A Curriculum for

Post Graduate Programs

offered by

Department of Electronics and Communication Engineering

The LNM Institute of Information Technology, Jaipur
Rajasthan 302031

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Table 1: Abbreviations used in the document

ECE:	Electronics and Communication Engineering
M.Tech.:	Master of Technology
M.S. :	Master of Science
Ph.D.:	Doctor of Philosophy
PEO:	Program Education Objectives
PO:	Program Outcomes
C:	Credits
IC:	Institute Core
PC :	Program Core
PE:	Program Electives
OE:	Other Electives
TWRM:	Technical Writing and Research Methodology
MSE:	Mathematical Structures for Engineers
ITC:	Information Theory and Coding
MDC:	Modern Digital Communication
MAS:	modeling and Simulations
WCom:	Wireless Communications
RPS:	Research Progress Seminar
DVLSI:	Digital VLSI
ESD:	Embedded Systems Design
RTS:	Real Time Systems
AVLSI:	Analog VLSI

Departmental Vision, Mission and Objectives

Vision

To become a unique and top-notch Department in the area of Electronics and Communication Engineering in the country, through pioneering excellence in teaching, research and scholarship.

Mission

- To impart, both in depth and content, the basic fundamental knowledge and understanding in the area of Electronics and Communication Engineering.
- To keep students fully tuned to the pace of growth of the modern trends of technology and their applications along with the challenging issues.
- To motivate students toward developing innovative approaches to learning and toward applying scientific and engineering skills for providing solutions to real-life challenges relevant to the societal and industry needs of the country.
- To motivate students and faculty to pursue higher research and to become an integral part of the process of conducting collaborative research.
- To promote life-long learning, and to preserve academic freedom, honesty and justice.

Objectives

- To consolidate the Undergraduate (UG) program through innovative curriculum planning and advanced laboratory development.
- To expand and diversify the scope of Post-graduate (PG) program.
- To strengthen the Ph.D. program in core and interdisciplinary areas.
- To strengthen the Faculty Development Program.
- To institute rigorous Academic Audit by external/internal agencies.
- To organize national/international conferences/workshops on a regular basis.
- To encourage faculty to get more involved in executing sponsored/consultancy projects from Government/industry/other funding agencies.
- To explore more opportunities for bilateral collaboration with reputed organizations in India and abroad.
- To nurture and build up a strong and coherent teacher-student relationship within the department.
- To encourage and enhance the skill development activities for students.

Chapter 1

Program Description

1.1 Introduction

The goals of the postgraduate programmes offered by the department of ECE, the LNMIIT Jaipur are: a broad grasp of the fundamental principles of the sciences and scientific methods, The development of scientific and engineering manpower of the highest quality, to cater to the needs of industry, R & D organizations and educational institutions, a deep understanding of the area of specialization. With these goals in view, the postgraduate programmes are designed to include courses of study, seminars and project/thesis through which a student may develop his/her concepts and intellectual skills.

This manual describes the curriculum for all the postgraduate programmes offered by the department.

1.2 Program Education Objectives (PEO)

The following *Program Educational Objectives* (PEO) are derived from the vision statement of the department, keeping in mind the objectivity and long term (2-years program duration) measurability. If necessary, these objectives can be revisited, based on the feedback received from the stake-holders (graduated students - alumni, industry and faculty). Usually PEO are evaluated at the end of the program duration.

PEO1 : Work productively as an electronics and communication engineer, in research and/or development industries, including supportive and leadership roles on multidisciplinary terms undertaking to solve complex problems

PEO2 : Communicate effectively, recognize and incorporate societal needs and constraints in their professional endeavors

PEO3 : Practice their profession with high regard to legal and ethical responsibilities including the responsibility towards green engineering

PEO4 : Engage in life-long learning, such as research/doctoral studies, acquiring skills and remain up-to-date in their profession

1.3 Program Outcomes (PO)

The way to measure the PEO is to derive a quantifiable outcome from the program. Broadly, these program outcomes must attain at least one of the PEO. The following are the program outcomes for our PG program: M.Tech. in Mobile Communication.

PO1 Engineering Knowledge

PO2 Problem Analysis

PO3 Design/Development of Solutions

PO4 Investigation

PO5 Modern Tool Usage

PO6 The Engineer and Society

PO7 Environment and Sustainability

PO8 Ethics

PO9 Individual and Team Work

PO10 Communication

PO11 Project Management and Finance

PO12 Life long Learning

The above mentioned POs are derived keeping the Washington Accord as a reference*.

*Please refer to http://www.washingtonaccord.org/Washington-Accord/

1.4 Mapping from PO to PEO

		Program Educational Objectives			
		Work productively as an electronics and communication engineer, including supportive and leadership roles on multidisciplinary terms undertaking to solve complex problems	Communicate effectively, recognize and incorporate societal needs and constraints in their professional endeavors	practice their profession with high regard to legal and ethical responsibilities including the responsibility towards green engineering	engage in life-long learning, such as higher study, acquiring skills and remain up-to-date in their profession
	Program Outcomes	**PE1**	**PE2**	**PE3**	**PE4**
PO1	Engineering Knowledge	x			x
PO2	Problem Analysis	x			
PO3	Design and Development of Solution	x			
PO4	Investigation of Complex Problems	x	x		
PO5	Modern Tool Usage	x			x
PO6	The Engineer and Society		x	x	
PO7	Environment and Sustainability		x	x	
PO8	Ethics			x	
PO9	Individual and Team Work		x		
PO10	Communication Skills	x	x		x
PO11	Project Management and Finance	x	x	x	
PO12	Life long learning				x

Figure 1.1: Mapping from Program Outcomes to Program Education Objectives

Chapter 2

M.Tech Program

2.1 M.Tech. Programs offered by the department

ECE Department offers 3 options for the student to complete his/her M.Tech program.

1. M.Tech in ECE
2. M.Tech in ECE with specialization in Mobile Communication
3. M.Tech in ECE with specialization in VLSI and Embedded Systems

2.2 M.Tech. in ECE

The student must complete a total of 72 credits with a minimum CGPA of 6.0 to be eligible for the award of the degree of M.Tech in ECE. These 72 credits should be completed as per the categories mentionedbelow.

- Two Institute Core (IC) courses (8 credits, MSE and TWRM)
- Four Program Core (PC) courses (16 credits)
- Two Program Core (PC) lab courses (4 credits)
- Two Program Elective (PE) (8 credits)
- One Other Elective (OE) (4 Credits)
- Thesis work (32 Credits)

The students should register for his/her courses in consultation of HoD (ECE)/thesis supervisor. A student is free to take extra credits in PE and OE categories.

2.2.1 Requirements for M.Tech in ECE

A students would be considered worthy of receiving M.Tech in ECE (without any specialization), if:

- He/she fulfills the credits requirements mentioned in each category of section 2.2.
- He/she can take the PE from any of PE offered by the department.
- A student is free to choose thesis topic from any area of research offered by the department.

The students should register for his/her courses in consultation of HoD (ECE)/thesis supervisor. A student is free to take extra credits in PE and OE categories.

Table 2.1: M.Tech in ECE Program Structure

Semester -I	**C**	**Semester-II**	**C**	**Semester-III**	**C**	**Semester-IV**	**C**
IC-1	4	IC - 2	4	M.Tech. Thesis	16	M.Tech. Thesis	16
PC - 1	4	PC - 3	4	RPS	P/F	RPS	P/F
PC - 2	4	PC - 4	4				
PE - 1	4	PE - 2	4				
PG Lab - 1	2	OE	4				
		PG Lab - 2	2				
	18		**22**		**16**		**16**
Total Credits = 72							

Here
IC - 1 = MSE
IC - 2 = TWRM
PC - 1 = MDC/ITC
PC - 2 = ESD/DVLSI
PC - 3 = MAS/WCOM
PC - 4 = AVLSI/RTS

2.3 M.Tech. ECE with specialization in Mobile Communication

The M.Tech. in ECE (with specialization in Mobile Communication) Program is designed carefully to incorporate a strong Mathematical fundamentals along with innovative and inclusive advanced-level Mobile Communication subjects, to create a Telecommunication Professional, capable of leading a successful career in higher research, R & D organizations and Industries in the broad areas of Wireless and Telecommunication.

