the Static and dynamic characteristics of medical instrumentation systems.
3. Classify the medical instrumentation systems.

Course Outcome 2 (CO2):

1. Define micro and macro shock.
2. Explain the impact of leakage current in cardiac patient and how it can be avoided?
3. List the standards followed in medical instrumentation systems.

Course Outcome 3 (CO3)

1. Construct the instrumentation amplifier with the gain of 10 and CMRR is 10dB.
2. Design a phase sensitive detector with a corner frequency of 100Hz.
3. Discuss different source of noise in low level signal measurements.

Course Outcome 4 (CO4)

1. With neat sketches explain the working principle of glucose sensor.
2. List the applications of immune sensors.
   Give the advantages of BioMEMS.

Course Outcome 5 (CO5)

1. Explain the electrical activity of Excitable cells with necessary sketches.
2. Describe 10-20 electrode placement system and explain the working of a multichannel EEG recording machine.
3. Classify and explain biopotential electrodes with neat diagram.

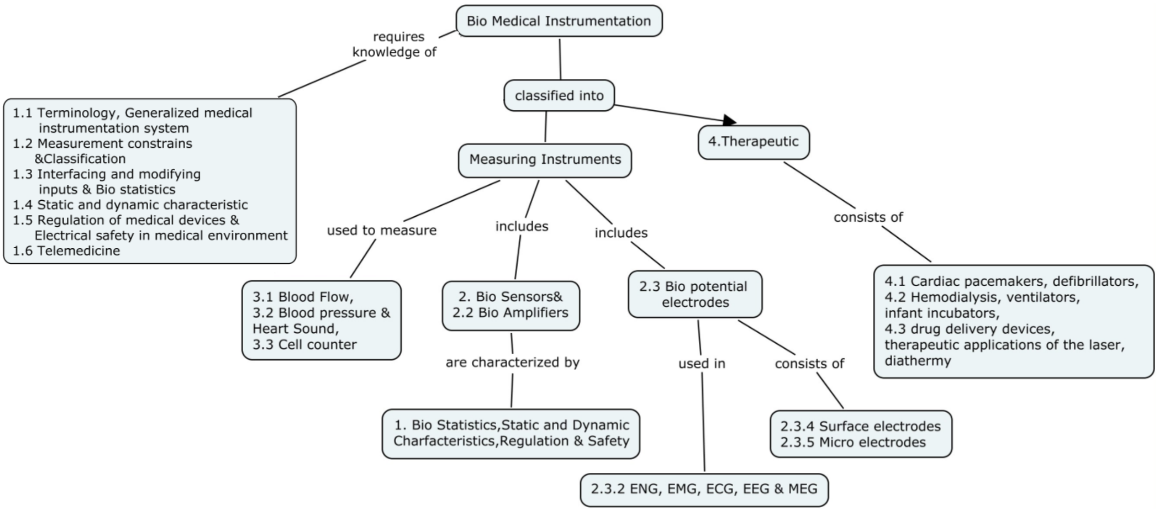
Course Outcome 6 (CO6)

1. Describe different types of Ultrasonic Blood flow meters
2. Explain ausculatory and oscillometric blood pressure Measurement.
3. With neat sketch explain the principle of Coulter counter.

Course Outcome 7 (CO7)

1. Explain the short wave diathermy with neat diagram.
2. Give the need for Pacemakers and explain different types of implantable pacemakers.
3. Explain the DC defibrillator with synchronizer.

Concept Map



Syllabus

BASIC CONCEPTS OF BIO MEDICAL INSTRUMENTATION

Terminology – Generalised medical instrumentation system – Measurement constrains – Classification – Interfacing and modifying inputs – Bio statistics – Static and dynamic characteristic – Regulation of medical devices – Electrical safety in medical environment, Telemedicine

BIO SENSORS AND BIOELECTRIC AMPLIFIERS

Ion exchange membrane electrodes, enzyme electrode, glucose sensors, immunosensors. Basic principles of MOSFET biosensors & BIOMEMS. Special features of bioelectric amplifiers, safety requirements, realization of bioelectric amplifiers, current amplifiers, chopper amplifiers, phase sensitive detector, isolation amplifiers, and instrumentation amplifiers.

BIO POTENTIALS AND MEASUREMENTS

Electric activity and excitable cells – Functional organization of peripheral nervous system. ENG, EMG, ECG, EEG & MEG and recording systems – Bio-potential electrodes – Electrolyte interface. Polarization – Body surface recording electrodes -microelectrodes– Electrodes for electric simulation of tissues – Practical hints for using electrodes.

BLOOD FLOW- Electromagnetic blood flow meter, ultrasonic blood flow meter, Doppler blood flow meter, NMR blood flow meter, cardiac output measurement – indicator dilution methods and impedance technique.

BLOOD PRESSURE AND HEART SOUND MEASUREMENT: Measurement of blood pressure using sphygmomanometer instrument based on Korotkoff sound, indirect measurement of blood pressure, automated indirect measurement, and specific direct measurement techniques. Heart sound measurement – stethoscope, phonocardiograph.

BLOOD CELL COUNTERS: Different methods for cell counting, Coulter Counters, automatic recognition and differential counting of cells.

THERAPEUTIC DEVICES

Cardiac pacemakers, defibrillators, Haemodialysis, ventilators, infant incubators, drug delivery devices, therapeutic applications of the laser, diathermy

Reference Books

1. 1. R. S. Khandpur “Handbook of Bio-Medical Instrumentation”, second edition Tata McGraw Hill 2005.
2. J.Webster, “Medical Instrumentation application and design”, third edition Wiley & Sons 2001.
3. Carr & Brown, “Introduction to Biomedical Equipment Technology” Pearson Education, Asia.
4. Leslie Cromwell, “ Biomedical Instrumentation and Measurements”

Course Contents and Lecture Schedule

Module No.	Topics	No of lecture hours
1	**BASIC CONCEPTS OF BIO MEDICAL INSTRUMENTATION**	
1.1	Terminology, Generalized medical instrumentation system	1
1.2	Measurement constrains &Classification	1
1.3	Interfacing and modifying inputs & Bio statistics	1
1.4	Static and dynamic characteristic	1
1.5	Regulation of medical devices & Electrical safety in medical environment	2
1.6	Telemedicine	1
2	**BIO SENSORS AND BIOELECTRIC AMPLIFIERS**	
2.1	Bio sensors	
2.1.1	Ion exchange membrane electrodes, enzyme electrode,	1
2.1.2	Glucose sensors, immune sensors. Basic principles of MOSFET biosensors & BIOMEMS.	2
2.2	Special features of bioelectric amplifiers & safety requirements	1
2.2.1	Realization of bioelectric amplifiers & current amplifiers	2
2.2.2	Chopper amplifiers & phase sensitive detector	1
2.2.3	Isolation amplifiers and instrumentation amplifiers	1
2.3	**Bio Potentials and Measurements**	
2.3.1	Electric activity and excitable cells – Functional organization of peripheral nervous system	2
2.3.2	ENG, EMG, ECG	2
2.3.3	EEG & MEG and recording systems – Bio-potential electrodes – Practical hints for using electrodes	2
2.3.4	Electrolyte interface. Polarization – Body surface recording electrodes	1
2.3.5	Microelectrodes, Electrodes for electric simulation of tissues	1
3	**Blood Flow**	
3.1	Electromagnetic blood flow meter, ultrasonic blood flow meter.	1
3.1.2	Doppler blood flow meter, NMR blood flow meter.	1
3.1.3	Cardiac output measurement – indicator dilution methods and impedance technique	1
3.2	**Blood pressure and heart sound measurement**	
3.2.1	Measurement of blood pressure using sphygmomanometer instrument based on Korotkoff sound	1
3.2.2	Indirect measurement of blood pressure, automated indirect measurement, and specific direct measurement techniques.	2
3.2.3	Heart sound measurement – stethoscope, phonocardiograph.	1

3.3	**Blood cell counters**	
3.3.1	Different methods for cell counting, Coulter Counters,	1
3.3.2	Automatic recognition and differential counting of cells.	1
4	**THERAPEUTIC DEVICES**	
4.1	Cardiac pacemakers, defibrillators	1
4.2	Haemodialysis, ventilators, infant incubators	2
4.3	Drug delivery devices, therapeutic applications of the laser, diathermy	1
	Total	**43**

Course Designers:

1. Dr.R.Helen rheee@tce.edu

14CIPC0	**DIGITAL SYSTEM DESIGN USING FPGA**	Category L T P Credit PE 4 0 0 4

Preamble

A decade back SSI, and MSI circuits were used largely to build digital systems. With advent of VLSI devices most of the designs moved to ASIC domain. Also, at the same time Filed Programmable devices started to evolve. As time progressed these devices has taken up the space of SSI and MSI devices and started to even replace ASICs at lowest end. Presently Field programmable devices are able to match the functional complexity of ASIC Devices such as PROM, PLDs (PLAs, PALs). PALs were widely used for glue logic and replaced SSI and MSI devices. Complex PLD's are hierarchical PLD's that connects smaller PLD's through a central programmable interconnect to enable the implementation of medium complexity digital circuits. Main feature of CPLDs are the wide decoding, but has a low register to logic ratio. CPLD's architecture is not scalable, due to the central switch used in connecting small PLD structures. Digital designs once built in custom silicon are increasingly implemented in field programmable gate arrays (FPGAs), but effective FPGA system design requires a understanding of new techniques developed for FPGAs. This course deals FPGA fabrics, introduces essential FPGA concepts, and compares multiple approaches to solving basic problems in programmable logic.

Prerequisite

Basic Digital Systems

Course Outcomes

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

CO1	Discuss the structure of ASICs such as PROM, PLA, PAL.	K2
CO2	Construct digital system using ASICs such as PROM, PLA,PAL	K3
CO3	Describe the architecture and features of XILINX XC9500 CPLD	K2
CO4	Explain architecture and features of SRAM, Flashed and antifuse based FPGA	K2
CO5	Write Verilog HDL programs for combinational and sequential circuits.	K3
CO6	Discuss the role of FPGA in Lift Control and Power Plant Instrumentation control	K2

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Which technology is used for CPLD Programmable elements?
2. Explain the programmable AND, fixed OR structure of SPLD.
3. Explain the architecture of PLA.

Course Outcome 2 (CO2):

1. Implement the following logic function using PLA structure.
   F1=ABC+ACD, F2=ACD+BC+AD and F3=ABC+ACD
2. Construct 7 segment decoder using PROM device.
3. Design BCD to Excess 3 Converter using PLA.

Course Outcome 3 (CO3)

1. Give the different logic density of XC9500 Device Family.
2. Write the advantages of Global buffer in CPLDs.
3. Explain the Architecture of XC9500 devices.

Course Outcome 4 (CO4)

1. With neat sketches explain the fabrics of SRAM based Xilinx Spartan-II.
2. Draw the Actel Axcelerator family logic element and write the procedure to perform fast addition.
3. A system have a 4 input LUT with inputs a,b,c,and d. write the lookup table contents for given functions
   a| (~b & ~c)|d
   (a & b) | c

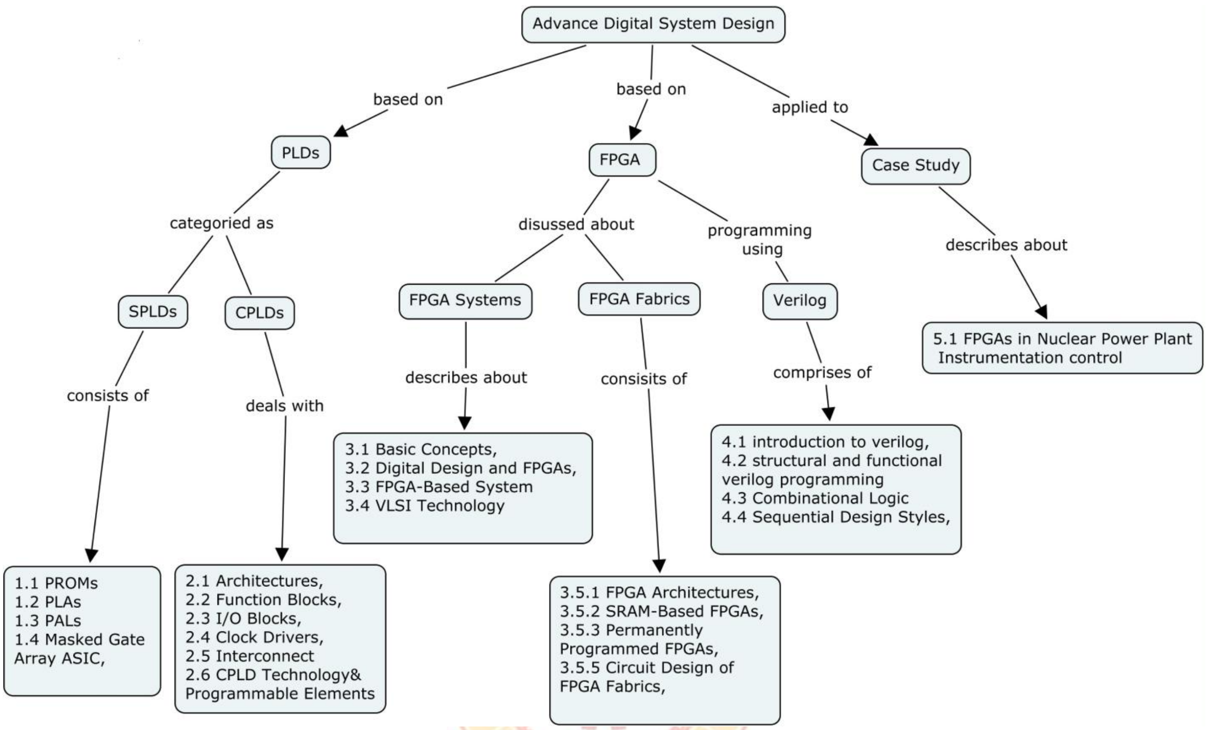
Course Outcome 5 (CO5)

1. Write verilog to perform 2 bit AxB multiplication based on structural modeling.
2. Apply top-down design methodology to develop 3 bit Ripple counter using verilog HDL.
3. With an example explain one hot state encoding method.

Course Outcome 6 (CO6)

1. Explain the advantages of FPGA controller in Power plant Drum level Control.
2. Explain the role of FPGA in Lift control.
3. Explain the role of FPGA controller in Nuclear power plant and give its advantages.

Concept Map



Syllabus

Programmable Logic to ASICs

Programmable Read Only Memories (PROMs), Programmable Logic Arrays (PLAs), Programmable Array Logic (PALs), the Masked Gate Array ASIC, CPLDs and FPGAs.

Complex Programmable Logic Devices

CPLD Architectures, Function Blocks, I/O Blocks, Clock Drivers, Interconnect CPLD Technology and Programmable Elements.

FPGA Systems

Basic Concepts, Digital Design and FPGAs, FPGA-Based System, **VLSI Technology-** Manufacturing Processes, Transistor Characteristics, CMOS logic gates, Wires, Registers and RAM, Packages and Pads, **FPGA Fabrics-** FPGA Architectures, SRAM-Based FPGAs, Permanently Programmed FPGAs, Chip I/O, Circuit Design of FPGA Fabrics, Architecture of FPGA Fabrics

Hardware Description Language VERILOG

Introduction to verilog, structural, functional verilog programming, **Combinational Logic-** Combinational Network Delay, Power and Energy Optimization, Arithmetic Logic, Logic Implementation for FPGAs, Physical Design for FPGAs, **Sequential Machines** -Sequential Design Styles, Rules for Clocking, Performance Analysis, Power Optimization.

Case Study

FPGAs in lift control and Power Plant Instrumentation control.

Rreference Books

1. Wayne Wolf “FPGA –Based System Design” Pearson Education, 2004.
2. Bob Zeidman, “Designing with FPGAs and CPLDs”, Elsevier, CMP Books, 2002.
3. M. Morris Mano and Michael D. Ciletti, “Digital Design”, PHI, fourth edition, 2008
4. R.F.Tinder: Engineering Digital Design, (2/e), Academic Press, 2000

5. Digital Electronics Principles, Devices and Applications Anil K. Maini – Wiley 2007
6. Samir Palnitkar, ”Verilog HDL”, Pearson Education, 2nd Edition, 2004.
7. Stephen Brown Zvonko Vranesic “Fundamentals of Digital Logic with VHDL Design” Tata McGraw- Hill Edition.
8. www.xilinx.com
9. www.acctel.com

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**Programmable Logic to ASICs**	
1.1	Programmable Read Only Memories (PROMs).	1
1.2	Programmable Logic Arrays (PLAs)	1
1.3	Programmable Array Logic (PALs)	2
1.4	The Masked Gate Array ASIC	1
1.5	CPLDs and FPGAs	1
2	**Complex Programmable Logic Devices (CPLDs)**	
2.1	CPLD Architectures	1
2.2	Function Blocks.	1
2.3	I/O Blocks	1
2.4	Clock Drivers	1
2.5	Interconnect	1
2.6	CPLD Technology and Programmable Elements	2
3	**FPGA Systems**	
3.1	Basic Concepts(Boolean Algebra and Karnaugh map)	1
3.2	Digital Design and FPGAs.	1
3.3	FPGA-Based System Design	1
3.4	**VLSI Technology**	
3.4.1	Manufacturing Processes	1
3.4.2	Transistor Characteristics	1
3.4.3	CMOS logic gatesand Wires	1
3.4.4	Registers and RAM	1
3.4.5	Packages and Pads	1
3.5	**FPGA Fabrics**	
3.5.1	FPGA Architectures	1
3.5.2	SRAM-Based FPGAs	1
3.5.3	Permanently Programmed FPGAs	1
3.5.4	Chip I/O	1
3.5.5	Circuit Design of FPGA Fabrics	1
3.5.6	Architecture of FPGA Fabrics	1
4	**Hardware Description Language VERILOG:**	
4.1	Introduction to verilog	1
4.2	Structural, functional verilog programming	1
4.3	**Combinational Logic-**Combinational Network Delay	1
4.3.1	Power and Energy Optimization	1
4.3.2	Arithmetic Logic	1
4.3.3	Logic Implementation for FPGAs	1
4.3.4	Physical Design for FPGAs	1
4.4	**Sequential Machines** -Sequential Design Styles	1
4.4.1	Rules for Clocking	1
4.4.2	Performance Analysis	1

4.4.3	Power Optimization	1
5	**Case Study:** FPGAs in lift control and Power Plant Instrumentation control	2
	Total	**40**

Course Designers:

1. Dr.R.Helen rheee@tce.edu

14CIPD0	INDUSTRIAL CONTROLLERS	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

This course is designed to impart the knowledge of industrial controllers and their implementation, and design procedures. Emphasis is also given to distributed, programmable controllers and model- free controllers.

