

Silicon Institute of Technology
| An Autonomous Institute |

Curriculum Structure and Detailed Syllabus

**Master of Technology
in
Electronics & Communication Engineering**



**Department of Electronics & Communication Engineering
Silicon Institute of Technology
Silicon Hills, Patia, Bhubaneswar - 751024**

Effective from Academic Year 2022-23
Version: 2.10 (Build: 22-08-2022)

Approval History

ACM#	Date	Resolutions
AC-8	13/08/2022	The curriculum structure and detailed syllabus of 1st and 2nd years as proposed by the Boards of Studies is approved by the Academic Council.

Program Outcomes

Program Outcomes (POs) form a set of individually assessable outcomes that are the components indicative of the post-graduate's potential to acquire competence to practice at the appropriate level. The following POs have been defined for the M.Tech programmes in line with NBA, so that the outcomes can be assessed in a similar manner to UG Engineering programmes:

- PO1. Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
- PO2. Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
- PO3. Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
- PO4. Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
- PO5. Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
- PO6. Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
- PO7. Understand the impact of electronics & communications in an economic, social and environment context.
- PO8. Understand intellectual property rights and overall professional & ethical responsibility.
- PO9. Communicate effectively in a technically sound manner with a wide range of audience.
- PO10. Continue to learn independently and engage in life-long learning.

Program Educational Objectives (PEOs)

- PEO1. To imbibe technical skills to create, find solutions, and propose improvements for complex problems encountered in Electronics & Communication Engineering for betterment of society, mankind, and environment.
- PEO2. To inculcate an attitude to adopt changing technologies in Electronics & Communication Engineering through critical observation, survey, experimentation, and research independently or collaboratively.
- PEO3. To provide professional & intellectual integrity, motivation to engage in research & development, and communicate innovative ideas effectively for advancement of society.

Program Specific Outcomes (PSOs)

- PSO1. Apply concepts of Electronics & Communication Engineering to design and implement complex systems.
- PSO2. Develop hardware, software, or embedded solutions & tools for solving real life problems in electronics and communication domains using acquired knowledge of science, mathematics, and engineering.
- PSO3. Engage as an electronics and communication engineering specialist in industry, higher studies, research & development, academics, or as an entrepreneur.

Course Types & Definitions

L	Lecture
T	Tutorial
P	Practical / Sessional / Laboratory
WCH	Weekly Contact Hours
BS	Basic Sciences
PC	Professional Core
PE	Professional Elective
MC	Mandatory Course
OO	MOOC (Massive Open Online Course)
PJ	Summer Internship / Project Work

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Part I
1st Year M.Tech. (ECE)

Curriculum Structure

Semester I								
Type	Code	Course Title	WCH L-T-P			Credits L-T-P		
THEORY								
PC	MTEC-T-PC-001	Mathematics for Communication Engineering	3	1	0	3	1	0
PC	MTEC-T-PC-002	Advanced Semiconductor Devices	3	1	0	3	1	0
PC	MTEC-T-PC-003	Modern Communication Systems	3	0	0	3	0	0
PC	MTEC-T-PC-004	IoT & Embedded Systems	3	0	0	3	0	0
PE		Professional Elective - I	3	0	0	3	0	0
MC	MTBS-T-MC-005	Research Methodology & IPR	2	0	0	2	0	0
PRACTICAL								
PC	MTEC-P-PC-002	Advanced SemiConductor Devices Lab	0	0	2	0	0	1
PC	MTEC-P-PC-003	Modern Communication Systems Lab	0	0	2	0	0	1
PC	MTEC-P-PC-004	IoT & Embedded Systems Design Lab	0	0	2	0	0	1
SUB-TOTAL			17	2	6	15	2	3
TOTAL			25			20		

Semester II								
Type	Code	Course Title	WCH L-T-P			Credits L-T-P		
THEORY								
PC	MTEC-T-PC-005	Advanced Digital Signal Processing	3	0	0	3	0	0
PC	MTEC-T-PC-006	VLSI System Design & Verification	3	0	0	3	0	0
PC	MTEC-T-PC-007	Soft Computing	3	0	0	3	0	0
PE		Professional Elective - II	3	0	0	3	0	0
PE		Professional Elective - III	3	0	0	3	0	0
MC	MTBS-T-MC-009	English for Research Paper Writing	2	0	0	0	0	0
PRACTICAL								
PC	MTEC-P-PC-006	VLSI System Design & Verification Lab	0	0	2	0	0	1
PC	MTEC-P-PC-008	Advanced Technologies Lab	0	0	4	0	0	2
SUB-TOTAL			17	0	6	15	0	3
TOTAL			23			18		

Note: Courses offered under each elective are given in "List of Electives" on Page 3.