2.3.1 Requirements for M.Tech in ECE with specialization in Mobile Communication

A student would be considered worthy of receiving M.Tech in ECE with specialization in Mobile Communication, if he/she fulfills the following criteria:

- Two Institute Core (IC) courses (8 credits , MSE and TWRM)
- Four Program Core (PC) courses (16 credits from ITC, MDC, WCom and MaS)
- Two Program Core (PC) lab courses (4 credits from Lab -1 and Lab -2)
- Two Program Elective (PE) in the area of Mobile Communication (8 credits)
- One Other Elective (OE) (4 Credits)
- Thesis work in the area of Mobile Communication (32 Credits).

The students should register for his/her courses in consultation of HoD (ECE)/thesis supervisor. A student is free to take extra credits in PE and OE categories.

Table 2.2: Semester wise course and credit distribution for M.Tech in ECE with specialization in Mobile Communication

Semester -I	**C**	**Semester-II**	**C**	**Semester-III**	**C**	**Semester-IV**	**C**
MSE	4	TWRM	4	M.Tech. Thesis	16	M.Tech. Thesis	16
ITC	4	MAS	4	RPS	P/F	RPS	P/F
MDC	4	WCom	4				
PE - 1	4	PE - 2	4				
PG Lab - 1	2	OE	4				
		PG Lab -2	2				
	18		**22**		**16**		**16**
Total Credits = 72							

2.4 M.Tech. ECE with specialization in VLSI and Embedded Systems

The M.Tech. in ECE (With specialization in VLSI and Embedded Systems) Program is designed carefully to incorporate a strong Mathematical fundamentals along with innovative and inclusive advanced-level VLSI and Embedded Systems subjects, to create a VLSI Professional, capable of leading a successful career in higher research , R & D organizations and Industries in the broad areas of VLSI and Embedded Systems.

2.4.1 Requirements for M.Tech in ECE with specialization in VLSI and Embedded Systems

A student would be considered worthy of receiving M.Tech in ECE with specialization in VLSI and Embedded Systems, if he/she fulfills the following criteria:

- Two Institute Core (IC) courses (8 credits , MSE and TWRM)
- Four Program Core (PC) courses (16 credits from ESD, DVLSI, AVLSI and RTOS)
- Two Program Core (PC) lab courses (4 credits from VLSI Lab -1 and VLSI Lab -2)
- Two Program Elective in the field of VLSI and ES(PE) (8 credits)
- One Other Elective (OE) (4 Credits)
- Thesis work in the area of VLSI and ES (32 Credits).

The students should register for his/her courses in consultation of HoD (ECE)/thesis supervisor. A student is free to take extra credits in PE and OE categories.

Table 2.3: Semester wise course and credit distribution for M.Tech in ECE with specialization in VLSI and Embedded Systems

Semester -I	**C**	**Semester-II**	**C**	**Semester-III**	**C**	**Semester-IV**	**C**
MSE	4	TWRM	4	M.Tech. Thesis	16	M.Tech. Thesis	16
ESD	4	AVLSI	4	RPS	P/F	RPS	P/F
DVLSI	4	RTS	4				
PE - 1	4	PE - 2	4				
PG Lab - 1	2	OE	4				
		PG Lab -2	2				
	18		**22**		**16**		**16**
Total Credits = 72							

Chapter 3

M.S. by Research in ECE

The M.S. by Research in ECE Program is designed carefully to incorporate a strong Mathematical fundamentals along with innovative and inclusive advanced-level Mobile Communication, RF, VLSI and Embedded Systems courses, to create an Electronics Professional, capable of leading a successful career in higher research, R & D organizations and Industries.

M.S. Students can take M.Tech. level Core/PE courses as Program Electives for their program after consulting HoD (ECE) or respective thesis supervisor.

3.1 Requirement for Completion of Program

The student must complete a total of 72 credits with CGPA of 6.0 to be eligible for the award of the degree of M.S. by research in ECE. These 72 credits should also meet the following credits requirements.

- Two Institute Core (IC) courses (8 credits , MSE and TWRM)
- Three Program Elective (PE) (12 credits)
- One Other Elective (OE) (4 Credits)
- Thesis work (48 Credits).

The students should register for his/her courses in consultation of HoD (ECE)/thesis supervisor. A student is free to take extra credits in PE and OE categories.

3.2 Semester-wise Curriculum

Table 3.1: Semester wise course and credit distribution for M.S. by Research in ECE

Semester -I	**C**	**Semester-II**	**C**	**Semester-III**	**C**	**Semester-IV**	**C**
MSE	4	TWRM	4	M.S. Thesis	16	M.S. Thesis	16
PE - 1	4	PE - 3	4	RPS	P/F	RPS	P/F
PE - 2	4	OE	4				
MS Thesis	8	MS Thesis	8				
	20		**20**		**16**		**16**
Total Credits = 72							

Chapter 4

M.S. by Research in CCE

The M.S. by Research in CCE Program is designed carefully to incorporate a strong Mathematical fundamentals along with innovative and inclusive advanced-level Mobile Communication, RF, VLSI and Embedded Systems courses, to create an Electronics Professional, capable of leading a successful career in higher research, R & D organizations and Industries.

M.S. Students can take M.Tech. level PC/PE courses offered by the departments of ECE or CSE, as Program Electives for their program after consulting HoD (ECE) or respective thesis supervisor.

4.1 Requirement for Completion of Program

The student must complete a total of 72 credits with CGPA of 6.0 to be eligible for the award of the degree of M.S. by research in CCE. These 72 credits should also meet the following credits requirements.

- Two Institute Core (IC) courses (8 credits , MSE and TWRM)
- Three Program Elective (PE) (12 credits)
- One Other Elective (OE) (4 Credits)
- Thesis work (48 Credits).

The students should register for his/her courses in consultation of HoD (ECE)/thesis supervisor. A student is free to take extra credits in PE and OE categories.

4.2 Semester-wise Curriculum

Table 4.1: Semester wise course and credit distribution for M.S. by Research in CCE

Semester -I	**C**	**Semester-II**	**C**	**Semester-III**	**C**	**Semester-IV**	**C**
MSE	4	TWRM	4	M.S. Thesis	16	M.S. Thesis	16
PE - 1	4	PE - 3	4	RPS	P/F	RPS	P/F
PE - 2	4	OE	4				
MS Thesis	8	MS Thesis	8				
	20		**20**		**16**		**16**
Total Credits = 72							

Chapter 5

Ph.D. in ECE

The Ph.D. Program in ECE is designed carefully to incorporate a strong Mathematical fundamentals along with innovative and inclusive advanced-level Mobile Communication, RF, VLSI and Embedded Systems subjects, to create an Electronics Professional, capable of leading a successful career in higher research, R & D organizations and Industries.

Course work requirements for Ph.D. scholars are mentioned below.
Ph.D. students have to take the courses in consultation with their respective supervisor. Ph.D. Students can opt for M.Tech. level Core/PE courses as Program Electives in Ph.D. curriculum.

5.1 Semester-wise Curriculum

Table 5.1: Course work requirements for Ph.D. in ECE

Course No.	Course Title	Credits
1	Mathematical Structures for Engineers	4
2	Technical Writing and Research Methodology	4
3	Program Elective -1	4
4	Program Elective -2 / Open Elective	4
	Total Credits	16

Chapter 6

Ph.D. in CCE

The Ph.D. Program in CCE is designed carefully to incorporate a strong Mathematical fundamentals along with innovative and inclusive advanced-level Mobile Communication, RF, VLSI and Embedded Systems subjects, to create an Electronics Professional, capable of leading a successful career in higher research, R & D organizations and Industries.

Course work requirements for Ph.D. scholars are mentioned below.
Ph.D. students have to take the courses in consultation with their respective supervisor. Ph.D. Students can opt for M.Tech. level PC/PE courses offered by the departments of ECE or CSE, as Program Electives in Ph.D. curriculum.

6.1 Semester-wise Curriculum

Table 6.1: Course work requirements for Ph.D. in CCE

Course No.	Course Title	Credits
1	Mathematical Structures for Engineers	4
2	Technical Writing and Research Methodology	4
3	Program Elective -1	4
4	Program Elective -2 / Open Elective	4
	Total Credits	16

Appendix-A: List of Elective courses offered by the department

General PE for M.Tech. in ECE

1. Modern Antennas
2. High Frequency Electronics
3. Radar, Sonar and Satellite Navigation Systems

Specific PE for M.Tech in ECE with specialization in Mobile Communication

1. Broadband Communication
2. Optical Communication
3. Switching and Telecommunication Networks
4. Wireless System Design
5. Statistical Estimation Theory
6. Cognitive Radio
7. Advanced Digital Signal Processing

Specific PE for M.Tech in ECE with specialization in Mobile Communication

1. VLSI technology
2. Hardware Software Co-Design

A List of Other Electives offered by the department

1. System Level Specifications and Design (SLSD)
2. Optimization for Engineers
3. AUTOSAR and Infotainment

Appendix-B: Program Core courses offered by the department

Course sketches of all the offered core courses are presented in this appendix.