Prerequisite

Logic circuits

Course Outcomes

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

CO1	Explain the components of programmable logic controller and different commercial controllers	Understand
CO2	Discuss the basic ladder logic instruction.	Understand
CO3	Write ladder logic program for the given industrial problems.	Apply
CO4	Explain the concept of distributed digital controllers	Understand

Mapping with Programme Outcomes

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Draw the flowchart for derivative mode.
2. Draw the basic blocks and mention the different parts of PLC.
3. Mention any four application of PLC.
4. Compare various types of digital controller modes.
   Explain the operation of SCADA with neat diagram.

Course Outcome 2 (CO2):

1. Explain the EXAMINE ON & EXAMINE OFF instructions used in PLC programming.
2. Write a PLC ladder program to start and stop a motor using two push buttons.
3. Explain the operation of ON delay retentive timer.

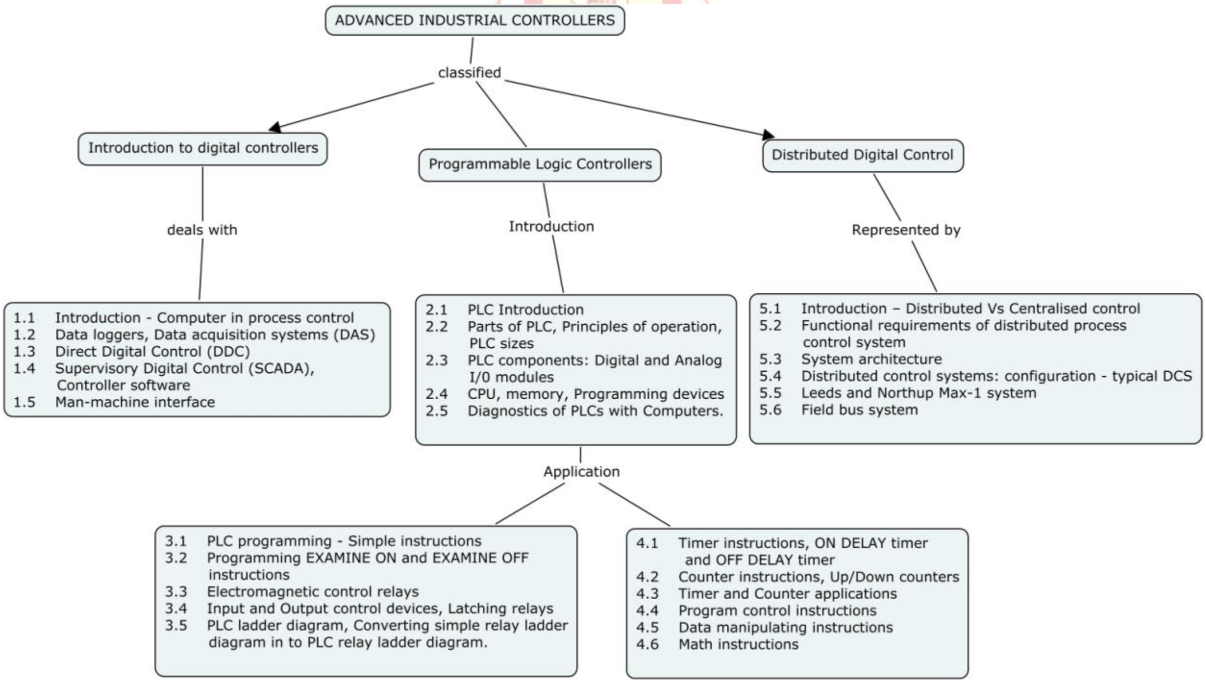
Course Outcome 3 (CO3):

1. Develop a PLC ladder logic program for parts counting process
   i) Count the parts coming off from an assembly line conveyer
   ii) After 100 counts the parts are packaged
   iii) Count the total number of packages for a day
   iv) Reset all the counters at the end of the day using a mater reset NO push button.
2. Three motors can be started by a single push button when the push button is released, switching of motors should be at 20 Secs intervals each. Develop a PLC ladder diagram for the above process.
3. Develop a PLC ladder logic program using Data manipulation instructions for the below process
   i) Solenoid A is energized immediately when start pushbutton is pressed.
   ii) Solenoid B is energized 5s later than solenoid A.
   iii) Solenoid C is energized 15s later than solenoid A.
   iv) Solenoid D is energized 25s later than solenoid A.

Course Outcome 4 (CO4):

1. What is the need for model-free controllers?
2. Compare various types of digital controller modes.
3. Demonstrate the architecture of distributed control systems in details.

Concept Map



Syllabus

Introduction to digital controllers

Introduction - Computer in process control - Data loggers, Data acquisition systems (DAS) - Direct Digital Control (DDC), Supervisory Digital Control (SCADA) - Controller software - man-machine interface.

Programmable Logic Controllers (PLC)

PLC Introduction – Parts of PLC - Principles of operation, PLC sizes - PLC components: Digital and Analog I/0 modules - CPU – memory - Programming devices - Diagnostics of PLCs with Computers.

PLC programming
PLC programming - Simple instructions - EXAMINE ON and EXAMINE OFF instructions – Electromagnetic control relays - Input and Output control devices - Latching relays - PLC ladder diagram – Functional blocks - Converting simple relay ladder diagram in to PLC relay ladder diagram.
PLC Advanced Instructions
Timer instructions - ON DELAY timer and OFF DELAY timer - Counter instructions - Up/Down counters - Timer and Counter applications - program control instructions - Data manipulating instructions - math instructions

Distributed Digital Control
Introduction – Distributed Vs Centralised control – Functional requirements of distributed process control system – system architecture – distributed control systems: configuration – typical DCS - Leeds and Northup Max-1 system – Field bus system, Interfacing PLC with SCADA

Case Studies (To be covered in assignments)
PLC based control of Industrial processes, Control of Robots using PLC, CNC with PLC, DCS implementation in Thermal plant, Cement Plant and Water Treatment plant

Reference Books

1. Krishna kant, "Computer based industrial control", PHI, second edition, 2010.
2. Frank D. Petruzella "Programmable Logic Controllers", TMH, Third Edition, 2010.
3. M.Chidambaram, "Computer Control of Processors" Narosa Publications, 2001.
4. John W Webb, Ronald A Reis, "Programmable Logic Controllers - Principles and Applications", Third Edition, PHI, 1995.
5. Krishna Kant, "Digital control systems", ISTE learning materials centre, First edition 2001.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Introduction to digital controllers**	
1.1	Introduction - Computer in process control	1
1.2	Data loggers, Data acquisition systems (DAS)	1
1.3	Direct Digital Control (DDC)	1
1.4	Supervisory Digital Control (SCADA), Controller software	1
1.5	Man-machine interface	1
2.0	**Programmable Logic Controllers (PLC)**	
2.1	PLC Introduction	1
2.2	Parts of PLC, Principles of operation, PLC sizes	1
2.3	PLC components: Digital and Analog I/0 modules	2
2.4	CPU, memory, Programming devices	1
2.5	Diagnostics of PLCs with Computers.	1
3.0	**PLC programming**	
3.1	PLC programming - Simple instructions	2
3.2	Programming EXAMINE ON and EXAMINE OFF instructions	2
3.3	Electromagnetic control relays	1
3.4	Input and Output control devices, Latching relays	2
3.5	PLC ladder diagram, Functional blocks - Converting simple relay ladder	2

	diagram in to PLC relay ladder diagram.	
4.0	**PLC Advanced Instructions**	
4.1	Timer instructions, ON DELAY timer and OFF DELAY timer	1
4.2	Counter instructions, Up/Down counters	2
4.3	Timer and Counter applications	2
4.4	Program control instructions	2
4.5	Data manipulating instructions	2
4.6	Math instructions	2
5.0	**Distributed Digital Control**	
5.1	Introduction – Distributed Vs Centralised control	1
5.2	Functional requirements of distributed process control system	2
5.3	System architecture	1
5.4	Distributed control systems: configuration - typical DCS	2
5.5	Leeds and Northup Max-1 system	1
5.6	Field bus system	2
	Total	**40**

Course Designers:

1. Dr. S.Arockia Edwin Xavier saexeee@tce.edu
2. Dr. S.Charles Raja charlesrajas@tce.edu

14CIPE0	**INTELLIGENT CONTROLLERS**	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Intelligent control achieves automation via the emulation of biological intelligence. It either seeks to replace a human who performs a control task (e.g., a chemical process operator) or it borrows ideas from how biological systems solve problems and applies them to the solution of control problems. This course provides an overview of several techniques used for intelligent control and discusses challenging industrial application domains where these methods may provide particularly useful solutions. The subject begins with a brief overview of the main areas in intelligent control, which are fuzzy control and neural networks

Prerequisite

- Control systems
- Process control

Course Outcomes

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

CO1	Explain the role of Artificial intelligence in industrial controllers and basics of fuzzy and neural systems.	Understand
CO2	Explain the modelling of a controller using fuzzy and neural systems	Understand
CO3	Apply fuzzy and neural systems for system identification	Apply
CO4	Analyze the performance of the controllers based on fuzzy and neural for industrial applications.	Analyze
CO5	Apply genetic algorithm to Optimal control problems	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

CAT3 MAY BE GIVEN AS A SINGLE CONTROL PROBLEM FOR WHICH NEURAL NETWORKS AND FUZZY LOGIC SHOULD BE APPLIED USING MATLAB AND PERFORMANCE SHOULD BE COMPARED.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the types of learning?
2. Mention the linear and non-linear activation functions used in ANN.
3. What is perceptron?
4. What is feed forward networks? Give example
5. Give some common applications of fuzzy logic?
6. What are the different methods of De-fuzzification?

Course Outcome 2 (CO2):

1. What do you mean by supervised and unsupervised learning?
2. Explain back propagation algorithm in detail.
3. Describe the learning expressions in the back propagation network.
4. Explain Sugeno type fuzzy model
5. Explain the construction of fuzzy model for a nonlinear equation

Course Outcome 3 (CO3):

1. Explain the basic idea behind SVM with suitable illustrations
2. With suitable illustration, explain how neural network is used for nonlinear system identification.
3. With suitable illustration, explain how ANFIS is used for nonlinear system identification.
4. What are the parameters to be considered for the design of membership function in system identification?

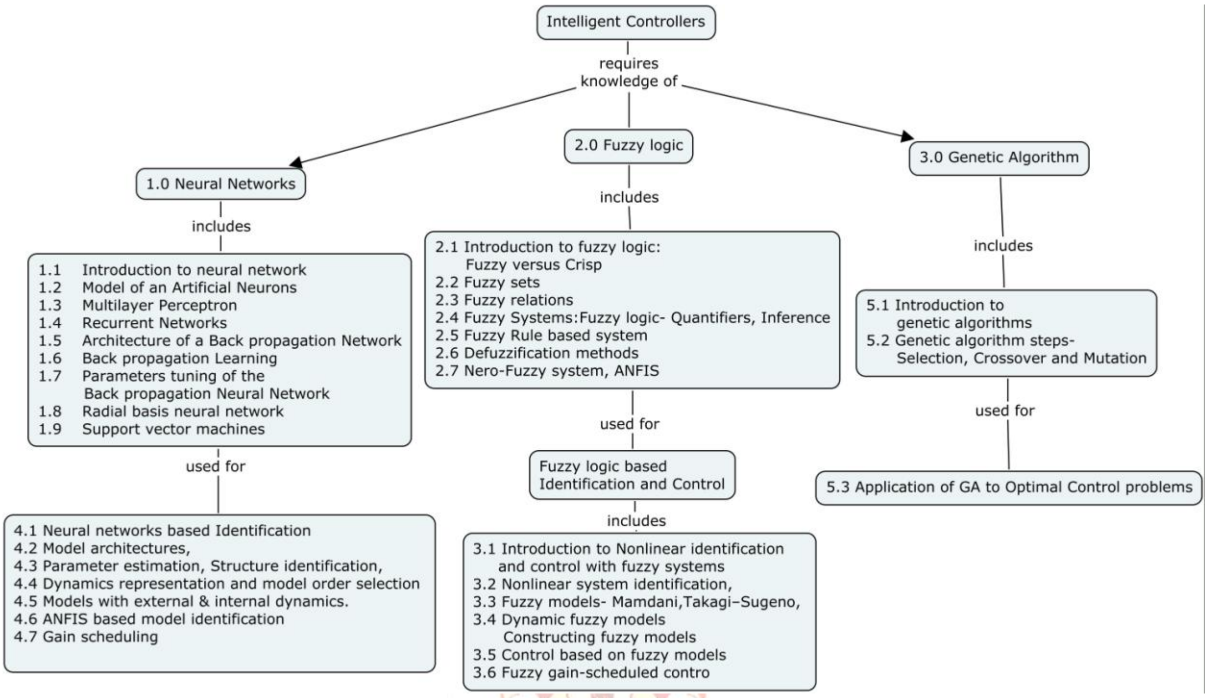
Course Outcome 4 (CO4):

1. Analyze the performance of the controller using fuzzy logic system and neural network for armature controlled DC motor seed control
2. Analyze the performance of neural network and fuzzy logic system for system identification.
3. Analyze the reason for better generalization capability of SVM as compared to Neural network.
4. Analyze the performance of fuzzy based gain scheduling control

Course Outcome 5 (CO5):

1. List the various operators used in GA
2. Explain the importance of selection operator in GA.
3. Explain the role of reproduction operator in GA
4. Explain the various steps involved in tuning PID controller using GA
5. Perform two generations of simple binary coded genetic algorithm to solve the following optimization problem. Maximize $f(x) = x^2$ $0 \leq x \leq 31$, x is an integer. Use proportionate selection, single point crossover, binary mutation and population size of six.

Concept Map



Syllabus

Neural Networks: Introduction to neural network - Model of an Artificial Neurons -Multilayer Perceptron, Recurrent Networks ,Architecture of a Back propagation Network, Backpropagation Learning, Parameters tuning of the Back propagation Neural Network, Radial basis neural network, support vector machines.

Fuzzy Logic: Introduction to fuzzy logic, Fuzzy versus Crisp, Fuzzy sets, Fuzzy relations, Fuzzy Systems:Fuzzy logic- universe discourse, membership function, Quantifiers, Inference, Fuzzy Rule based system, Defuzzification methods, Nero-Fuzzy system, ANFIS.

Fuzzy logic based Identification and Control: Introduction to Nonlinear identification and control with fuzzy systems, Nonlinear system identification, Fuzzy models- Mamdani,Takagi–Sugeno, Dynamic fuzzy models. Constructing fuzzy models, Control based on fuzzy models - Fuzzy gain-scheduled control

Neural network Based identification and control: Model architectures, Parameter estimation, Structure identification, Dynamics representation and model order selection - Models with external & internal dynamics. ANFIS based model identification. Gain scheduling

Genetic Algorithms: Introduction to genetic algorithms; genetic algorithm steps-Selection, Crossover and Mutation; Application of GA to optimal control problems

Reference Books

1. A.E. Ruano, 'Intelligent Control Systems using computational Intelligence technique', IET, 2008.
2. Simon Haykin, 'Neural Networks', Pearson Education, 2003.
3. John Yen Timothy J. Ross, 'Fuzzy Logic with Engineering Applications', Tata McGraw Hill, 1997.

4. John Yen and Reza Langari, ‘Fuzzy Logic – Intelligence Control & Information’, Pearson Education, New Delhi, 2003
5. S.Rajasekaran, G.A. Vijayalakshmi pai, ‘Neural Networks, Fuzzy logic and Genetic Algorithms synthesis and Applications’, Prentice Hall, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.	**Neural Networks**	
1.1	Introduction to neural network	1
1.2	Model of an Artificial Neurons	1
1.3	Multilayer Perceptron	1
1.4	Recurrent Networks	1
1.5	Architecture of a Back propagation Network	1
1.6	Back propagation Learning	1
1.7	Parameters tuning of the Back propagation Neural Network	1
1.8	Radial basis neural network	1
1.9	Support vector machines	1
2.	**Fuzzy Logic**	
2.1	Introduction to fuzzy logic: Fuzzy versus Crisp	1
2.2	Fuzzy sets	1
2.3	Fuzzy relations	1
2.4	Fuzzy Systems:Fuzzy logic- Quantifiers, Inference	1
2.5	Fuzzy Rule based system	1
2.6	Defuzzification methods	1
2.7	Nero-Fuzzy system, ANFIS	1
3.	**Fuzzy logic based Identification and Control**	
3.1	Introduction to Nonlinear identification and control with fuzzy systems	1
3.2	Nonlinear system identification,	1
3.3	Fuzzy models- Mamdani,Takagi–Sugeno,	1
3.4	Dynamic fuzzy models, Constructing fuzzy models	2
3.5	Control based on fuzzy models	2
3.6	Fuzzy gain-scheduled control	2
4.	**Neural network Based identification and control**	
4.1	Neural networks based Identification	
4.2	Model architectures,	2
4.3	Parameter estimation, Structure identification,	2
4.4	Dynamics representation and model order selection	1
4.5	Models with external & internal dynamics.	1
4.6	ANFIS based model identification	2
4.7	Gain scheduling	2

5	**Genetic Algorithms**	
5.1	Introduction to genetic algorithms	1
5.2	Genetic algorithm steps-Selection, Crossover and Mutation	2
5.3	Application of GA to Optimal Control problems	2
	Total	**40**

Course Designers:

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2. Dr.D.Kavitha dkeee@tce.edu

14CIPF0	OPTIMAL CONTROL AND FILTERING	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Optimal control theory, which is playing an increasingly important role in the design of modern systems, has maximizing the returns while minimizing the operational efforts as its objectives. Often the optimal control is described by a feedback law. Such a law determines the optimal control. This subject deals with deriving optimal control laws for control systems, as functions of time, and decisions that must be made as time proceeds.

Prerequisite

- Linear Control System Analysis
- Systems Theory

Course Outcomes

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

CO1	Explain various optimal control formulations and necessary conditions of optimal control	Explain
CO2	Design optimal controller using calculus of variations	Apply
CO3	Use dynamic programming to design optimal controller for a given system	Apply
CO4	Explain various optimal filtering/estimation methods	Explain
CO5	Implement Kalman filter and Extended Kalman filter for a given linear /nonlinear system	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**									
CO2	**S**	**M**	**L**		**L**						**L**
CO3	**S**	**M**	**L**		**L**						**L**
CO4	**M**	**L**									
CO5	**S**	**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	45	35	40	30
Apply	35	45	45	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Using simple diagram, state the condition for optimality for dynamic programming.
2. What is linear tracking problem?
3. State any two properties of optimal solution

Course Outcome 2(CO2)

1. Explain the principle of optimality
2. Derive Hamiltonian Jacobi equation
3. Using dynamic programming, find the control law for the performance measure to be minimized for the equation X(k+1)=-0.5 X(k+1)+u (k) ,J=1/2/o∞(x2+u2)with limits zero to infinity.