List of Electives

Code	Elective # and Subjects
<i>Professional Elective - I</i>	
MTEC-T-PE-001	IC Fabrication Technology
MTEC-T-PE-002	Smart Sensors for IoT Applications
MTEC-T-PE-003	Information Theory and Coding
<i>Professional Elective - II</i>	
MTEC-T-PE-004	Analog & Mixed Signal Design
MTEC-T-PE-005	IoT Protocols & Architecture
MTEC-T-PE-006	Digital Video & Speech Processing
<i>Professional Elective - III</i>	
MTEC-T-PE-007	Digital Integrated Circuit Design
MTEC-T-PE-008	Embedded Systems for Wireless Communication
MTEC-T-PE-009	Image Processing & Computer Vision

Type	Code	Mathematics for Communication Engineering	L-T-P	Credits	Marks
PC	MTEC-T-PC-001		3-1-0	4	100

Objectives	The objective of this course is to learn Linear Algebra, Probability theory and other mathematics components which are required to formulate electronics and communication engineering problems.
Pre-Requisites	Knowledge of set theory, matrix algebra, integration, differentiation, and Calculus of several variables is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Vector Spaces, subspaces, linear independence, basis, dimension, linear transformation, perpendicular vectors and orthogonal subspaces, inner product and projection, least square approximation, orthogonal basis.	9 Hours
Module-2	Eigen values and Eigen vector, Diagonalisation, complex vectors and matrices, Singular value decomposition, pseudo inverse of a matrix.	9 Hours
Module-3	Joint Distribution of Random variables, Independent Random variables, Covariance and correlation coefficient, Expected value of a Random vector and variance-covariance matrix, Conditional Distribution, Conditional Expectation given a σ Algebra, Multivariate Normal Distribution, The weak and strong law of Large numbers, Central limit Theorem.	11 Hours
Module-4	Definitions and properties of stochastic process, Discrete-time Markov chain, Continuous-time Markov chain, Poisson process.	10 Hours
Module-5	Optimization Techniques: Calculus of several variables, Implicit function theorem, Nature of singular points, Necessary and sufficient conditions for optimization, Constrained Optimization, Lagrange multipliers, Gradient method - steepest descent method.	8 Hours
Module-6	Constrained Optimization: Frank Wolfe's Method, Rosen's Gradient Projection method, Penalty function method, Barrier function method.	9 Hours
Total		56 Hours

Text Books:

- T1. G. Strang, *Linear Algebra and Applications*, 4th Edition, Cengage Learning, 2005.
- T2. L. B. Castaneda, V. Arunachalam, and S. Dharmaraja, *Introduction to Probability and Stochastic Processes with Applications*, 1st Edition, Wiley, 2012.
- T3. S. S. Rao, *Optimization: Theory and Application*, 2nd Edition, Wiley Eastern Ltd., 1984.
- T4. S. Chandra, Jayadeva, and A. Mehera, *Numerical Optimization with Applications*, 1st Edition, Narosa Publishing House, 2013.

P.T.O

Reference Books:

- R1. K. E. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 1989.
 R2. S. S. Rao, *Engineering Optimization: Theory and Practice*, Wiley-Interscience Publication, 1996.

Online Resources:

1. <https://nptel.ac.in/courses/111/107/111107106/>: by Prof. P. N. Agrawal, IIT Roorkee
2. <https://nptel.ac.in/courses/111104137/>: by Prof. A. K. Lal, IIT Kanpur
3. <https://nptel.ac.in/courses/111/102/111102134/>: by Prof. N. Chatterjee, IIT Delhi
4. <https://nptel.ac.in/courses/111107104/>: by Prof. S. K. Gupta, IIT Roorkee
5. <http://www.math.iitb.ac.in/~baskar/book.pdf>
6. <http://www2.math.umd.edu/~dlevy/books/na.pdf>
7. <http://www.sam.math.ethz.ch/~hiptmair/tmp/NumCSE/NumCSE15.pdf>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Apply the concepts of least square approximation to engineering problems.
CO2	Use Eigen values and eigenvectors of a matrix to factorize it.
CO3	Apply the concepts of probability to signal processing.
CO4	Apply the concepts of Stochastic Process to signals.
CO5	Optimize and solve real life problems in communication engineering.
CO6	Solve constrained optimization problems in communication engineering.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	3	2						2	1	1	3
CO2	3	3	3	2						3	1	1	3
CO3	3	3	3	2						2	1	1	3
CO4	3	3	3	3						3	2	1	3
CO5	3	3	2	2						2	2	1	1
CO6	3	3	2	2						2	2	1	1

Type	Code	Advanced Semiconductor Devices	L-T-P	Credits	Marks
PC	MTEC-T-PC-002		3-1-0	4	100