Course: Mathematical Structures for Engineers

Category: Core course - First year PG Program (ECE/CCE/CSE)

Credits: 4 (3-0-0)

Prerequisites: Nil

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: TBD

Objectives of the Course

Students entering PG program usually find that their mathematical foundation is inadequate to pursue research for their thesis. It is also a fact that, for them to achieve the required level of mathematical maturity entirely through self-study is difficult. This course is designed with an objective to provide the essential knowledge required to remove this inadequacy. The content of the course is designed keeping in mind the mixed audience coming from electronics and communication engineering and computer science and engineering disciplines. At the conclusion of this course, students should have a sound understanding of what mathematics is about, and should have acquired a level of mathematical literacy that would enable them to see its relevance in their own domain of knowledge.

Course Content

- Foundations of Computation [1]: Representation of Numbers, Finite Floating-point Representation, Floating-point Computation, Propagation of Errors (4 Hrs)
- Sets, Relations and Functions [3]: Order, Equivalence and Correspondence (4 Hrs)
- Evaluation of Functions: Recursion-Iteration and Root finding, Numerical Integration, Solution of Differential Equations (5 Hrs)
- Groups, Rings and Fields [2, 4]: Permutations, Symmetries, Polynomials (7 Hrs)
- Vector Space [6]: Basis, Linear transformations, Norm and Inner-Product: Energy, Orthogonality, Metric [3]: continuity, convergence and completeness, Finite Dimensional Vector Space [6]: System of linear equations, Eigen values, Eigen vectors, Matrix inverse, Least squares and Pseudo inverse, Change of basis and similarity transform (14 Hrs)
- Introduction to Graphs and Connections with Linear Algebra: Adjacency and Incident matrices, Graph spectrum, Graph Partitioning and Clustering, Max-Min flow and Graph cuts, Shortest path algorithms [5] (6 Hrs)
- Case studies for domain specific applications like: Google page ranking, cryptographic systems, codes in communication, audio/video processing, SVM for classification. These case studies will be taken up along with the associated topics.

Course Outcomes

CO1 Students will understand the need of various mathematical structures and also be able to model a given engineering problem mathematically.

CO2 Students will be able to grasp the concepts of data (data processing system) representation and will be able to use the basic results from linear algebra and function analysis to process them.

CO3 Students will read and simulate a well established algorithm from a research paper in the domain of their specialization in groups.

CO4 Students will write a term paper on any one of the mathematical structures taught in the course.

Evaluation Pattern and Grading Policy

- Weekly Tutorials (~ 5) 5%
- Assignments (~ 3) 20%

- Mid-Term Examination 25%
- End-Term Examination 30%
- Simulation of a research paper 10%
- Term Paper 10%

Text and Reference Books

1. C.D. Cantrell. *Modern Mathematical Methods for Physicists and Engineers*. Cambridge University Press, 2000.
2. A. Papantonopoulou. *Algebra: Pure & Applied*. Prentice Hall, 2002.
3. G.F. Simmons. *Introduction to Topology and Modern Analysis*. International series in pure and applied mathematics. Krieger Publishing Company, 2003.
4. V.P. Sinha. *Symmetries and Groups in Signal Processing: An Introducuction*. Signals and Communication Technology. Springer, 2010.
5. Daniel A Spielman. Spectral graph theory and its applications. *Most*, i:1–75, 2007.
6. G. Strang. *Introduction to Linear Algebra*. Wellsley-Cambrige Press, 2003.

Course: Information Theory and Coding

Category: Core course - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: A basic course in Communication

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

- To provide basic concepts of Information theory and coding.
- To enable the students to propose, design and analyze suitable coding/decoding scheme for a particular digital communication application.

Course Outline

Information theory is concerned with the fundamental limits of communication. What is the ultimate limit to data compression? e.g. how many bits are required to represent a music source. What is the ultimate limit of reliable communication over a noisy channel, e.g. how many bits can be sent in one second over a telephone line.
Coding theory is concerned with practical techniques to realize the limits specified by information theory. Source coding lowers as much redundancy as possible from the data (e.g., ZIP, JPEG, MPEG2 etc.). Channel coding is used to defeat channel noise by putting a modest amount of redundancy in the data. It provides the reliable digital transmission and storage by using redundancy to do error detection or correction A rough breakup for the topics covered with the amount of time to be spent on each is presented below.

Unit 1 (10 Hrs): Information theory - information and entropy - properties of entropy of a binary memory less source extension of a binary memory less source - source coding theorem-Shannon fano coding - Huffman coding - Lempel ziv coding-discrete memoryless source - binary symmetric channel - mutual information - properties-channel capacity - channel coding theorem.

Unit 2 (10 Hrs): Introduction to algebra - groups - fields - binary field arithmetic - construction of Galois field - basic properties - computations - vector spaces - matrices - BCH codes - description - coding and decoding - Reed Solomon codes - coding and decoding.

Unit 3 (10 Hrs): Coding - linear block codes - generator matrices - parity check matrices - encoder - syndrome and error correction - minimum distance - error correction and error detection capabilities - cyclic codes - coding and decoding.

Unit 4 (10 Hrs): Coding - convolutional codes - encoder - generator matrix - transform domain Representation - state diagram - distance properties - maximum likelihood decoding - viterbi decoding - sequential decoding interleaved convolutional codes - Turbo coding - coding and decoding - Trellis coding - coding and decoding.

Course Outcomes

CO1 Students will understand the fundamental limits of communication.

CO2 Students will be able to grasp the concepts of source coding and channel coding.

Evaluation Pattern and Grading Policy

- Assignments (~ 4) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. J. G. Prokais, *Digital Communication Systems*, 5th Edition, McGraw Hill.
2. Simon Haykin, *Communication Systems*, John Wiley.
3. T. M. Coveer and A. Thomas *Elements of Information Theory*, 2nd Edition, Wiley (2006).
4. S.Lin and D. Castello, *Error Control Coding*, 2nd Edition, Pearson.

Course: Modern Digital Communication

Category: Core course - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: Background knowledge of Analog and Digital Communications.

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

- To provide basic concepts of modern digital communication.
- To enable the students to propose, design and analyze digital communication system.

Course Outline

Digital communication today pervades every mode of modern communication viz., wire-line, wireless, satellite, deep space etc. The course will expose the basic principles of modern digital communication such as modulation, synchronization, error correction and detection, equalization etc; analysis techniques and performance evaluation.
A rough breakup for the topics covered with the amount of time to be spent on each is presented below

1. Communication channel models, (6 Hrs)
2. Capacity of wireless channels, (4 Hrs)
3. Advanced modulation techniques (4 Hrs),
4. Combined modulation and coding (4 Hrs),
5. Equalization and channel estimation (6 Hrs),
6. Multiple antennas and space-time communication (4 Hrs),
7. Multi-carrier modulation (4 Hrs),
8. Spread spectrum (4 Hrs),
9. Multi-user systems (6 Hrs).

Course Outcomes

CO1 Students will be able to analyze and simulate modern digital communication systems.

Evaluation Pattern and Grading Policy

- Assignments ($\sim$ 6) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. A. Bruce Carlson *Communication Systems*, 3rd Edition, McGraw Hill.
2. Simon Haykin, *Digital Communication Systems*, John Wiley & Sons.
3. J. G. Prokais, *Digital Communication Systems*, 5th Edition, McGraw Hill.
4. B. P. Lathi, *Modern Digital and Analog Communication System*, 3rd Edition, Oxford University Press.

Course: Digital VLSI

Category: Core course - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: None

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

This course is to teach thorough understanding of the Digital VLSI circuits using MOSFET, design, application, and technology of integrated circuits and systems. To teach MOS transistor models, CMOS logic families including static, dynamic and dual rail logic. Integrated Circuit Layout: Design Rules, Parasitic elements. It covers building blocks like ALU's, FIFO's, counters, memories etc. It also includes VLSI system design with various methodologies like data and control path design, practical design aspects like floor-planning, interconnect issues and various hazards.

