ANNA UNIVERSITY, CHENNAI

AFFILIATED INSTITUTIONS

M.E. ELECTRONICS AND COMMUNICATION ENGINEERING (INDUSTRY INTEGRATED)

REGULATIONS – 2017

CHOICE BASED CREDITSYSTEM

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

- To enable graduates to possess skills to develop new innovation in the field of Electronics and Communication Engineering (Industry Integrated) using analytical reasoning and state-of-the-art approaches derived from the Engineering Sciences and Engineering practice.
- To enable graduates to create useful systems, components, or processes through agile, skillful, and innovative analysis and design, while respecting economic, environmental, cultural, and ethical standards or constraints and acquire technical and managerial leadership positions in their chosen fields.
- To enable graduates to engage in lifelong learning, adapt to evolving Technology, work in multidisciplinary research for designing innovative products & solutions and become Entrepreneurs and understand current professional issues, apply latest technologies and come out with innovative solutions for the betterment of the nation and society.

PROGRAMME OUTCOMES (POs) for PG

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

1. To apply the core aspects of Electronics and Communication Engineering principles such as Signal Processing, Embedded Systems, Cyber Physical Systems, Networking and Semiconductor Technology for designing industry ready products.
2. To identify and utilize the strengths of current technologies in the Microelectronics, Signal Processing and Communication System domains in implementing ICT enabled services for industrial and societal needs.
3. To identify user needs to provide suitable design solutions for a given specification and function.

The program will have Core courses, Elective courses and Project works. The project may also have seminar practical/Industrial training summer project.

Contribution 1: Reasonable 2: Significant 3: Strong

MAPPING OF PROGRAMME EDUCATIONAL OBJECTIVES WITH PROGRAMME OUTCOMES

A broad relation between the Programme Objectives and the outcomes is given in the following table

Programme Educational Objectives	**Programme Outcomes**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	3	3	3	3	3	3	2	1	1	2	2	2
2	3	3	3	3	3	3	3	3	2	2	1	1
3	2	2	2	2	1	1	1	1	3	3	3	3

MAPPING OF PROGRAMME SPECIFIC OBJECTIVES WITH PROGRAMME OUTCOMES

A broad relation between the Programme Specific Objectives and the outcomes is given in the following table.

PROGRAMME SPECIFIC OUTCOMES	PROGRAMME OUTCOMES											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	3	3	3	3	3	2	1	1	2	2	2	2
2	3	3	3	3	3	3	3	1	2	1	2	2
3	3	3	3	3	3	2	3	3	2	1	2	3

M.E. ELECTRONICS AND COMMUNICATION ENGINEERING
(INDUSTRY INTEGRATED)
SEMESTER COURSE WISE PO MAPPING

Year/ Semester		SUBJECTS	Programme Outcomes (POs)												Programme Specific Outcomes (PSOs)		
			PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
I YEAR	SEMESTER I	Applied Mathematics for Electronics Engineers	3	3	2	1	1	1	1	1	1	1	1	1	1	1	1
		Advanced Digital Signal Processing	3	3	3	3	3	1	1	1	3	1	2	3	3	3	3
		Embedded Controllers	3	3	3	3	3	3	2	1	3	1	3	3	3	3	3
		Industrial Automation and Control	3	3	3	3	3	2	1	3	3	2	3	2	3	3	3
		Network Security Technologies	3	3	3	3	2	1	1	2	2	1	2	2	3	2	1
		Virtual Instrumentation	3	3	3	3	3	2	2	1	2	1	2	2	3	2	3
		Embedded Systems Programming Laboratory	3	3	3	3	3	2	1	3	3	2	3	3	3	3	3
	SEMESTER II	ASIC and FPGA Design	3	3	3	3	2	2	1	1	2	1	1	2	3	3	3
		Wireless Communication and Networking	3	3	3	3	3	1	1	1	2	1	2	2	3	3	3
		Cyber Physical Systems	3	3	3	3	3	2	2	1	3	2	3	2	3	3	3
		IoT and Cyber Physical Systems Laboratory	3	3	3	3	3	3	2	2	3	3	3	2	3	3	3
		Research methodology and Seminar	2	3	3	3	3	2	1	3	3	3	3	2	3	3	2
		Professional Elective I															
		Internet of Things	3	3	3	3	3	2	2	2	3	3	3	2	3	3	3
		Soft Computing Techniques	3	3	1	1	2	1	1	1	2	1	1	1	2	2	1
		Optical Networks	3	3	2	2	1	1	1	1	2	1	2	1	3	2	1
		Computer Vision	3	3	3	2	3	2	1	1	2	1	2	2	3	2	2

Professional Elective II															
Industry 4.0	3	3	3	3	3	3	2	3	3	2	3	2	3	3	3
Broadband Access Technologies	3	2	2	2	1	1	1	2	2	1	1	1	3	2	1
Automotive Electronics	2	3	3	3	2	3	2	3	3	2	3	2	3	2	2
Smart Antennas	3	3	2	2	2	1	1	1	2	2	2	2	3	2	1
Electromagnetic Interference and Compatibility	3	3	2	2	1	1	1	1	1	2	1	1	2	2	2
Professional Elective III															
System on Chip	3	3	3	2	1	1	2	1	2	2	1	2	3	2	1
Software Defined Networks	3	3	2	2	2	1	1	2	2	2	2	2	3	2	2
Machine Learning	3	3	3	3	3	2	2	2	3	1	3	2	3	3	3
Real Time Systems	3	3	2	2	2	1	2	2	3	2	2	2	3	2	2
Electronics for Solar Power	3	3	3	2	3	2	3	2	3	2	3	1	3	3	3

Year/ Semester		SUBJECTS	Programme Outcomes (POs)												Programme Specific Outcomes (PSOs)		
			PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
	SEMESTER III	Wireless Adhoc and Sensor Networks	3	3	3	3	2	2	3	2	3	3	3	2	3	3	3
		Summer internship (in Industry)	2	3	3	3	3	2	1	3	3	3	3	1	3	2	2
		Project Work Phase I (Industry supported)	3	3	3	3	3	3	2	2	3	3	3	2	3	3	3
		Professional Elective IV															
		Healthcare Technologies and IoMT	3	3	3	2	2	3	2	2	3	1	3	2	3	3	2
		Robotics and Automation	3	3	3	2	3	3	2	2	3	1	2	1	3	2	2
		Cognitive radio communications	2	3	3	2	2	2	2	3	3	2	2	2	3	2	2
		Micro and Nano Electromechanical Systems	3	3	2	2	1	2	2	1	1	2	1	2	3	2	1
		Quantum computing	3	3	2	2	1	1	1	1	2	3	2	2	3	1	1
		Professional Elective V															
		Deep Learning Techniques	3	3	3	3	3	2	1	2	3	3	2	2	3	3	2
		Cloud computing Technologies	3	3	3	2	2	2	1	1	2	3	2	2	3	2	2
		Renewable Energy Resources	3	3	3	3	2	2	3	2	3	2	3	1	3	3	2
		E - Vehicle Technologies	3	3	3	3	3	2	2	3	3	3	3	2	3	3	3
		Intelligent Transportation Systems	3	2	2	2	1	2	2	2	2	1	2	1	3	1	1
		Intellectual property and rights	2	3	3	3	1	2	2	3	3	2	3	1	3	2	1

Year/ Semester	SUBJECTS	Programme Outcomes (POs)												Programme Specific Outcomes (PSOs)		
		PO 1	PO 2	PO 3	PO 4	PO5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
SEMEST ER IV	Project Work Phase – II	3	3	3	3	3	2	2	2	3	3	3	3	3	3	3

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M.E. ELECTRONICS AND COMMUNICATION ENGINEERING (INDUSTRY INTEGRATED)
CURRICULA AND SYLLABI

SEMESTER I

Sl. No.	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	MA5152	Applied Mathematics for Electronics Engineers	FC	4	4	0	0	4
2.	AP5152	Advanced Digital Signal Processing	PC	5	3	2	0	4
3.		Embedded Controllers	PC	3	3	0	0	3
4.		Industrial Automation and Control	PC	3	3	0	0	3
5.		Network Security Technologies	PC	3	3	0	0	3
6.		Virtual Instrumentation	PC	3	3	0	0	3
PRACTICAL								
7.		Embedded Systems Programming Laboratory	PC	4	0	0	4	2
			Total	**25**	**19**	**2**	**4**	**22**

SEMESTER II

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	AP5252	ASIC and FPGA	PC	3	3	0	0	3
2.	EL5201	Wireless Communication and Networking	PC	3	3	0	0	3
3.		Cyber Physical Systems	PC	3	3	0	0	3
4.		Professional Elective I	PE	3	3	0	0	3
5.		Professional Elective II	PE	3	3	0	0	3
6.		Professional Elective II	PE	3	3	0	0	3
PRACTICAL								
7.		IoT and Cyber Physical Systems Laboratory	PC	4	0	0	4	2
8.		Research methodology and Seminar	EEC	2	0	0	2	1
			Total	**24**	**18**	**0**	**6**	**21**

SEMESTER III

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
THEORY								
1.	CU5097	Wireless Adhoc and Sensor Networks	PC	3	3	0	0	3
2.		Professional Elective IV	PE	3	3	0	0	3
3.		Professional Elective V	PE	3	3	0	0	3
PRACTICAL								
4.		Summer internship (in Industry)		(30 days min)				2
5.		Project Work Phase I (Industry supported)	EEC	12	0	0	12	6
			Total	**21**	**9**	**0**	**12**	**17**

Summer internship credits ½; Prerequisite for the programme : Offered if commitment for summer internship followed by projects; collaboration with industry for lectures

Eligibility : ECE, E&I

is assured by the institute to provide industry project (Statement to Affiliation)

SEMESTER IV

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
PRACTICALS								
1		Project Work Phase II (Industry supported)	EEC	24	0	0	24	12
			Total	**24**	**0**	**0**	**24**	**12**

Total No. of Credits: 72

PROFESSIONAL ELECTIVES (PE)

SEMESTER II
ELECTIVE I

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.	CP5292	Internet of Things	PE	3	3	0	0	3
2.	MP5092	Soft Computing Techniques	PE	3	3	0	0	3
3.	CU5192	Optical Networks	PE	3	3	0	0	3
4.	CP5095	Computer Vision	PE	3	3	0	0	3

ELECTIVE II

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1		Industry 4.0	PE	3	3	0	0	3
2	EL5071	Broadband Access Technologies	PE	3	3	0	0	3
3		Automotive Electronics	PE	3	3	0	0	3
4	EL5004	Smart Antennas	PE	3	3	0	0	3
5	CU5292	Electromagnetic Interference and Compatibility	PE	3	3	0	0	3

ELECTIVE III

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1		System on Chip	PE	3	3	0	0	3
2		Software Defined Networks	PE	3	3	0	0	3
3		Machine Learning	PE	3	3	0	0	3
4	MP5291	Real Time Systems	PE	3	3	0	0	3
5		Electronics for Solar Power	PE	3	3	0	0	3

SEMESTER III
ELECTIVE IV

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1		Healthcare Technologies and IoMT	PE	3	3	0	0	3
2		Robotics and Automation	PE	3	3	0	0	3
3		Cognitive radio communications	PE	3	3	0	0	3
4		Micro and Nano Electromechanical Systems	PE	3	3	0	0	3
5		Quantum computing	PE	3	3	0	0	3

ELECTIVE V

Sl. No	COURSE CODE	COURSE TITLE	CATEGORY	CONTACT PERIODS	L	T	P	C
1.		Deep Learning Techniques	PE	3	3	0	0	3
2.	CP5092	Cloud computingTechnologies	PE	3	3	0	0	3
3.		Renewable Energy Resources	PE	3	3	0	0	3
4.		E - Vehicle Technologies	PE	3	3	0	0	3
5.		Intelligent Transportation Systems	PE	3	3	0	0	3
6.		Intellectual property and rights	PE	3	3	0	0	3

MA5152 APPLIED MATHEMATICS FOR ELECTRONICS ENGINEERS L T P C
4 0 0 4

OBJECTIVES:

The main objective of this course is to demonstrate various analytical skills in applied mathematics and extensive experience with the tactics of problem solving and logical thinking applicable in electronics engineering. This course also will help the students to identify, formulate, abstract, and solve problems in electrical engineering using mathematical tools from a variety of mathematical areas, including fuzzy logic, matrix theory, probability, dynamic programming and queuing theory.

UNIT I FUZZY LOGIC 12

Classical logic – Multivalued logics – Fuzzy propositions – Fuzzy quantifiers.

UNIT II MATRIX THEORY 12

Cholesky decomposition - Generalized Eigenvectors - Canonical basis - QR factorization - Least squares method - Singular value decomposition.

UNIT III PROBABILITY AND RANDOM VARIABLES 12

Probability – Axioms of probability – Conditional probability – Baye's theorem - Random variables - Probability function – Moments – Moment generating functions and their properties – Binomial, Poisson, Geometric, Uniform, Exponential, Gamma and Normal distributions – Function of a Random variable.

UNIT IV DYNAMIC PROGRAMMING 12

Dynamic programming – Principle of optimality – Forward and backward recursion – Applications of dynamic programming – Problem of dimensionality.

UNIT V QUEUEING MODELS 12

Poisson Process – Markovian queues – Single and multi server models – Little's formula - Machine interference model – Steady state analysis – Self service queue.

TOTAL: 60 PERIODS

OUTCOMES:

After completing this course, students should demonstrate competency in the following skills:

- Concepts of fuzzy sets, knowledge representation using fuzzy rules, fuzzy logic, fuzzy prepositions and fuzzy quantifiers and applications of fuzzy logic.
- Apply various methods in matrix theory to solve system of linear equations.
- Computation of probability and moments, standard distributions of discrete and continuous random variables and functions of a random variable.
- Conceptualize the principle of optimality and sub-optimization, formulation and computational procedure of dynamic programming
- Exposing the basic characteristic features of a queuing system and acquire skills in analyzing queuing models.
- Using discrete time Markov chains to model computer systems.

REFERENCES:

1. Bronson, R., "Matrix Operations", Schaum's Outline Series, McGraw Hill, 2011.
2. George, J. Klir. and Yuan, B., "Fuzzy sets and Fuzzy logic, Theory and Applications", Prentice Hall of India Pvt. Ltd., 1997.
3. Gross, D., Shortle J. F., Thompson, J.M., and Harris, C. M., "Fundamentals of Queueing Theory", 4th Edition, John Wiley, 2014.
4. Johnson, R.A., Miller, I and Freund J., "Miller and Freund's Probability and Statistics for Engineers", Pearson Education, Asia, 8th Edition, 2015.

5. Taha, H.A., “Operations Research: An Introduction”, 9th Edition, Pearson Education, Asia, New Delhi, 2016.

AP5152 ADVANCED DIGITAL SIGNAL PROCESSING L T P C

3 2 0 4

OBJECTIVES:

- The student comprehends mathematical description and modelling of discrete time random signals.
- The student is conversant with important theorems and random signal processing algorithms.
- The student learns relevant figures of merit such as power, energy, bias and consistency.
- The student is familiar with estimation, prediction, filtering, multi rate concepts and techniques.