Objectives	The objective of this course is to study the characteristics of different advanced semiconductor devices including MOSFETs and advanced CMOS technologies used in modern electronics equipment.
Pre-Requisites	Basics of circuit analysis, Laplace transform, Fourier transform and differential equations are required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: Review of quantum mechanics, Electrons in periodic lattices, E-K diagrams, Energy bands in solids; Electrons and Holes in Semiconductors: Silicon crystal structure, Donors and acceptors in the band model, effective mass, Density of states (D(E)), Thermal equilibrium, Fermi-Dirac distribution function (f(E)) for electrons and holes, Fermi energy, Fermi level and carrier concentrations.	12 Hours
Module-2	PN Junction Diode: P-N junction characteristics; Building blocks of the pn junction theory, Energy band diagram and depletion layer of a pn junction, Built-in potential, Carrier injection under forward bias-Quasi-equilibrium boundary condition; Current continuity equation, I-V characteristics, Reverse biased P-N junction: Avalanche breakdown, Zener diode.	11 Hours
Module-3	MOS Capacitor and MOSFET: The MOS structure, Energy band diagrams, Surface accumulation, Surface depletion, Flat-band condition and flat-band voltage, Threshold condition and threshold voltage, C-V characteristics of ideal MOS capacitor, Basic structure of MOSFET, Threshold Voltage of MOSFET, Inversion charge and I-V Characteristics	11 Hours
Module-4	Scaling and Short Channel Effects: ITRS roadmap for semiconductor, different groups of MOSFETs, Three MOS types, low leakage MOSFETs, Gate-Oxide Scaling, GIDL and Gate tunnel currents, Gate length scaling, Short channel effects.	11 Hours
Module-5	Advanced CMOS Technologies and Nanoscale Devices: Heterojunction MOSFET, Strained Si MOSFET for higher mobility, Staggered heterojunction MOSFET, High-K materials, Gate stack and Channel stack technology, Reverse short channel effect and HALO doping, SOI technologies: SOI CMOS design, Multiple Gate MOS Structures: Double Gate MOSFET, FinFET and Surrounding Gate MOSFET.	11 Hours
Total		56 Hours

Text Books:

T1. D. A. Neamen, *Semiconductor Physics and Devices*, 4th Edition, McGraw-Hill, 2012.

- T2. S. M. Sze and K. N. Kwok, *Physics of Semiconductor Devices*, 3rd Edition, John Wiley & Sons, 2006.
 T3. A. Sarkar, S. De, and C. K. Sarkar, *VLSI Design and EDA Tools*, 1st Edition, SciTech, 2013.

Reference Books:

- R1. G. Streetman and S. K. Banerjee, *Solid State Electronic Devices*, 7th Edition, Pearson, 2014.
 R2. C. C. Hu, *Modern Semiconductor Devices for Integrated Circuits*, 1st Edition, Pearson, 2010.
 R3. R. S. Muller and T. I. Kamins, *Device Electronics for Integrated Circuits*, 3rd Edition, Wiley, 2007.
 R4. Y. Tsividis and M. Colin, *Operation and Modelling of MOS Transistor*, 3rd Edition, Oxford University Press, 2011.
 R5. C. K Maiti, S. Chattopadhyay, and L. K. Bera, *Strained-Si Heterostructure Field Effect Devices*, 1st Edition, CRC Press, 2007.

Online Resources:

1. <https://nptel.ac.in/courses/108108122/>: by Prof. D. N. Nath, IISc Bangalore
2. <https://nptel.ac.in/courses/117108047/>: by Dr. N. Bhat and others, IISc Bangalore
3. <https://www.digimat.in/nptel/courses/video/108107129/L01.html>
4. <https://www.digimat.in/nptel/courses/video/117107149/L42.html>
5. <http://www.digimat.in/nptel/courses/video/117108047/L17.html>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the fundamentals of energy band structure in semiconductors and carrier distribution under equilibrium.
CO2	Describe the detail characteristic of p-n junction diode and its applications.
CO3	Articulate MOS transistor structure and its characteristics.
CO4	Understand the limitations of downscaling the size of MOS transistor.
CO5	Explore advanced CMOS technologies and the nanoscale MOS structures.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3		2	2		1			2	3	2	3
CO2	3	3		3	2		2			2	3	3	2
CO3	3	3		3	3		2			3	3	3	3
CO4	3	3		2	3		2			2	2	3	2
CO5	3	3		3	2		3			2	3	3	2

Type	Code	Modern Communication Systems	L-T-P	Credits	Marks
PC	MTEC-T-PC-003		3-0-0	0	100