Course Outline

- UNIT – I - 8 hours Introduction, MOS Transistor Basics and Theory, Threshold voltage, MOSFET I-V and C-V characteristics, characterization of resistive, capacitive elements of MOS devices, Logic implementation by CMOS.
- Unit - II 8 hours Static CMOS invertor and its Transfer characteristics, Transistor sizing, Technology scaling, Gate delay and power models, Static and Dynamic characteristics, Noise margins, Interconnect basics and crosstalk.
- UNIT - III 8 hours Logical effort, Electrical effort, intrinsic/extrinsic delay, Circuit topologies and transistor sizing for optimal delay and power, Circuit Styles: Static CMOS circuits, Pass transistor logic, Transmission gate, Dynamic CMOS, Dual-rail-domino logic, Pseudo MOS logic and other families.
- UNIT - IV 8 hours Combination circuit design with various architectures, Sequential circuit design, Basic understanding, design and timing analysis of sequential circuits like Flip- Flops and Latches, Time borrowing and pipelining.
- UNIT - V 8 hours Circuit pitfalls, Clocking techniques, and Layout design basics, Memory design, EEPROM, DRAM, SRAM and sense amplifiers, IOs,Low Power Techniques, Design methods and tools, CMOS testing, System Design Examples.

Course Outcomes

CO1 Explain the key concepts of MOSFETs in Digital VLSI circuit design, theory and implementation aspects and Understand the MOS device/circuits working, characteristics and logic implementation.

C02 Offer the design understanding based on the specification and constrains given with optimization and to design and simulate the analog circuits and layout using IC design tools like cadence, spice, electric etc.

C03 List the various second/ third order effects, practical limitations and non-linearity associated with the technology, design and circuit and basic understanding regarding the layout, circuit and system level understanding of the design.

C04 Offer the explanation, usage and application of the specific design methodology in the suitable circuit to achieve desire outcome in like integration, speed, area, power, fabrication or cost.

C05 Explain the role of the MOS family in VLSIC domain by offering the very high level of the integration in current technologies.

Evaluation Pattern and Grading Policy

- Assignments (~ 4) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. N. Weste and David Harris, Principles of CMOS VLSI Design, Addison Wesley. 2004
2. J. Rabaey, Digital Integrated Circuits: A Design Perspective, Prentice Hall India, 1997.
3. L. Glaser and D. Dobberpuhl, The Design and Analysis of VLSI Circuits, Addison Wesley, 1985.
4. C. Mead and L. Conway, Introduction to VLSI Systems, Addison Wesley, 1979.

Course: Embedded Systems and Designs

Category: Program Core - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: Microprocessors and Interfaces

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Dr. Deepak Nair

Objectives of the Course

It will expose students to the field of embedded systems, and will provide a knowledge foundation which will enable students to pursue subsequent courses in real-time embedded systems software and computer design. Students will become familiar with the relevant technical vocabulary and will learn about potential career opportunities in the field of embedded systems design. Students will have the opportunity to design and develop an embedded systems from the ground up, starting with analog and digital electronic components and data sheets, and progressing through development of hardware and implementation of firmware. This will provide students with an opportunity to achieve a thorough understanding of the phases of embedded system development and familiarity with hardware and software development and debugging tools. Students will be given the opportunity to develop design skills, through well-bounded as well as open-ended design assignments. Students will have the opportunity to learn how information gained in multiple other core engineering classes comes together to be applied to real-world applications. After completion of this course, students will be given an opportunity to experience embedded system design, and will gain knowledge beneficial for obtaining a job in this field.

Course Outline

- **UNIT – I: Introduction to Embedded Systems** Course overview, expectations, syllabus, FAQ, and prerequisite material, Design considerations and requirements, processor selection and tradeoffs process. Microprocessor / microcontroller architectures and instruction sets, Atmega-328 and TI-MSP430G2 series microcontroller architecture and busses. SPLD and CPLD devices

- **UNIT – II: Embedded System Organization** Major components in a typical embedded system, operating requirement, modes of operation, hardware/software code designs, hardware-software trade-offs. Architectural differences in microcontrollers and memories used. Digital I/O, Timers, Pulse Width Modulation (PWM) and Demodulation, Analog interfaces, Interrupt services. Analog-to-Digital Converters (ADCs), Digital-to-Analog Converters (DACs) and their applications. Power management techniques in microcontrollers, Voltage regulators, Thermal considerations, heat sinks. Data sheets, and importance of Electromagnetic Compatibility (EMC), and Electromagnetic Interference EMI in embedded systems. Microcontroller supervisory circuits, Oscillators and Reset circuits, Watchdog timer and its applications. Hardware development and Debugging strategies and techniques. Logic probes, voltmeters and oscilloscopes. Schematics and wiring diagrams, recommended practices and CAD tools.

- **UNIT – III: Embedded C Programming** Programming in assembly vs assembly languages, Embedded C programming review. Defining variables, Bit operations, Software Interrupt design in C. Mathematical operators, Flow control techniques, Pointers and arrays, multidimensional arrays. Constructs, Data structures, Compiler directives. Interfacing different logic families, fanout, signal buffering, noise margins, pullup / pulldown. Timing requirements, propagation delay, setup, hold, rise / fall times, timing analysis, Clock skew. Decoding logic, Glue logic. Code development using Arduino IDE and TI-Energia IDE. Software based switch / key debouncing in hardware and firmware, keypad decoding. Timers/counters.
- **UNIT – IV: I/O Interfacing Concepts** Bus structures, Peripheral and external communication interfaces. Operating System: Design and organization of embedded and real-time operating systems, scheduling, power management, debugging. Serial communication, RS-232/485, UART, line drivers/receivers, charge pumps, terminal emulation, USB, SPI, I2C. Synchronous serial communication. Interrupt based serial port management in C.
- **UNIT – V: Project Development and Troubleshooting Techniques** Submit PDR presentations, Final Project Design Review (PDR). Each project team presents development plan and milestones. Code review exercise: Firmware design, main loop / interrupt driven designs, device drivers. Final project design. Debugging session.

Course Outcomes

CO1 Analyze and explore an embedded system design space, including processors, memories, networks, and sensors

CO2 Address contemporary design challenges pertaining to reliability, power and thermal efficiency, real-time performance

CO3 Model embedded hardware and software components for simulation and exploration

CO4 Program in Embedded C and its application in real time embedded system design

CO5 Design, troubleshoot hardware and software in embedded systems

Evaluation Pattern and Grading Policy

- Attendance 15%
- Assignment 25%
- Hardware Project 30%
- Project Report 5%
- End Semester Exam 25%

Text and Reference Books

1. David E. Simon, An Embedded Software Primer, Addison-Wesley Longman Publishing Co., Inc., Boston, MA, 1999
2. In The Art of Programming Embedded Systems, edited by Jack G. Ganssle, Academic Press, San Diego, 1992
3. Michael Barr, Programming Embedded Systems in C and C++, O'Reilly & Associates, Inc., Sebastopol, CA, 1998
4. The Circuit Designer's Companion (Second Edition), edited by Tim Williams, Newnes, Oxford, 2005

Course: PG Lab 1

Category: Core - PG Program (ECE)

Credits: 2 (0-0-2)

Prerequisites:
Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

This lab will have 4 modules based on 4 theory courses ITC, MDC, DVLSI and ESD. The M.Tech. students will opt for 2 modules based on the courses taken by him/her

The course coordinators of ITC, MDC, DVLSI and ESD are requested to send list of 4-5 experiments related to their course.

Lab aims at developing simulation skills of Modern Digital communication and Optical Communication. For communication experiments simulation will be done on MATLAB.

Course Outline

A List of Lab exercises are given below

1. **Simulation of GVD Effect on Pulse Propagation**
2. **Implementation of Slit-step Fourier Method**
3. **Dispersion and Non-linearity Compensation by Optical Phase Conjugation (OPC)**
4. **Simulation Experiment on Distributed Raman Amplifier (DRA)**
5. **Single-channel Dispersion and Nonlinearity Compensation by OPC-DRA Combination**
6. **Design of a Uniform Fibre Bragg Grating (FBG)**
7. **Dispersion Compensation of NRZ-DPSK by CFBG**
8. **Design and Simulation of a Micro-ring Resonator Filter for DPSK Demodulation**
9. **Performance Analysis of QAM**
10. **Timing Recovery using Gardener's Algorithm**

11. **Channel Equalization : ZFE, MMSE**
12. **Convolutional coding and viterbie decoding**

Course: Wireless Communication

Category: Core course - First year PG Program (Mobile Communication)

Credits: 4 (4-0-0)

Prerequisites: An undergraduate course in communication system and wireless communication

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

This course is intended as an introductory course for Postgraduate Students in the areas of Communications and Signal Processing. The treatment would look at current and upcoming wireless communications technologies for broadband wireless access.