UNIT I DISCRETE RANDOM SIGNAL PROCESSING 9+6

Discrete random processes – Ensemble averages – Wide sense stationary process – Properties - Ergodic process – Sample mean & variance - Auto-correlation and Auto-correlation matrices- Properties – White noise process – Weiner Khitchine relation - Power spectral density – Filtering random process – Spectral Factorization Theorem – Special types of Random Processes – AR,MA, ARMA Processes – Yule-Walker equations.

UNIT II SPECTRUM ESTIMATION 9+6

Bias and Consistency of estimators - Non-Parametric methods – Periodogram – Modified Periodogram – Barlett’s method – Welch’s mehod – Blackman-Tukey method – Parametric methods – AR, MA and ARMA spectrum estimation - Performance analysis of estimators.

UNIT III SIGNAL MODELING AND OPTIMUM FILTERS 9+6

Introduction- Least square method – Pade approximation – Prony’s method – Levinson Recursion – Lattice filter - FIR Wiener filter – Filtering – Linear Prediction – Non Causal and Causal IIR Weiner Filter -– Mean square error – Discrete Kalman filter**.**

UNIT IV ADAPTIVE FILTERS 9+6

FIR Adaptive filters - Newton's steepest descent method – Widrow Hoff LMS Adaptive algorithm – Convergence – Normalized LMS – Applications – Noise cancellation - channel equalization – echo canceller – Adaptive Recursive Filters - RLS adaptive algorithm – Exponentially weighted RLS-sliding window RLS.

UNIT V MULTIRATE SIGNAL PROCESSING 9+6

Decimation - Interpolation – Sampling Rate conversion by a rational factor I/D – Multistage implementation of sampling rate conversion – Polyphase filter structures – Applications of multirate signal processing.

TOTAL: 45+30: 75 PERIODS

OUTCOMES:

- Formulate time domain and frequency domain description of Wide Sense Stationary process in terms of matrix algebra and relate to linear algebra concepts.
- State W-K theorem, spectral factorization theorem, spectrum estimation, bias and consistency of estimators.
- Wiener filtering, LMS algorithms, Levinson recursion algorithm, applications of adaptive filters
- Decimation, interpolation, Sampling rate conversion, Applications of multirate signal processing

REFERENCES:

1. John G. Proakis, Dimitris G. Manolakis, “Digital Signal Processing”, Prentice Hall of
2. India, New Delhi, 2005.
3. Monson H. Hayes, “Statistical Digital Signal Processing and Modeling”, John Wiley and
4. Sons Inc., New York, 2006.
5. P. P. Vaidyanathan, “Multirate Systems and Filter Banks”, Prentice Hall, 1992.
6. S. Kay,” Modern spectrum Estimation theory and application”, Prentice Hall, Englehood
7. Cliffs, NJ1988.
8. Simon Haykin, “Adaptive Filter Theory”, Prentice Hall, Englehood Cliffs, NJ1986.
9. Sophoncles J. Orfanidis, “Optimum Signal Processing “, McGraw-Hill, 2000.

EMBEDDED CONTROLLERS L T P C

3 0 0 3

OBJECTIVES:

- Understand the features of 8,16, 32 bit microcontrollers
- Use microcontroller for interfacing real time applications
- Develop assembly and embedded programs for various real time applications
- Understand RTOS

UNIT I 8051 MICROCONTROLLER AND INTERFACING APPLICATIONS 9

Introduction to Embedded Systems - Embedded Design Life Cycle - 8051 Micro controller Architecture, I/O Ports – Timer/Counters – Interrupts – Serial Communication – ADC- DAC - interfacing with seven segment display, LCD, stepper motors and Key pad.

UNIT II PIC MICROCONTROLLER AND INTERFACING APPLICATIONS 9

Introduction to PIC controllers - 12F series, 16F series, 18F series - Architecture - I/O Ports – Timer/Counters – Interrupts – PWM- Serial Communication – ADC- DAC -interfacing with seven segment display, LCD, stepper motors and Key pad.

UNIT III MSP430MICROCONTROLLER AND INTERFACING APPLICATIONS 8

MSP 430 controllers - Architecture - I/O Ports – Timer/Counters – Interrupts – PWM- Serial Communication and other features - interfacing with seven segment display, LCD, stepper motors and Key pad.

UNIT IV ARM CONTROLLERS AND INTERFACING APPLICATIONS 9

ARM LPC 2148, Cortex M4 Controllers: Architecture - I/O Ports – Timer/Counters – Interrupts – PWM- Serial Communication – interfacing with seven segment display, LCD, stepper motors and Key pad Memory Management - Program Memory - Data Memory - AHB and APB Bus Structure QEI, RTC, WDT, DMA, EEPROM and PLL. Serial - Peripherals: UART, I2C, SPI, CAN and USB. Hardware and Software Interrupts, Analog Peripherals: ADC, DAC and Analog Comparators-interfacing with seven segment display, LCD, stepper motors and Key pad.

UNIT V REAL-TIME OPERATING SYSTEMS 10

Basic concepts of RTOS and its types – Concurrency- Reentrancy –Inter task communication - scheduling, IPC, RPC, CPU Scheduling, scheduling criteria, scheduling algorithms Threads: Multi-threading models, threading issues, thread libraries, synchronization Mutex: creating, deleting, prioritizing mutex, mutex internals

Messages, Buffers, mailboxes, queues, semaphores, deadlock, priority in version Process stack management - run-time buffer size - swapping, overlays, block/page management, replacement algorithms - real-time garbage collection- Implementation of RTOS with some case studies

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- Use the features of 8,16, 32 bit microcontrollers for various Industrial Applications
- Develop Industry Application Programs using Embedded Programming
- Apply RTOS principles for real time applications
- Interface microcontrollers with real time applications

REFERENCES:

1. User Manuals of 8051, Arduino, AVR, PIC 16F877A, MSP 430, ARM LPC 2148, and Cortex M4 controllers
2. Jonathan W. Valvano, “Embedded Systems: Real-Time Interfacing to Arm(r) Cortex -M Microcontrollers: Volume 2”, Create Space Independent Publishing Platform, 2012.
3. Jonathan W. Valvano, “Embedded Systems: Real-Time Interfacing to Arm(r) Cortex -M Microcontrollers: Volume 1”, Create Space Independent Publishing Platform, 2011.
4. SteveFurber,” ARM System-on-Chip Architecture”, Prentice Hall of India, New Delhi, 2009. MSP 430 controller manual
5. Arnold S. Berger, “Embedded Systems Design: An Introduction to Processes, Tools, and Techniques” CMP Books, 2002.
6. J. J .Labrosse, “Micro C/OS-II: The Real –Time Kernel”, Newnes, 2002.
7. Jane W. S. Liu, “Real-time systems”, Prentice Hall, 2000.

INDUSTRIAL AUTOMATION AND CONTROL **LTP C**
3 0 0 3

OBJECTIVES: The students will be able to

- Understand PLC Instructions
- Develop Ladder Logic for working models
- Use SCADA programming
- Interface various sensors with Arduino for industrial Automation

UNIT I PROGRAMMABLE LOGIC CONTROLLERS 9

Programmable Logic Controllers (PLCs) – architecture-Types- features -Programming a PLC using ladder/connected Component workbench-Input & Output Modules- Bit Instructions- Timer & Counter Instructions- Comparison & Data Handling Instructions- Program Control Instructions- Sequencing Instructions- PLC Programming Exercises for Industrial Applications- DOL starter- Star Delta starter- Automatic water level controller- Conveyor-Lift-Bottle filling and process control applications-Analog I/Os -High speed counter-PTO PWM and RTC

.

UNIT II SCADA SYSTEM 9

Evolution of SCADA, Various SCADA architectures, advantages and disadvantages of each system, SCADA System Components: Schemes- Remote Terminal Unit (RTU), Intelligent Electronic Devices (IED), Communication Network, SCADA Server Data acquisition systems, SCADA applications in Automation, SCADA –Memory tag, Device tag, Alarm logging, Data logging, OPC server- HMI Systems –DCS- DCS integration with PLC and Computers - Features of DCS

UNIT III ARDUINO AND SENSORS FOR INDUSTRIAL AUTOMATION AND CONTROL 9

Arduino board and IDE – Digital and Analog I/Os – Interfacing with Sensors –IR-PIR-Ultrasonic sensor – colour sensor -barometric pressure-Pulse- smoke-Temperature - Sound-Flame – Touch-Accelerometer-Humidity and temperature - Seven segment display – LCD – Stepper Motor and DC Motor control, Graphical display, robot arm, Joystick, Wi fi interface, Blue tooth interface, Home automation, GPS tracker

UNIT IV DATA ACQUISITION SYSTEM 9

Data acquisition of digital and analog signals (input and output) – Stand alone, LabVIEW compatible, Mat lab compatible, Real time data acquisition and storing using different data acquisition cards. Retrieving the stored data for analysis – High level language programming for using data acquisition system

UNIT V PROCESS CONTROL AND PNEUMATICS 9

Process control- P, PI, PD.PID–Tuning methods- Statistical Process Control, Model Predictive Control, Fuzzy Logic Based Control, Neural-Network Based Control

Actuators in motor vehicles, power switches, electrical rotary and linear actuators - pneumatic system - Properties of air – Perfect Gas Laws –Components of pneumatic system- ISO symbols for their elements -Control and regulation Elements—Direction, flow and pressure control valves--Methods of actuation, types, Design of Pneumatic and Electro pneumatic circuit– Simulation of Pneumatic and Electro pneumatic circuits - Applications using Robotics

TOTAL: 45PERIODS

OUTCOMES: **The students will be able to**

- Program PLC for Industrial Applications
- Interface PLC with working models
- Control Applications using SCADA programming
- Develop industrial Automationusing Arduino with various sensors

TEXT BOOKS:

- Gary Dunning, Introduction to Programmable Logic Controllers,3rd India edition, Cengage Learning, 2007
- John Webb, Programmable Logic Controllers: Principles and Applications,5th edition Prentice Hall of India, 2012.
- Krishna Kant Computer Based Process Control, Prentice Hall of India, 2004.
- Michael P. Lukas, Distributed Control Systems: Their Evaluation and Design, Van Nostrand Reinhold Co., 1986

REFERENCES:

1. B. G. Liptak Instrument Engineers Handbook – Process Software and Digital Network, 3rd edition, CRC Press,2002.
2. Jose A. Romagnoli, AhmetPalazoglu, Introduction to Process control, CRC Taylor and Francis group, 2005.
3. Richard Cox, Programmable Controllers, Delmer Thomson learning, 2001.
4. RichardZurawski, Industrial Communication Technology Handbook 2nd edition, CRC Press, 2015.
5. W.Bolton, “Mechatronics, Electronic Control Systems in Mechanical and Electrical Engineering”, Pearson Education, 2003
6. “Automation, Production Systems and Computer Integrated Manufacturing”- M.P. Grover, Pearson Education.
7. “Computer Based Industrial Control” – Krishna Kant, EEE-PHI 2.

NETWORK SECURITY TECHNOLOGIES **L T P C**
3 0 0 3

OBJECTIVES:

- Understand concepts and importance of Network Security
- Comprehend application and network layer security
- Analyze about wireless and mobile security

UNIT I INTRODUCTION **9**

Introduction to Security in Networks – Characteristics of Networks – IntrusionKinds of security breaches – Plan of attack - Points of vulnerability – Methods of defense – Control measures – Effectiveness of controls

UNIT II APPLICATION LAYER SECURITY **9**

Application Layer Security: PGP and S/MIME – Email – PGP –S/MIME – SSL Architecture – Hand shake, Change Cipher Space, Alert And Record Protocols – SSL Message Formats – Transport Layer Security

UNIT III NETWORK LAYER SECURITY 9

Network Layer Security: Modes – Two Security Protocols – Security Association – Security Policy – Internet Key Exchange – System Security: Description – Buffer Overflow And Malicious Software – Malicious Programs – Intrusion Detection System – Firewall

UNIT IV WIRELESS NETWORK SECURITY 9

Wireless Network Security: Wireless Security – Mobile Device Security -Wireless LAN Overview - Wireless LAN Security - Wireless Application Protocol Overview - Wireless Transport Layer Security - WAP End-To-End Security

UNIT V SECURITY IN MOBILE AND IoT 9

Security In Mobile And IoT : Security - Threats To SDN – NFV Security Attack Surfaces – ETSI Perspective – Cloud Security – Security Issues – Risks – Data Protection – Security As A Service – Addressing Cloud Security -IOT Security – Vulnerability Patching – Requirements By ITU-T – Security Framework

OUTCOMES: **The students will be able to**

- Develop attack detection model
- Apply basic security features in wire and wireless applications
- Incorporate security aspects in IoT

TEXT BOOKS:

- Behrouz A Forouzan, Cryptography and Network Security , McGraw-Hill Education, 2011
- William Stallings, Network Security Essentials: Applications and Standards, Prentice Hall India, 4th Edition
- Foundations of Modern Networking: SDN, NFV, QoE, IoT, and Cloud" William Stallings Publisher: Addison-Wesley 2015
- William Stallings, Cryptography and Network Security: Principles and Standards, Prentice Hall India, 3rd Edition, 2003

REFERENCES:

1. Charles P. Pleeger, Security in Computing, Person Education Asia.
2. Charlie Kaufman,Radia Perlmanand MikeSpeciner, Network Security:Private Communication in a public world, Prentice Hall India, 2nd Edition, 2002
3. WilliamStallings,NetworkSecurityEssentials:Applicationsandstandards,PersonEducation Asia, 2000
4. JyrkiT.J.Penttinen,WirelessCommunicationsSecurity:SolutionsfortheInternetofThings, JohnWiley&Sons,2016

VIRTUAL INSTRUMENTATION **L T PC**
3 0 0 3

OBJECTIVES: The students will be able to

- understand the basics of Virtual Instrumentation
- differentiate analog and digital I/Os
- use LabVIEW for experiments
- analyze tools and applications in VI

UNIT I REVIEW OF DIGITAL INSTRUMENTATION 8

Representation of Analog signals in the Digital domain – Review of quantization in amplitude and time axis, sample and hold, sampling theorem, ADC and DAC types.

UNIT II FUNDAMENTALS OF VIRTUAL INSTRUMENTATION 10

Concept of virtual instrumentation – PC based data acquisition – Typical on board DAQ card, Resolution and sampling frequency - Multiplexing of analog inputs – Single-ended and differential inputs – Different strategies for sampling of multi-channel analog inputs. Concept of universal DAQ card - Use of timer-counter and analog outputs on the universal DAQ card.