Course Outcome 3 (CO3)

1. Derive the necessary conditions of optimal control
2. Explain any one algorithm used for solving split boundary value problems
3. Consider the system $\dot{x} = \begin{bmatrix} 0 & 1 \\ -3 & -2 \end{bmatrix} x + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$. Design a regulator for the system which reaches the final state in minimum time.

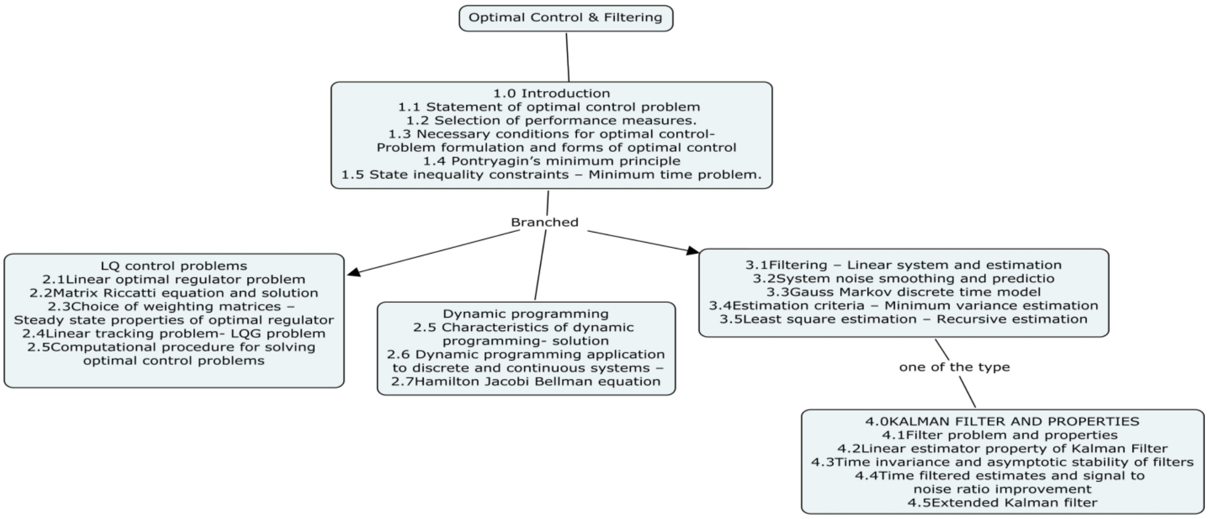
Course Outcome 4 (CO4)

1. Derive the Least square estimation for a first order ARMA process
2. Explain the advantages of recursive estimation over least square estimation
3. The measured output of a simple moving average process is $y_k = w_k + w_{k-1}$, where $\{w_k\}$ is zero mean white noise with variance 1
   a. Generate a state-space description for this system with the first element of state, x_k equal to w_{k-1} and second element equal to w_k.
   b. Suppose that the initial estimation-error covariance is equal to the identity matrix. Show that the a posteriori estimation-error covariance is given by $P_{k^+} = \frac{1}{k+1}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$.

Course Outcome 5 (CO5)

1. Explain the properties of Kalman filter
2. Consider the system given below. $\{w_k\}$ & $\{v_k\}$ are zero mean process noise with variance Q and R respectively?
   $x_{k+1} = x_k + w_k$
   $y_k = x_k + v_k^2$
   a. What is the mean of the a posteriori estimation error of discrete EKF?
   b. Modify the measurement equation by subtracting the known bias of the measurement noise so that modified measurement noise is zero-mean. What is the variance of modified measurement noise?
3. Consider a nonlinear system $x_{k+1} = -x_k - x_k^3 + w_k$ & $y_k = x_k^2 + v_k$ where u is the input, w_k and v_k are zero mean white process and measurement noises with covariance 5 and 10 respectively. Design Extended Kalman filter to estimates the state x_k of the system.

Concept Map



Syllabus

Introduction

Statement of optimal control problem – Problem formulation and forms of optimal control – Selection of performance measures. Necessary conditions for optimal control – Pontryagin's minimum principle – State inequality constraints – Minimum time problem.

LQ Control Problems and Dynamic Programming

Linear optimal regulator problem – Matrix Riccatti equation and solution method – Choice of weighting matrices – Steady state properties of optimal regulator – Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems – Hamilton Jacobi Bellman equation – Case Studies using MATLAB

Filtering and estimation

Filtering – Linear system and estimation – System noise smoothing and prediction – Gauss Markov discrete time model – Estimation criteria – Minimum variance estimation – Least square estimation – Recursive estimation.

KALMAN Filter and properties

Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement – Extended Kalman filter – Case studies using MATLAB

Reference Books

1. Kirk D.E., 'Optimal Control Theory – An introduction', Dover Publications, 2004.
2. Dan Simon, "Optimal State Estimation Kalman, H-infinity and Non-linear Approaches", John Wiley and Sons, 2006
3. B. D. O. Anderson and J. B. Moore. Linear Optimal Control., Dover Publications, New York, 2005
4. S.M. Bozic, "Digital and Kalman Filtering", Edward Arnould, London, 1994.
5. K. J. AStrom, "Introduction to Stochastic Control Theor", Dover, New York, 2006.

6. C.K. Chui and G. Chen," Kalman Filtering with Real-Time Applications", Springer Ser. Info. Sci., Vol. 17. Springer, Berlin, Heidelberg, 1987.
7. A.V.Bala Krishnan ,"Kalman filtering Theory" , Springer; 1 edition, 28, 1984

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**INTRODUCTION**	
1.1	Statement of optimal control problem	1
1.2	Selection of performance measures.	1
1.3	Necessary conditions for optimal control- Problem formulation and forms of optimal control	2
1.4	Pontryagin's minimum principle	2
1.5	State inequality constraints – Minimum time problem.	2
2.	**LQ CONTROL PROBLEMS AND DYNAMIC PROGRAMMING**	
2.1	Linear optimal regulator problem	2
2.2	Matrix Riccatti equation and solution	2
2.3	Choice of weighting matrices – Steady state properties of optimal regulator	2
2.2	Linear tracking problem- LQG problem	3
2.4	Computational procedure for solving optimal control problems	2
2.5	Characteristics of dynamic programming- solution	1
2.6	Dynamic programming application to discrete and continuous systems	3
2.7	Hamilton Jacobi Bellman equation	2
2.8	Case Studies using MATLAB	1
3.	**FILTERING AND ESTIMATION**	
3.1	Filtering – Linear system and estimation	1
3.2	System noise smoothing and prediction	1
3.3	Gauss Markov discrete time model	1
3.4	Estimation criteria – Minimum variance estimation	1
3.5	Least square estimation – Recursive estimation	2
4.	**KALMAN FILTER AND PROPERTIES**	
4.1	Filter problem and properties	2
4.2	Linear estimator property of Kalman Filter	1
4.3	Time invariance and asymptotic stability of filters	2
4.4	Time filtered estimates and signal to noise ratio improvement	1
4.5	Extended Kalman filter	1
4.6	Case studies using MATLAB	1
	Total	**40**

Course Designers:

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2. Dr.D.Kavitha dkeee@tce.edu

14CIPG0	ROBUST CONTROL	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

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

Prerequisite

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

Course Outcomes

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

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

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

(CO5 may be evaluated through assignments /case studies)

Course Level Assessment Questions

Course Outcome 1 (CO1):

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

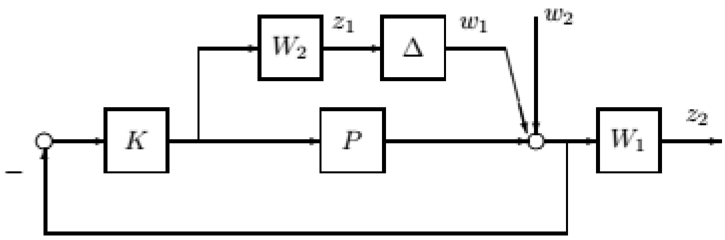
Course Outcome 2(CO2):

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

Course Outcome 3(CO3):

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

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



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

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

Course Outcome 4(CO4):

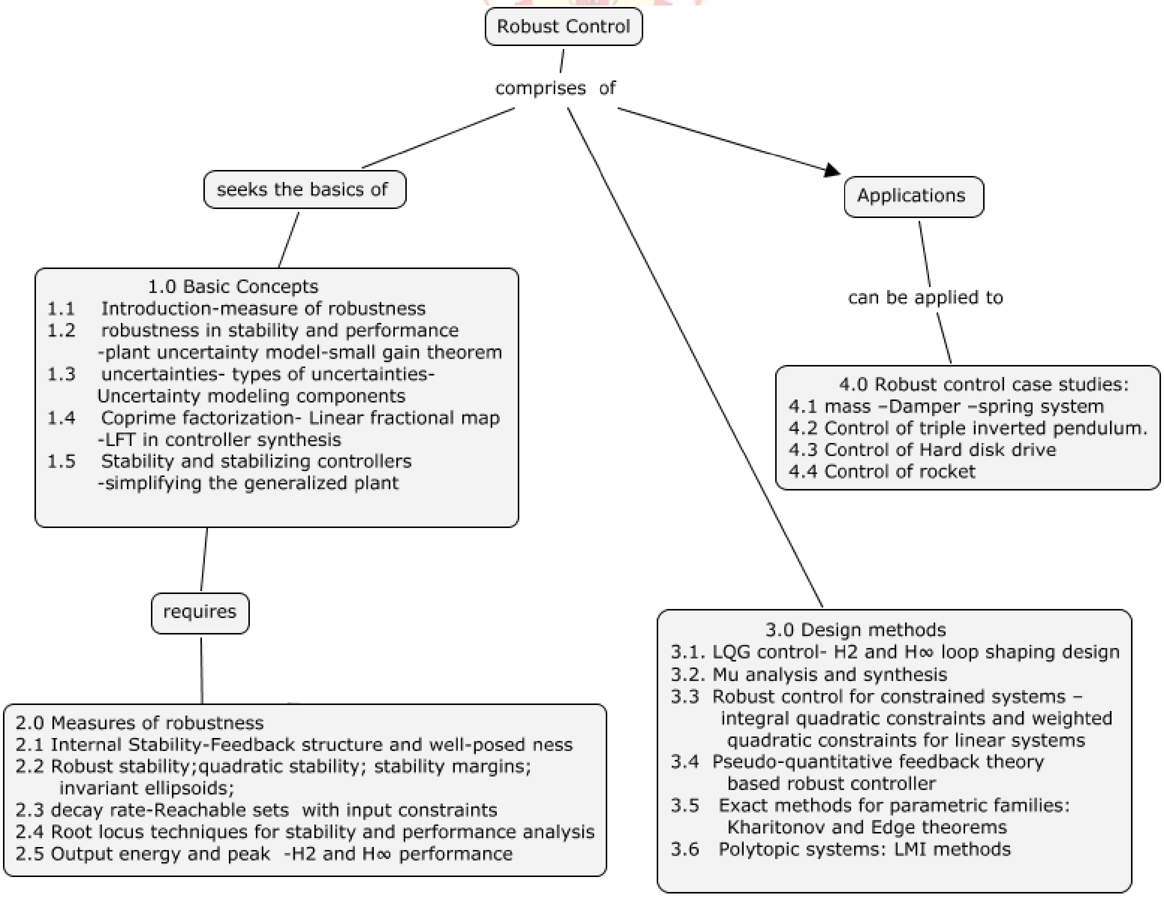
1. Explain edge theorem
2. Consider the system in state space representation shown below. Find the state feedback control law that robustly stabilizes the closed loop system

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

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

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

Concept Map



Syllabus

Basic Concepts

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

Measures of robustness

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

Various approaches of robust control design

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

Applications using MATLAB

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

Reference Books

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

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Basic Concepts**	
1.1	Introduction-measure of robustness	1
1.2	robustness in stability and performance-plant uncertainty model-small gain theorem	2
1.3	uncertainties- types of uncertainties-Uncertainty modeling components	3
1.4	Co-prime factorization- Linear fractional map -LFT in controller synthesis	3
1.5	Stability and stabilizing controllers -simplifying the generalized plant	3
2.0	**Measures of robustness**	
2.1	Internal Stability- Feedback structure and well-posedness	2
2.2	Robust stability; quadratic stability; stability margins; invariant ellipsoids;	3
2.3	Decay rate-Reachable sets with input constraints	2
2.4	Root locus techniques for stability and performance analysis	3
2.5	Output energy and peak -H_2 and H_∞ performance	2
3.0	**Various approaches of robust control design**	
3.1.	LQG control- H_2 and H_∞ loop shaping design	3
3.2.	Mu analysis and synthesis	2
3.3	Robust control for constrained systems –integral quadratic constraints and weighted quadratic constraints for linear systems	4
3.4	Pseudo-quantitative feedback theory based robust controller	2
3.5	Exact methods for parametric families: Kharitonov and Edge theorems	2
3.6	Polytopic systems: LMI methods	2
4.	**Applications using MATLAB**	
4.1	Robust control case studies: mass –Damper –spring system	2
4.2	Control of triple inverted pendulum.	1
4.3	Control of Hard disk drive	1
4.4	Control of rocket	2
	Total	**45**

Course Designers:

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2. Mr.M.Varatharajan varatharajan@tce.edu

14CIPH0/ 14PSPG0	POWER PLANT INSTRUMENTATION AND CONTROL	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

This course aims to give the fundamental concepts and practical aspects of power plant instrumentation and control. A power station is a complex entity. It involves a wide range of engineering disciplines. The basic principles of steam and water cycles, fuel, air and flue gas circuits are discussed. Also the steam generator, boiler drum and circulation, water treatment and various types of controls in a steam power plant has been discussed. It includes compression and draught control, feed water control, steam temperature control and control equipment have been discussed. The updated information on combined cycle generation is also provided.

Prerequisite

- Measurements & instrumentation

Course Outcomes

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

CO1.	Explain the basic principles of power system instrumentation and control	Understand
CO2.	Illustrate the boiler operation and its control in a thermal power plant.	Understand
CO3.	Determine the performance of various power plant instrumentation and control systems.	Apply
CO4.	Choose from currently commercially available power plant instrumentation and control systems for a given application.	Analyse

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Name the different methods of conventional power generation.
2. Explain the importance of instrumentation.
3. Explain the basic principles of power system control.

Course Outcome 2 (CO2):

1. Explain the nature of steam and the uses of steam.
2. Define the term thermal efficiency.
3. Explain the operation of Gas turbine and combined cycle plants.
4. List the different modules of boiler control mechanism.

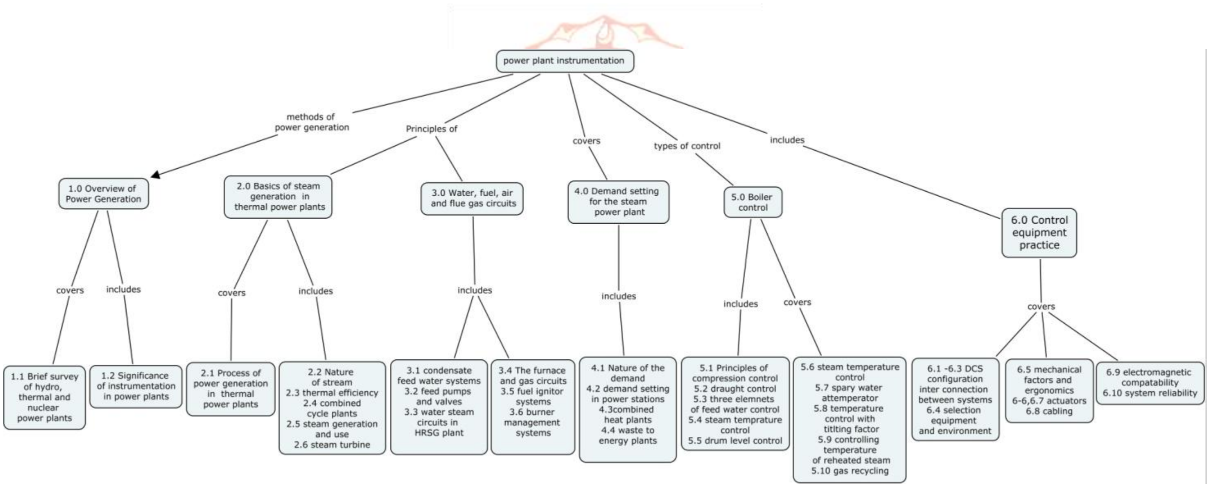
Course Outcome 3 (CO3):

1. Describe how the demand setting in power station is done.
2. Discuss briefly about waste to energy plants.
3. Explain how temperature is controlled with tilting burners.
4. List any two types of attemperator.
5. Compare the operation of two element and three element control used for feed water pumping.

Course Outcome 4 (CO4):

1. Organise the steps involved in compression control.
2. Compare and contrast between an oxygen analyser and a flue gas analyser.
3. Define DCS.
4. State any two advantages of electrical actuators.

Concept Map



Syllabus

Overview of Power Generating Stations: Brief survey of different methods of conventional power generation (hydro, thermal and nuclear)-Importance of instrumentation in power generating stations.