Course Outline

A rough breakup for the topics covered with the amount of time to be spent on each is presented below

- Wireless Channel Models : Path Loss and Shadowing Models, Statistical Fading Models, Narrow-band Fading, Wide-band Fading Models. [6 Hrs]
- The Cellular Concept- System Design Fundamentals : Frequency reuse, Handoff strategies, Interference and System Capacity, Grade of Service, Improving Coverage and Capacity. [5 Hrs]
- Impact of Fading and ISI on Wireless Performance : Capacity of Wireless Channels, Digital Modulation and it's performance. [4 Hrs]
- Flat Fading Countermeasures : Diversity, Adaptive Modulation, MIMO. [8 Hrs]
- ISI Countermeasures : Equalization, Multi-carrier systems, Multicarrier Modulation, OFDM. [8 Hrs]
- Multiple access techniques for wireless communication [4 Hrs]
- 3G and 4G wireless standards : GSM, GPRS, WCDMA, LTE, WiMAX.

Course Outcomes

CO1 Students will understand the wireless channel and it's limitations.

CO2 Students will learn the techniques to overcome wireless channel deficiencies.

CO3 Students will understand cellular concept.

CO4 Students will learn about current wireless technologies.

Evaluation Pattern and Grading Policy

- Weekly Tutorials ($\sim$ 5) 5%
- Assignments ($\sim$ 3) 20%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. "Wireless Communications, Andrea Goldsmith", Cambridge University Press
2. "Wireless Communications: Principles and Practice", Theodore Rappaport, Prentice Hall
3. "Fundamentals of Wireless Communications", David Tse and Pramod Viswanath, Cambridge University Press.

Course: Analog VLSI

Category: Core course - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: None

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

This course is to teach the fundamentals of analog integrated circuits design using MOSFET for advanced integrated-circuit applications. Topics to be covered include device/process background, IC passives, analog amplifiers, current mirrors, op-amp design, noise fundamentals, oscillators and switched capacitor circuits and other analog circuitry used in today's analog and mixed-signal ICs. The course includes circuit, layout design and simulation using EDA tools like spice, cadence, ADS, electric etc.

Course Outline

- **Unit - I** Analog MOS transistor models, fundamentals and analog IC specification parameters, Threshold voltage, MOSFET I-V and C-V characteristics, characterization of resistive, capacitive elements of MOS devices, Second order effects. MOS small signal model.
- **Unit - II**] Basics of single stage amplifier, small signal analysis of common source, common drain, common gate and cascode stage amplifier with various kind of loads, Various type of reference/bias voltage and current generators, passive current mirrors various architectures, active current mirrors, Supply independent and temperature independent references Band gap references, PTAT current generation and constant Gm biasing, Frequency response of amplifiers.
- **Unit - III** CMOS Differential Amplifiers with balanced and unbalanced output, CMOS Operational Amplifiers: telescopic, diff-amp, folded cascode and multistage architecture, boosting Common mode feedback (CMFB), feedback topologies in amplifiers, Stability and frequency compensation.
- **Unit - IV** Noise in amplifiers, Non-linearity and mismatch analysis
- **Unit - V** Switch capacitor circuits, Oscillators: LC oscillator and ring oscillators, VCO and PLL, state-of-the-art analog IC.

Course Outcomes

CO1 Explain the key concepts including specification and design aspects of analog integrated circuits and their implementation using MOSFETs. Understand the MOS device/circuits working, modeling and characteristics.

C02 Offer the design of important analog building blocks (like amplifies, oscillators, reference signal generators etc.) based on the specification and constrains given with optimization.

C03 Offer the specific design methodology and architecture or given specification to achieve desire outcome in like integration, speed, area, power, fabrication and cost.

C04 Understand the practical challenges and limitations of analog system design come from the difference between theoretical, simulation and real life hardware level design.

C05 To design and simulate the analog circuits and layout using IC design design tools like cadence, spice, electric etc.

Evaluation Pattern and Grading Policy

- Assignments (~ 4) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. Design of Analog CMOS Integrated Circuits, B. Razavi, McGraw-Hill, 2001
2. Analog Integrated Circuit Design, David. A. Johns and Ken Martin, John Wiley and Sons, 2001.
3. MOS Analog Circuit Design, Philip Allen & Douglas Holberg, Oxford University Press, 2002.
4. Analysis and Design of Analog Integrated Circuits, 5th Edition, Paul R. Gray, Paul J. Hurst, Stephen H. Lewis, Robert G. Meyer.
5. CMOS circuit design, layout and simulation, 2nd Edition, R. Baker, John Wiley and Sons, 2005.

Course: Real Time Systems

Category: Core course - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: None

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

The purpose of this course is to teach students the fundamentals of systems with timing constraints. The student will be able to incorporate these concepts into their system designs where control and occurrence of events can be scheduled. In this course, students will understand the co-design system development with soft and hard time constrains, Memory managements issues, systems architectures including memory based and distributed system architectures. The Course will offers students to understand design mechanism to eliminate deadlocks, considering latency and shared resource managements.

Course Outline

- **Unit - I** Definitions, multidisciplinary design challenges, Evolution of real-time systems.
- **Unit - II** Topic Hardware for Real Time Systems, Basic Processor Architectures and Architectural Advancements, Peripheral interfacing, Memory technologies, Distributed Real Time Architectures
- **Unit - III** Topic Scheduling Real-Time Tasks, Types of Schedulers, Table-driven scheduling, Cyclic schedulers, EDF and RMA
- **Unit - IV** Topic Shared resource management, Priority Inheritance, Highest Locker Protocol, Priority Ceiling, Multiprocessor Task Allocation, Dynamic Allocation, Clock in scheduling
- **Unit - V** Topic Real Time Operating Systems (RTOS), From Pseudokernels to OS, System Services for application programs, Memory management Issues, Real-time communication and database

Course Outcomes

CO1 Students should be able understand the basic concepts of Real Time Systems

CO2 Students should be able to demonstrate programming proficiency using C/Embedded C to design bootstrap code and RTOS.

CO3 Students should be able to program using the capabilities of the scheduling mechanism

CO4 Students should be able to apply knowledge of hardware and software by use of a PC based simulator to design applications for Real-Time Systems.

Evaluation Pattern and Grading Policy

- Assignments (~ 4) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. Philip Laplante, Real-Time Systems Design and Analysis, 4th Edition, Wiley, 2012.
2. Albert M.K Cheng. Real-Time Systems, Wiley, 2002.
3. Rajib Mall, Real-Time Systems: Theory and Practice, Pearson, 2008.
4. Jane W. Liu, Real-Time Systems, Pearson Education, 2001.
5. Krishna and Shin, Real-Time Systems, Tata McGraw Hill. 1999.

Course: Lab 2 : Wireless Communication and Computer Network

Category: Core - PG Program (ECE)

Credits: 2 (0-0-2)

Prerequisites:
Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

This lab will have 4 modules based on 4 theory courses MAS, WCOM, RTS and AVLSI. The M.Tech. students will opt for 2 modules based on the courses taken by him/her

The course coordinators of MAS, WCOM, RTS and AVLSI are requested to send list of 4-5 experiments related to their course.

Lab aims at developing simulation skills of wireless communication and networking. For communication experiments simulation will be done on MATLAB. For networking experiments C language will be used.

Course Outline

A List of Lab exercises are given below

1. **Shortest Path between two nodes in a network using Dijkshtra algorithm**
   Represent a network using linked list data structure with random positive weights. Find shortest path between to nodes using dijkshtra algorithm.

2. **Bellman-Ford Algorithm**
   Represent a network using linked list data structure with random weights. Apply Bellman-Ford algorithm to find shortest path between two nodes as well as to detect a negative cycle.

3. **Krushkal Algorithm**
   Make a graph with random weights. Make a minimum weight spanning tree for the graph using krushkal algorithm.

4. **Buffer Management : Printer Sharing Problem**
   Consider there are N number of computers. All Computer shares one printer. Job generated by each computer per time instant is Poisson Distributed. Each computer transmits the entire document(job) to printer and then resumes work. Printer stores this job in it's buffer till it

is served. When buffer is full and another job enters, it is dropped. Simulate printer sharing problem and obtain following results

- Loss vs number of computers without local buffer and with fixed printer buffer size
- Loss vs printer buffer size with fixed number of computers.
- Jobs serviced vs number of computers with infinite local buffer.
- Jobs lost vs printer buffer size for a finite local buffer.