UNIT III CLUSTER OF INSTRUMENTS IN VI SYSTEM 10

Interfacing of external instruments to a PC – RS232, RS 422, RS 485 and USB standards - IEEE 488 standard – ISO-OSI model for serial bus – Introduction to bus protocols of MOD bus and CAN bus, PXI Bus

UNIT IV GRAPHICAL PROGRAMMING ENVIRONMENT IN VI 10

Concepts of graphical programming language LabVIEW – Concept of VIs and sub VI – Graphs & charts – Dataflow programming - Loops – Case and sequence structures - Types of data – Arrays & clusters – Formula nodes –math scrip integration - Local and global variables – String and file I/O – Building executables and installers – Web publishing tools

UNIT V ANALYSIS TOOLS AND SIMPLE APPLICATIONS IN VI 7

Build virtual instruments like oscilloscope, FFT analyzer – Windowing and filtering tools – Introduction of Electrical power measurement suite - Simple temperature ON/OFF controller – P-I-D controller design - Simulation of a simple second order system – Building autonomous embedded system using FPGA target

TOTAL:45 PERIODS

OUTCOMES: **The students will be able to**

- use VI basics for Industrial Applications
- develop Virtual Instrumentation using LabVIEW
- use DAQ for Real Time Applications

REFERENCES:

1. Jovitha Jerome, Virtual Instrumentation using LabVIEW, PHI publications, 2010
2. S.Gupta and J.P Gupta, 'PC Interfacing for Data Acquisition and Process Control', Instrument society of America, 1994.
3. Peter W. Gofton, 'Understanding Serial Communications', Sybex International.

4. Robert H. Bishop, 'Learning with Lab-view', Prentice Hall, 2003.
5. Richard Jennings & Fabiola De La Cueva, LabVIEW Graphical Programming - Fifth Edition, McGraw-Hill
6. John Essick, Hands-On-Introduction to LabVIEW for Scientists and Engineers – Fourth Edition, OXFORD Publications
7. BehzadEhsani, Data Acquisition using LabVIEW, Packt Publishing, 2016

EMBEDDED SYSTEMS PROGRAMMING LABORATORY **L T P C**
0 0 4 2

OBJECTIVES: The students will be able to

- Understand concepts of Embedded Systems Programming

LIST OF EXPERIMENTS:

Programs using 8051 microcontroller (To list specific experiments)
Programs using PIC microcontroller
Programs using MSP430 microcontroller
Programs using LPC 2148 microcontroller

List of experiments to be carried out using above four controllers are:

1. Write a program to ON and OFF a LED
2. Interface switches with LEDs
3. Use timers to introduce delays
4. Use counters to count switching events
5. Increment bar graph using switches
6. Use external and internal interrupts
7. Apply Serial Communication peripherals to transmit and receive the data
8. Interface Seven Segment Display
9. Interface LCD
10. Interface Key pad
11. Interface Stepper and DC motors

Programs using Arduino/AVR microcontrollers

12. Interface various Analog and Digital Sensors using Arduino micro controller

Programs using RTOS

13. Write a program to ON and OFF a LED
14. Interface switches with LEDs
15. Use timers to introduce delays

TOTAL: 60 PERIODS

OUTCOMES: **The students will be able to**

- Develop Embedded Systems Progamming for Real Time Applications

AP5252 ASIC AND FPGA DESIGN L T P C
3 0 0 3

OBJECTIVES: The students will be able to

- study the design flow of different types of ASIC.
- familiarize the different types of programming technologies and logic devices.
- learn the architecture of different types of FPGA.
- gain knowledge about partitioning, floor planning, placement and routing including circuit extraction of ASIC

UNIT I OVERVIEW OF ASIC AND PLD 9

Types of ASICs - Design flow – CAD tools used in ASIC Design – Programming Technologies: Antifuse – static RAM – EPROM and EEPROM technology, Programmable Logic Devices: ROMs and EPROMs – PLA –PAL. Gate Arrays – CPLDs and FPGAs

UNIT II ASIC PHYSICAL DESIGN 9

System partition -partitioning - partitioning methods – interconnect delay models and measurement of delay - floor planning - placement – Routing: global routing - detailed routing - special routing - circuit extraction - DRC

UNIT III LOGIC SYNTHESIS, SIMULATION AND TESTING 9

Design systems - Logic Synthesis - Half gate ASIC -Schematic entry - Low level design language - PLA tools -EDIF- CFI design representation. Verilog and logic synthesis -VHDL and logic synthesis - types of simulation - boundary scan test - fault simulation - automatic test pattern generation.

UNIT IV FIELD PROGRAMMABLE GATE ARRAYS 9

FPGA Design: FPGA Physical Design Tools -Technology mapping - Placement & routing - Register transfer (RT)/Logic Synthesis - Controller/Data path synthesis - Logic minimization.

UNIT V SOC DESIGN 9

System-On-Chip Design - SoC Design Flow, Platform-based and IP based SoC Designs, Basic Concepts of Bus-Based Communication Architectures. High performance algorithms for ASICs/ SoCs as case studies: Canonical Signed Digit Arithmetic, Knowledge Crunching Machine, Distributed Arithmetic, High performance digital filters for sigma-delta ADC.

OUTCOMES: The students will be able to

- analyze the synthesis, Simulation and testing of systems.
- apply different high performance algorithms in ASICs.
- discuss the design issues of SOC.

TOTAL: 45 PERIODS

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REFERENCES:

1. David A.Hodges, Analysis and Design of Digital Integrated Circuits (3/e), MGH 2004
2. H.Gerez, Algorithms for VLSI Design Automation, John Wiley, 1999
3. Jan.M.Rabaey et al, Digital Integrated Circuit Design Perspective (2/e), PHI 2003
4. J. Old Field, R.Dorf, Field Programmable Gate Arrays, John Wiley& Sons, New York.
5. M.J.S. Smith : Application Specific Integrated Circuits, Pearson, 2003
6. P.K.Chan& S. Mourad, Digital Design using Field Programmable Gate Array, Prentice Hall.
7. Sudeep Pasricha and NikilDutt, On-Chip Communication Architectures System on Chip Interconnect, Elsevier, 2008
8. S.Trimberger, Edr., Field Programmable Gate Array Technology, Kluwer Academic Pub.

S.Brown,R.Francis, J.Rose, Z.Vransic, Field Programmable Gate Array, Kluwer Pub. 5. Richard FJinder , “Engineering Digital Design ,”Academic press

EL5201 **WIRELESS COMMUNICATION AND NETWORKING** **L T P C**
3 0 0 3

OBJECTIVES:

- To understand the characteristics of wireless channels and the fundamental limits on the capacity of wireless channels
- Understand various types of local area networks, WiMax and wide area networks.
- Understand various wireless networking standards such as 3G and 4G.
- To interwork between WLAN and WWAN.
- To have a good understanding of emerging wireless networks such as Adhoc, Sensor networks and cooperative wireless networks.

UNIT I THE WIRELESS CHANNEL **9**

Overview of wireless systems – Physical modeling for wireless channels – Time and Frequency coherence – Statistical channel models – Capacity of wireless Channel- Capacity of Flat Fading Channel –– Channel Distribution Information known – Channel Side Information at Receiver – Channel Side Information at Transmitter and Receiver – Capacity with Receiver diversity – Capacity comparisons – Capacity of Frequency Selective Fading channels.

UNIT II 3G EVOLUTIONS **9**

IMT-2000 - W-CDMA, CDMA 2000 – radio & network components, network structure, packet-data transport process flow, Channel Allocation, core network, interference-mitigation techniques, UMTS-services, air interface, network architecture of 3GPP, UTRAN – architecture, High Speed Packet Data-HSDPA,HSUPA.

UNIT III 4G AND BEYOND **9**

Introduction to LTE-A – Requirements and Challenges, network architectures – EPC, E-UTRAN architecture - mobility management, resource management, services, channel - logical and transport channel mapping, downlink/uplink data transfer, MAC control element, PDU packet formats, scheduling services, random access procedure.

UNIT IV 5G components **9**

Introduction to WLAN – IEEE 802.11and HIPERLAN, Bluetooth, WiMAX. Characteristics of MANETs, Table-driven and Source-initiated On Demand routing protocols, Hybrid protocols, Wireless Sensor networks- Classification, MAC and Routing protocols.

UNIT V INTERWORKING CONCEPTS AND COOPERATIVE WIRELESS NETWORKS **9**

Interworking objectives and requirements, Schemes to connect WLANs and 3GNetworks, Session Mobility, Interworking Architectures for WLAN and GPRS. Introduction to User cooperation and cognitive systems- Relay channels- A general three node relay channel- Wireless relay channel- User cooperation in wireless networks- Two user cooperative network

TOTAL : 45 PERIODS

OUTCOMES:

On successful completion of this course, student will be able to

- Understand the concepts of wireless LAN, WAN and various wireless standards.
- Work with different wireless networks.
- Familiarize with advanced wireless networks such as Adhoc, Sensor networks and cooperative wireless networks.

REFERENCES:

1. Andrea Goldsmith, “Wireless Communications”, Cambridge University Press, 2005.
2. Andrea Goldsmith, “Wireless Communications”, Cambridge University Press, 2005.
3. Cognitive Radio Communication and Networks- Alexander M. Wyglinski published by Academic Press December 2009.
4. Clint Smith,P.E, Dannel Collins, “3G Wireless Networks” 2nd edition, Tata McGraw-Hill, 2008.
5. Jochen H.Schiller, “Mobile Communications”, 2/e, Pearson, 2014.
6. Kaveh Pahlavan, “Principles of wireless networks”, Prentice-Hall of India, 2008.
7. Sassan Ahmadi, “LTE-Advanced – A practical systems approach to understanding the 3GPP LTE Releases 10 and 11 radio access technologies”, Elsevier, 2014.
8. Sumit Kasera and Nishit Narang, “3G Networks – Architecture, Protocols and Procedures”, Tata McGraw Hill, 2007.
9. Vijay K.Garg, “Wireless Network Evolution- 2G & 3G” Pearson, 2013.

CYBER PHYSICAL SYSTEMS

L T P C

3 0 0 3

OBJECTIVES: The students will be able to

- Understand Cyber Physical System
- Analyse Intelligent CPS
- Apply modern tools to develop CPS applications

UNIT I CYBER PHYSICAL SYSTEMS 9

Cyber-Physical Systems (CPS) in the real world - Basic principles of design and validation of CPS - models of physical process, finite state machines, computation, converters between physical and cyber variables, and digital networks - Industry 4.0 – Auto SAR - IIOT implications - Building Automation - Medical CPS

UNIT II CPS - PLATFORM COMPONENTS 9

CPS HW platforms - Processors, Sensors, Actuators - mCPS Network – Wireless Hart, CAN, Automotive Ethernet - CPS Sw stack - RTOS - Scheduling Real Time control tasks

UNIT III PRINCIPLES OF AUTOMATED CONTROL DESIGN 9

Dynamical Systems and Stability - Controller Design Techniques - Stability Analysis: CLFs,

MLFs, stability under slow switching - Performance under Packet drop and Noise - Tutorial: Matlab toolboxes - Simulink, State flow

Features to software components - Mapping software components to ECUs - CPS Performance Analysis - effect of scheduling, bus latency, sense and actuation faults on control performance, network congestion

UNIT IV INTELLIGENT CPS 9

Safe Reinforcement Learning - Robot motion control - Autonomous Vehicle control - Gaussian Process Learning - Smart Grid Demand Response - Building Automation

UNIT V SECURE DEPLOYMENT OF CPS& APPLICATIONS OF CPS 9

Secure Task mapping and Partitioning - State estimation for attack detection - Automotive Case study : Vehicle ABS hacking - Power Distribution Case study : Attacks on Smart Grids – Virtual Instrumentation – Applications of CPS.

TOTAL: 45 PERIODS

OUTCOMES: **The students will be able to**

- Develop CPS real time Applications
- Use Modern tools for CPS applications
- Solve Security issues in CPS

REFERENCES:

1. E. A. Lee and S. A. Seshia, “Introduction to Embedded Systems: A Cyber-Physical Systems Approach”, 2011.
2. R. Alur, “Principles of Cyber-Physical Systems,” MIT Press, 2015.
3. T. D. Lewis “Network Science: Theory and Applications”, Wiley, 2009.
4. P. Tabuada, “Verification and control of hybrid systems: a symbolic approach”, Springer-Verlag 2009.
5. C. Cassandras, S. Lafortune, “Introduction to Discrete Event Systems”, Springer 2007.
6. ConstanceHeitmeyer and Dino Mandrioli, “Formal methods for real-time computing”, Wiley publisher, 1996.

IoT and CYBER PHYSICAL SYSTEMS LABORATORY LT P C

0 0 4 2

OBJECTIVES: The students will be able to

- Understand concepts of IoT and Cyber Physical Systems

LIST OF EXPERIMENTS:

- Programming using LabVIEW – Virtual Instrumentation
- Programming using MATLAB for Industrial Applications
- Raspberry Pi – GPIO and Cloud
- Arduino – I/O and Sensor Interfacing
- Applications using FPGA
- Electromechanical modelling of QUBE Servo Inertia Disk system

- Analysis of Physical system with RIO hardware integration (Step response, time domain, stability)
- Mathematical modelling of Second-order system with PID Controller design
- Mathematical modelling of Pendulum system and design a balance control and swing-up control
- Design and Develop Cloud based master and slave systems using Internet
- Development of Machine Learning algorithms in the physical system and validate

OUTCOMES: **The students will be able to**

- Develop IoT and Cyber Physical S based Real Time Applications

TOTAL: 60 PERIODS

RESEARCH METHODOLOGY AND SEMINAR **LT P C**
0 0 2 1

OBJECTIVES: The students will be able to

- Understand foundations of research
- Design Research models
- Develop statistical model

UNIT I FOUNDATIONS OF RESEARCH

Meaning, Objectives, Motivation, Utility. Concept of theory, empiricism, deductive and inductive theory. Characteristics of scientific method – Understanding the language of research – Concept, Construct, Definition, Variable. Research Process

Problem Identification & Formulation – Research Question – Investigation Question – Measurement Issues – Hypothesis – Qualities of a good Hypothesis –Null Hypothesis & Alternative Hypothesis. Hypothesis Testing – Logic & Importance

UNIT II RESEARCH DESIGN

Concept and Importance in Research – Features of a good research design –
Exploratory Research Design – concept, types and uses, Descriptive Research Designs – concept, types and uses. Experimental Design: Concept of Independent & Dependent variables.

UNIT III QUALITATIVE AND QUANTITATIVE RESEARCH

Qualitative research – Quantitative research – Concept of measurement, causality, generalization, replication. Merging the two approaches.

UNIT IV MEASUREMENT

Concept of measurement– what is measured? Problems in measurement in research – Validity and Reliability. Levels of measurement – Nominal, Ordinal, Interval, Ratio.

Sampling

Concepts of Statistical Population, Sample, Sampling Frame, Sampling Error, Sample Size, Non Response. Characteristics of a good sample. Probability Sample – Simple Random Sample, Systematic Sample, Stratified Random Sample & Multi-stage sampling. Determining size of the

sample – Practical considerations in sampling and sample size.

UNIT V DATA ANALYSIS

Data Preparation – Univariate analysis (frequency tables, bar charts, pie charts,percentages), Bivariate analysis – Cross tabulations and Chi-square test including testing hypothesis of association.

Interpretation of Data and Paper Writing – Layout of a Research Paper, Journals in Computer Science, Impact factor of Journals, When and where to publish? Ethical issues related to publishing, Plagiarism and Self-Plagiarism.

Use of Encyclopedias, Research Guides, Handbook etc., Academic Databases for Computer Science Discipline.