Basics of steam generation in thermal power plants: Process of power generation in coal-fired and oil fired in thermal power plants-Nature of steam-Thermal efficiency-Gas turbine and combined cycle plants-Steam turbine and use-Steam turbine

Water, fuel, air and flue gas circuits: The condensate and feed water system

Feed pumps and valves-The water and steam circuits in HRSC plant

Setting the demand for the steam generator: Nature of the demand-Setting the demand in power stations applications-Master demand in power station applications-Load demand in combined heat and power plants-Waste to energy plants

Boiler control: The principles of compression control-Draught control-The principles of feed water control-One, two and three elements feed water control

Drum level control-Steam temperature control-Spray-water attemperator-Temperature control with tilting burners-controlling temperature of reheated steam-Gas Recycling

Control Equipment Practice: DCS configuration in power plant-A Typical DCS configuration-Interconnections between systems-Equipment selection and environment-

Mechanical factors and ergonomics-Electrical actuators-Hydraulic actuators-Cabling-Electromagnetic compatibility-Reliability of systems

Reference Books

1. David Lindsley, “Power Plant Control & Instrumentation ”,IEE Publications, London, UK (2001).
2. Sam G.Dukelow, The control of Boilers, Instrument Society of America, 1991.
3. Elonka, S.M. and Kohal A.L.Standard Boiler Operations, McGraw Hill, New Delhi, 1994.
4. R.K.Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 1995.
5. P.K.Nag, ”Power Plant Engineering” Tata McGraw-Hill, New Delhi, 2005.
6. A.K.Mahalanbias-“Power System Instrumentation”-Tata McGraw Hill.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**OVERVIEW OF POWER GENERATING STATIONS**	
1.1	Brief survey of different methods of conventional power generation (hydro, thermal and nuclear)	1
1.2	Importance of instrumentation in power generating stations	1
2.0	**Basics of steam generation in thermal power plants**	
2.1	Process of power generation in coal-fired and oil fired in thermal power plants	1
2.2	Nature of steam	1
2.3	Thermal efficiency	1
2.4	Gas turbine and combined cycle plants	1
2.5	Steam generation and use	1
2.6	Steam turbine	1
3.0	**Water, fuel, air and flue gas circuits**	
3.1	The condensate and feed water system	1
3.2	Feed pumps and valves	1
3.3	The water and steam circuits in HRSG plant	1
3.4	The air and gas circuits	1
3.5	Fuel and Igniter systems	1
3.6	Burner- management systems	1
4.0	**Setting the demand for the steam generator**	
4.1	Nature of the demand	1
4.2	Setting the demand in power station applications	1
4.3	Master demand in power station applications	1
4.5	Load demand in combined heat and power plants	1
4.6	Waste to energy plants	1
5.0	**Boiler control**	
5.1	The principles of compression control	1
5.2	Draught control	1
5.3	The principles of feed water control	1
5.4	One, two and three elements feed water control	1
5.5	Drum level control	2
5.6	Steam temperature control	1
5.7	Spray-water attemperator	1
5.8	Temperature control with tilting burners,	1
5.9	controlling temperature of reheated steam	1
5.10	Gas Recycling	1

6.0	**CONTROL EQUIPMENT PRACTICE**	
6.1	DCS configuration in power plant	1
6.2	A Typical DCS configuration	1
6.3	Interconnections between systems	1
6.4	Equipment selection and environment	1
6.5	mechanical factors and ergonomics	1
6.6	Electrical actuators	1
6.7	Hydraulic actuators	1
6.8	Cabling,	1
6.9	Electromagnetic compatibility	1
6.10	Reliability of systems	1
	Total	**40**

Course Designers:

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14CIPJ0	ANALYTICAL INSTRUMENTATION	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

Analytical instruments are an exciting and fascinating part of chemical analysis that interacts with all areas of chemistry and with many other areas of applied science. An analytical instrument plays an important role in the production and evaluation of new products and also provides lower detection limits required to assure safe food, drugs, water and air. This course emphasizes the principles of analytical instruments and their applications in hospitals for routine clinical analysis, drugs, pharmaceutical laboratories and environmental pollution monitoring and control.

Prerequisite

CN13 Transducer Engineering

CN21 Advanced Instrumentation system

Course Outcomes

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

CO1	Explain the basic components of analytical instruments, laws and performance requirements.	Understand
CO2	Explain the operating principle, sources and detectors of Spectrometers used in UV, Visible Infrared region ,Flame emission and FTIR Spectrometers	Understand
CO3	Explain the electrodes used in PH measurement and conductivity measurements along with some applications of electrodes.	Understand
CO4	Explain the building blocks and operation of NMR,XRAY and MASS Spectrometers	Understand
CO5	Explain the techniques used in measuring industrial gases.	Understand
CO6	Explain the principle of Chromatography and its types	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	30	30
Understand	70	70	70	70
Apply	0	0	0	0
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1(CO1):

1. List the elements of analytical Instruments.
2. Describe the advantages of intelligent analytical instrumentation systems.
3. Write the wavelength range of visible Radiation

Course Outcome 2(CO2):

1. Explain the two essential requirements of optical filters
2. Write the principle of Flame photometry
3. List the advantages of FTIR over dispersive IR spectroscopy

Course Outcome (CO3):

1. Define specific conductance.
2. Explain the principle of pH measurement.
3. Explain the measurement of conductance using Null method.

Course Outcome (CO4):

1. List the two types of NMR spectrometry.
2. Explain the different ways of interaction of X rays with matter.
3. Explain the advantages of Mass spectrometer over NMR spectrometer.

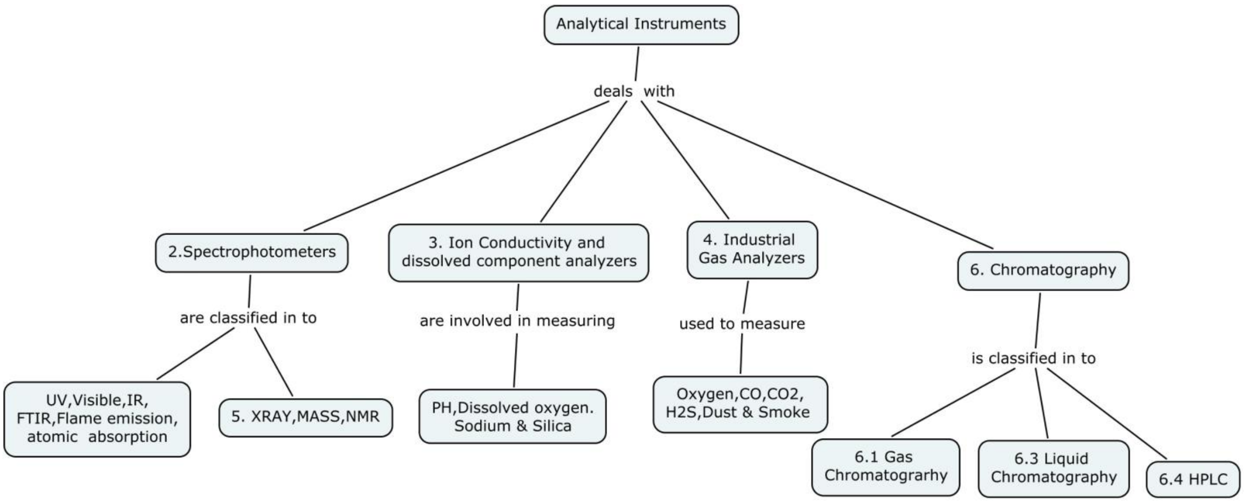
Course Outcome (CO5):

1. Illustrate the operating principle of Infrared gas analyzer.
2. List the techniques used for measuring Sulphur dioxide
3. Explain the principle of operation of paramagnetic oxygen analyzer.

Course Outcome (CO6):

1. Define chromatogram.
2. State the types of liquid chromatography.
3. Describe the role of vapor pressure GC.

Concept Map



Syllabus

Introduction to Analytical instruments
Basic Components of Analytical Instruments, Intelligent analytical Instrumentation systems, Performance requirements of Analytical Instruments, Laws of photometry (Beer and Lambert's law),

Spectrophotometers
UV, Visible, Infrared, Fourier transform infrared spectrometry, atomic absorption, Flame emission Spectrophotometers, Sources and detectors used in spectrophotometers, **Case Study:** Analyzing the absorption characteristics of different solutions.

Conductivity and dissolved component analyzer
Ion selective electrodes, Conductivity meters, pH meters, Dissolved oxygen analyzer, Sodium analyzer, Silica Analyzer, Turbidity meter

NMR,XRAY and MASS Spectrometric Techniques
NMR Spectroscopy :Principle & Detection-GM Counters, Proportional Counters, X-ray spectrometry: Instrumentation for X-ray spectrometry, X-ray diffractometer , X ray absorption meter, Mass Spectrometer (MS): Principle, mass analyzer types - magnetic deflection type, time of flight.

Industrial Gas analyzers
paramagnetic gas analyzer, Infrared gas analyzer, Environmental Pollution Monitoring Instruments- Carbon monoxide: non dispersive infrared analyzer (NDIR), Sulphur dioxide- flame photometric, coulometry, UV fluorescence ,Hydrogen sulfide, NOX and SOX analyzer

Chromatography
Gas chromatography: principle, constructional details, GC detectors, Liquid Chromatography, High Performance Liquid Chromatography (HPLC): principle, constructional details, **Case Study:** Design of column for analyzing different samples.

Reference books

1. Instrumental Methods of Analysis, Willard, Merritt, Dean, Settle, CBS Publishers & Distributors, New Delhi, Seventh edition.
2. Handbook of Analytical Instruments, R. S. Khandpur, Tata McGraw–Hill Publications, 3rd edition
3. Principles of Instrumental Analysis, Skoog, Holler, Nieman, Thomson books-cole publications, 5th edition.
4. Instrumental Methods of Chemical Analysis, Galen W. Ewing, McGraw-Hill Book Company, Fifth edition.
5. Introduction to Instrumental Analysis, Robert D. Braun, McGraw-Hill Book Company.

Course contents and Lecture schedule

Module No.	Topic	No.of Lecture Hours
1	**Introduction to Analytical Instruments**	1
1.1	Basic Components of Analytical Instruments & Intelligent analytical Instrumentation systems.	2
1.2	Performance requirements of Analytical Instruments.	1
1.3	Laws of photometry (Beer and Lambert's law).	1
2	**Spectrophotometers**	
2.1	UV Spectrophotometers, Visible Spectrophotometers, Infrared Spectrophotometers	2
2.2	Fourier transform infrared spectrometry, atomic absorption Spectrophotometers	2
2.3	Flame emission Spectrophotometers,	1
2.4	Sources and detectors used in spectrophotometers	1
2.4.1	**Case Study:** Analyzing the absorption characteristics of different solutions.	1
3	**Conductivity and dissolved component analyzer**	
3.1	Ion selective electrodes, pH meters	2
3.2	Conductivity meters, Dissolved oxygen analyzer,	2
3.3	Sodium analyzer, Silica Analyzer, Turbidity meter	2
4	**NMR,XRAY and MASS Spectrometric Techniques**	
4.1	NMR Spectroscopy Principle	1
4.2	NMR Detectors-GM Counters, Proportional Counters	2
4.3	X-ray spectrometry, Instrumentation for X-ray spectrometry,	1
4.4	X-ray diffractometer & X ray absorption meter,	2
4.5	Mass Spectrometer (MS): Principle,	1
4.6	Mass analyzer -magnetic deflection type, time of flight.	2
5	**Industrial Gas analyzers**	
5.1	paramagnetic gas analyzer, Infrared gas analyzer,	2
5.2	Environmental Pollution Monitoring Instruments	1
5.3	Carbon monoxide-non dispersive infrared analyzer(NDIR),	1
5.4	Sulphur dioxide:flame photometric, coulometry, UV fluorescence ,	2
5.5	Hydrogen sulfide , Nitrous oxide , SOX analyser	2
6	**Chromatography**	
6.1	Gas chromatography: principle, constructional	1
6.2	Gas chromatography detectors,	1

6.3	Liquid Chromatography principle, construction	1
6.4	High Performance Liquid Chromatography (HPLC): principle, construction details	1
6.4.1	**Case Study:** Design of column for analyzing different samples.	1
	Total	**40**

Course Designers

1. Mr.B.Ashok Kumar ashokudt@tce.edu
2. Mr.G.Sivasankar qsiva@tce.edu

14CIPK0	MEMS	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

The technological advances of Microsystems engineering have been truly impressive in both pace of development and number of new applications. Microsystem engineering involves the design, manufacture and packaging of micro electro mechanical systems (MEMS) and peripherals. Applications of Microsystems include aerospace, automotive, biotechnology, environmental protection, safety and healthcare, etc. The strong demand for MEMS and microsystems has generated strong interest as well as a need for engineering educators to offer a course on this subject.

Prerequisite

Transducer Engineering

Course Outcomes

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

CO1	Explain the working principles of MEMS and Microsystems.	Understand
CO2	Apply engineering mechanics for MEMS and Microsystems design.	Apply
CO3	Use scaling laws in miniaturization	Apply
CO4	Explain the properties of materials used for MEMS and Microsystems	Understand
CO5	Explain micro system fabrication process	Understand
CO6	Explain the processes in design of micro system sensor	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

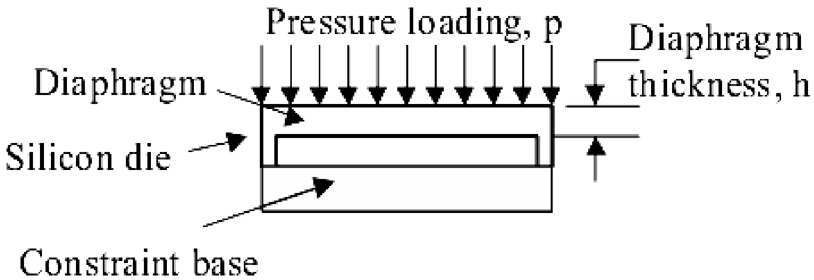
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define micro actuation
2. Explain the difference between MEMS and micro system
3. Illustrate the role of MEMS in automobile sensors

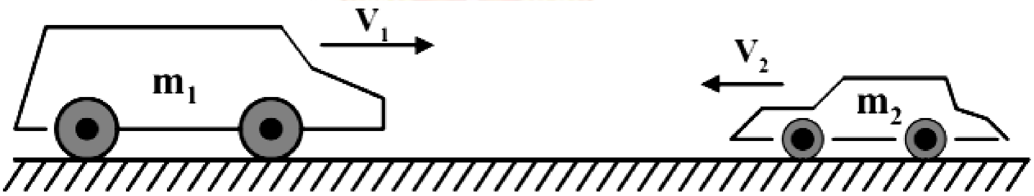
Course Outcome 2 (CO2):

1. Determine the minimum thickness of the circular diaphragm of a micro pressure sensor made of Silicon as shown below with conditions:



Diameter d = 600 μm; Applied pressure p = 20 MPa Yield strength of silicon σ y = 7000 MPaE = 190,000 MPa and v = 0.25.

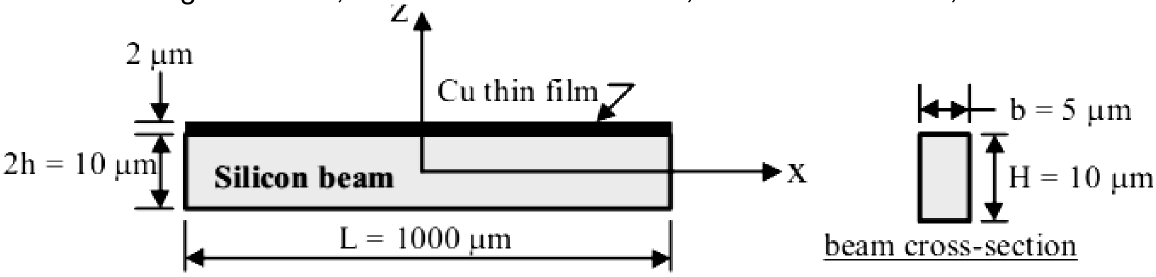
2. Using beam spring design an inertia sensor for airbag deployment system in automobile application shown below



m_1 = 12,000 Kg, m_2 = 8000 Kg; $V_1 = V_2$ = 50 Km/h

3. Determine the thermal stresses and strains as well as the deformation of a thin beam at 1 μ sec after the top surface of the beam is subjected to a sudden heating by the resistance heating of the attached thin copper film. The temperature at the top surface resulting from the heating is 40 o C. The geometry and dimensions of the beam is illustrated below. The beam is made of silicon and has the following material properties

Mass density, ρ = 2.3 g/cm^3 ; specific heats, c = 0.7 J/g- ^{o}C;
Thermal conductivity, k = 1.57 w/cm- o C (or J/cm- ^{o}C-sec);
Coefficient of thermal expansion, α = 2.33 x 10 -6 / ^{o}C;
Young's modulus, E = 190000 x 10 6 N/m 2 ; and Poisson's ratio, v = 0.25.

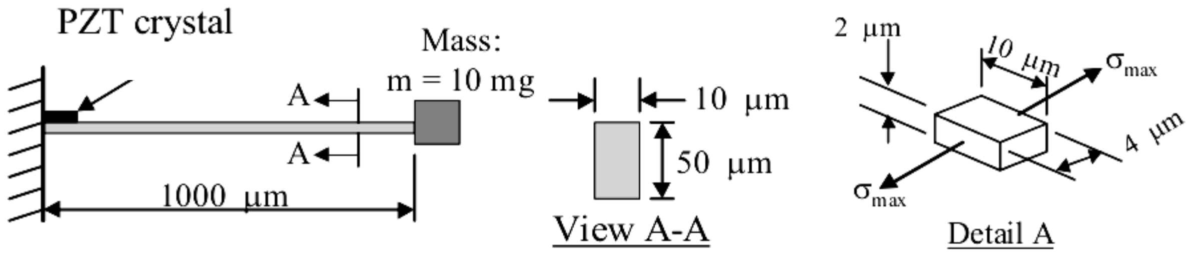


Course Outcome 3 (CO3):

1. Calculate the reduction in amount of torque required to rotate a cuboid with 50% reduction in all the sides
2. Discuss the scaling in rigid body dynamics
3. Calculate the associate changes in the acceleration (a) and the time (t) and the power supply (P) to actuate a MEMS component if its weight is reduced by a factor of 10.

Course Outcome 4 (CO4):

1. With suitable diagram explain Czochralski method of producing single crystal silicon
2. Explain the characteristics of Gallium Arsenide
3. Thin piezoelectric crystal film, PZT is used to transduce the signal in a micro accelerometer involving a cantilever beam made of silicon. Design the accelerometer is for maximum acceleration/deceleration of 10 g.



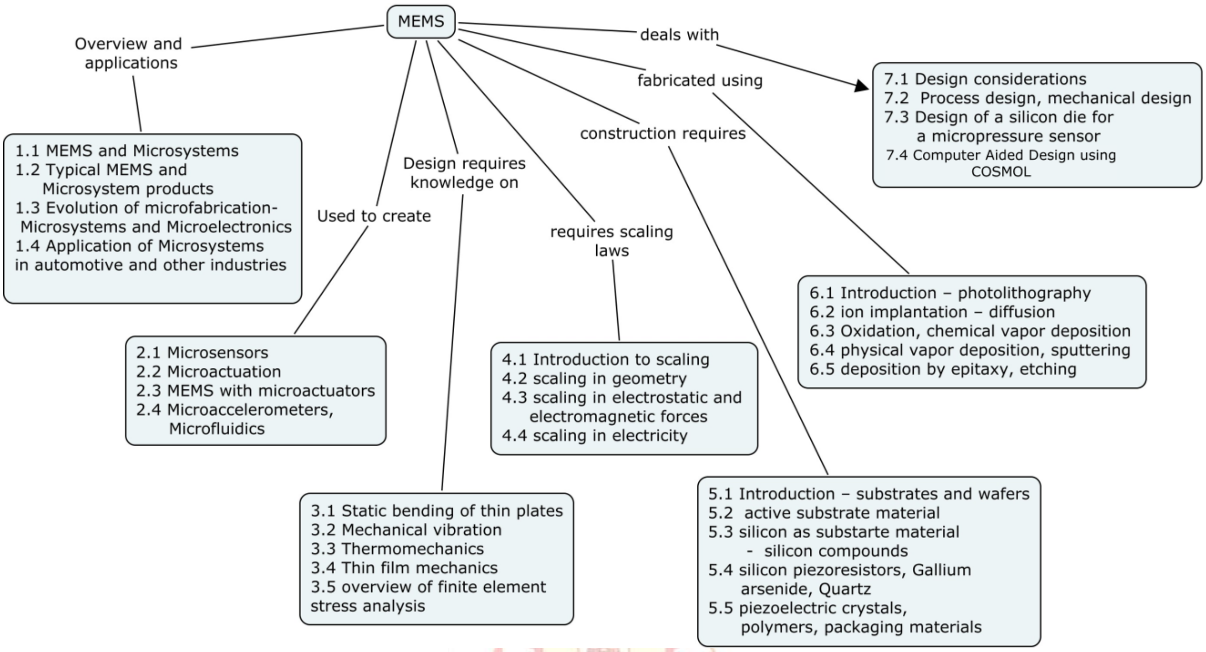
Course Outcome 5(CO5):

1. List various methods of epitaxy.
2. With suitable diagram explain the process of photo lithography.
3. Discuss the role of chemical vapour deposition in micro fabrication.