5. **Performance analysis of rayleigh fading channel**
   Plot probability of error vs SNR plot for bpsk signal for different values of rayleigh variance.
6. **Orthogonal Frequency Division Multiplexing**
   Probability of error vs SNR plot and PAPR calculation.
7. **Diversity Techniques**
   Plot BER vs number of antennas for selection and Maximal Ratio combining. Calculate the probability that the signal strength will be above 10dB in each of the case for combining strategy and no. of antenna.
8. **Frequency Reuse and sectoring**
   Plot cumulative density function of carrier to interference ratio for different-2 frequency reuse. Consider first one sector per cell then three sectors per cell.

Appendix-C: CIF of Elective courses

Course sketches of all the elective courses relevant to the program are presented in this appendix.

Course: Broadband Communication

Category: Elective - PG Program (ECE/CCE/CSE)

Credits: 4 (4-0-0)

Prerequisites: A prior course in Digital Communication

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Prof. Ranjan Gangopadhyay and Dr. Soumitra Debnath

Objectives of the Course

The course will provide up-to-date advanced techniques as used in current broadband photonic networks and broadband wireless technologies.

Course Outline

A rough breakup for the topics covered with the amount of time to be spent on each is presented below

- Broadband Photonics and Broadband Wireless Communication: Photonics communication and networks review, High data-rate transmission, Non-linear effects, Optically amplified system (EDFA/ Raman/ SOA), Dispersion and nonlinearity management, Advanced modulation, FECs, Optical networks. [3 Hrs]

- Dense Wavelength Division Multiplexing Technology: Evolution, State-of-the art system design, Analysis and performance evaluation, Future challenges. [3 Hrs]
- Wavelength-Routed Optical Network: Routing and wavelength assignment, Benefit of lambda-conversion, Lightpath versus semi-lightpath, Survivable routing, Traffic grooming, Waveband switching, Multi-granularity OXC, MILB algorithm, Integrated routing, Survivability in optical networks. [6 Hrs]
- Optical Burst-Switched Network: OBS node architecture, Burst assembly schemes, Scheduling, OBS reservation protocols (JIT/JET), Contention resolution, QoS issues. [4 Hrs]
- Fiber Based Access Network: PON, WDM-PON, EPON, MAC for EPON, IPACT, DBA. [3 Hrs]
- MIMO Wireless System: MIMO channel model, SIMO/MISO/MIMO channel capacity, SVD for channel matrix, Examples. [4 Hrs]
- Diversity Techniques: Space/ time/ frequency diversity, Combining techniques for space diversity, Selection, Maximum ratio, Equal-gain combining, SNR of diversity receiver, Array gain, Diversity gain, SNR advantage. [3 Hrs]
- Space-Time Codes: Alamouti code, Transmit diversity, Spatial multiplexing, V-Blast. [4 Hrs]
- Orthogonal Frequency Division Multiplexing: OFDM implementation, Transceiver design, IEEE 802.11a standards, Cyclic prefix, PAPR reduction schemes, OFDM channel estimation, MIMO-OFDM. [6 Hrs]
- Spread Spectrum Techniques and CDMA: DD-SS system, Processing gain, Jamming margin, CDMA, MAI, Near-field effect, Rake receiver, MUD/SIC/PIC, MC-CDMA. [4 Hrs]

Course Outcomes

CO1 Students will acquire design skills, architectural alternatives, and algorithmic developments for broadband photonic networks.

CO2 Students will acquire advanced communication techniques, algorithms, and system simulation strategies for broadband wireless communication system design.

CO3 The course will be very relevant for the students joining networking and wireless technology companies in the country.

Evaluation Pattern and Grading Policy

References

[1] J. G. Prokais. Digital Communication. McGraw Hill.

[2] M. Janakiraman. Space Time Codes and MIMO Systems. Artech House.

[3] M. A. Abu Rgheff. Introduction to CDMA Wireless Communication. Academic Press.

[4] S. Haykin and M. Moher. Modern Wireless Communication. Pearason Education.

[5] J. Zheng and H. Mouftah. Optical WDM Networks. Wiley-InterScience.

[6] R. Ramaswami and K. N. Sivarajan. Optical Networks: A Practical Perspective. Morgan-Kaufmann Publisher.

Course: Advanced Digital Signal Processing

Category: Elective course - PG Program (ECE/CCE)

Credits: 4 (3-0-0)

Prerequisites: Digital Signal Processing

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Pratik Shah

Objectives of the Course

This course is designed to give an appreciation of the theory and application of digital signal processing. The first part begins with the fundamental theory including the multirate systems [2]. The theory and applications of adaptive filters is the second part [3]. Modelling the signal as a random process will be the major step. We will derive Wiener-Hopf equation (MMSE) and look at the practical implementations of it, Least Mean Square filter [1]. The course has a very strong Matlab based coding component. Which includes exercises and simulation examples. As applications we will take up Pilot cockpit problem, Channel equalization and Echo cancellation.

Course Content

A rough breakup for the topics covered with the amount of time to be spent on each is presented below

- Review of Digital Signal Processing from convolution to DFT and change of basis in $\mathbb{R}^n$ (6 Hrs)
- Decimator, Expandor (4 Hrs)
- Fractional and Arbitrary Sampling Rate Conversion (4 Hrs)
- Efficient implementations of FIR filters using Multirate structure (4 Hrs)
- White noise proces and Regression (4 Hrs)
- Wiener-Hopf Equation (MMSE) (4 Hrs)
- Widrow's LMS algorithm : From error surface to algorithm implementation (8 Hrs)
- Variants of LMS algorithm (4 Hrs)
- Applications in Communication and Signal Processing (6 Hrs)

Course Outcomes

CO1 Students will learn to apply stochastic gradient descent algorithm for solution of adaptive system problems.

CO2 Students will grasp the concept of time variant systems including multirate systems.

CO3 Students will learn the sampling rate conversion and various efficient structures for implementing digital filters.

CO4 Students will write a term paper on the recent developments in multirate and/or adaptive signal processing domain.

Evaluation Pattern and Grading Policy

- Weekly Tutorials (~ 5) 5%
- Assignments (~ 3) 20%
- Mid-Term Examination 25%
- End-Term Examination 30%
- Simulation of a research paper 10%
- Term Paper 10%

Text and Reference Books

1. S.S. Haykin. *Adaptive filter theory*. Prentice-Hall information and system sciences series. Prentice Hall, 2002.
2. P.P. Vaidyanathan. *Multirate Systems And Filter Banks*. Prentice Hall signal processing series. Pearson Education, 1993.
3. B. Widrow. *Adaptive Signal Processing*. Prentice-Hall Signal Processing Series. Pearson Education, 1985.

Course: Introduction to Image Processing

Category: Elective course - PG Program (ECE/CCE)

Credits: 4 (3-0-0)

Prerequisites: Signals and Systems, Digital Signal Processing

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Joyeeta Singha

Objectives of the Course

This course will introduce the analytical tools and methods which are currently used in digital image processing as applied to image information for human viewing. There is a substantial body of scientific knowledge about computer processing of visual information and the future promises even greater developments. The course is cross-disciplinary, drawing on mathematics and statistics, information theory, as well as computer science, and has many applications including remote sensing, space exploration, security, surveillance, manufacturing, robotics, and medicine.

Course Content

A rough breakup for the topics covered with the amount of time to be spent on each is presented below

- **UNIT – I Digital Image Fundamentals** Human visual system and image perception, applications of image processing, pixels, coordinate conventions, image geometry, perspective projection, sampling and quantization.

- **UNIT – I Spatial domain filtering** Gray-level transformations, contrast stretching, histogram equalization, correlation and convolution, smoothening filters, sharpening filters, gradient and Laplacian.

- **UNIT – III Image filtering in frequency domain** 2D DFT, 2D DFT for image matching, FFT, 2D DCT, correlation, convolution, KLT/PCA, SVD, Hamhard transform, Haar transform, Slant transform.

- **UNIT – IV Image restoration** Image deformation, classification of image restoration technique, image restoration model, blind deconvolution, image denoising, noise restoration filters (inverse filtering, Weiner filtering).

- **UNIT – V Morphological image processing** Basic operations- dilation, erosion, opening, closing, Hit-Miss transformations, boundary extraction, region filling, connected components, convex hull, thinning, thickening, skeletons, pruning.
- **UNIT – V Image segmentation** Point, line, edge detection, edge linking, Hough transform, Watershed algorithm.
- **UNIT – VI Applications** Panoramic image stitching, image morphing, watermarking, object detection, face recognition, gesture recognition.

Course Outcomes

CO1 Understand image formation and the role human visual system plays in perception of gray and color image data.

CO2 Understand the spatial filtering techniques, including linear and nonlinear methods used in image processing.