Use of tools / techniques for Research: methods to search required information effectively, Reference Management Software like Zotero/Mendeley, Software for paper formatting like LaTeX/MS Office, Software for detection of Plagiarism

OUTCOMES: **The students will be able to**

- Do Literature survey
- Analyse the Research gaps
- Formulate research problem
- Do Qualitative and Quantitative Analysis
- Write research articles

TOTAL: 30 PERIODS

REFERENCES:

1. Business Research Methods – Donald Cooper & Pamela Schindler, TMGH, 9th edition
2. Business Research Methods – Alan Bryman & Emma Bell, Oxford University Press.
3. Research Methodology – C.R.Kothari
4. Select references from the Internet

CU5097	**WIRELESS ADHOC AND SENSOR NETWORKS**	**L T PC** **3 00 3**

OBJECTIVES: The students will be able to

- understand the basics of Ad-hoc & Sensor Networks.
- learn various fundamental and emerging protocols of all layers.
- study about the issues pertaining to major obstacles in establishment and efficient
- manage of Ad-hoc and sensor networks.
- understand the nature and applications of Ad-hoc and sensor networks.
- understand various security practices and protocols of Ad-hoc and Sensor Networks.

UNIT I MAC & TCP IN AD HOC NETWORKS **9**

Fundamentals of WLANs – IEEE 802.11 Architecture - Self configuration and Auto

configuration-Issues in Ad-Hoc Wireless Networks – MAC Protocols for Ad-Hoc Wireless Networks – Contention Based Protocols - TCP over Ad-Hoc networks-TCP protocol overview - TCP and MANETs – Solutions for TCP over Ad-Hoc Networks.

UNIT II ROUTING IN AD HOC NETWORKS 9

Routing in Ad-Hoc Networks- Introduction-Topology based versus Position based Approaches-Proactive, Reactive, Hybrid Routing Approach-Principles and issues – Location services - DREAM – Quorums based location service – Grid – Forwarding strategies – Greedy packet forwarding – Restricted directional flooding- Hierarchical Routing- Issues and Challenges in providing QoS.

UNIT III MAC, ROUTING & QOS IN WIRELESS SENSOR NETWORKS 9

Introduction – Architecture - Single node architecture – Sensor network design considerations – Energy Efficient Design principles for WSNs – Protocols for WSN – Physical Layer : Transceiver Design considerations – MAC Layer Protocols – IEEE 802.15.4 Zigbee – Link Layer and Error Control issues - Routing Protocols – Mobile Nodes and Mobile Robots - Data Centric & Contention Based Networking – Transport Protocols & QOS – Congestion Control issues – Application Layer support.

UNIT IV SENSOR MANAGEMENT 9

Sensor Management - Topology Control Protocols and Sensing Mode Selection Protocols - Time synchronization - Localization and positioning – Operating systems and Sensor Network programming – Sensor Network Simulators.

UNIT V SECURITY IN AD HOC AND SENSOR NETWORKS 9

Security in Ad-Hoc and Sensor networks – Key Distribution and Management – Software based Anti-tamper techniques – water marking techniques – Defense against routing attacks - Secure Adhoc routing protocols – Broadcast authentication WSN protocols – TESLA – Biba – Sensor Network Security Protocols – SPINS.

TOTAL : 45 PERIODS

OUTCOMES:

Upon Completion of the course, the students should be able to:

- Identify different issues in wireless ad hoc and sensor networks.
- To analyze protocols developed for ad hoc and sensor networks.
- To identify and address the security threats in ad hoc and sensor networks.
- Establish a Sensor network environment for different type of applications.

REFERENCES:

1. Adrian Perrig, J. D. Tygar, "Secure Broadcast Communication: In Wired and Wireless Networks", Springer, 2006.
2. Carlos De Morais Cordeiro, Dharma Prakash Agrawal “Ad Hoc and Sensor Networks: Theory and Applications (2nd Edition), World Scientific Publishing, 2011.
3. C.K.Toh, “Ad Hoc Mobile Wireless Networks”, Pearson Education, 2002.
4. C.Siva Ram Murthy and B.S.Manoj, “Ad Hoc Wireless Networks – Architectures and Protocols”, Pearson Education, 2004.
5. Erdal Çayırcı , Chunming Rong, “Security in Wireless Ad Hoc and Sensor Networks”, John Wiley and Sons, 2009.
6. Holger Karl, Andreas willig, Protocols and Architectures for Wireless Sensor

Networks, John Wiley & Sons, Inc .2005.
7. Subir Kumar Sarkar, T G Basavaraju, C Puttamadappa, “Ad Hoc Mobile Wireless Networks”, Auerbach Publications, 2008.
8. Waltenegus Dargie, Christian Poellabauer, “Fundamentals of Wireless Sensor Networks Theory and Practice”, John Wiley and Sons, 2010.

CP5292 INTERNET OF THINGS L T P C
3 0 0 3

OBJECTIVES:

- To understand the fundamentals of Internet of Things
- To learn about the basics of IOT protocols
- To build a small low cost embedded system using Raspberry Pi.
- To apply the concept of Internet of Things in the real world scenario.

UNIT I INTRODUCTION TO IoT 9

Internet of Things - Physical Design- Logical Design- IoT Enabling Technologies - IoT Levels & Deployment Templates - Domain Specific IoTs - IoT and M2M - IoT System Management with NETCONF-YANG- IoT Platforms Design Methodology

UNIT II IoT ARCHITECTURE 9

M2M high-level ETSI architecture - IETF architecture for IoT - OGC architecture - IoT reference model - Domain model - information model - functional model - communication model - IoT reference architecture

UNIT III IoT PROTOCOLS 9

Protocol Standardization for IoT – Efforts – M2M and WSN Protocols – SCADA and RFID Protocols – Unified Data Standards – Protocols – IEEE 802.15.4 – BACNet Protocol – Modbus– Zigbee Architecture – Network layer – 6LowPAN - CoAP – Security

UNIT IV BUILDING IoT WITH RASPBERRY PI & ARDUINO 9

Building IOT with RASPERRY PI- IoT Systems - Logical Design using Python – IoT Physical Devices & Endpoints - IoT Device -Building blocks -Raspberry Pi -Board - Linux on Raspberry Pi - Raspberry Pi Interfaces -Programming Raspberry Pi with Python - Other IoT Platforms - Arduino.

UNIT V CASE STUDIES AND REAL-WORLD APPLICATIONS 9

Real world design constraints - Applications - Asset management, Industrial automation, smart grid, Commercial building automation, Smart cities - participatory sensing - Data Analytics for IoT – Software & Management Tools for IoT Cloud Storage Models & Communication APIs - Cloud for IoT - Amazon Web Services for IoT.

TOTAL : 45 PERIODS

OUTCOMES:

Upon completion of this course, the students should be able to:

- Analyze various protocols for IoT
- Develop web services to access/control IoT devices.

- Design a portable IoT using Rasperry Pi
- Deploy an IoT application and connect to the cloud.
- Analyze applications of IoT in real time scenario

REFERENCES:

1. Arshdeep Bahga, Vijay Madisetti, “Internet of Things – A hands-on approach”, Universities Press, 2015
2. Dieter Uckelmann, Mark Harrison, Michahelles, Florian (Eds), “Architecting the Internet of Things”, Springer, 2011.
3. Honbo Zhou, “The Internet of Things in the Cloud: A Middleware Perspective”, CRC Press, 2012.
4. Jan Ho¨ ller, Vlasios Tsiatsis , Catherine Mulligan, Stamatis , Karnouskos, Stefan Avesand. David Boyle, "From Machine-to-Machine to the Internet of Things - Introduction to a New Age of Intelligence", Elsevier, 2014.
5. Olivier Hersent, David Boswarthick, Omar Elloumi , “The Internet of Things – Key applications and Protocols”, Wiley, 2012

MP5092	SOFT COMPUTING TECHNIQUES	L	T	P	C
		3	0	0	3

OBJECTIVES: The students will be able to

- know the basics of artificial neural networks
- provide adequate knowledge about feed forward /feedback neural networks
- apply the concept of fuzzy logic in various systems.
- have the idea about genetic algorithm
- provide adequate knowledge about the applications of Soft Computing.

UNIT I ARTIFICIAL NEURAL NETWORK 9

Introduction-Basic concepts of Neural Network-Model of an Artificial Neuron-Characteristics of Neural Network-Learning Methods-Backpropagation Network Architecture-Backpropagation Learning-Counter Propagation Network-Hopfield/Recurrent Network-Adaptive Resonance Theory.

UNIT II FUZZY LOGIC 9

Basic concepts of Fuzzy Logic-Fuzzy Sets and Crisp Sets-Fuzzy Set Theory and Operations-Properties of Fuzzy Sets-Fuzzy and Crisp relations, Fuzzy to Crisp Conversion-Membership Functions-Interference in Fuzzy Logic-Fuzzy if-then Rules, Fuzzy implications and Fuzzy Algorithms, Fuzzification & Defuzzification-Fuzzy Controller.

UNIT III NEURO-FUZZY MODELLING 9

ANFIS Architecture-Classification and Regression Trees-Data Clustering algorithms-Rulebase Structure Identification.

UNIT IV GENETIC ALGORITHMS 9

Basic concepts-Working Principle-Inheritance Operators-Cross Over-Inversion & Deletion-Mutation Operator-Generation Cycle.

UNIT V APPLICATIONS OF SOFTCOMPUTING 9

Genetic Algorithm Application- Bagley and Adaptive Game-Playing Program- Greg Viols Fuzzy Cruise Controller-Air Conditioner Controller-Application of Back Propagation Neural Network.

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- gain knowledge on concepts of soft computational techniques.
- apply soft computational techniques to solve various problems.
- solve research oriented problems.

REFERENCES:

1. George J. Klir and Bo Yuan, 'Fuzzy Sets and Fuzzy Logic Theory and Applications', Printice Hall of India, 2002.
2. J.S.R.Jang,C.T.Sun and E.Mizutani,"Neuro-Fuzzy and Soft Computing",PHI,2004,
3. Pearson Education 2004.
4.
5. Laurene Fausett,"Fundamentals of Neural Networks: Architectures, Algorithms and Applications", Pearson Education India, 2006.
6. S.Rajasekaran and G.A.V.Pai."Neural Networks, Fuzzy Logic and Genetic
7. Algorithms", PHI, 2010.
8. Timothy J Ross, "Fuzzy logic with Engineering Applications", John Wiley and Sons, 2009.
9. Zimmermann H.J."Fuzzy Set Theory and Its Application" Springer International
10. Edition,2011.

CU5192 OPTICAL NETWORKS L T P C
3 0 0 3

OBJECTIVES:

The students should be made to understand:

- Optical system components like optical amplifiers, wavelength converters.
- Up-to-date survey of development in Optical Network Architectures.
- Packet switching.
- Network design perspectives.
- Different Optical Network management techniques and functions.

UNIT I 9

Introduction to Optical Networks: Telecommunications Networks Architecture, Services, circuit switching and packet switching, Optical Networks: Multiplexing Techniques, Second generation Optical Networks, Optical Packet Switching, Transmission Basics: Wavelength, frequencies, and channel spacing, Wavelength standards, Optical power and loss, Network Evolution, Nonlinear Effects: Self-phase Modulation, Cross-phase Modulation, Four Wave mixing, Solitons. Components: Couplers, Isolators and Circulators, Multiplexers and Filters, Optical Amplifiers, Transmitters, Detectors, Switches, Wavelength Converters.

UNIT II 9

Transmission System Engineering: System Model, Power Penalty, Transmitter, Receiver, Optical Amplifiers, Crosstalk, Dispersion, Wavelength Stabilization, Overall Design Considerations. Optical Internets: Migration to IP optical networking, IP and Optical backbone,

IP Routing table, MPLS and optical cross connect table, Protocol stack Alternatives, Internetworking SS7 and Legacy Transport, Internet transport network protocol stack.

UNITIII **9**

SONET, SDH and Optical Transport Networks (OTNs): SONET and SDH: SONET multiplexing hierarchy, Frame structure, Functional Component, problem detection, concatenation. Architecture of Optical Transport Networks (OTNs): Digital wrapper, in-band and out-ofband control signaling, Importance of Multiplexing and multiplexing hierarchies, SONET multiplexing hierarchies, SDH multiplexing hierarchies, New Optical Transport, OTN layered Model, Generic Framing Procedure (GFP).

UNIT IV **9**

WDM, Network topologies, MPLS and Optical Networks: WDM: WDM operation, Dense Wavelength Division Multiplexing (DWDM), Erbium-doped Fiber (EDF), WDM amplifiers, Add-Drop Multiplexers, Wavelength Continuity Property, Higher dispersion for DWDM, Tunable DWDM Lasers.

UNITV **9**

Network topologies and protection schemes: Robust networks, Line and path protection switching, Types of topology, Point to point topology, bi-directional line-switched ring (BLSR), meshed topology, Passive optical networks, Metro optical networks 28 MPLS and Optical Networks: IS label switching, Forwarding equivalence class (FEC), Types of MPLS nodes, Label distribution and binding, label swapping and traffic forwarding, MPLS support of Virtual Private Networks (VPN), MPLS traffic engineering, Multi protocol Lambda switching (MPIS).

TOTAL : 45 PERIODS

OUTCOMES:

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

- Design and Analyze Network Components
- Assess and Evaluate optical networks

REFERENCES:

1. Rajiv Ramaswami and Kumar Sivarajan, Optical Networks – Practical Perspective, 3rd Edition,Morgan - Kaufmann Publishers.
2. Optical Networks, Third Generation Transport Systems, Uyless Black, Pearson

CP5095 **COMPUTER VISION** **LT PC**

3 0 0 3

OBJECTIVES:

The students should be made to:

- To review image processing techniques for computer vision.
- To understand shape and region analysis.
- To understand Hough Transform and its applications to detect lines, circles, ellipses.
- To understand three-dimensional image analysis techniques.
- To understand motion analysis.
- To study some applications of computer vision algorithms

UNIT I IMAGE PROCESSING FOUNDATIONS **9**

Review of image processing techniques – classical filtering operations – thresholding techniques – edge detection techniques – corner and interest point detection – mathematical morphology – texture.

UNIT II SHAPES AND REGIONS 9

Binary shape analysis – connectedness – object labeling and counting – size filtering – distance functions – skeletons and thinning – deformable shape analysis – boundary tracking procedures – active contours – shape models and shape recognition – centroidal profiles – handling occlusion – boundary length measures – boundary descriptors – chain codes – Fourier descriptors – region descriptors – moments.

UNIT III HOUGH TRANSFORM 9

Line detection – Hough Transform (HT) for line detection – foot-of-normal method – line localization – line fitting – RANSAC for straight line detection – HT based circular object detection– accurate center location – speed problem – ellipse detection – Case study: Human Iris location– hole detection – generalized Hough Transform (GHT) – spatial matched filtering – GHT for ellipse detection – object location – GHT for feature collation.

UNIT IV 3D VISION AND MOTION 9

Methods for 3D vision – projection schemes – shape from shading – photometric stereo – shape from texture – shape from focus – active range finding – surface representations – point-based representation – volumetric representations – 3D object recognition – 3D reconstruction – introduction to motion – triangulation – bundle adjustment – translational alignment – parametric motion – spline-based motion – optical flow – layered motion.