Course Outcome 6(CO6):

1. Explain the factors to be considered during initial design of micro systems
2. With suitable diagram explain the general structure of computer aided design of micro systems
3. Discuss about bio-medical and optical interfaces in micro systems packaging

Concept Map



Syllabus

OVERVIEW OF MEMS AND MICROSYSTEMS
MEMS and Microsystems - Typical MEMS and Microsystem products – Evolution of microfabrication- Microsystems and Microelectronics – Application of Microsystems in automotive and other industries.

WORKING PRINCIPLES OF MICROSYSTEMS – Microsensors – Microactuation- MEMS with microactuators-Microaccelerometers- Microfluidics

ENGINEERING MECHANICS FOR MICROSYSTEMS DESIGN –Static bending of thin plates-Mechanical vibration-Thermomechanics – Thin film mechanics – overview of finite element stress analysis

SCALING LAWS IN MINIATURIZATION - Introduction to scaling – scaling in geometry – scaling in electrostatic and electromagnetic forces – scaling in electricity

MATERIAL FOR MEMS AND MICROSYSTEMS – Introduction – substrates and wafers – active substrate material – silicon as substrate material - silicon compounds – silicon piezo resistors – Gallium arsenide – Quartz – piezoelectric crystals – polymers –packaging materials

MICROSYSTEM FABRICATION PROCESSES – Introduction – photolithography – ion implantation – diffusion – oxidation – chemical vapor deposition – physical vapor deposition – sputtering – deposition by epitaxy –etching

MICROSYSTEM DESIGN – Design considerations – process design – mechanical design – design of a silicon die for a micro pressure sensor, Computer Aided Design using COMSOL

Reference Books

1. Tai –Ran Hsu, MEMS & MICROSYSTEMS Design and manufacture, TATA McGraw Hill, 2002
2. Thomas M.Adams, Richard A.Layton, Introductory MEMS –fabrication and applications, springer, 2010.
3. Mohamed Gad-El-Hak, MEMS: Design and fabrication, CRC/Taylor & Francis, 2006.
4. COMSOL-MEMS module manual "http://www.comsol.co.in/showcase/mems"

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**OVERVIEW OF MEMS AND MICROSYSTEMS**	
1.1	MEMS and Microsystems	1
1.2	Typical MEMS and Microsystem products	1
1.3	Evolution of microfabrication- Microsystems and Microelectronics	2
1.4	Application of Microsystems in automotive and other industries.	1
2.0	**WORKING PRINCIPLES OF MICROSYSTEMS**	
2.1	Microsensors	2
2.2	Microactuation	2
2.3	MEMS with microactuators	2
2.4	Microaccelerometers, Microfluidics	1
3.0	**ENGINEERING MECHANICS FOR MICROSYSTEMS DESIGN**	
3.1	Static bending of thin plates	1
3.2	Mechanical vibration	2
3.3	Thermomechanics	2
3.4	Thin film mechanics	1
3.5	Overview of finite element stress analysis	1
4.0	**SCALING LAWS IN MINIATURIZATION**	
4.1	Introduction to scaling	1
4.2	Scaling in geometry	1
4.3	Scaling in electrostatic and electromagnetic forces	2
4.4	Scaling in electricity	1
5.0	**MATERIAL FOR MEMS AND MICROSYSTEMS**	
5.1	Introduction – substrates and wafers	1
5.2	Active substrate material	1
5.3	Silicon as substrate material, silicon compounds	2
5.4	Silicon piezo resistors, Gallium arsenide, Quartz	2
5.5	Piezoelectric crystals, polymers, packaging materials	1
6.0	**MICROSYSTEM FABRICATION PROCESSES**	
6.1	Introduction – photolithography	1
6.2	Ion implantation, diffusion	1
6.3	Oxidation, chemical vapor deposition	1
6.4	Physical vapor deposition, sputtering	1
6.5	Deposition by epitaxy, etching	1

7.0.	**MICROSYSTEM DESIGN**	
7.1	Design considerations	2
7.2	Process design, mechanical design	2
7.3	Design of a silicon die for a micro pressure sensor,	2
7.4	Computer Aided Design using COMSOL	3
	Total	**45**

Course Designers:

1. Dr.M.Saravanan mseee@tce.edu
2. Dr.D.Nelson Jayakumar dnjeee@tce.edu

14CIPL0	MULTI SENSOR DATA FUSION	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Multi Sensor data fusion is a subset of information fusion and is generally defined as the use of techniques that combine data from multiple sources and gather that information into discrete, actionable items in order to achieve inferences, which will be more efficient and narrowly tailored than if they were achieved by means of disparate sources. In this course reference has been made about the algorithms for data fusion and estimation and advanced filtering of signals from sensors. It also includes designing of optimal sensor systems. The proposed course is offered as an elective. The subject requires the fundamental knowledge of sensors, control theory, digital signal processing and mathematical knowledge of probability theory, statistical estimation and linear algebra.

Prerequisite

CN12 Systems Theory

CN13 Transducer Engineering

Course Outcomes

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

CO1	Explain the various algorithms for data fusion	Understand
CO2	Estimate and filter the data from multi sensors	Understand
CO3	Design optimal sensor and filter systems	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

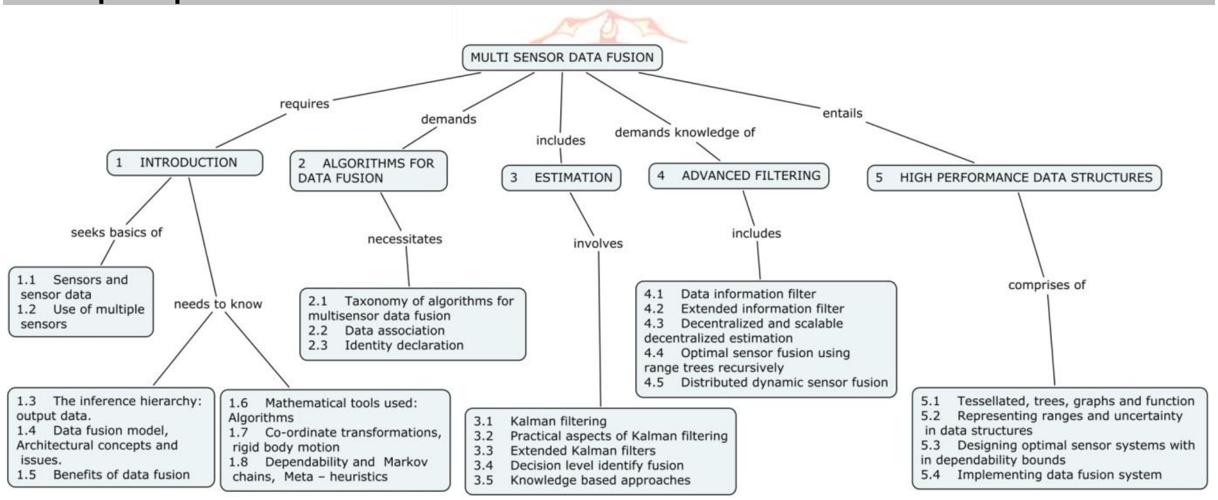
1. Name the sensors available for data fusion.
2. Specify the different forms of output from sensor.
3. Mention the data fusion models.
4. Exemplify data sensor fusion with suitable applications.

5. List the benefits of data fusion.
6. State the limitations of data fusion.
7. Compare the algorithms for data fusion.

Course Outcome 2 (CO2):
1. Explain how kalman filter is used for estimation.
2. What are the practical aspects of kalman filtering?
3. Compare the knowledge based approaches for estimation.
4. Elaborate on the advanced filtering techniques for multi sensor data fusion.
5. Explain decision level identity fusion.

Course Outcome 3 (CO3):
1. Design an extended kalman filter for estimation.
2. With suitable figures, elaborate the process of implementing data fusion systems.
3. Design optimal sensor system for a robot.
4. Apply uncertainty analysis to determine the error in inference during data fusion with multiple sensors.

Concept Map



Syllabus

INTRODUCTION: Sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data. Data fusion model. Architectural concepts and issues. Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta – heuristics.

ALGORITHMS FOR DATA FUSION: Taxonomy of algorithms for multisensor data fusion. Data association. Identity declaration.

ESTIMATION:
Kalman filtering, practical aspects of Kalman filtering, extended Kalman filters. Decision level identify fusion. Knowledge based approaches.

ADVANCED FILTERING: Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

HIGH PERFORMANCE DATA STRUCTURES: Tessellated, trees, graphs and function. Representing ranges and uncertainty in data structures. Designing optimal sensor systems with in dependability bounds. Implementing data fusion system.

CASE STUDIES: (To be covered in Assignments)Servo mechanism, Target tracking, Quadruple Tank Process

Reference Books

1. David L. Hall, Mathematical techniques in Multisensor data fusion, Artech House, Boston, 1992.
2. R.R. Brooks and S.S. Iyengar, Multisensor Fusion: Fundamentals and Applications with Software, Prentice Hall Inc., New Jersey, 1998.
3. Aurthur G.O.Mutambara, “Decentralized Estimation and Control of Multisensor Systems”, CRC Press, 1998
4. Arthur Gelb, Applied Optimal Estimation, The M.I.T. Press, 1982.
5. James V. Candy, Signal Processing: The Model Based Approach, McGraw –Hill Book Company, 1987.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**INTRODUCTION**	
1.1	Sensors and sensor data	1
1.2	Use of multiple sensors, Fusion applications.	1
1.3	The inference hierarchy: output data.	1
1.4	Data fusion model, Architectural concepts and issues.	1
1.5	Benefits of data fusion	1
1.6	Mathematical tools used: Algorithms	1
1.7	Co-ordinate transformations, rigid body motion	1
1.8	Dependability and Markov chains, Meta – heuristics	1
2	**ALGORITHMS FOR DATA FUSION**	
2.1	Taxonomy of algorithms for multi sensor data fusion	4
2.2	Data association	2
2.3	Identity declaration	2
3	**ESTIMATION**	
3.1	Kalman filtering	2
3.2	Practical aspects of Kalman filtering	1
3.3	Extended Kalman filters	1
3.4	Decision level identify fusion	1
3.5	Knowledge based approaches	3
4	**ADVANCED FILTERING**	
4.1	Data information filter	1
4.2	Extended information filter	1
4.3	Decentralized and scalable decentralized estimation	2
4.4	Optimal sensor fusion using range trees recursively	3
4.5	Distributed dynamic sensor fusion	1
5	**HIGH PERFORMANCE DATA STRUCTURES**	
5.1	Tessellated, trees, graphs and function	2
5.2	Representing ranges and uncertainty in data structures	1
5.3	Designing optimal sensor systems with in dependability bounds	3
5.4	Implementing data fusion system	2
	Total	**40**

Course Designers:

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2. Dr.D.Kavitha dkavitha@tce.edu

14CIPM0	ROBOTICS	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Robotics is a multidisciplinary field involving mechanics, control, instrumentation, artificial intelligence, computer science etc. Applications of robotics range from routine pick and place jobs in industries to intelligent remote operated vehicles in space research. This course mainly discusses about robot anatomy, coordinate frames, mapping and transforms, direct kinematic modelling of robots and inverse kinematics, dynamic modelling, trajectory planning, linear and nonlinear control of manipulators.

Prerequisite

Ordinary differential Equations

Laplace Transforms

Linear Control System Analysis

System Theory

Course Outcomes

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

CO1	Explain the components of robot	Explain
CO2	Develop forward and inverse kinematics of a given manipulator	Apply
CO3	Develop dynamic model of a given manipulator	Apply
CO4	Calculate trajectories of end effector and joints for a given set of via points	Apply
CO5	Apply linear and nonlinear control schemes for a given manipulator	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**									**L**
CO2	**S**	**M**	**L**								**L**
CO3	**S**	**M**	**L**								**L**
CO4	**S**	**M**	**L**								**L**
CO5	**S**	**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	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Illustrate the role of degree of freedom in selection of robots
2. With suitable diagram describe the working principle of any one tactile and touch sensor used in robotics
3. Explain various components of robots

Course Outcome 2 (CO2):

1. A vector OP defined in the reference frame {0} is $[1\ 2\ 3]^T$. Origin of frame is displaced by +2units along y axis and +3 units along z axis. Frame {0} is then rotated about z axis by 90^o and about x axis by -90^o. Find the vector OP w.r.t the transformed frame.
2. Compute the manipulator transformation matrix for 3DOF manipulator arm with Cartesian Arm (PPP) configuration.
3. Compute the manipulator transformation matrix and inverse kinematics for 3DOF manipulator arm with Polar (RRP) configuration.

Course Outcome 3 (CO3):

1. Explain the method of static force analysis of manipulators
2. Using Euler Lagrange equation derive the dynamic model of 2 DOF planar manipulator
3. Derive the dynamic model of 3DOF manipulator arm with Cartesian configuration

Course Outcome 4 (CO4):

1. It is desired to have the first joint of a six-axis robot go from initial angle of 30 degree to final angle of 60 degree in 5 seconds. Using fifth order polynomial calculate the joint angle at 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} second. Assume initial acceleration and final retardation be 5 degree/sec^2
2. Determine the trajectory of pick and place robot which has to pass through three via-points using piecewise linear interpolation with parabolic blends for each segment. The path points are [0 10 45 30 5] degrees and travel times for the segments are [0.5 1.5 2.0 1.0] seconds respectively. Assume the magnitude of acceleration at each parabolic blend is 25 degree / sec^2
3. Derive the cubic polynomial trajectory model of point to point motion without via points

Course Outcome 5 (CO5):

1. Consider the servo motor driven joint-link with dynamic model $\tau = I\ddot{\theta}_a$. It is driven by a armature controlled servo motor. Dynamic model of servo motor model is $e_a = K_b\dot{\theta}_a + i_a R_a$, and $\tau_a = K_t i_a$, where,

   $e_a \rightarrow \text{Control voltage(V)}$

   $K_b \rightarrow \text{Back emf constant (V/rad/s)}$

   $i_a \rightarrow \text{Armature current(A)}$

   $R_a \rightarrow \text{Armature resistance}(\Omega)$

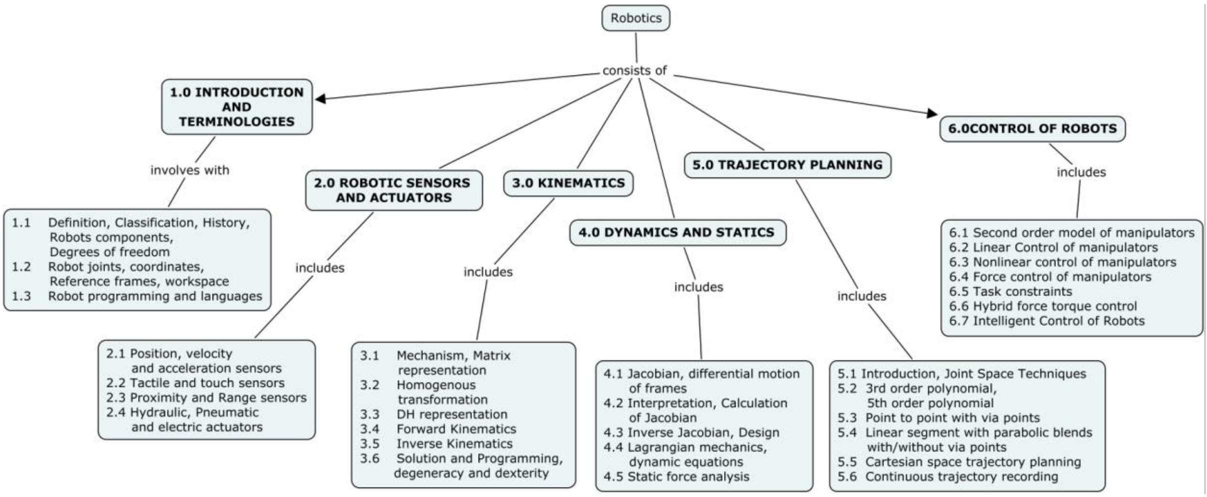
   $K_t \rightarrow \text{Torque Constant(Nm/A)}$

   $\tau_a \rightarrow \text{Torque produced by servo motor (Nm)}$

This setup is to be controlled by a PID controller with partitioning scheme to track the reference trajectory. Find the closed loop error dynamics of the system and the condition for critically damped response.

2. Consider a manipulator with linear, second order dynamic model $\tau = I\ddot{\theta} + B\theta$, where I is the total inertia and B is the total friction.
   a. Design suitable partitioned control scheme to achieve the error dynamics $\ddot{e} + 4\dot{e} + 4e = 0$
   b. Assuming that there is a constant disturbance torque τ_d, design suitable control scheme to eliminate the effect of disturbance and achieve the error dynamics $\dddot{e} + 3\ddot{e} + 4\dot{e} + 4e = 0$
3. With suitable diagram illustrate hybrid position /force control scheme.

Concept Map



Syllabus

INTRODUCTION AND TERMINOLOGIES
Definition, Classification, History, Robot components, Degrees of freedom, Robot joints, coordinates, Reference frames, workspace, Robot programming languages.