CO3 Understand the 2D Fourier transform concept, including the 2D DFT, FFT, DCT and their use in frequency domain filtering.

CO4 Analyse the signal processing algorithms and technique in image enhancement such as histogram modification, contrast manipulation, and edge detection.

CO5 Be able to conduct independent study and analysis of image processing problems and techniques.

Evaluation Pattern and Grading Policy

- Midterm 20%
- Endterm 40%
- Quiz 10%
- Assignment (MATLAB + Theory) 20%
- Project 10%

Text and Reference Books

1. R. C. Gonzalez and R.E. Woods, “Digital Image Processing”, Pearson Education, 2008.
2. A. K. Jain, “Fundamentals of Digital Image Processing”, Pearson Education, 2009.

3. W. K. Pratt, “Digital Image Processing”, John Wiley & Sons, 2006.

4. S. Chanda and D. Dutta Majumdar, “Digital Image Processing and Applications”, Prentice Hall of India, 2000.

5. S. Ahmed, “Image Processing”, McGraw-Hill, 1994.

Course: System Level Specification and Design

Category: Elective course - PG Program (ECE/CCE)

Credits: 4 (3-0-0)

Prerequisites: NA

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Sandeep Saini, Kusum Lata

Objectives of the Course

The emergence of the system-on-chip (SoC) era is creating many new challenges at all stages of the design process. At the systems level, engineers are reconsidering how designs are specified, partitioned and verified. Today, with systems and software engineers programming in C/C++ and their hardware counterparts working in hardware description languages such as VHDL and Verilog, problems arising from the use of different design languages, incompatible tools and fragmented tool flows are becoming common. This course aims at understanding the modeling and design aspects of digital systems.

Course Content

A rough breakup for the topics covered with the amount of time to be spent on each is presented below

- UNIT - I, Introduction ,Design Methodologies, Level of abstraction, Design architectures.
- UNIT - II Models and Architectures, Capture and simulate, Describe and synthesize, Specify and explore
- UNIT - III System Translation, State Machine Translation, Fork Join Translation, Exception Translation
- UNIT - IV System Partitioning, Structural Vs Functional, Natural Vs Executable, Partitioning issues, Hardware/Software partitioning, Partitioning techniques
- UNIT-V Estimation, Accuracy vs speed, Fidelity, Quality metrices

Course Outcomes

CO1 knowledge of different types of system models and architectures

CO2 detailed knowledge of a digital system with implementation modules.

CO3 the knowledge of different partitioning techniques for system design

CO4 understand the quality metrics for system estimation

CO5 ability to translate one system into another.

Evaluation Pattern and Grading Policy

- Assignments ($\sim$ 3) 10%
- Quiz 20%
- Mid-Term Examination 30%
- End-Term Examination 40%
- Term Paper 10%

Text and Reference Books

1 Gajski, Daniel D., Frank Vahid, Sanjiv Narayan, and Jie Gong. ”Specification and Design of Embedded Systems.” (1994).

2 Gajski, Daniel D., and Jon Kleinsmith. Principles of digital design. Vol. 42. New York: Prentice Hall, 1997.

Course: Cognitive Radio

Category: Elective - PG Program (ECE/CCE/CSE)

Credits: 4 (4-0-0)

Prerequisites: A prior course in Communication and Signal Processing

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Prof. Ranjan Gangopadhyay

Objectives of the Course

The objective of the course is to provide up-to-date information about Software Defined Radio (SDR) and Cognitive Radio (CR), to be able to handle both design and operational requirements of the future generation wireless networks.

Course Outline

A rough breakup for the topics covered with the amount of time to be spent on each is presented below

- Elements of Software Defined Radio (SDR): SDR and its evolution, RF front-ends, ADC/DAC and implementation issues, Multi-rate signal processing, Smart antennas, Digital hardware, SDR transceivers (multi-band/ multi-rate/ multi-carrier), SDR-3000, Case studies. [8 Hrs]
- Cognitive Radio (CR) Physical Layer: Key features of CR, CR channel model, RF spectrum and regulation, Spectrum sensing methods, Spectrum mobility, Dynamic spectrum access, Spectrum sharing, Diversity, Co-operation and relaying, Interference mitigation in CR. [14 Hrs]
- CR Network Layer: CR network architecture, MAC, Network layer design and cross-layer optimization, Security issues. [12 Hrs]
- CR Platform: Hardware/ FPGA implementation, IEEE 802.22/802.11 Y/802.11 K-standards, CR applications. [6 Hrs]

Course Outcomes

CO1 Students will gain understanding and acquire competencies of the technologies of CR network in terms of software architectures, algorithms and hardware implementation.

CO2 Students will be able to design, operate and manage the evolving future generation wireless network.

Evaluation Pattern and Grading Policy

Text and Reference Books

1. A. M. Wyglinsky, M. Nekoree, and Y. T. Hou. Cognitive Radio Communication and Networks: Principles and Practices. Academic Press

2. Y. Xiao and F. Hu. Cognitive Radio Networks. CRC Press.

3. E. Hossain and V. K. Bhargava. Cognitive Wireless Communication Networks. Springer.

4. K C Chen and Ramjee Prasad. Cognitive Radio Networks. Wiley

5. J H Reed. Software Radio. Prentice Hall.

Course: Modern Antennas

Category: Elective course - PG Program (ECE/CCE)

Credits: 4 (3-0-0)

Prerequisites:

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor: Prof. R. Tomar

Objectives of the Course

The objective of the course is to provide students with an in-depth understanding of modern antenna concepts, and an ability to independently face modern antenna design challenges.

Course Content

- Fundamental Concepts (10 lectures): Physical concept of radiation, mathematical expressions for radiated field for Herzian dipole, short dipole/monopole, and diploe/monopole of arbitrary length, near-field and far-field, radiation integrals, radiation pattern, gain, directivity, effective aperture, polarization, input impedance, efficiency, antenna feeds, friis transmission equation, the concept of nose temperature, and G/T ratio.

- Antenna Arrays (6 lectures): Analysis and design of uniformly-spaced arrays with uniform and non-uniform excitation, planar arrays, synthesis of antenna arrays using Schelkunof polynomial method, Woodward-Lawson method.

- Aperture and Reflector Antennas (6 lectures): Huygens ' Principle, radiation from circular and rectangular apertures, design considerations, Babinet's principle, radiation from sectoral and pyramidal horns, design concepts, parabolic reflector and Cassegrain antennas.

- Broadband Antennas (6 lectures): Log periodic and Yagi antennas, frequency-independent antennas, broadcast antennas, spiral antennas.

- Microstrip Antennas (6 lectures): Basic characteristics (resonant frequency, input impedance, feed technique, radiation pattern, etc.) of microstrip antennas, methods of analysis, design of rectangular and circular patch antennas, design of printed dipoles.

- Smart Antennas (6 lectures): Concepts and benefits of smart antennas, Fixed weight beam-forming basics, Adaptive beam-forming.

Course Outcomes

CO1 Ability to design commonly used antennas in wireless communication systems

CO2 Ability to undertake new research challenges in the field

Evaluation Pattern and Grading Policy

1. Three quizzes 15%
2. Random attendance checks 10%
3. Mid-term examination (s) 25%
4. Final Examination 50%

Text and Reference Books

1. Edward C. Jordan and Keith G. Balmain, *Electromagnetic Waves and Radiating Systems*, PHI Learning Private Limited, New Delhi, 2011.
2. R. S. Elliot, *Antenna Theory and Design*, Willey-IEEE Press, 2003.
3. Internet Based Material

Course: Switching and Telecommunication Networks

Category: Elective - PG Program (ECE/CCE/CSE)

Credits: 4 (4-0-0)

Prerequisites: Computer Networks, Wireless Networks (either one)

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

Course Outline

- Basics: General architecture of telecommunication networks, Core and access networks, Circuit, packet and message switching, Architecture of public switched telephone networks, Speech coding, A- law, u- law, Space, time and frequency division multiplexing, Circuit switched networks: T- and E carrier systems, Signaling: in-band and out of band signaling, SS7 , General architecture of electronic switches: TS, ST and TST switching N-ISDN, B-ISDN, ATM, Tele-traffic theory: blocking probability, Network management, billing and accounting

- Fundamentals of packet switched networks: Review of ISO/OSI architecture, Review of Internet architecture, Review of DLC, Network and Transport layers, CSMA/CD: Ethernet, Metro area Ethernet, xDSL, Service differentiation over packet switched networks, IPv4, IPv6, DHCP etc, Congestion control: packet dropping strategies, Wireless data networks: infrastructure and infrastructure less, networks; WLAN basics

- Fundamentals of network Security: Cryptographic basics, Provisioning of security, Trust, privacy, authentication, Authentication, authorization, accounting ,

- Cellular networks: GSM, Architecture of GSM PLMN, Radio interface, Channel structure, Speech and data services, NSS, BSS and OMC elements, Channel measurements, Call management, location management, handover management,

- Convergence: Network convergence: merging of circuit and packet switched networking architectures, Service convergence: residual bit rate, interactive, streaming and real time conversational services , Quality of services management, Security management in a converged network, Mobility management MIP, FMIP, HMIP and MIPv6, Issues with mobility management in WLAN: WISPr and WAVE, Session initiation protocol (SIP), Traffic engineering: MPLS , UMTS, W-CDMA and LTE architectures

Course Outcomes

CO1 The students will learn about fundamentals of telecommunication networks in the context of wireless networks, mobility, security and Qoality of services management, network and service convergence etc.