UNIT V APPLICATIONS 9

Application: Photo album – Face detection – Face recognition – Eigen faces – Active appearance and 3D shape models of faces Application: Surveillance – foreground-background separation – particle filters – Chamfer matching, tracking, and occlusion – combining views from multiple cameras – human gait analysis Application: In-vehicle vision system: locating roadway – road markings – identifying road signs – locating pedestrians.

TOTAL : 45 PERIODS

OUTCOMES:

Upon completion of this course, the students should be able to

- Implement fundamental image processing techniques required for computer vision.
- Perform shape analysis.
- Implement boundary tracking techniques.
- Apply chain codes and other region descriptors.
- Apply Hough Transform for line, circle, and ellipse detections.
- Apply 3D vision techniques.
- Implement motion related techniques.
- Develop applications using computer vision techniques.

INDUSTRY 4.0 **LT P C**
3 0 0 3

OBJECTIVES: The students will be able to

- understand Industry 4.0
- apply IoT and IIoT for Industry 4.0
- understand CPS for Industry 4.0

UNIT I **9**

Introduction to Industry 4.0 The Various Industrial Revolutions - Digitalisation and the Networked Economy - Drivers, Enablers, Compelling Forces and Challenges for Industry 4.0 - Comparison of Industry 4.0 Factory and Today's Factory - Trends of Industrial Big Data and Predictive Analytics for Smart Business Transformation

UNIT II **9**

Road to Industry 4.0 - Internet of Things (IoT) & Industrial Internet of Things (IIoT) & Internet of Services - Smart Manufacturing - Smart Devices and Products - Smart Logistics - Smart Cities -Predictive Analytics

UNIT III **9**

System, Technologies for enabling Industry 4.0–Cyber Physical Systems - Robotic Automation and Collaborative Robots - Support System for Industry 4.0 - Mobile Computing - Cyber Security

UNIT IV **9**

Role of data, information, knowledge and collaboration in future organizations - Resource-based view of a firm - Data as a new resource for organizations - Harnessing and sharing knowledge in organizations - Cloud Computing Basics -Cloud Computing and Industry 4.0

UNIT V **9**

Industry 4.0 IIoT case studies - Opportunities and Challenges - Future of Works and Skills for Workers in the Industry 4.0 Era - Strategies for competing in an Industry 4.0 world – Society 5.0

OUTCOMES: **The students will be able to**

- use Industry 4.0 for Industrial Applications
- use IoT and IIoT for Industry 4.0
- apply smart devices Industrial Applications

TEXT BOOKS

1. Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things
2. Arsheep Bahga, Internet of Things: A Hands-On Approach

EL5071 **BROADBAND ACCESS TECHNOLOGIES** **L T P C**
3 0 0 3

OBJECTIVES: The students will be able to

- give fundamental concepts related to broadband access technologies.
- understand the current and emerging wired and wireless access technologies.
- acquire knowledge about cable modems and fiber access technologies.
- have an exposure to different systems standards for next generation broadband access networks.

UNIT I REVIEW OF ACCESS TECHNOLOGIES 5

Phone-Line modem, cable-access, ISDN, Emerging Broad band Technologies, Cable DSL, Fiber and Wireless, Standards for access network.

UNIT II DIGITAL SUBSCRIBER LINES 10

Asymmetric Digital subscriber lines (ADSL) – Rate Adaptive subscriber line (RADSL)-ISDN Digital subscriber line (IDSL) - High bit rate DSL (HDSL)-Single line DSL (SDSL) - very high bit rate DSL (VDSL) - Standards for XDSL & Comparison.

UNIT III CABLE MODEM 10

Cable Modem, DOCSIS – Physical Cabling, Dual Modem Operation, Hub Restriction, Upstream Operation – Downstream operation – Access control – framing Security sub layer – Data link layer – LLC & Higher layers – ATM centric VS IP – centric cable modem.

UNIT IV FIBER ACCESS TECHNOLOGIES 10

Optical Fiber in access networks, Architecture and Technologies- Hybrid fiber – Coax (HFC) system, Switched Digital Video (SDV) – Passive optical networks (PON) – FTTX (FTTH, FTTB, FTTC, FTT cab) comparison, Broadband PON , Gigabit-Capable PON.

UNIT V BROAD BAND WIRELESS 10

Fixed Wireless, Direct Broadcast Satellite (DBS), Multi channel multi point distribution services (MMDS), Local multi point distribution services (LMDS), and Wideband integrated Digital Interactive Services (WIDIS), Mobile Wireless 3G – IMT 2000 - Introduction to LTE-A.

TOTAL : 45 PERIODS

OUTCOMES: The students will be able to

- to design systems meeting out the requirements of the recent standards.
- meet out the industry requirements for man power in next generation networks.
- contribute towards the enhancement of the existing wireless technologies.

REFERENCES:

1. Dennis J. Rauschmayer, “ADSL/VDSL Principles: A Practical and Precise Study of
2. Asymmetric Digital Subscriber Lines and Very High Speed Digital Subscriber Lines”, Macmillan Technology Series, 1998.
3. Gilbert Held, “Next Generation Modems: A Professional Guide to DSL and Cable Modems”, John Wiley & Sons, 2000.
4. Leonid G. Kazovsky, Ning Cheng, Wei-Tao Shaw, David Gutierrez, Shing-Wa Wong, “Broadband Optical Access Networks”, John Wiley and Sons, New Jersey, 2011.
5. Martin P. Clarke, “Wireless Access Network: Fixed Wireless Access and WLL Network Design and Operation”, John Wiley & Sons 2000.

6.
7. Niel Ransom and Albert A. Azzam, “Broadband Access Technologies: ADSL, VDSL Cable Modem, Fiber and LMDS", McGraw Hill, 1999.
8. Sassan Ahmadi, “LTE-Advanced – A practical systems approach to understanding the 3GPP LTE Releases 10 and 11 radio access technologies”, Elsevier, 2014.
9. Walter J Woralski, “ADSL and DSL Technologies”, McGraw Hill Computer Communication Series, Second Edition Oct 2001.
10. William Webb, “Introduction to Wireless Local Loop Broadband and Narrow Band System”, Mobile Communication Series, Artech House Publishers, Second Edition 2000.

AUTOMOTIVE ELECTRONICS

L T PC
3 0 0 3

OBJECTIVES

- In Automobiles the electrical systems are important. It has number of subsystems like starting system, Charging system etc. Also most of the control systems are being converted from mechanical to electronics. In this course the function and construction of various electrical components and electronic components and system are described.

UNIT I BATTERIES AND CHARGING SYSTEM 9

Principle and construction of lead acid battery, characteristics of battery, rating capacity and efficiency of batteries, various tests on batteries, maintenance and charging. Lighting system: insulated and earth return system, details of head light and side light, LED lighting system, head light dazzling and preventive methods–Horn, wiper system and trafficator.

Generation of direct current, shunt generator characteristics, armature reaction, third brush regulation, cutout. Voltage and current regulators, compensated voltage regulator, alternators principle and constructional aspects and bridge rectifiers, new developments

UNIT II STARTING SYSTEM 9

Condition at starting, behavior of starter during starting, series motor and its characteristics, principle and construction of starter motor, working of different starter drive units, care and maintenances of starter motor, starter switches.

UNIT III FUNDAMENTALS OF AUTOMOTIVE ELECTRONICS 9

Current trends in automotive electronic engine management system, electromagnetic interference suppression, electromagnetic compatibility, electronic dashboard instruments, onboard diagnostic system, security and warning system.

UNIT IV INFOTAINMENT & NAVIGATION SYSTEMS 9

Infotainment & Navigation Systems: Vehicle multimedia, Driver Assistance & Navigation - ADAS features - Case Studies

UNIT V SENSORS AND ACTUATORS 9

Types of sensors: sensor for speed, throttle position, exhaust oxygen level, manifold pressure, crankshaft position, coolant temperature, exhaust temperature, air mass flow for engine application. Solenoids, stepper motors, relay.

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- use Electronics for automotive industries
- use sensors for automation
- apply smart devices for infotainment

REFERENCES

1. Young A.P. & Griffiths. L. “Automotive Electrical Equipment”, ELBS & New Press-1999.
2. William B.Riddens “Understanding Automotive Electronics”, 5th edition - Butter worth Heinemann Woburn, 1998.
3. Bechhold “Understanding Automotive Electronics”, SAE, 1998.
4. Crouse, W.H “Automobile Electrical Equipment”, McGraw-Hill Book Co., Inc., New York, 3rd edition, 1986.
5. Judge A.W “Modern Electrical Equipment of Automobiles”, Chapman & Hall, London, 1992.
6. Kholi.P.L “Automotive Electrical Equipment”, Tata McGraw-Hill Co., Ltd., New Delhi, 1975.
7. Robert Bosch “Automotive Hand Book”, SAE (5th Edition), 2000.
8. Ganesan.V. “Internal Combustion Engines”, Tata McGraw-Hill Publishing Co., New Delhi, 2003.

EL5004 SMART ANTENNAS L T P C
3 0 0 3

OBJECTIVES:

- To understand smart antenna environments
- To learn channel models
- To learn algorithms for Multi target decision

UNIT I 9

Spatial processing for wireless systems. Adaptive antennas. Beam forming networks. Digital radio receiver techniques and software radios.

UNIT II 9

Coherent and non-coherent CDMA spatial processors. Dynamic re-sectoring. Range and capacity extension – multi-cell systems.

UNIT III 9

Spatio – temporal channel models. Environment and signal parameters. Geometrically based single bounce elliptical model.

UNIT IV 9

Optimal spatial filtering – adaptive algorithms for CDMA. Multi target decision – directed algorithm.

UNIT V **9**

DOA estimation – conventional and subspace methods. ML estimation techniques. Estimation of the number of sources using eigen decomposition. Direction finding and true ranging PL systems. Elliptic and hyperbolic PL systems. TDOA estimation techniques.

TOTAL :45 PERIODS

OUTCOMES:

- To compare algorithms for target decision
- To explain DOA estimation techniques

REFERENCES:

1. M.J. Bronzel, Smart Antennas, John Wiley, 2004. Recent literature in Smart Antennas.
2. R.Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, Kluwer, 2001.
3. T.S.Rappaport&J.C.Liberti, Smart Antennas for Wireless Communication, Prentice Hall (PTR) , 1999.

CU5292 ELECTROMAGNETIC INTERFERENCE AND COMPATIBILITY **L T P C**
3 0 0 3

OBJECTIVES:

At the end of the course the student able to learn the concepts of :

- The basics of EMI.
- EMI sources.
- EMI problems.
- Solution methods in PCB.
- Measurements techniques for emission.
- Measurement techniques for immunity.

UNIT I BASIC THEORY **9**

Introduction to EMI and EMC, Intra and inter system EMI, Elements of Interference, Sources and Victims of EMI, Conducted and Radiated EMI emission and susceptibility, Case Histories, Radiation hazards to humans, Various issues of EMC, EMC Testing categories EMC Engineering Application.

UNIT II COUPLING MECHANISM **9**

Electromagnetic field sources and Coupling paths, Coupling via the supply network, Common mode coupling, Differential mode coupling, Impedance coupling, Inductive and Capacitive coupling, Radioactive coupling, Ground loop coupling, Cable related emissions and coupling, Transient sources, Automotive transients.

UNIT III EMI MITIGATION TECHNIQUES **9**

Working principle of Shielding and Murphy‟s Law, LF Magnetic shielding, Apertures and shielding effectiveness, Choice of Materials for H, E, and free space fields, Gasketting and sealing, PCB Level shielding, Principle of Grounding, Isolated grounds, Grounding strategies for Large systems, Grounding for mixed signal systems, Filter types and operation, Surge protection devices, Transient Protection .

UNIT IV STANDARD AND REGULATION **9**

Need for Standards, Generic/General Standards for Residential and Industrial environment, Basic Standards, Product Standards, National and International EMI Standardizing

Organizations; IEC, ANSI, FCC, AS/NZS, CISPR, BSI, CENELEC, ACEC. Electro Magnetic Emission and susceptibility standards and specifications, MIL461E Standards.

UNIT V EMI TEST METHODS AND INSTRUMENTATION 9

Fundamental considerations, EMI Shielding effectiveness tests, Open field test, TEM cell for immunity test, Shielded chamber , Shielded anechoic chamber, EMI test receivers, Spectrum analyzer, EMI test wave simulators, EMI coupling networks, Line impedance stabilization networks, Feed through capacitors, Antennas, Current probes, MIL -STD test methods, Civilian STD test methods.

TOTAL : 45 PERIODS

OUTCOMES:

At the end of this course, the student should be able to:

- Identify Standards
- Compare EMI test methods
- Discuss EMI mitigation techniques

REFERENCES:

1. Bemhard Keiser, “Principles of Electromagnetic Compatibility”, 3rd Ed, Artech house, Norwood, 1986.
2. Clayton Paul, “Introduction to Electromagnetic Compatibility”, Wiley Interscience, 2006.
3. Daryl Gerke and William Kimmel, “EDN‟s Designer‟s Guide to Electromagnetic Compatibility”, Elsevier Science & Technology Books, 2002
4. Dr Kenneth L Kaiser, “The Electromagnetic Compatibility Handbook”, CRC Press 2005.
5. Electromagnetic Compatibility by Norman Violette ,Published by Springer, 2013
6. Electromagnetic Interference and Compatibility: Electrical noise and EMI specifications Volume 1 of A Handbook Series on Electromagnetic Interference and Compatibility, Donald R. J. White Publisher-Don white consultants Original from the University of Michigan Digitized 6 Dec 2007
7. Henry W. Ott, “Electromagnetic Compatibility Engineering”, John Wiley & Sons Inc, Newyork, 2009
8. V Prasad Kodali, “Engineering Electromagnetic Compatibility”, IEEE Press, Newyork, 2001.
9. W Scott Bennett, “Control and Measurement of Unintentional Electromagnetic Radiation”, John Wiley & Sons Inc., (Wiley Inter science Series) 1997.

SYSTEM ON CHIP

L T P C

3 0 0 3

OBJECTIVES:

- To introduce architecture and design concepts underlying system on chips.
- Students can gain knowledge of designing SoCs.
- To impart knowledge about the hardware-software design of a modest complexity chip allthe way from specifications, modeling, synthesis and physical design.

UNIT I SYSTEM ARCHITECTURE: OVERVIEW 9

Components of the system – Processor architectures – Memory and addressing – system levelinterconnection – SoC design requirements and specifications – design integration – design complexity – cycle time, die area and cost, ideal and practical scaling, area-time-power tradeoff in processor design, Configurability.

UNIT II PROCESSOR SELECTION FOR SOC 9

Overview – soft processors, processor core selection. Basic concepts – instruction set, branches, interrupts and exceptions. Basic elements in instruction handling – Minimizing pipeline delays – reducing the cost of branches – Robust processors – Vector processors, VLIW processors, Superscalar processors.

UNIT III MEMORY DESIGN 9

SoC external memory, SoC internal memory, Scratch pads and cache memory – cache organization and write policies – strategies for line replacement at miss time – split I- and Dcaches – multilevel caches – SoC memory systems – board based memory systems – simpleprocessor/memory interaction.