ROBOTIC SENSORS AND ACTUATORS
Position, velocity and acceleration sensors, Torque sensors, tactile and touch sensors, proximity and range sensors, Hydraulic, Pneumatic and electric actuators

KINEMATICS (limited to 3-DOF manipulators)
Mechanism-matrix representation, Homogenous transformation, DH representation, Forward Kinematics, Inverse kinematics, Solution and programming, degeneracy and dexterity

DYNAMICS AND STATICS (limited to 3-DOF manipulators)
Jacobian, differential motion of frames, Interpretation, Calculation of Jacobian, Inverse Jacobian, Design, Lagrangian mechanics, dynamic equations, static force analysis

TRAJECTORY PLANNING

Introduction, Joint Space Techniques, 3rd order polynomial, 5th order polynomial, Point to point with via points, Linear segment with parabolic blends with/without via points, and Cartesian space trajectory planning, Continuous trajectory recording

CONTROL OF ROBOTS

Second order model of manipulators, Linear Control of manipulators – Nonlinear control of manipulators, Force control of manipulators, Task constraints, Hybrid force torque control, Intelligent Control of Robots

Reference Books

1. Saeed B. Niku ,"Introduction to Robotics ", Pearson Education, 2002
2. John J.Craig, “Introduction to Robotics, Mechanics and control”, third edition, Pearson education, 2005
3. R.K. Mittal, I.J. Nagrath, Robotics and control, Tata McGraw-Hill, 2003.
4. R.D. Klafter, TA Chmielewski and Michael Negin, "Robotic Engineering, An Integrated approach", Prentice Hall of India, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**INTRODUCTION AND TERMINOLOGIES**	
1.1	Definition, Classification, History, Robots components, Degrees of freedom	1
1.2	Robot joints, coordinates, Reference frames, workspace	1
1.3	Robot programming languages	1
2.0	**ROBOTIC SENSORS AND ACTUATORS**	
2.1	Position, velocity and acceleration sensors	1
2.2	Tactile and touch sensors	1
2.3	Proximity and Range sensors	1
2.4	Hydraulic, Pneumatic and electric actuators	1
3.0	**KINEMATICS**	
3.1	Mechanism, Matrix representation	1
3.2	Homogenous transformation	2
3.3	DH representation	1
3.4	Forward Kinematics	3
3.5	Inverse Kinematics	2
3.6	Solution and Programming, degeneracy and dexterity	1
4.0	**DYNAMICS AND STATICS**	
4.1	Jacobian, differential motion of frames	1
4.2	Interpretation, Calculation of Jacobian	1
4.3	Inverse Jacobian, Design	2
4.4	Lagrangian mechanics, dynamic equations	4
4.5	Static force analysis	2
5.0	**TRAJECTORY PLANNING**	1
5.1	Introduction, Joint Space Techniques	1
5.2	3rd order polynomial, 5th order polynomial	1
5.3	Point to point with via points	1
5.4	Linear segment with parabolic blends with/without via points	2

5.5	Cartesian space trajectory planning	1
5.6	Continuous trajectory recording	1
6.0	**CONTROL OF ROBOTS**	
6.1	Second order model of manipulators	1
6.2	Linear Control of manipulators	2
6.3	Nonlinear control of manipulators	2
6.4	Force control of manipulators	1
6.5	Task constraints	1
6.6	Hybrid force torque control	2
6.7	Intelligent Control of Robots	1
	Total	**45**

Course Designers:

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14CIPN0	EMBEDDED SYSTEM DESIGN	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

This course provides a broad introduction to embedded system design. It explores the characteristics and quality attributes of Embedded systems with Application. It also explains the designing of embedded systems with microcontroller. The hardware software co-design and program modeling for real time application is discussed.

Prerequisite

Microprocessors

Microcontrollers

Basics of 'C' programming

Course Outcomes

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

CO1	Explain the design process of embedded system	Understand
CO2	Explain interfacing of I/O devices, serial and parallel communication buses	Understand
CO3	Explain interrupts and memories in Embedded Systems	Understand
CO4	Develop Embedded C program for interfacing devices	Apply
CO5	Explain the principle of Real Time Operating Systems	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	0	20
Understand	30	30	0	30
Apply	40	40	100*	50
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

*CAT3 shall be conducted as practical exam

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the components of embedded system.
2. With the use of design metrics explain the design process in embedded system.
3. With neat diagram explain the different components in SoC embedded system.

Course Outcome 2 (CO2)

1. List the RS-232 serial port signals.
2. Write working principle of any two wireless devices.
3. In a synchronous serial communication, the time for transferring one byte of data is 8 micro second. What is the data transfer rate in bits per second?

Course Outcome 3 (CO3)

1. How the interrupt latency for servicing an interrupt is calculated under different cases? Explain.
2. Write the expression for worst case interrupt latency.
3. List the uses of flash memory.

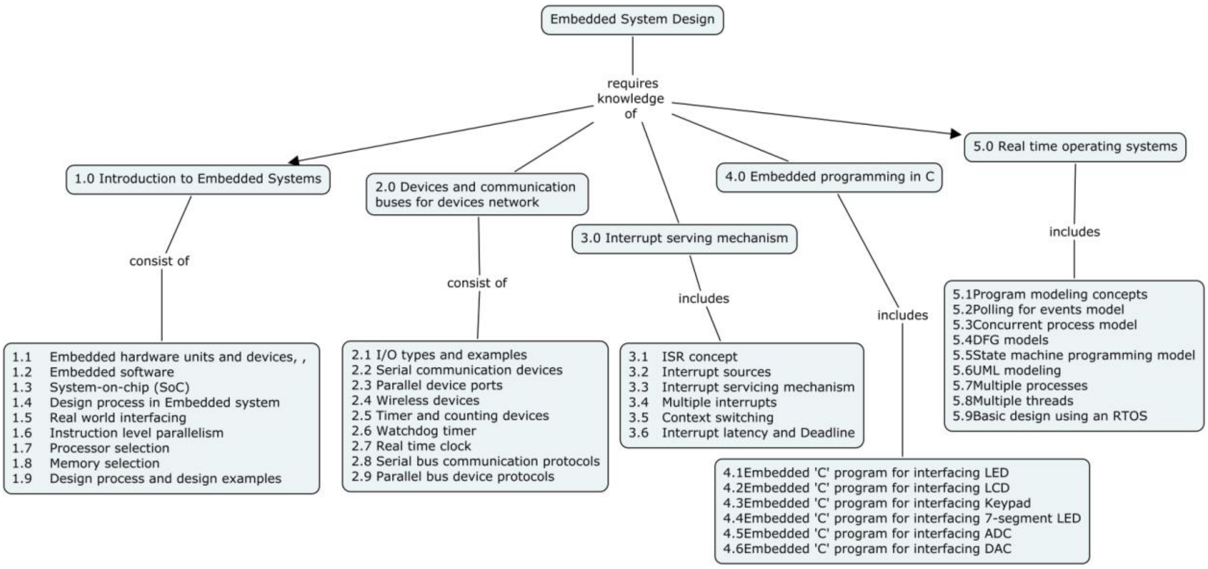
Course Outcome 4 (CO4)

1. Write embedded 'C' program to display your *NAME* in the first row of LCD and simultaneously 'ON' the first row of LEDs. After 10 seconds your *REGISTER NUMBER* to be displayed in the second row of LCD and simultaneously 'ON' the second row of LEDs. Draw the necessary flowchart.
2. Write embedded 'C' program for the given task using keypad and 7-segment LED:
   When Key '1' is pressed, the 7-segment LED count increases from '0' to '100'
   When Key '2' is pressed, the 7-segment LED count decreases from '100' to '0'.
3. Write algorithm and 8051 ‘C’ program to interface DAC to generate two cycles of sine wave with 5V peak value with 10 samples.

Course Outcome 5 (CO5)

1. List the different UML modeling diagrams.
2. Illustrate the operation of pre-emptive scheduler with an example.
3. What is data flow graph model of programming?

Concept Map



Syllabus

Introduction to Embedded Systems
Embedded hardware units and devices, Embedded software, System-on-chip (SoC), Design process in Embedded system, Real world interfacing, Instruction level parallelism, Processor selection, Memory selection, Design process and design examples.

Devices and communication buses for devices network
I/O types and examples, Serial communication devices, Parallel device ports, wireless devices, Timer and counting devices, Watchdog timer, Real time clock, Serial bus communication protocols, Parallel bus device protocols.

Interrupt serving mechanism
ISR concept, Interrupt sources, Interrupt servicing mechanism, Multiple interrupts, Context switching, Interrupt latency and Deadline.

Embedded programming in C
Embedded 'C' program for interfacing LED, LCD, Keypad, 7-segment LED, ADC, DAC.

Real time operating systems
Program modeling concepts, Polling for events model, Concurrent process model, DFG models, State machine programming model, UML modeling, Multiple processes, Multiple threads, Basic design using an RTOS.

Linux based embedded systems.

Reference Books

1. Raj kamal, ‘Embedded Systems Architecture, Programming and Design’, Tata McGraw-Hill, second edition 2010.
2. Shibu K V, ‘Introduction to Embedded Systems’, Tata McGraw Hill Education Private Limited, 2007.
3. Frank Vahid and Tony Givargis, ‘Embedded System Design: A Unified Hardware/Software Introduction’, John Wiley & Sons, Inc. 2002.

4. Tim Wilmshurst, 'Designing Embedded Systems with PIC Microcontrollers-Principles and Applications', Second Edition, Newnes, 2009.
5. C.M. Krishna, Kang, G.Shin, "Real Time Systems", McGraw Hill, 1997.
6. Embedded linux primer,
7. Embeeded system hardware, Oreily publishers

Course Contents and Lecture Schedule

Module No.	Topic	No. Of Lecture Hours
1	**Introduction to Embedded Systems**	
1.1	Embedded hardware units and devices, ,	1
1.2	Embedded software	1
1.3	System-on-chip (SoC)	1
1.4	Design process in Embedded system	1
1.5	Real world interfacing	1
1.6	Instruction level parallelism	1
1.7	Processor selection	1
1.8	Memory selection	1
1.9	Design process and design examples	2
2	**Devices and communication buses for devices network**	
2.1	I/O types and examples	1
2.2	Serial communication devices	1
2.3	Parallel device ports	1
2.4	Wireless devices	1
2.5	Timer and counting devices	1
2.6	Watchdog timer	1
2.7	Real time clock	1
2.8	Serial bus communication protocols	1
2.9	Parallel bus device protocols	1
3	**Interrupt serving mechanism**	
3.1	ISR concept	1
3.2	Interrupt sources	1
3.3	Interrupt servicing mechanism	1
3.4	Multiple interrupts	1
3.5	Context switching	1
3.6	Interrupt latency and Deadline	1
4	**Embedded programming in C**	
4.1	Embedded 'C' program for interfacing LED	1
4.2	Embedded 'C' program for interfacing LCD	2
4.3	Embedded 'C' program for interfacing Keypad	2
4.4	Embedded 'C' program for interfacing 7-segment LED	2
4.5	Embedded 'C' program for interfacing ADC	1
4.6	Embedded 'C' program for interfacing DAC	1
5	**Real time operating systems**	
5.1	Program odelling concepts	2
5.2	Polling for events model	1
5.3	Concurrent process model	1
5.4	DFG models	1
5.5	State machine programming model	1
5.6	UML modeling	1

5.7	Multiple processes	1
5.8	Multiple threads	1
5.9	Basic design using an RTOS	1
5.10	Linux based embedded systems	1
	Total	**45**

Course Designers:

1. Dr. P.S.Manoharan psmeee@tce.edu

14CIPP0/ 14PSPJ0	SCADA	Category	L	T	P	Credit
		PE	4	0	0	4

Preamble

Knowledge of basic control theory is essential for studying this course. This course is designed to impart the knowledge of industrial SCADA system implementation. Emphasis is also given to modems and trouble shooting.

Prerequisite

- Measurements and Instrumentation

Course Outcomes

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

CO1	Explain the basic building blocks of SCADA system	Understand
CO2	Illustrate the role of PLC as RTU in SCADA system	Understand
CO3	Describe the hardware and firmware requirements of SCADA Systems	Understand
CO4	Explain the communication protocols of SCADA system	Understand
CO5	Outline the troubleshooting mechanisms of SCADA System	Understand

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	30	30	30
Understand	70	70	70	70
Apply	0	0	0	0
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Outline the hierarchy of a typical SCADA system.
2. Explain about SCADA system hardware and firmware
3. List the Key features of SCADA software.

Course Outcome 2(CO2):

1. State the need for RTU in SCADA system.
2. Explain the role of multiplexers in Signal conditioning stage.
3. Explain about the possible power supply requirement for RTU.

Course Outcome 3(CO3):

1. List any three hardware used in SCADA system.
2. Explain the need for software in information exchange between RTU's.
3. State the role of application programs for RTU.

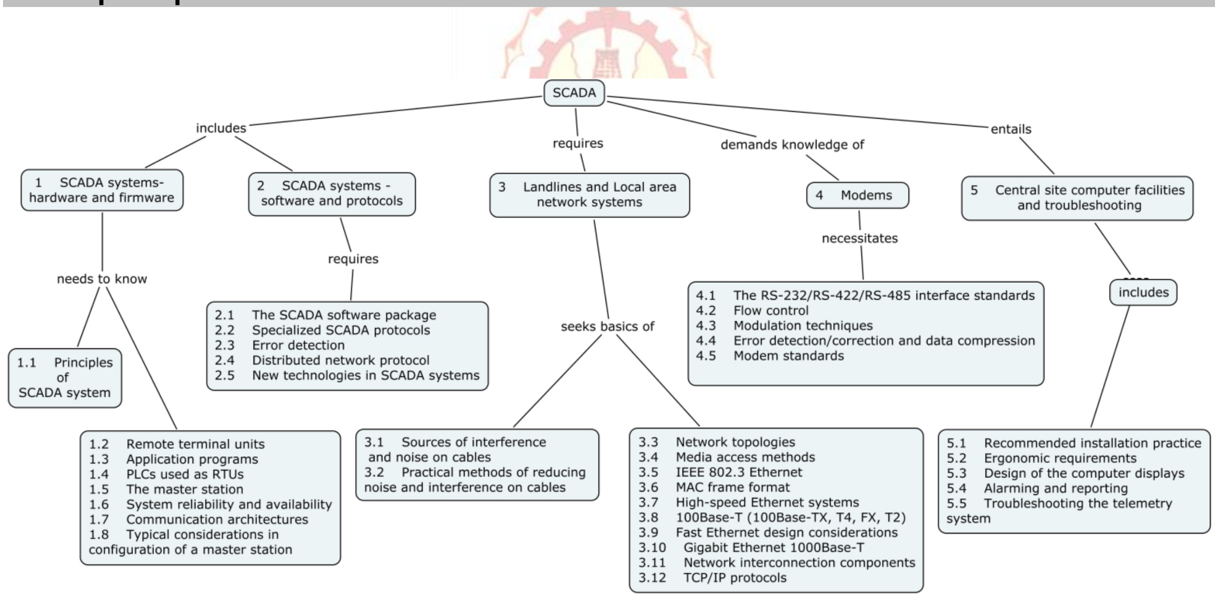
Course Outcome 4(CO4):

1. Describe the role of communication protocols in SCADA system.
2. List any three advantages of LAN in SCADA system
3. State the merits of point to point communication in SCADA system.

Course Outcome 5(CO5):

1. List the two methods of representing a data.
2. Describe the procedures for troubleshooting RTU.
3. List any three key ideas for effective maintenance of system program.

Concept Map



Syllabus

SCADA systems- hardware and firmware

Principles of SCADA system - Remote terminal units - Application programs- PLCs used as RTUs - The master station - System reliability and availability - Communication architectures - Typical considerations in configuration of a master station

SCADA systems - software and protocols

The SCADA software package - Specialized SCADA protocols - Error detection - Distributed network protocol - New technologies in SCADA systems

Landlines and Local area network systems

Sources of interference and noise on cables - Practical methods of reducing noise and interference on cables - Network topologies - Media access methods - IEEE 802.3 Ethernet - MAC frame format - High-speed Ethernet systems - 100Base-T (100Base-TX, T4, FX, T2) -

Fast Ethernet design considerations - Gigabit Ethernet 1000Base-T - Network interconnection components - TCP/IP protocols

Modems

The RS-232/RS-422/RS-485 interface standards - Flow control - Modulation techniques - Error detection/correction and data compression - Modem standards

Central site computer facilities and troubleshooting

Recommended installation practice - Ergonomic requirements - Design of the computer displays - Alarming and reporting - Troubleshooting the telemetry system

Reference Books

1. David Bailey, Edwin Wright, “Practical SCADA for Industry”, Newnes, An imprint of Elsevier 2006.
2. Gordon Clarke, Deon Reynders, Edwin Wright “Practical Modern SCADA Protocols:DNP3, 60870.5 and Related Systems”, Newnes, An imprint of Elsevier 2004.

Course contents and Lecture Schedule

Module No.	Topic	No. Of Lecture hours
1	**SCADA systems- hardware and firmware**	
1.1	Principles of SCADA system	1
1.2	Remote terminal units	1
1.3	Application programs	1
1.4	PLCs used as RTUs	2
1.5	The master station	1
1.6	System reliability and availability	1
1.7	Communication architectures	2
1.8	Typical considerations in configuration of a master station	1
2	**SCADA systems - software and protocols**	
2.1	The SCADA software package	1
2.2	Specialized SCADA protocols	2
2.3	Error detection	2
2.4	Distributed network protocol	1
2.5	New technologies in SCADA systems	1
3	**Landlines and Local area network systems**	
3.1	Sources of interference and noise on cables	1
3.2	Practical methods of reducing noise and interference on cables	1
3.3	Network topologies	2
3.4	Media access methods	1
3.5	IEEE 802.3 Ethernet	1
3.6	MAC frame format	1
3.7	High-speed Ethernet systems	1
3.8	100Base-T (100Base-TX, T4, FX, T2)	1
3.9	Fast Ethernet design considerations	1
3.10	Gigabit Ethernet 1000Base-T	1
3.11	Network interconnection components	1
3.12	TCP/IP protocols	1

4	**Modems**	
4.1	The RS-232/RS-422/RS-485 interface standards	1
4.2	Flow control	1
4.3	Modulation techniques	1
4.4	Error detection/correction and data compression	1
4.5	Modem standards	1
5	**Central site computer facilities and troubleshooting**	
5.1	Recommended installation practice	1
5.2	Ergonomic requirements	1
5.3	Design of the computer displays	1
5.4	Alarming and reporting	1
5.5	Troubleshooting the telemetry system	1
	Total	**40**

Course Designers

1. Mr.S.Sivakumar siva@tce.edu
2. Dr.D.Kavitha dkavitha@tce.edu
3. Mr.B.Ashok Kumar ashokudt@tce.edu

14CIPQ0/ 14PSPC0	REAL TIME OPERATING SYSTEM	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

This course provides a broad introduction to real time operating system (RTOS).It explores the functions of the RTOS to manage the sharing of internal memory among multiple tasks, to handle input and output to and from attached hardware devices, to send messages about the status of operation. It explains the design of embedded system by programming using µCOS-II.

Prerequisite

Microprocessors

Microcontrollers

Embedded system

Course Outcomes

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

CO1	Explain the different program models for embedded system programming	Understand
CO2	Explain interprocess communication and synchronization in embedded system	Understand
CO3	Explain OS services, file, I/O and memory management, interrupt handling and scheduling mechanism in RTOS	Understand
CO4	Explain the RTOS Programming concepts	Understand
CO5	Design an Embedded System by programming using RTOS µCOS-II	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the different program models used in programming?
2. List the basic elements of UML.
3. Illustrate the data flow graph model of programming with an example.