Evaluation Pattern and Grading Policy

Text and Reference Books

The course will be primarily guided by recent research literature. The following list is illustrative and not exhaustive.

1. IEEE Communications Magazine
2. IEEE Networks Magazine
3. MPLS-Enabled Applications: Emerging Developments and New Technologies, 3rd Ed (Ina Minei & Lucek)
4. Computer Networks: Tanenbaum, 5th Ed, 2010
5. Digital Telephony: John Bellamy 3rd Ed, 2006
6. IMS Multimedia telephony over cellular Systems: Shyam Chakraborty, Janne Peisa, T. Frankkila, P. Sunnergren. J. Wiley 2007
7. Heterogeneous Wireless Networks: H. Fathi, Shyam Chakraborty, R. Prasad, Springer 2008
8. ntelligent Transport Systems: 802.11-based Roadside-to-Vehicle Communication, Hasan, Siddique, Chakraborty, Springer, 2012
9. VoIP in Wireless Heterogeneous Networks: Signaling, Mobility, Security: Fathi, Chakraborty, Prasad, Springer 2008
10. Optimization of Mobile IPv6-Based Handovers to Support VoIP Services in Wireless Heterogeneous Networks, Fathi, Chakraborty, Prasad, IEEE Trans Vehicular Technology 2007
11. On the impact of security on latency in WLAN 802.11b, Fathi, Chakraborty, Prasad, Globecom 2005
12. PhD thesis of Allen Miu, MIT, 2005
13. Method For Performing Handoff In A Packet-Switched Cellular Communications System, Torsner, Sagfors, Chakraborty, International Patent, WO/2007/045280

Course: Design System Design

Category: Program Elective - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: Digital Circuits and Systems

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

The goal of the course is to introduce digital design techniques using field programmable gate arrays (FPGAs). We will discuss FPGA architecture, digital design flow using FPGAs, and other technologies associated with field programmable gate arrays.

Course Outline

- **UNIT – I - 4 hours** Number Systems and Codes, Digital Circuits, Sequential Circuits, Arithmetic Circuits, Timing Issues in Combinational and Sequential System, Digital System Design using SSI/MSI Components, Algorithmic State Machine (ASM), Digital System Design using ASM Chart
- **Unit - II 7 hours** Behavioral, Data Flow, Structural Models, Simulation Cycles, Concurrent Statements, Sequential Statements, Delay Models, Sequential Circuits, FSM coding, Advanced Topics for VHDL Coding, Introduction to Test bench, Advanced Testbench Writing
- **UNIT - III 5 hours** FPGA's History and Future, The key thing about FPGAs, Fusible link technologies, Antifuse technologies, Mask-programmed devices, PROMs, EPROM-based technologies, EEPROM-based technologies, FLASH-based technologies, SRAM-based technologies, Programmable Read Only Memories (PROMs), Programmable Logic Arrays (PLAs), Programmable Array Logic (PALs), The Masked Gate Array ASIC, CPLDs and FPGAs.
- **UNIT - IV 6 hours** FPGA Architectures, Configurable Logic Blocks, Configurable I/O Blocks, Embedded Devices, Programmable Interconnect, Clock Circuitry, SRAM vs. Antifuse Programming, Antifuse versus SRAM, Fine-medium and coarse grained architectures, MUX vs. LUT based-logic blocks, CLBs versus LABs slices, Fast Carry Chains, Embedded RAMs,Embedded multipliers, adders, MACs, Embedded processor cores (hard and soft), Clock trees and clock managers, General Purpose I/O

- **UNIT - V 8 hours** The Y-Chart - Levels and Domains of Description, Design Flow and Taxonomy of Synthesis: System- Level Synthesis, High-Level Synthesis, Register-Transfer Level Synthesis, Logic-Level Synthesis, Technology Mapping
- **UNIT - VI 10 hours** Digital System Design Methods: Top-Bottom, Bottom-Top, Design Partitioning, Functional modeling, RTL Design, RTL Optimization, Logic Synthesis, Mapping, Place & Route, Case Studies

Course Outcomes

CO1 Develop skills, techniques and learn state-of-the-art engineering tools to design, implement and test modern-day digital systems on FPGAs

CO2 Analyze the results of logic and timing simulations and to use these simulation results to debug digital system.

CO3 Learn by using Xilinx Foundation tools and Hardware Description Language (VHDL).

CO4 Understand modern CAD tools for design of complex digital circuits using FPGA.

CO5 Learn through hands-on experimentation the Xilinx tools for FPGA design as well as the basics of VHDL to design and simulate systems.

Evaluation Pattern and Grading Policy

- Assignments (~ 4) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. ”Digital Design: Principles and Practises”, John F. Wakerly, 2006 Pearson.
2. ”Circuit Design and Simulation with VHDL” Volnei A. Pedroni, 2nd Ed., MIT Press, Cambridge, Massachusetts.
3. Navabi, Zinalabedin. VHDL: Analysis and Modeling of Digital Systems, 2nd. ed. 1998. McGraw Hill. ISBN 0-07-046479-0

4. ”VHDL Design: Representation and Synthesis” 2nd Edition, by J. Armstrong and F. G. Gray, 2000

5. ”Logic Design Principles” by Edward McCluskey, Prentice Hall, 1986

6. ”Digital Design Using FPGAs” by Pak Chan et. al. Prentice Hall, 1994

7. ”VHDL for Programmable Logic”, Kevin Skahill, Cypress SemiConductor.

Course: Design for Testability

Category: Program Elective - First year PG Program (ECE)

Credits: 4 (3-0-0)

Prerequisites: Digital VLSI

Course Resources: `http://learning.lnmiit.ac.in/moodle`

Course Instructor:

Objectives of the Course

Overview of digital systems testing and testable design. Test economics, fault modeling, logic and fault simulation, testability measures, test generation for combinational circuits, memory test, delay test, IDDQ test, scan design, and boundary scan.

Course Outline

- **UNIT – I - 10 hours** Introduction, VLSI Testing Process and Test Equipmentm Test Economics and Product Quality, Fault Modeling
- **Unit - II 20 hours** Logic and fault simulation, Diagnosis ,Testability measures, Combinational circuit Automatic Test Pattern Generation (ATPG),Sequential circuit ATPG, Memory test and Delay test, IDDQ test
- **UNIT - III 10 hours** Scan design, Built-In-Self-Test (BIST), Boundary Scan Standard, System test and core-based design

Course Outcomes

CO1 Understand the economics of testable design and the concept of yield.

CO2 Learn about defects, errors and faults and their models.

CO3 Learn about logic and fault simulation: compiled-code and event-driven simulation.

CO4 Learn about combinational circuit test generation, Memory test, delay test and IDDQ test.

CO5 Learn about Digital DFT and scan design.

Evaluation Pattern and Grading Policy

- Assignments (~ 4) 25%
- Mid-Term Examination 25%
- End-Term Examination 40%
- Simulation of a research paper 10%

Text and Reference Books

1. Bushnell and V. Agrawal, “Essentials of Electronic Testing for Digital, Memory & Mixed-Signal VLSI Circuits”, Kluwer Academic Publishers, 2000
2. M. Abramovici, M. Breuer, and A. Friedman, “Digital Systems Testing and Testable Design, IEEE Press, 1990
3. J. Van De Goor, “Testing Semiconductor Memories: Theory and Practice”, Wiley and Sons, 1991
4. Krstic and K. Cheng, “Delay Fault Testing for VLSI Circuits”, Kluwer Academic Publishers, 1998
5. Stroud, “A Designer’s Guide to Built-in Self Test”, Kluwer Academic Publishers, 2002