UNIT IV INTERCONNECT ARCHITECTURES AND SOC CUSTOMIZATION 9

Bus architectures – SoC standard buses – AMBA, CoreConnect – Processor customization approaches – Reconfigurable technologies – mapping designs onto reconfigurable devices - FPGA based design – Architecture of FPGA, FPGA interconnect technology, FPGA memory, Floor plan and routing.

UNIT V FPGA BASED EMBEDDED PROCESSOR 9

Hardware software task partitioning – FPGA fabric Immersed Processors – Soft Processors andHard Processors – Tool flow for Hardware/Software Co-design –Interfacing Processor with memory and peripherals – Types of On-chip interfaces – Wishbone interface, Avalon Switch Matrix, OPB Bus Interface, Creating a Customized Microcontroller - FPGA-based Signal Interfacing and Conditioning.

TOTAL:45 PERIODS

OUTCOMES:

Upon successful completion of the program the students shall

- Explain all important components of a System-on-Chip and an embedded system, i.e.
- digital hardware and embedded software;
- Outline the major design flows for digital hardware and embedded software;
- Discuss the major architectures and trade-offs concerning performance, cost and power
- consumption of single chip and embedded systems;

REFERENCES:

1. Wayne Wolf, “Modern VLSI Design – System – on – Chip Design”, Prentice Hall, 3rd Edition, 2008.
2. Wayne Wolf , “Modern VLSI Design – IP based Design”, Prentice Hall, 4th Edition, 2008

SOFTWARE DEFINED NETWORKS LT P C

3 0 0 3

OBJECTIVES:

- To learn about what software defined networks are
- To understand the separation of the data plane and the control plane
- To learn about the use of SDN in data centers
- To learn about different applications of SDN

UNIT I INTRODUCTION 9

History of Software Defined Networking (SDN) – Modern Data Center – Traditional Switch Architecture – Why SDN – Evolution of SDN – How SDN Works – Centralized and Distributed Control and Date Planes

UNIT II OPEN FLOW & SDN CONTROLLERS 9

Open Flow Specification – Drawbacks of Open SDN, SDN via APIs, SDN via Hypervisor Based Overlays – SDN via Opening up the Device – SDN Controllers – General Concepts

UNIT III DATA CENTERS 9

Multitenant and Virtualized Multitenant Data Center – SDN Solutions for the Data Center Network – VLANs – EVPN – VxLAN – NVGRE

UNIT IV SDN PROGRAMMING 9

Programming SDNs: Northbound Application Programming Interface, Current Languages andTools, Composition of SDNs – Network Functions Virtualization (NFV) and Software Defined Networks: Concepts, Implementation and Applications.

UNIT V SDN 9

Juniper SDN Framework – IETF SDN Framework – Open Daylight Controller – Floodlight Controller – Bandwidth Calendaring – Data Center Orchestration

TOTAL :45 PERIODS

OUTCOMES:

Upon completion of the course, the students will be able to:

- Critically analyze and appreciate the evolution of software defined networks
- Point out the various components of SDN and their uses
- Explain the use of SDN in the current networking scenario
- Design and develop various applications of SDN

TEXT BOOKS:

1. Thomas D. Nadeau, Ken Gray, ―SDN: Software Defined Networks‖, O'Reilly Media, 2013.
2. Paul Goransson and Chuck Black, ―Software Defined Networks: A Comprehensive Approach‖, First Edition, Morgan Kaufmann, 2014.

REFERENCES:

1. SiamakAzodolmolky, ―Software Defined Networking with Open Flow‖, PacketPublishing, 2013.
2. Vivek Tiwari, ―SDN and Open Flow for Beginners‖, Amazon Digital Services, Inc.,2013.
3. Fei Hu, Editor, ―Network Innovation through Open Flow and SDN: Principles andDesign‖, CRC Press, 2014.

MACHINE LEARNING **L T PC**
3 0 0 3

OBJECTIVES:

- To introduce students to the basic concepts and techniques of Machine Learning.
- To have a thorough understanding of the Supervised and Unsupervised learning techniques
- To study the various probability based learning techniques
- To understand graphical models of machine learning algorithms

UNIT I INTRODUCTION **9**

Learning – Types of Machine Learning – Supervised Learning – The Brain and the Neuron – Design a Learning System – Perspectives and Issues in Machine Learning – Concept Learning Task – Concept Learning as Search – Finding a Maximally Specific Hypothesis – Version Spaces and the Candidate Elimination Algorithm – Linear Discriminants – Perceptron – Linear Separability – Linear Regression.

UNIT II LINEAR MODELS **9**

Multi-layer Perceptron – Going Forwards – Going Backwards: Back Propagation Error – Multi-layer Perceptron in Practice – Examples of using the MLP – Overview – Deriving Back-Propagation – Radial Basis Functions and Splines – Concepts – RBF Network – Curse of Dimensionality – Interpolations and Basis Functions – Support Vector Machines

UNIT III TREE AND PROBABILISTIC MODELS **9**

Learning with Trees – Decision Trees – Constructing Decision Trees – Classification and Regression Trees – Ensemble Learning – Boosting – Bagging – Different ways to Combine Classifiers – Probability and Learning – Data into Probabilities – Basic Statistics – Gaussian Mixture Models – Nearest Neighbor Methods – Unsupervised Learning – K means Algorithms – Vector Quantization – Self Organizing Feature Map- Case studies and Industrial Applications

UNIT IV DIMENSIONALITY REDUCTION AND EVOLUTIONARY MODELS **9**

Dimensionality Reduction – Linear Discriminant Analysis – Principal Component Analysis – Factor Analysis – Independent Component Analysis – Locally Linear Embedding – Isomap – Least Squares Optimization – Evolutionary Learning – Genetic algorithms – Genetic Offspring: - Genetic Operators – Using Genetic Algorithms – Reinforcement Learning – Overview – Getting Lost Example – Markov Decision Process – Case studies and Industrial Applications

UNIT V GRAPHICAL MODELS **9**

Markov Chain Monte Carlo Methods – Sampling – Proposal Distribution – Markov Chain Monte Carlo – Graphical Models – Bayesian Networks – Markov Random Fields – Hidden Markov Models – Tracking Methods - Case studies and Industrial Applications

TOTAL: 45 PERIODS

OUTCOMES:

Upon completion of the course, the students will be able to:

- Distinguish between, supervised, unsupervised and semi-supervised learning
- Apply the apt machine learning strategy for any given problem
- Suggest supervised, unsupervised or semi-supervised learning algorithms for any given problem

- Design systems that uses the appropriate graph models of machine learning
- Modify existing machine learning algorithms to improve classification efficiency

TEXT BOOKS:

1. Stephen Marsland, ―Machine Learning – An Algorithmic Perspective‖, Second Edition, Chapman and Hall/CRC Machine Learning and Pattern Recognition Series, 2014.
2. Tom M Mitchell, ―Machine Learning‖, First Edition, McGraw Hill Education, 2013.

REFERENCES:

1. Peter Flach, ―Machine Learning: The Art and Science of Algorithms that Make Sense of Data‖, First Edition, Cambridge University Press, 2012.
2. Jason Bell, ―Machine learning – Hands on for Developers and Technical Professionals‖, First Edition, Wiley, 2014
3. EthemAlpaydin, ―Introduction to Machine Learning 3e (Adaptive Computation and Machine Learning Series)‖, Third Edition, MIT Press, 2014

MP5291	REAL TIME SYSTEMS	L T PC
		3 0 03

OBJECTIVES:

- To learn real time operating system concepts, the associated issues & Techniques.
- To understand design and synchronization problems in Real Time System.
- To explore the concepts of real time databases.
- To understand the evaluation techniques present in Real Time System.

UNIT I REAL TIME SYSTEM AND SCHEDULING 9

Introduction– Structure of a Real Time System –Task classes – Performance Measures for Real Time Systems – Estimating Program Run Times – Issues in Real Time Computing – Task Assignment and Scheduling – Classical uniprocessor scheduling algorithms –Fault Tolerant Scheduling.

UNIT II SOFTWARE REQUIREMENTS ENGINEERING 9

Requirements engineering process – types of requirements – requirements specification for real time systems – Formal methods in software specification – structured Analysis and Design – object oriented analysis and design and unified modelling language – organizing the requirements document – organizing and writing documents – requirements validation and revision.

UNIT III INTERTASK COMMUNICATION AND MEMORY MANAGEMENT 9

Buffering data – Time relative Buffering- Ring Buffers – Mailboxes – Queues – Critical regions – Semaphores – other Synchronization mechanisms – deadlock – priority inversion – process stack management – run time ring buffer – maximum stack size – multiple stack arrangement – memory management in task control block - swapping – overlays – Block page management – replacement algorithms – memory locking – working sets – real time garbage collection – contiguous file systems.

UNIT IV REAL TIME DATABASES 9

Real time Databases – Basic Definition, Real time Vs General Purpose Databases, Main Memory Databases, Transaction priorities, Transaction Aborts, Concurrency control issues, Disk Scheduling Algorithms, Two– phase Approach to improve Predictability – Maintaining Serialization Consistency – Databases for Hard Real Time Systems.

UNIT V EVALUATION TECHNIQUES AND CLOCK SYNCHRONIZATION 9

Reliability Evaluation Techniques – Obtaining parameter values, Reliability models for Hardware Redundancy–Software error models. Clock Synchronization–Clock, A Nonfault–Tolerant Synchronization Algorithm – Impact of faults – Fault Tolerant Synchronization in Hardware – Fault Tolerant Synchronization in software.

TOTAL : 45 PERIODS

OUTCOMES:

Upon completion of this course, the students should be able to:

- Apply principles of real time system design techniques to develop real time applications.
- Make use of database in real time applications.
- Make use of architectures and behaviour of real time operating systems.
- Apply evaluation techniques in application.

REFERENCES:

1. C.M. Krishna, Kang G. Shin, “Real-Time Systems”, McGraw-Hill International Editions, 1997
2. Philip.A.Laplante, “Real Time System Design and Analysis”, Prentice Hall of India, 3rd Edition, 2004
3. Rajib Mall, “Real-time systems: theory and practice”, Pearson Education, 2009
4. R.J.A Buhur, D.L Bailey, “An Introduction to Real-Time Systems”, Prentice Hall International, 1999
5. Stuart Bennett, “Real Time Computer Control-An Introduction”, Prentice Hall of India, 1998
6. Allen Burns, Andy Wellings, “Real Time Systems and Programming Languages”, Pearson Education, 2003.

ELECTRONICS FOR SOLAR POWER LT P C

3 0 0 3

OBJECTIVES

- Study the behavior of photovoltaic solar energy systems, focusing on the behavior of "stand-alone" systems.
- Do a first order, conceptual design of a stand-alone system for a location anywhere in India
- Introduce the hardware elements and their behavior.
- Select battery for a PV system and battery sizing
- Simulate standalone and grid tied PV system

UNIT I INTRODUCTION TO SOLAR POWER 9

Semiconductor – properties - energy levels - basic equations of semiconductor devices physics- Basic characteristics of sunlight - Solar angles - day length - angle of incidence on tiltedsurface – Sun path diagrams – Equivalent circuit of PV cell, PV cell characteristics (VI curve,PV curve) - Maximum power point, Vmp, IMP, Voc, ISC – types of PV cell - Block diagram of solarphoto voltaic system, PV array sizing.

UNIT II DC-DC CONVERTER 9

Principles of step-down and step-up converters – Analysis and design issues of buck, boost,buckboost and Cuk converters – time ratio and current limit control – Full bridge converter –Resonant and quasi – resonant converters.

UNIT III MAXIMUM POWER POINT TRACKING 9

Direct Energy transmission, Impedance Matching, Maximum Power Point Tracking (MPPT) - Function of MPPT, P&O method, INC Method, Fractional Open circuit voltage method,Fractional short circuit current method, parasitic capacitance and other MPPT techniques,Development of hardware, algorithms using processors for Standalone and Grid tied systems.

UNIT IV BATTERY 9

Types of Battery, Battery Capacity – Units of Battery Capacity-impact of charging anddischarging rate on battery capacity -Columbic efficiency -Voltage Efficiency, Charging – ChargeEfficiency, Charging methods, State of Charge, Charging Rates, Discharging - Depth ofdischarge -Discharge Methods, Circuits for Battery Management System (BMS), selection ofBattery and sizing.

UNIT V PV MODULE & CONVERTERS TBC 9

Characterization of PV module - VI Plot, PV Plot, finding VMP, IMP, Voc, Isc of PV module, Simulation of DC to DC converter -buck, boost, buck-boost and Cuk converters, standalone and grid tiedphoto voltaic system.

TOTAL:45 PERIODS

OUTCOMES:

- Ability to collect solar power characteristics at a given location
- Ability to design and realize dc-dc converters for solar power utilization
- Ability to design algorithms for improving solar power utilization
- Ability to deal with battery issues and selection
- Ability to design and simulate PV systems to validate its performance.

REFERENCES:

1. Chetan Singh Solanki, “Solar Photovoltaic: Fundamentals, Technologies andApplications”, PHI Ltd., 2013.
1. Tommarkvart, Luis castaner, “Solar cells; materials, manufacture and operation”,Elsevier, 2005.
2. G.D .Rai, “Solar energy utilization “, Khanna publishes, 1993.
3. Ned Mohan, Undeland and Robbin, “Power Electronics: converters, Application andDesign”, John Wiley and sons.Inc, Newyork, 1995.

HEALTH CARE TECHNOLOGIES AND IoMT LTPC

3 0 03

OBJECTIVES: The students will be able to

- know the principles and applications of biomedical devices
- comprehend the basics of healthcare technologies
- understand the applications of computer in medicine

- comprehend the telemedicine technology
- understand the applications of IoT for medical field and IoMT

UNIT I BIOMEDICAL TRANSDUCERS AND AMPLIFIERS 9

Introduction to Anatomy & Physiology of Human Body- Categories and Characteristics of Transducer - Signal conditioning units - Multichannel data acquisition system - various types recorders - necessity for low noise pre amplifiers - Difference amplifier - Chopper amplifier - Different types of electrode and its equivalent circuits.

UNIT II BIOPOTENTIAL RECORDING& MEASUREMENTS 9

ECG, EEG, EMG, PCG, EOG, ERG lead system and recording methods - typical waveform - frequency spectrum - abnormal waveform.

NON ELECTRICAL PARAMETER MEASUREMENTS : Respiration rate - Pulse rate – Temperature - Blood Pressure - O_2 , CO_2 measurements - Respiratory volume measurement - BMR measurement - Plethysmography technique - Impedance technique - Bipolar and Tetra polar circuits - Detection of various physiological parameters using impedance technique – Blood Flow meter – Biochemical measurements.

UNIT III COMPUTER APPLICATIONS IN MEDICINE 9

Computer Applications in Medicine – ICT - Networking - Data Security and Standards: Encryption, Cryptography - Mechanisms of encryption - phases of Encryption. Realtime Telemedicine integrating doctors / Hospitals, Clinical laboratory data - Radiological data and other clinically significant biomedical data - Administration of centralized medical data - Medical Informatics – Medical Information System - security and confidentially of medical records and access control - Cyber laws related to telemedicine.