Course Outcome 2 (CO2)

1. What is a binary semaphore?
2. What are the different task states?
3. Illustrate the application of semaphore as resource key and for executing critical section codes with an example for each.

Course Outcome 3 (CO3)

1. Explain the following Kernel services in an OS
   i) Process management
   ii) Memory management
2. List any four basic functions provided by an RTOS.
3. Define context switching.

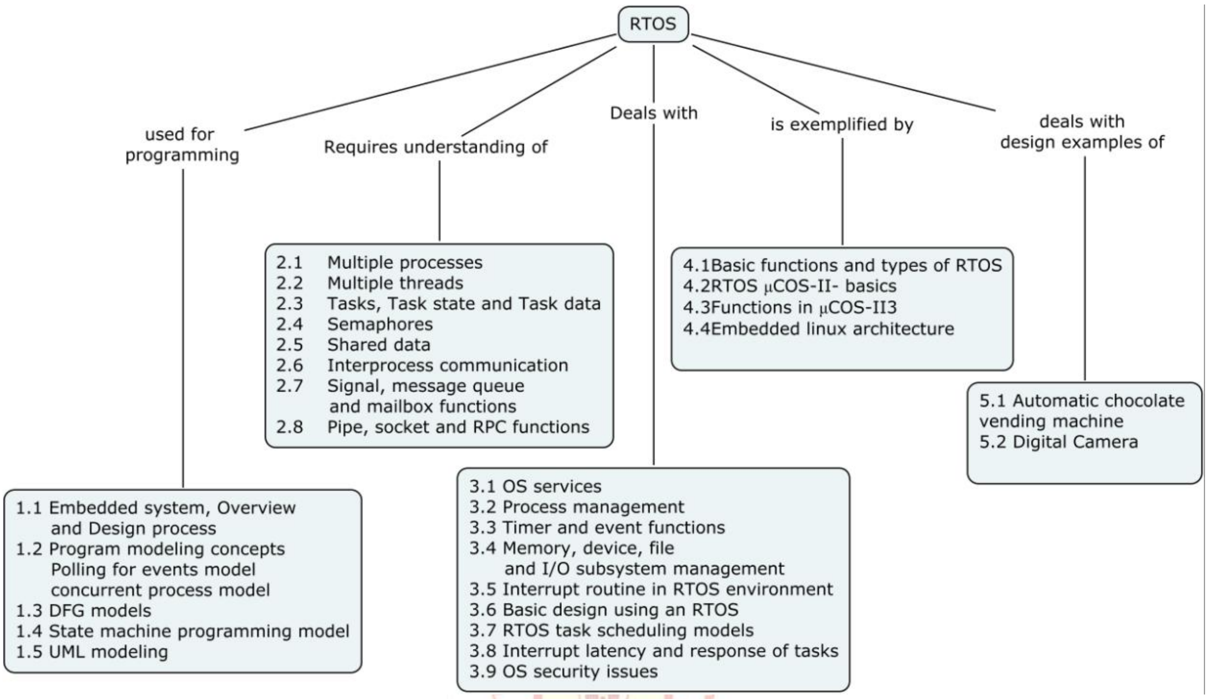
Course Outcome 4 (CO4)

1. Explain the application of any four task service functions in µCOS-II.
2. What are the types of RTOSes?
3. Write the use of OSTickInit ( ) and OSIntEnter ( ) functions in µCOS-II.

Course Outcome 5 (CO5)

1. Design the software architecture and synchronization diagram for the automatic chocolate vending machine and explain them.
2. Write the C program with comments in µCOS-II environment to initialize all the tasks and IPC functions along with the main ( ) and FirstTask ( ) functions for the automatic chocolate vending machine.
3. Design the software architecture and synchronization diagram for the digital camera and explain them.

Concept Map



Syllabus

Introduction and Programming of embedded systems
Embedded system, Overview and Design process, Program modeling concepts, Polling for events model, Concurrent process model, DFG models, State machine programming model, UML modeling
Interprocess communication and synchronization
Multiple processes, Multiple threads, Tasks, Task state and Task data, Semaphores, Shared data, Interprocess communication, Signal, message queue and mailbox functions, Pipe, socket and RPC functions.
Real time operating systems
OS services- process management, Timer and event functions, Memory, device, file and I/O subsystem management, Interrupt routine in RTOS environment, Basic design using an RTOS, RTOS task scheduling models, Interrupt latency and response of tasks, OS security issues.
RTOS programming
Basic functions and types of RTOSes, RTOS µCOS-II- basics, Functions in µCOS-II, Embedded linux system architecture

Design examples with µCOS-II
Automatic chocolate vending machine, Digital Camera.

Reference Books

1. Raj kamal, 'Embedded Systems Architecture, Programming and Design', Tata McGraw-Hill, second edition 2010.
2. David E.Simon, "An Embedded Software Primer", Pearson Education, 2006
3. C.M. Krishna, Kang, G.Shin, "Real Time Systems", McGraw Hill, 1997.
4. Phillip A. Laplante, Real Time Systems Design and Analysis, An Engineer's Handbook, Second Edition, PHI India, 1997.

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lecture Hours
1.	**Introduction and Programming of Embedded systems**	
1.1	Embedded system – Overview and Design process	1
1.2	Program modeling concepts- Polling for events model, concurrent process model	1
1.3	DFG models	2
1.4	State machine programming model	2
1.5	UML modeling	2
2.	**Interprocess communication and synchronization**	
2.1	Multiple processes	1
2.2	Multiple threads	1
2.3	Tasks, Task state and Task data	1
2.4	Semaphores	2
2.5	Shared data	2
2.6	Interprocess communication	2
2.7	Signal, message queue and mailbox functions	1
2.8	Pipe, socket and RPC functions	2
3	**Real time operating systems**	
3.1	OS services	1
3.2	Process management	1
3.3	Timer and event functions	2
3.4	Memory, device, file and I/O subsystem management	2
3.5	Interrupt routine in RTOS environment	2
3.6	Basic design using an RTOS	2
3.7	RTOS task scheduling models	2
3.8	Interrupt latency and response of tasks	2
3.9	OS security issues	1
4	**RTOS programming**	
4.1	Basic functions and types of RTOS	1
4.2	RTOS µCOS-II- basics	1
4.3	Functions in µCOS-II	3
4.4	Embedded linux architectures	1
5	**Design examples with µCOS-II**	
5.1	Automatic chocolate vending machine	2
5.2	Digital Camera	2
	Total	**45**

Course Designers:

1. Dr. P.S.Manoharan psmeee@tce.edu

14CIPR0	NON LINEAR CONTROL	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

Physical systems are inherently nonlinear. So non-linear control systems have gained importance in many industrial areas and research has undergone significant developments recently. Nonlinear control theory studies how to apply existing linear methods to these more general nonlinear control systems. Additionally, it provides novel control methods that cannot be analysed using LTI system theory. This course aims at giving an adequate exposure in perturbation theory, singular perturbations, gain scheduling and feedback linearization, sliding mode and back-stepping control.

Prerequisite

Ordinary differential Equations

Laplace Transforms

Linear Control System Analysis

CN12 Systems Theory

Course Outcomes

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

CO1	Use perturbation theory to solve nonlinear systems	Apply
CO2	Apply gain scheduling approach to control non-linear systems for different operating points	Apply
CO3	Use feedback linearization to transform a given nonlinear system to linear system	Apply
CO4	Apply sliding mode control to alter the dynamics of the nonlinear system	Apply
CO5	Use Lyapunov based control schemes to stabilize a class of nonlinear systems	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**S**	**M**	**L**								**L**
CO2	**S**	**M**	**L**								**L**
CO3	**S**	**M**	**L**								**L**
CO4	**S**	**M**	**L**								**L**
CO5	**S**	**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	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain standard singular perturbation model
2. Consider the singularly perturbed system given by the equations $\dot{x} = -\eta(x) + az$ and $\in \dot{z} = -\frac{x}{a} - z$. Where "a" is a positive constant and $\eta(x)$ is a smooth nonlinear function which satisfies the condition $\eta(0) = 0$ and $x\eta(x) > 0$ for $x \in (-\infty, b) - \{0\}$.Find the stability of origin for small $\in$ using singular perturbation method
3. Consider the singularly perturbed system

   $$\dot{x}_1 = x_2$$
   $$\dot{x}_2 = -x_2 + z$$
   $$\in \dot{z} = \tan^{-1}(1 - x_1 - z)$$

   a) Find the reduced and boundary layer models

   b) For x1(0)=x2(0)=z(0)=0 find O($\in$) approximation of the solution

Course Outcome 2(CO2)

1. Explain about regulation via integral control
2. Consider the tank level control problem with tank cross sectional area β varying with height h. Its model is given by the equation $\frac{d}{dt}\left(\int_0^h \beta(y)dy\right) = q - c\sqrt{2h}$. Where q is the inflow rate, h is the liquid height in tank and c is a positive constant. Design gain scheduling controller to track the reference h_{ref} with same dynamics (i.e. same $\varsigma \,\&\, \omega_n$) for all operating points
3. Consider the pendulum equation $\ddot{\theta} = -a\sin(\theta) - b\dot{\theta} + cT$ where a, b>0 are constants. T is the torque applied to the pendulum. θ is the angle subtended by vertical axis and rod. Derive suitable control law to stabilize the pendulum around $\theta = \theta_{ref}$

Course Outcome 3(CO3):

1. Explain internal dynamics and zero dynamics

2. Consider the second-order system $\dot{x}_1 = -x_1 - x_2 + \psi(x_2)$, $\dot{x}_2 = x_1 + \psi(x_2) + u$, $y = x_2$ where *Ψ* is a continuously differentiable function such that *Ψ(0)=0, Ψ'(0)=1,and 0< Ψ'(x_2)<1* for all *x_2≠0.*

(a) Is the system input-output linearizable?

(b) Is it minimum phase?

(c) Is it feedback linearizable?

3. Consider the first-order system $\dot{y} = u - k_1 - k_2 y - k_3 y^2$ where k_1, k_2, and k_3 are positive constants. Using linearization, design a feedback control law to (locally) stabilize the system at y = y_{ss} > 0.

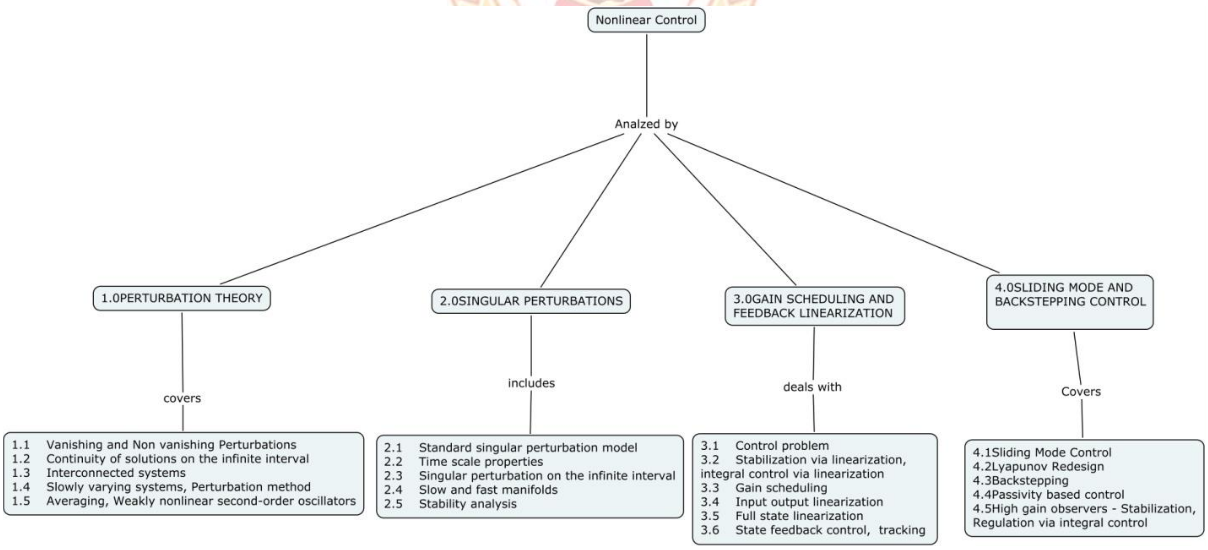
Course Outcome 4(CO4):

1. Explain the methods to reduce the effects of chattering in sliding mode control
2. Consider the second-order system $\dot{x}_1 = x_2$, $\dot{x}_2 = \psi(x_1, x_2) + u$ where Ψ is an unknown function that satisfies $|\psi(x_1, x_2)| < x_1^{\,2} + x_2^{\,2}$ for all x. Design a state feedback, continuous, sliding mode control to globally stabilize the origin.
3. Consider the system $\ddot{y} = -y_1^{\,3} + \sin(x_1)u$ .Design sliding mode controller with PID sliding surface to track the reference $y_{ref}(t) = 10 * \sin(0.1t)$

Course Outcome 5 (CO5):

1. Explain the basic mechanism of back stepping control.
2. Consider the system $\ddot{x} = -x - \dot{x}^2 + u$. Design back stepping controller to stabilize the system at origin.
3. Consider the second-order system $\dot{x}_1 = x_1 + \dfrac{x_2}{1 + x_1^2}$, $\dot{x}_2 = -x_2 + u$ Using backstepping, design a globally stabilizing state feedback control law.

Concept Map



Syllabus

PERTURBATION THEORY

Vanishing and Non vanishing Perturbations – Continuity of solutions on the infinite interval – Interconnected systems – Slowly varying systems – Perturbation method – Averaging - Weakly nonlinear second-order oscillators – Exercises.

SINGULAR PERTURBATIONS

Standard singular perturbation model – Time scale properties – Singular perturbation on the infinite interval – Slow and fast manifolds – stability analysis – exercises.

GAIN SCHEDULING AND FEEDBACK LINEARIZATION

Control problem – stabilization via linearization – integral control via linearization – gain scheduling – Input output linearization – Full state linearization – state feedback control – tracking- exercises.

SLIDING MODE AND BACKSTEPPING CONTROL

Sliding Mode Control - Lyapunov Redesign - Backstepping - Passivity based control – High gain observers – stabilization – Regulation via integral control – exercises.

Reference Books

1. Hasan Khalil," Nonlinear systems and control", 3rd edition, Prentice Hall of India Publisher, 2002.
2. Slotine, J A E Slotine and W Li, "Applied Nonlinear control", 1st edition Prentice Hall of India Publisher, 1991.
3. S.H. Zak," Systems and control", 1st edition, Oxford University Press 2003

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**PERTURBATION THEORY**	**10**
1.1	Vanishing and Non vanishing Perturbations	2
1.2	Continuity of solutions on the infinite interval	1
1.3	Interconnected systems	2
1.4	Slowly varying systems, Perturbation method	2
1.5	Averaging, Weakly nonlinear second-order oscillators,	2
1.6	Exercises	1
2.0	**SINGULAR PERTURBATIONS**	**10**
2.1	Standard singular perturbation model	2
2.2	Time scale properties	2
2.3	Singular perturbation on the infinite interval	1
2.4	Slow and fast manifolds	1
2.5	Stability analysis	2
2.6	Exercises	2
3.0	**GAIN SCHEDULING AND FEEDBACK LINEARIZATION**	**10**
3.1	Control problem	1
3.2	Stabilization via linearization, integral control via linearization	2
3.3	Gain scheduling	2
3.4	Input output linearization	2
3.5	Full state linearization	1
3.6	State feedback control, tracking	1
3.7	Exercises	1
4.0	**SLIDING MODE AND BACKSTEPPING CONTROL**	**10**
4.1	Sliding Mode Control	2
4.2	Lyapunov Redesign	1
4.3	Backstepping	2

4.4	Passivity based control	1
4.5	High gain observers - Stabilization, Regulation via integral control	2
4.6	Exercises	2
	Total	**40**

Course Designers:

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14CIPS0	DIGITAL IMAGE PROCESSING	Category	L	T	P	Credit
		PE	2	1	1	4

Preamble

During the last four decades image processing has grown from a dedicated scientific research field limited to a small set of researchers to technical area that has found use in many scientific and commercial applications. Image processing and computer vision focuses on improvement of pictorial information for human interpretation and Processing of image data for storage, transmission and representation for autonomous machine perception. This course helps the students for a comprehensive understanding of algorithms to perform specific image processing tasks.

Prerequisite

CN16 :Advanced Digital Signal processing

Course Outcomes

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

CO1	Implement the different types of Image enhancement and restoration process for given image.	K3
CO2	Implement the different types of image restoration process for given image.	K3
CO3	Implement the different types of Image compression and morphological process for given image.	K3
CO4	Implement the various segmentation techniques.	K3
CO5	Explain the basics concept of object recognition and Texture analysis methods.	K2

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Differentiate Image Enhancement and image Restoration.
2. Discuss about different types basic gray level transformation employed in image enhancement.
3. Compute Discrete Cosine Transform for given 3x3 image.

$$A = \begin{bmatrix} 1 & 1 & -2 \\ 1 & 0 & 2 \\ 1 & -1 & 3 \end{bmatrix}$$

Course Outcome 2 (CO2):

1. Discuss basic steps for filtering in the frequency domain.
2. Explain and compare Weiner filter and inverse filter.
3. Discuss about constrained least square restoration techniques

Course Outcome 3 (CO3):

1. With an example explain Huffman Coding technique in image compression.
2. For the symbols a, b, c, d, e, f the respective probabilities are p(a)=0.1, p(b)=0.4, p(c)=0.06, p(d)=0.1, p(e)=0.04, p(f)=0.3. Find the average length of the code and the Huffman code efficiency.
3. With example explain image dilation and Erosion.