UNIT IV TELEMEDICINE APPLICATIONS 9

Telemedicine - Tele radiology: Definition - Basic parts of teleradiology system: Image Acquisition system Display system - Tele pathology - multimedia databases - Medical information storage and management for telemedicine- patient information medical history - medical images diagnosis and treatment. Hospital information system - Telemedicine access to health care services – Introduction to robotics surgery - Telesurgery. Telecardiology – Teleoncology - Telemedicine in neurosciences – Mobile Telemedicine.

UNIT V CONNECTED HEALTH 9

E-Health – E-health services security and interoperability - Internet of Things (IoT) in Medical Field – Internet of Medical Things (IoMT) - Applications of IoMT – M- Helath - Connected Health –Innovations in Healthcare Technologies.

TOTAL: 45 PERIODS

OUTCOMES:

By the completion of this course the student will to

- Identify various functional blocks present inbiosignal acquisition system
- Designthe data acquisition system.
- Analyze different biopotential characteristics and recording methods of biosignals.
- Develop measurement systems by selecting different types of sensors, signal conditioning circuits for acquiring and recording various physiological parameters.
- Use the Applications of Computers in Medicine

- Differentiate the Protocols behind encryption techniques for secure transmission of data.
- Use the techniques, skills, and tools necessary for Telemedicine
- Apply new knowledge as needed in Connected Health including IoMT in healthcare

REFERENCES:

1. Leslie Cromwell, Fred J. Weibell and Erich A. *Pfeiffer's*, Biomedical Instrumentation and Measurements, Biomedical Instrumentation and Measurements, Prentice Hall, 2001
2. Joseph J Carr and John m Brown – Introduction to Biomedical equipment Technology Pearson Education 4th edition New Delhi 2001.
3. Webster J.G Medical Instrumentation application and design, John Wiley and sons New York 3rd edition 1999
4. Khandpur R.S, Hand Book of Biomedical Instrumentation – Tata Mc Graw Hill publication, New Delhi 2nd edition 2003
5. Bernard Fong, A.C.M. Fong, C.K. Li, Telemedicine Technologies: Information Technologies in Medicine and Telehealth, Wiley, 2011.
6. Magnuson, J.A., Fu, Jr., Paul C. (Eds.), Public Health Informatics and Information systems, ISBN 978-1-4471-4237-9, Springer, 2014
7. Norris, A.C. Essentials of Telemedicine and Telecare. Wiley, 2002.
8. Wootton, R., Craig, J., Patterson, V. (Eds.), Introduction to Telemedicine. Royal Society of Medicine Press Ltd (ISBN 1853156779), 2006.
9. Teresa L. Thompson, Roxanne Parrott, Jon F. Nussbaum, TheRoutledge Handbook of Health Communication, Routledge, 2011.
10. Ahmed**,**Mobyen Uddin, Begum**,**Shahina, Fasquel**,** Jean-Baptiste (Eds.), Internet of Things (IoT) Technologies for HealthCare, Proceedings of 4th International Conference, HealthyIoT 2017, Angers, France, October 24-25, 2017.
11. Nishu Gupta & Sara Paiva, "IoT and ICT for Healthcare Applications", Springer International Publishing, 2020

ROBOTICS AND AUTOMATION

L T C P
3 0 0 3

OBJECTIVES: The students will be able to

- understand the basics of robotics for industrial needs
- understand how to select robotics according to different applications
- analyse material handling techniques

UNIT I INTRODUCTION: **7**

Types of industrial robots - Load handling capacity - general considerations in Robotic material handling - material transfer - machine loading and unloading - CNC machine tool loading, Robot centered cell- robots for Industrial automation.

UNIT II ROBOTS FOR INSPECTION: **9**

Robotic vision systems - image representation - object recognition and categorization - depth measurement - image data compression - visual inspection - software considerations. Application of Robots in Spray painting, assembly operation, cleaning - robot for underwater applications.

UNIT III END EFFECTORS: **10**

Gripper force analysis and gripper design for typical applications - design of multiple degrees of freedom - active and passive grippers - Forward and inverse kinematics, DH matrices and Trajectory control.

UNIT IV SELECTION OF ROBOT:

Factors influencing the choice of a robot - robot performance testing - economics of robotisation - Impact of robot on industry and society.

UNIT V MATERIAL HANDLING: 9

Concepts of material handling - principles and considerations in material handling systems design - conventional material handling systems - industrial trucks, monorails, rail guided vehicles, conveyor systems, cranes and hoists - advanced material handling systems - automated guided vehicle systems - automated storage and retrieval systems(ASRS) - bar code technology - radio frequency identification technology.

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- assemble basic robot for industrial automation
- select robots for industrial applications
- use robots for material handling

REFERENCES:

1. Richard D Klafter, Thomas Achmielewski and MickaelNegin, —Robotic Engineering – An integrated Approach‖ Prentice HallIndia, New Delhi, 2001.
2. Mikell P Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", Pearson Education, 2015.
3. James A Rehg, —Introduction to Robotics in CIM Systems‖, Prentice Hall of India, 2002.
4. Deb S R, "Robotics Technology and Flexible Automation", Tata McGraw Hill, New Delhi, 1994.

COGNITIVE RADIO COMMUNICATIONS L T P C

OBJECTIVES: 3 0 0 3

- To enable the student to understand the evolving paradigm of cognitive radio communication and theenabling technologies for its implementation.
- To enable the student to understand the essential functionalities and requirements in designingsoftware defined radios and their usage for cognitive communication.
- To expose the student to the evolving next generation wireless networks and their associatedchallenges.

UNIT I INTRODUCTION TO SDR 9

Definitions and potential benefits - software radio architecture evolution – foundations, technology tradeoffs and architecture implications - Antenna for Cognitive Radio.

UNIT II SDR ARCHITECTURE 9

Essential functions of the software radio - architecture goals - quantifying degrees of

programmability - top level component topology - computational properties of functional components - interface topologies among plug and play modules, architecture partitions.

UNIT III INTRODUCTION TO COGNITIVE RADIOS 9

Marking radio self-aware, the cognition cycle - organization of congnition tasks - structuring knowledge for cognition tasks - Enabling location and environment awareness in cognitive radios – concepts, architecture, design considerations.

UNIT IV COGNITIVE RADIO ARCHITECTURE 9

Primary Cognitive Radio functions, Behaviors, Components, A–Priori Knowledge taxonomy, observe – phase data structures, Radio procedure knowledge encapsulation - components of orient, plan, decide phases, act phase knowledge representation, design rules.

UNIT V NEXT GENERATION WIRELESS NETWORKS 9

The XG Network architecture - spectrum sensing - spectrum management - spectrum mobility, spectrum sharing - upper layer issues - cross – layer design.

TOTAL: 45 PERIODS

OUTCOMES:

- The student would be able to appreciate the motivation and the necessity for cognitive radiocommunication strategies.
- The student would be able to evolve new techniques and demonstrate their feasibility usingmathematical validations and simulation tools.
- The student would be able to demonstrate the impact of the evolved solutions in future wireless network design.

REFERENCES:

1. Alexander M. Wyglinski, MaziarNekovee, And Y. Thomas Hou, “Cognitive Radio Communications And Networks - Principles And Practice”, Elsevier Inc. , 2010.
2. Kwang-Cheng Chen and Ramjee Prasad, ” Cognitive Radio Networks” , John Wiley & Sons, Ltd, 2009.
3. Khattab, Ahmed, Perkins, Dmitri, Bayoumi, Magdy, “Cognitive Radio Networks - From Theory to Practice”, Springer Series: Analog Circuits and Signal Processing, 2009.
4. J. Mitola, “ Cognitive Radio: An Integrated Agent Architecture for software defined radio”,Doctor of Technology thesis, Royal Inst. Technology, Sweden 2000.
5. Simon Haykin, “Cognitive Radio: Brain –empowered wireless communications”, IEEE Journal on selected areas in communications, Feb 2005.
6. Ian F. Akyildiz, Won – Yeol Lee, Mehmet C. Vuran, ShantidevMohanty, “ NeXt generation /dynamic spectrum access / cognitive radio wireless networks: A Survey Elsevier ComputerNetworks, May 2006.

MICRO AND NANO ELECTROMECHANICAL SYSTEMS L T P C
3 0 0 3

OBJECTIVES:

- To introducing the concepts of micro electro mechanical devices.
- To know the fabrication process of Microsystems.
- To know the design concepts of micro sensors and micro actuators.
- To introducing concepts of quantum mechanics and nano systems.

UNIT I OVERVIEW AND INTRODUCTION 9

New trends in Engineering and Science: Micro and Nanoscale systems Introduction to Design of MEMS and NEMS - Overview of Nano and Microelectromechanical Systems - Applications of Micro and Nanoelectromechanical systems - Microelectromechanical systems, devices and structures Definitions - Materials for MEMS: Silicon, silicon compounds, polymers, metals

UNIT II MEMS FABRICATION TECHNOLOGIES 9

Microsystem fabrication processes - Photolithography - Ion Implantation – Diffusion – Oxidation -Thin film depositions - LPCVD, Sputtering, Evaporation, Electroplating - Etching techniques - Dry and wet etching, electrochemical etching - Micromachining: Bulk Micromachining, Surface Micromachining, High Aspect-Ratio (LIGA and LIGA-like) Technology - Packaging: Microsystems packaging - Essential packaging technologies - Selection of packaging materials

UNIT III MICRO SENSORS 9

MEMS Sensors: Design of Acoustic wave sensors, resonant sensor - Vibratory gyroscope - Capacitive and Piezo Resistive Pressure sensors - engineering mechanics behind these Microsensors. Case study: Piezo-resistive pressure sensor

UNIT IV MICRO ACTUATORS 9

Design of Actuators: Actuation using thermal forces - Actuation using shape memory Alloys - Actuation using piezoelectric crystals - Actuation using Electrostatic forces (Parallel plate, Torsion bar, Comb drive actuators) - Micromechanical Motors and pumps. Case study: Comb drive actuators

UNIT V NANOSYSTEMS AND QUANTUM MECHANICS 9

Atomic Structures and Quantum Mechanics - Molecular and Nanostructure Dynamics: Shrodinger Equation and Wavefunction Theory - Density Functional Theory - Nanostructures and Molecular Dynamics - Electromagnetic Fields and their quantization - Molecular Wires and Molecular Circuits

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- use the principles of MEMS and NEMS
- use micro sensors and actuators for the required field
- analyse the quantum machines for industrial applications

REFERENCES:

1. Marc Madou, “Fundamentals of Micro fabrication”, CRC press 1997.
2. Stephen D. Senturia,” Micro system Design”, Kluwer Academic Publishers,2001

3. Tai Ran Hsu ,"MEMS and Microsystems Design and Manufacture" ,Tata McGraw Hill, 2002.
4. Chang Liu, "Foundations of MEMS", Pearson education India limited, 2006,
5. Sergey Edward Lyshevski, "MEMS and NEMS: Systems, Devices, and Structures" CRC Press, 2002

QUANTUM COMPUTING

L T P C
3 0 0 3

OBJECTIVES: The students will be able to

- understand the principles of quantum computing
- learn algorithms using quantum computing
- know the procedures for estimating computation complexity

UNIT I FOUNDATION 9

Overview of traditional computing – Church-Turing thesis – circuit model of computation – reversible computation – quantum physics – quantum physics and computation – Dirac notation and Hilbert Spaces – dual vectors – operators – the spectral theorem – functions ofoperators – tensor products – Schmidt decomposition theorem

UNIT II QUBIT SAND QUANTUM MODEL OF COMPUTATION 9

State of a quantum system – time evolution of a closed system – composite systems – measurement – mixed states and general quantum operations – quantum circuit model – quantum gates – universal sets of quantum gates – unitary transformations – quantum circuits

UNIT III QUANTUM ALGORITHMS – I 9

Superdense coding – quantum teleportation – applications of teleportation – probabilistic versus quantum algorithms – phase kick-back – the Deutsch algorithm – the Deutsch-Jozsa algorithm – Simon's algorithm – Quantum phase estimation and quantum Fourier Transform – eigenvalue estimation

UNIT IV QUANTUM ALGORITHMS – II 9

Order-finding problem – eigenvalue estimation approach to order finding – Shor's algorithm for order finding – finding discrete logarithms – hidden subgroups – Grover's quantum search algorithm – amplitude amplification – quantum amplitude estimation – quantum counting – searching without knowing the success probability 101

UNIT V QUANTUM COMPUTATIONAL COMPLEXITY AND ERROR CORRECTION 9

Computational complexity – black-box model – lower bounds for searching – general black-box lower bounds – polynomial method – block sensitivity – adversary methods – classical error correction – classical three-bit code – fault tolerance – quantum error correction – three- and nine-qubit quantum codes – fault-tolerant quantum computation

TOTAL: 45 PERIODS

OUTCOMES: **The students will be able to**

- use the principles of quantum computing
- develop quantum computing algorithms
- estimate Computational complexity

REFERENCES:

1. P. Kaye, R. Laflamme, and M. Mosca, “An introduction to Quantum Computing”, Oxford University Press, 1999.
2. V. Sahni, “Quantum Computing”, Tata McGraw-Hill Publishing Company, 2007

DEEP LEARNING TECHNIQUES

L T P C
3 0 0 3

OBJECTIVES: The students will be able to

- understand deep learning techniques
- study deep learning models
- understand the algorithms using deep learning technique

UNIT I MACHINE LEARNING FUNDAMENTALS 9

Machine Learning Fundamentals - linear classifiers, loss functions -Neural networks and deep feedforward neural networks - Regularization techniques for deep learning - Activation functions, initialization, regularization, batch normalization, model selection, ensembles- Optimization techniques for training deep neural networks- Fundamental principles and techniques to deep learning and reinforcement learning Successful application examples

UNIT II DEEP LEARNING FUNDAMENTALS 9

Convolutional neural networks - Fundamentals, architectures, pooling, visualization - Recurrent and recursive neural networks - Deep learning for spatial localization Transposed convolution, efficient pooling, object detection, semantic segmentation. Deep learning applications with a focus on the ones that have achieved superhuman performance (in face recognition, object recognition, speech recognition, natural language processing (machine translation)

UNIT III DEEP LEARNING MODELS 9

long-short term memory (LSTM), language models, machine translation, image captioning, video processing, visual question answering, learning from descriptions, attention. Deep generative models Auto-encoders, variational auto-encoders, generative adversarial networks, autoregressive models, generative image models, unsupervised and self-supervised representation learning.

UNIT IV LEARNING TECHNIQUES IN DEEP LEARNING 9

Reinforcement learning framework - Dynamic programming algorithms for reinforcement learning - Monte Carlo methods for reinforcement learning - Temporal-difference learning and n-step bootstrapping algorithms for reinforcement learning Deep reinforcement learning • Policy gradient methods, Q-Learning

UNIT V APPLICATIONS OF DEEP LEARNING 9

Function approximation algorithms for reinforcement learning -Case studies of reinforcement learning applications that have achieved superhuman performance - Active research topics in deep and reinforcement learning Q-learning for wire less sensor networks.

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- use deep learning basics for industrial applications
- develop deep learning algorithms
- develop deep learning model based applications

REFERENCES:

1. Deep Learning Fundamentals Author: Pan Chao Publisher: Create space Independent Publishing Platform Genre ISBN: 9781721230884, 9781721230884
2. Deep Learning from Scratch: Building with Python from First Principles 1st Edition, Kindle Edition, by Seth Weidman
3. Deep Learning (MIT Press Essential Knowledge series) Kindle Edition by John D. Kelleher
4. Deep Learning (Adaptive Computation and Machine Learning series) by Ian Goodfellow, YoshuaBengio, Aaron Courville, Francis Bach
5. Deep Learning for Natural Language Processing: Applications of Deep Neural Networks to Machine Learning Tasks by Pearson Learn IT
6. Advanced Deep Learning with Keras by Rowel Atienza

CP5092	CLOUD COMPUTING TECHNOLOGIES	LT P C 3 0 0 3

OBJECTIVES:

- To understand the concepts of virtualization and virtual machines
- To gain expertise in server, network and storage virtualization.
- To understand and deploy practical virtualization solutions and enterprise solutions
- To gain knowledge on the concept of virtualization that is fundamental to cloud computing
- To understand the various issues in cloud computing
- To be able to set up a private cloud
- To understand the security issues in the grid and the cloud environment

UNIT I VIRTUALIZATION 9

Basics of Virtual Machines - Process Virtual Machines – System Virtual Machines –Emulation –Interpretation – Binary Translation - Taxonomy of Virtual Machines. Virtualization – Management Virtualization –– Hardware Maximization – Architectures – Virtualization Management – Storage Virtualization – Network Virtualization

UNIT II VIRTUALIZATION INFRASTRUCTURE 9

Comprehensive Analysis – Resource Pool – Testing Environment –Server Virtualization – Virtu Workloads – Provision Virtual Machines – Desktop Virtualization – Application Virtualization - Implementation levels of virtualization – virtualization structure – virtualization of CPU, Memory and I/O devices – virtual clusters and Resource Management – Virtualization for data center automation.

UNIT III CLOUD PLATFORM ARCHITECTURE 9

Cloud deployment models: public, private, hybrid, community – Categories of cloud computing: Everything as a service: Infrastructure, platform, software- A Generic Cloud Architecture Design – Layered cloud Architectural Development – Virtualization Support and Disaster Recovery –Architectural Design Challenges - Public Cloud Platforms : GAE,AWS – Inter-cloud Resource Management

UNIT IV PROGRAMMING MODEL 9

Introduction to Hadoop Framework - Mapreduce, Input splitting, map and reduce functions, specifying input and output parameters, configuring and running a job –Developing Map Reduce Applications - Design of Hadoop file system –Setting up Hadoop Cluster - Cloud Software Environments -Eucalyptus, Open Nebula, Open Stack, Nimbus

UNIT V CLOUD SECURITY 9

Cloud Infrastructure security: network, host and application level – aspects of data security, provider data and its security, Identity and access management architecture, IAM practices in the cloud, SaaS, PaaS, IaaS availability in the cloud - Key privacy issues in the cloud – Cloud Security and Trust Management

TOTAL : 45 PERIODS

OUTCOMES:

Upon completion of this course, the students should be able to:

- Employ the concepts of storage virtualization, network virtualization and its management
- Apply the concept of virtualization in the cloud computing
- Identify the architecture, infrastructure and delivery models of cloud computing
- Develop services using Cloud computing
- Apply the security models in the cloud environment

REFERENCES:

1. Danielle Ruest, Nelson Ruest, “Virtualization: A Beginner‟s Guide”, McGraw-Hill Osborne Media, 2009.
2. Jim Smith, Ravi Nair , "Virtual Machines: Versatile Platforms for Systems and Processes", Elsevier/Morgan Kaufmann, 2005
3. John W.Rittinghouse and James F.Ransome, "Cloud Computing: Implementation,
4. Management, and Security", CRC Press, 2010.
5. Kai Hwang, Geoffrey C Fox, Jack G Dongarra, "Distributed and Cloud Computing, From Parallel Processing to the Internet of Things", Morgan Kaufmann Publishers, 2012.
6. Tim Mather, Subra Kumaraswamy, and Shahed Latif ,"Cloud Security and Privacy", O’Reilly Media, Inc.,2009.
7. Toby Velte, Anthony Velte, Robert Elsenpeter, "Cloud Computing, A Practical Approach", McGraw-Hill Osborne Media, 2009.
8. Tom White, "Hadoop: The Definitive Guide", Yahoo Press, 2012.

RENEWABLE ENERGY RESOURCES L T PC
3 0 0 3

OBJECTIVES:

- To get exposure on solar radiation and its environmental impact to power.
- To know about the various collectors used for storing solar energy.
- To know about the various applications in solar energy.
- To learn about the wind energy and biomass and its economic aspects.
- To know about geothermal energy with other energy sources.

UNIT I PRINCIPLES OF SOLAR RADIATION 10

Role and potential of new and renewable source - the solar energy option - Environmental impact of solar power - physics of the sun - the solar constant - extraterrestrial and terrestrial solar radiation - solar radiation on titled surface - instruments for measuring solar radiation and sun shine, solar radiation data.

UNIT II SOLAR ENERGY COLLECTION 8

Flat plate and concentrating collectors - classification of concentrating collectors - orientation and thermal analysis - advanced collectors.

UNIT III SOLAR ENERGY STORAGE AND APPLICATIONS 7

Different methods - Sensible, latent heat and stratified storage - solar ponds - Solar Applications - solar heating/cooling technique - solar distillation and drying - photovoltaic energy conversion.

UNIT IV WIND ENERGY 10

Sources and potentials - horizontal and vertical axis windmills - performance characteristics – Betz criteria BIO-MASS: Principles of Bio-Conversion - Anaerobic/aerobic digestion - types of Bio-gas digesters - gas yield - combustion characteristics of bio-gas - utilization for cooking - I.C.Engine operation and economic aspects.

UNIT V GEOTHERMAL ENERGY 9

Resources - types of wells, methods of harnessing the energy - potential in India - OCEAN ENERGY: OTEC, Principles utilization - setting of OTEC plants - thermodynamic cycles - Tidal and wave energy: Potential and conversion techniques - mini-hydel power plants and their economics - DIRECT ENERGY CONVERSION: Need for DEC - Carnot cycle, limitations, principles of DEC.

TOTAL: 45 PERIODS

OUTCOMES:

- Understanding the physics of solar radiation.
- Ability to classify the solar energy collectors and methodologies of storing solar energy.
- Knowledge in applying solar energy in a useful way.
- Knowledge in wind energy and biomass with its economic aspects.
- Knowledge in capturing and applying other forms of energy sources like wind, biogas and geothermal energies.

REFERENCES:

1. Rai G.D. , “Non-Conventional Energy Sources”, Khanna Publishers, 2011
2. Twidell&Wier, “Renewable Energy Resources”, CRC Press (Taylor & Francis), 2011
3. Tiwari and Ghosal, “Renewable energy resources”, Narosa Publishing House, 2007
4. Ramesh R & Kumar K.U , “Renewable Energy Technologies”,Narosa Publishing House, 2004
5. Mittal K M , “Non-Conventional Energy Systems”, Wheeler Publishing Co. Ltd, New Delhi, 2003
6. Kothari D.P, Singhal ., K.C., “Renewable energy sources and emerging technologies”, P.H.I, New Delhi, 2010 OCS551 SOFTWARE ENGIN

E - VEHICLE TECHNOLOGIES **L T P C**
3 0 0 3

OBJECTIVES: The students will be able to

- understand need for E-Vehicles
- understand electric drives for EVs
- know the need for battery management systems in EVs
- study EV infrastructure

UNIT I ELECTRIC VEHICLES (EV) 9

History Overview and Modern Applications - Ground vehicles with mechanical powertrain and reasons for EV development- EV configurations - Advantages and challenges in EV design - Power Flow and Power Management Strategies in EV - Vehicle Dynamics - Basics of Vehicle Architecture- IC Engine Vs E-Motor Characteristics. - Major components in Powertrain-Controls Integration-Component sizing and integration tradeoffs

UNIT II ELECTRIC DRIVES FOR EV 9

Setup of an electric drive- Electromagnetism- Maxwell's equations- Magnetic Circuits- Application of Governing laws- Magnetic Force/Torque Production - Fundamentals, Performance and Control of PMBLDC Motor - Synchronous Machines Wound-field, Permanent Magnet- Reluctance Machines- Switched Reluctance- Synchronous Reluctance- Flux Modulating Machines.

UNIT III BATTERIES FOR ELECTRIC VEHICLE SYSTEM AND BATTERY MANAGEMENT SYSTEM 9

Modern Lead–Acid Batteries Technologies- Nickel–Cadmium (NiCd) Batteries- Nickel–Metal Hydride (NiMH) Batteries- Lithium-Ion (Li-ion) Based Technologies – Cell Balancing: Active versus passive, strategies-Sensing Requirements- Cell/module level: cell voltage, cell/module temperature, (humidity, smoke, air/fluid flow) Pack level: current, pre-charge temperature, bus voltage, pack voltage, isolation- Ultracapacitors -Battery System Requirements-Electrochemical Storage Systems- Battery Types-Storage Technology (Rechargeable)-Battery Components-Lithium Battery Systems & Safety Management-Potential hazards of electrochemical storage systems-Hazards &Failure mechanisms of Li-Ion system-Protective Measures & Potential to increase safety-Battery Management (BMS) & Charging-Battery State Detection-Safety & Monitoring-Cell Balancing-Thermal Management

UNIT IV POWER ELECTRONICS IN ELECTRIC VEHICLES 9

Gate driver Rectifiers - Buck convertor - Bidirectional DC-DC converters - PEV configurations - Voltage source inverter - Current source inverter - Power management problems - Control of the Electric Drive

UNIT V EV CHARGING TECHNOLOGY & INFRASTRUCTURE 9

Types of EV Charging- Design of charging systems with case studies-Charging Infrastructure Requirements - Safety Guidelines for Design of EV Charging Equipment's.-Power Quality Issues and Design Requirements.

TOTAL: 45 PERIODS

OUTCOMES: The students will be able to

- use electric drives for EV
- use power electronics for EV
- develop components for EV
- develop EV infrastucture

REFERENCES:

1. John G. Hayes, G. AbasGoodarzi, Electric Powertrain: Energy Systems, Power Electronics and Drives for Hybrid, Electric and Fuel Cell Vehicles, ISBN: 978-1-119-06364-3 Wiley Publications 2018
2. R.W.Erickson, D.Maksimovic, Fundamentals of Power Electronics, 2nd edition, Springer, ISBN: 0-7923-7270-0. online access from computers on the colorado.edu network
3. Toyota Prius Power Split Device animation
4. The Electropaedia, a site on battery and energy technologies
5. Mehrdad Ehsani, Yimin Gao, Sebastien E. Gay, and Ali Emadi, Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC Press 2004. online access from computers on the colorado.edu network.
6. Evaluation of the 2004 Toyota Prius Hybrid Electric Drive System, Oak Ridge National Lab 2006 report
7. Evaluation of the 2010 Toyota Prius Hybrid Electric Drive System, Oak Ridge National Lab 2011 report
8. Davide Andrea, Battery Management Systems for Large Lithium-Ion Battery Packs, Artech House, 2010.
9. C.Mi, M.A.Masrur, D.W.Gao, Hybrid Electric Vehicles, Wiley 2011**.**

INTELLIGENT TRANSPORTATION SYSTEMS L T P C
3 0 0 3

OBJECTIVES

- Understand the concepts related to ITS technologies and industry applications of the field.
- conduct a comprehensive independent research project, on topics related to ITS

UNIT I INTRODUCTION 9

Introduction to Intelligent Transportation Systems (ITS) - Advanced Transportation Management Systems (ATMS) - Advanced Traveler Information Systems (ATIS) - Federal ITS Programs

UNIT II ITS ENVIRONMENT AND SAFETY 9

ITS Highway Safety Perspective- Environmental Aspects of ITS

UNIT III ITS STANDARDS 9

Connected Vehicle Technology and Applications- ITS Standards and Architecture - ITS Telecommunications- Travel Information Systems

UNIT IV ITS APPLICATIONS 9

Interactive Voice Recognition (IVR) - Mobile Applications - Economics of ITS – Revenue Generation Models - Case Studies

UNIT V ITS SECURITY and POLICY 9

ITS and Security- ITS Policy Issues - International ITS Programs - Careers in the ITS Field

TOTAL: 45 PERIODS

OUTCOMES The students will be able to:

- use the ITS principles to develop ITS
- develop ITS applications
- Analyse ITS security

REFERENCES:

1. Sussman, Joseph. Perspectives on Intelligent Transportation Systems (ITS). New York, NY:Springer, 2010.
2. Mashrur A. Chowdhury, and Adel Sadek, Fundamentals of Intelligent Transportation Systems Planning, Artech House, Inc., 2003.

INTELLECTUAL PROPERTY RIGHTS LT P C 3 0 0 3

OBJECTIVE:

- To give an idea about IPR, registration and its enforcement.

UNIT I INTRODUCTION 9

Introduction to IPRs, Basic concepts and need for Intellectual Property – Patents, Copyrights, Geographical Indications, IPR in India and Abroad – Genesis and Development – the way from WTO to WIPO –TRIPS, Nature of Intellectual Property, Industrial Property, technological Research, Inventions and Innovations – Important examples of IPR.

UNIT II REGISTRATION OF IPRs 10

Meaning and practical aspects of registration of Copy Rights, Trademarks, Patents, Geographical Indications, Trade Secrets and Industrial Design registration in India and Abroad

UNIT III AGREEMENTS AND LEGISLATIONS 10

International Treaties and Conventions on IPRs, TRIPS Agreement, PCT Agreement, Patent Act of India, Patent Amendment Act, Design Act, Trademark Act, Geographical Indication Act.

UNIT IV DIGITAL PRODUCTS AND LAW 9

Digital Innovations and Developments as Knowledge Assets – IP Laws, Cyber Law and Digital Content Protection – Unfair Competition – Meaning and Relationship between Unfair Competition and IP Laws – Case Studies.

UNIT V ENFORCEMENT OF IPRs 7

Infringement of IPRs, Enforcement Measures, Emerging issues – Case Studies.

TOTAL: 45 PERIODS

OUTCOME:

- Ability to manage Intellectual Property portfolio to enhance the value of the firm.

REFERENCES:

1. V. Scople Vinod, Managing Intellectual Property, Prentice Hall of India pvt Ltd, 2012
2. S. V. Satakar, - Intellectual Property Rights and Copy Rights, Ess Ess Publications, New Delhi, 2002.
3. Deborah E. Bouchoux, - Intellectual Property: The Law of Trademarks, Copyrights, Patents and Trade Secrets, Cengage Learning, Third Edition, 2012.
4. Prabuddha Ganguli,Intellectual Property Rights: Unleashing the Knowledge Economy, McGraw Hill Education, 2011.
5. Edited by Derek Bosworth and Elizabeth Webster, The Management of Intellectual Property, Edward Elgar Publishing Ltd., 2013.