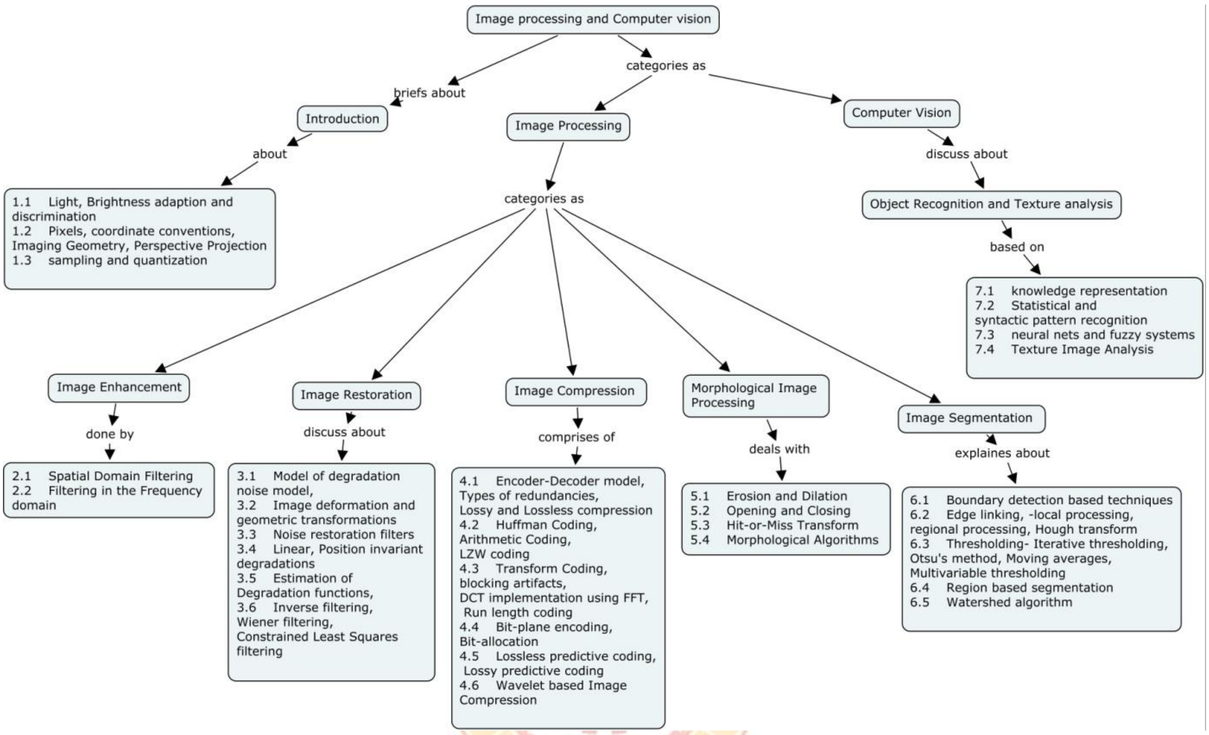
Course Outcome 4 (CO4)

1. Define image Segmentation and need of segmentation.
2. Explain Chain codes and polygon approximation in image segmentation.
3. Explain different types of thresholding techniques.

Course Outcome 5 (CO5)

1. Define image Texture.
2. Derive the standard feature obtain from Co-occurrence matrices.
3. With example role of neural net in Object recognition.

Concept Map



Syllabus

Introduction

Light, Brightness adaption and discrimination, Pixels, coordinate conventions, Imaging Geometry, Perspective Projection, sampling and quantization.

Image Enhancement

Spatial Domain Filtering- Intensity transformations, contrast stretching, histogram processing, Arithmetic/Logic Operations, Smoothing filters, sharpening filters, gradient and Laplacian. Filtering in the Frequency domain - Discrete Fourier Transforms and properties, FFT (Decimation in Frequency and Decimation in Time Techniques), Convolution, Correlation, Discrete Cosine Transform, KL Transform, Smoothing Frequency Domain Filters, Sharpening Frequency Domain Filters, Homomorphic Filtering.

Image Restoration

Model of degradation/restoration process, noise model, Image deformation and geometric transformations, Noise restoration filters-mean filters, Adaptive filters, Linear, Position invariant degradations, Estimation of Degradation functions, Inverse filtering, Wiener filtering, Constrained Least Squares filtering, Case study- Night Vision image Enhancement and filtering.

Image Compression

Encoder-Decoder model, Types of redundancies, Lossy and Lossless compression, Huffman Coding, Arithmetic Coding, LZW coding, Transform Coding, blocking artifacts, DCT implementation using FFT, Run length coding, Bit-plane encoding, Bit-allocation, Lossless predictive coding, Lossy predictive coding. Wavelet based Image Compression- Expansion of functions, Multi-resolution analysis, Scaling functions, Wavelet series expansion, Discrete Wavelet Transform (DWT), Fast Wavelet Transform, 2-D wavelet Transform, Digital Image Watermarking, Case study – Photograph image compression.

Morphological Image Processing
Erosion and Dilation, Opening and Closing, Hit-or-Miss Transform, Morphological Algorithms - Boundary Detection, Hole filling, Connected components, convex hull, thinning, thickening, skeletons, pruning.

Image Segmentation
Boundary detection based techniques- Point, line detection, Edge detection, Edge linking, -local processing, regional processing, Hough transform, Thresholding, Iterative thresholding, Otsu's method, Moving averages, Multivariable thresholding, Region based segmentation, Watershed algorithm, Case study- Medical image segmentation and classification.

Object Recognition and Texture analysis
Knowledge representation, Statistical and syntactic pattern recognition, neural nets and fuzzy systems, Texture Image Analysis-Co-occurrence matrices, Fractal texture description.

Reference Books

1. Rafael C Gonzalez and Richard E Woods, “Digital Image Processing”, Pearson Education, 3rd Edition,2009
2. Milan Sonka, Vaclav Hlavac and Roger Boyle, “Image Processing, Analysis and Machine Vision”, Vikas Publishing House, 2nd edition, 2010
3. Anil K Jain, “Fundamentals of Digital Image Processing” PHI Learning Private Limited, 2010.

Course Contents and Lecture Schedule

Module No.	Topics	No. of lecture hours
1	Introduction	
1.1	Light, Brightness adaption and discrimination	1
1.2	Pixels, coordinate conventions, Imaging Geometry, Perspective Projection	1
1.3	sampling and quantization	1
2	Image Enhancement	
2.1	Spatial Domain Filtering	
2.1.1	Intensity transformations, contrast stretching, Arithmetic/Logic Operations	1
2.1.2	Histogram processing	1
2.1.3	Smoothing filters, sharpening filters	1
2.1.4	gradient and Laplacian	1
2.2	Filtering in the Frequency domain	
2.2.1	Discrete Fourier Transforms and properties	1
2.2.2	FFT (Decimation in Frequency and Decimation in Time Techniques), Convolution, Correlation	1
2.2.3	Discrete Cosine Transform, KL Transform	1
2.2.4	Smoothing Frequency Domain Filters	1
2.2.5	Sharpening Frequency Domain Filters	1
2.2.5	Homomorphic Filtering.	1
3	Image Restoration	
3.1	Model of degradation/restoration process, noise model,	1
3.2	Image deformation and geometric transformations	1

3.3	Noise restoration filters- mean filters, Adaptive filters	1
3.4	Linear, Position invariant degradations	1
3.5	Estimation of Degradation functions,	1
3.6	Inverse filtering, Wiener filtering, Constrained Least Squares filtering	1
3.7	Case study- Night Vision image Enhancement and filtering	1
4	Image Compression	
4.1	Encoder-Decoder model, Types of redundancies, Lossy and Lossless compression	1
4.2	Huffman Coding, Arithmetic Coding, LZW coding	1
4.3	Transform Coding, blocking artifacts, DCT implementation using FFT, Run length coding	1
4.4	Bit-plane encoding, Bit-allocation	1
4.5	Lossless predictive coding, Lossy predictive coding	1
4.6	Wavelet based Image Compression	
4.6.1	Expansion of functions, Multi-resolution analysis	1
4.6.2	Scaling functions, Wavelet series expansion	1
4.6.3	Discrete Wavelet Transform (DWT), Fast Wavelet Transform, 2-D wavelet Transform	1
4.6.4	Digital Image Watermarking.	1
4.7	Case study – Photograph image compression	1
5	**Morphological Image Processing**	
5.1	Erosion and Dilation	1
5.2	Opening and Closing	1
5.3	Hit-or-Miss Transform	1
5.4	Morphological Algorithms – Boundary Detection, Hole filling, Connected components, convex hull, thinning, thickening, skeletons, pruning	1
6	**Image Segmentation**	
6.1	Boundary detection based techniques- Point, line detection, Edge detection	1
6.2	Edge linking, -local processing, regional processing, Hough transform	1
6.3	Thresholding- Iterative thresholding, Otsu's method, Moving averages, Multivariable thresholding	1
6.4	Region based segmentation	1
6.5	Watershed algorithm	1
7	**Object Recognition and Texture analysis**	
7.1	Knowledge representation	
7.2	Statistical and syntactic pattern recognition	1
7.3	neural nets and fuzzy systems	1
7.4	Texture Image Analysis	
7.4.1	Co-occurrence matrices	1
7.4.2	Fractal texture description	1
7.5	Case study – Medical Image segmentation and classification	1
	Total	**45**

Course Designers:

1. Dr.R.Helen rheee@tce.edu

14CIPT0	STATE ESTIMATION	Category	L	T	P	Credit
		PE	3	1	0	4

Preamble

State estimation includes computational algorithms that process measurements to deduce a minimum error estimate of the state of a system by utilizing knowledge of system and measurement dynamics, assumed statistics of system noises and measurement errors, and initial condition information. This course introduces various state estimation methods for linear and nonlinear systems.

Prerequisite

- Applied Mathematics for Electrical Engineers
- System Theory
- Digital Control System

Course Outcomes

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

CO1	Explain about various estimation concepts	Understand
CO2	Use Kalman filter to estimate the states of a given linear system	Apply
CO3	Use Extended Kalman filter to estimate the states of a given linear system	Apply
CO4	Build unscented Kalman filter for a given nonlinear system	Apply
CO5	Implement Particle Kalman filters for a given nonlinear system	Apply
CO6	Develop robust Kalman filters using H-infinity techniques for a given uncertain linear system	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	15	15	20
Understand	45	25	25	30
Apply	35	60*	60*	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

*Apply level of COs 4,5 and 6 may be evaluated through assignments

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State Bayes theorem
2. Explain the advantages of recursive estimation over batch estimation
3. With an example illustrate explain the working principle of least square estimator

Course Outcome 2(CO2):

1. Explain the properties of Kalman filter.
2. Consider the RLC circuit with R = 3, L = 1, and C = 0.5. The input voltage is zero-mean, unity variance white noise. Suppose that the capacitor voltage is measured at 10 Hz with zero-mean, unity variance white noise. Design a Kalman filter to estimate the inductor current, with an initial covariance $P_0^+ = 0$. Also calculate the steady state value of P
3. The measured output of a simple moving average process is $y_k = w_k + w_{k-1}$, where $\{w_k\}$ is zero mean white noise with variance 1
   c. Generate a state-space description for this system with the first element of state, x_k equal to w_{k-1} and second element equal to w_k.
   d. Suppose that the initial estimation-error covariance is equal to the identity matrix. Show that the a posteriori estimation-error covariance is given by $P_{k^+} = \frac{1}{k+1}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$.
   e. Find $E\left(\|x_k - \hat{x}_k\|_2^{\,2}\right)$ as a function of k.

Course Outcome 3 (CO3)

1. With suitable derivations illustrate the working principle of extended Kalman filter
2. Consider the system given below. $\{w_k\}$ & $\{v_k\}$ are zero mean process noise with variance Q and R respectively?

   $x_{k+1} = x_k + w_k$

   $y_k = x_k + v_k^{\,2}$

   c. What is the mean of the a posteriori estimation error of discrete EKF?
   d. Modify the measurement equation by subtracting the known bias of the measurement noise so that modified measurement noise is zero-mean. What is the variance of modified measurement noise?
3. Consider a nonlinear system $x_{k+1} = -x_k - x_k^{\,3} + w_k$ & $y_k = x_k^{\,2} + v_k$ where u is the input, w_k and v_k are zero mean white process and measurement noises with covariance 5 and 10 respectively. Design Extended Kalman filter to estimates the state x_k of the system.

Course Outcome 4 (CO4)

1. Explain the role of unscented transformation in approximation of nonlinear transformation
2. A random variable x is uniformly distributed over [-1,1] and $y = e^x$. Calculate the unscented approximation to $E(y)$ and variance of y
3. Compare simplex unscented transformation and spherical unscented transformation.

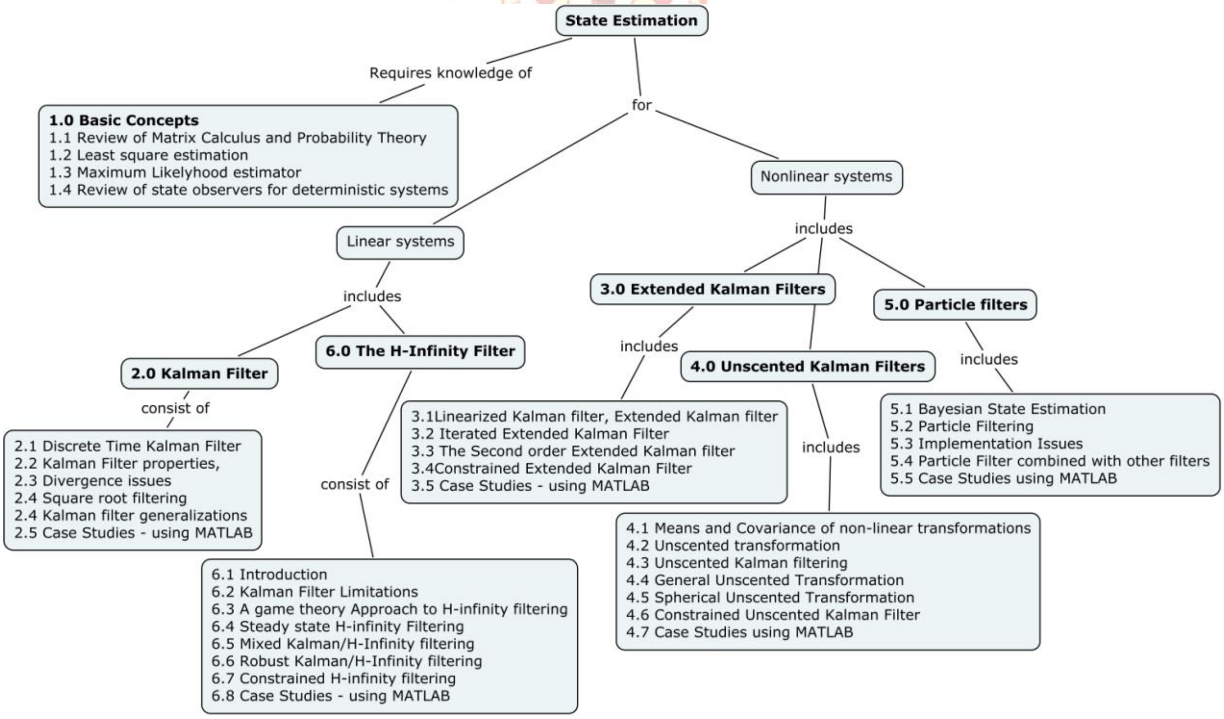
Course Outcome 5 (CO5)

1. Explain Bayesian estimation with suitable derivations
2. Explain the particle filter algorithm.
3. Consider the measurement $y_k = \frac{v_k}{x_k}$ where $v_k \sim N(9,1)$. Suppose five priori particles $x_{k,i}^-$ are given as 0.8, 0.9, 1.0, 1.1, 1.2 and the measurement obtained is $y_k = 10$. Calculate the relative likelihoods of each of the priori particles

Course Outcome 6 (CO6)

1. Explain the limitations of Kalman filter
2. Explain robust Kalman/H∞ filtering algorithm
3. Consider the system $x_k = \frac{1}{2}x_{k-1} + w_{k-1}$ and $y_k = x_k + v_k$. Calculate the steady state value of P_k for H∞ filter using variable θ and L=R=S=Q=1. Also calculate the bound on θ such that H∞ filter exists

Concept Map



Syllabus

Basic Concepts

Review of Matrix Calculus and Probability Theory, Review of state observers for deterministic systems, Least square estimation, Weighted Least square estimation, Maximum Likelihood estimation

Kalman Filter

Discrete time Kalman filter, Kalman Filter properties, Divergence issues, Square root filtering, Kalman filter generalizations – (correlated Process and measurement noise & colored process and measurement noise), Case Studies

Extended Kalman Filter

Linearized Kalman filter, Extended Kalman filter, Iterated Extended Kalman Filter, The Second order Extended Kalman filter, Constrained Extended Kalman Filter, Case Studies – using MATLAB

Unscented Kalman Filter

Means and Covariance of non-linear transformations, unscented transformation, Unscented Kalman filtering, General Unscented transformation, Simplex Unscented transformation, Spherical Unscented transformation, Constrained Unscented Kalman filter, Case Studies - using MATLAB

Particle Filter

Bayesian state Estimation, Particle filtering, Implementation issues: Sample Impoverishment, Particle filter combined with other filters, Case Studies – using MATLAB

The H-Infinity Filter

Introduction, Kalman filter Limitations, A game theory Approach to H-infinity filtering, Steady state H-infinity Filtering, Mixed Kalman/H-Infinity filtering, Robust Kalman/H-infinity filtering, Constrained H-infinity filtering, Case Studies – using MATLAB

Reference Books

1. Dan Simon, "Optimal State Estimation Kalman, H-infinity and Non-linear Approaches", John Wiley and Sons, 2006
2. Branko Ristic, Sanjeev Arulampalam, Neil Goodon, "Beyond the Kalman Filter: Particle filters for Tracking Application", Artech House Publishers, Boston, London, 2004
3. Gelb, Arthur, ed., "Applied optimal estimation", MIT press, Cambridge 2001

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Basic Concepts**	
1.1	Review of Matrix Calculus and Probability Theory	2
1.2	Least square estimation	1
1.3	Maximum Likelihood estimation	1
1.4	Review of state observers for deterministic systems	1
2.0	**Kalman Filter**	
2.1	Discrete time Kalman filter	2
2.2	Kalman Filter properties, Divergence issues,	3
2.3	Square root filtering	2

2.4	Kalman filter generalizations – (correlated Process and measurement noise & colored process and measurement noise)	2
2.5	Case Studies – using MATLAB	1
3.0	Extended Kalman Filter	
3.1	Linearized Kalman filter, Extended Kalman filter	1
3.2	Iterated Extended Kalman Filter	1
3.3	The Second order Extended Kalman filter	1
3.4	Constrained Extended Kalman Filter	1
3.5	Case Studies	1
4.0	**Unscented Kalman filter**	
4.1	Means and Covariance of non-linear transformations	1
4.2	Unscented transformation	1
4.3	Unscented Kalman filtering	1
4.4	General Unscented Transformation	1
4.5	Spherical Unscented Transformation	1
4.6	Constrained Unscented Kalman Filter	1
4.7	Case Studies – using MATLAB	1
5.0	**Particle Filter**	
5.1	Bayesian State Estimation	2
5.2	Particle Filtering	2
5.3	Implementation Issues	2
5.4	Particle Filter combined with other filters	2
5.5	Case Studies – using MATLAB	1
6.0	**The H-Infinity Filter**	
6.1	Introduction	1
6.2	Kalman Filter Limitations	1
6.3	A game theory Approach to H-infinity filtering	1
6.4	Steady state H-infinity Filtering	1
6.5	Mixed Kalman/H-Infinity filtering	1
6.6	Robust Kalman/H-Infinity filtering	1
6.7	Constrained H-infinity filtering	2
6.8	Case Studies – using MATLAB	1
	Total	**45**

Course Designers:

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