Objectives	The objective of this course is to study the basic concepts of digital communication systems including the performance of optimum receiver in presence of AWGN, multi-channel, multi-carrier systems and spread spectrum techniques.
Pre-Requisites	Knowledge of analog and digital communication is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Digital Communication Systems: Introduction, concepts of sampling in transmitting multiple band limited signals, concepts of signal reconstruction, quantization of signals, uniform and non-uniform quantization system, companding, μ -law and A-law compressions, input-output characteristics, PCM, DPCM and DM.	9 Hours
Module-2	Digital Modulation Schemes: Representation of digitally modulated signals, Generation, Detection, Signal-space diagram, Error probability calculation and power spectra: Binary phase shift keying (BPSK), Quadrature phase shift keying (QPSK), Quadrature Amplitude modulation (QAM), Binary frequency shift keying (BFSK), and Minimum shift keying (MSK).	9 Hours
Module-3	Optimum Receivers: Base-band signal Receiver, Peak signal to RMS noise output voltage ratio, Probability of error, Optimum threshold, Optimum receiver for both base-band and pass-band: Calculation of optimum filter transfer function, Optimum filter realization using matched filter, Probability error of the matched filter, Optimum filter realization using correlator.	8 Hours
Module-4	Multi-channel and Multi-carrier Systems: Multichannel Digital Communications in AWGN Channels; Binary Signals, M-ary Orthogonal Signals. Multicarrier Communications; Single Carrier verses Multicarrier Modulation, Capacity of a Non ideal Linear Filter Channel, OFDM, Modulation & Demodulation using OFDM.	8 Hours
Module-5	Spread Spectrum Signals for Digital Communication: Model of Spread spectrum Digital Communication System, Direct Sequence Spread Spectrum Signals, Error Rate Performance of the Decoder, Some Applications of DS Spread Spectrum Signals, Frequency-Hopped Spread-Spectrum Signals, Performance of FH Spread Spectrum Signals in an AWGN Channel, A CDMA System Based on FH Spread Spectrum Signals.	8 Hours
Total		42 Hours

Text Books:

- T1. H. Taub, D. L. Schilling, and G. Saha, *Principles of Communication Systems*, 4th Edition, Tata McGraw-Hill, 2013.
- T2. B. P. Lathi and Z. Ding, *Modern Digital and Analog Communication Systems*, 4th Edition, Oxford University Press, 2010.
- T3. S. Haykin, *An Introduction to Analog and Digital communications*, 2nd Edition, Wiley, 2007.
- T4. J. G. Proakis and M. Salehi, *Digital Communication*, 5th Edition, McGraw-Hill, 2014.

Reference Books:

- R1. L. W. Couch-II, *Digital and Analog Communication System*, 8th Edition, Pearson Education, 2013.
- R2. B. Sklar, *Digital Communications - Fundamentals and Applications*, 2nd Edition, Pearson Education, 2009.

Online Resources:

1. <https://nptel.ac.in/courses/117101051>: by Prof. B. K. Dey, IIT Bombay
2. <https://nptel.ac.in/courses/117104115>: by Prof. A. K. Jagannatham
3. <https://freevideolectures.com/course/2314/communication-engineering/32>
4. <https://www.digimat.in/nptel/courses/video/117105136/L39.html>
5. <https://freevideolectures.com/course/4701/nptel-principles-communication-systems-i/51>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the sampling theorem, practical issues related to sampling, signal reconstruction, quantization, encoding along with applications.
CO2	Apply digital modulation & demodulation techniques considering bandwidth, SNR and power spectral efficiency.
CO3	Design optimum receivers for pass band and base band communications and compare the performance of correlator receiver with matched filter reception.
CO4	Apply the concepts of high-speed signal transmission simultaneously (multiplexing) using multiple carrier signals for efficient bandwidth requirements.
CO5	Analyze the performance of spread spectrum systems in the presence of inter reference and AWGN.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

P.T.O

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	1	2				2	1	2	2	1
CO2	3	3	2	3	2				2	1	3	2	1
CO3	2	3	2	1					1		2	1	1
CO4	3	2	3	2	3				2	1	3	2	1
CO5	3	2	2	1					1	1	2	1	2

Type	Code	IoT & Embedded Systems	L-T-P	Credits	Marks
PC	MTEC-T-PC-004		3-0-0	3	100

Objectives	The objective of this course is to learn the different components of Internet of Things, Embedded Systems and their applications in the real world.
Pre-Requisites	Basic knowledge of Microcontrollers and Sensors is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on theory and programming activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction to IoT : Applications of IOT, Structure of IoT, Physical and logical design of IoT, IoT Level and deployment template.	10 Hours
Module-2	IoT Sensors: Industrial sensors - Description & Characteristics – First Generation, Advanced Generation, Integrated IoT Sensors, Polytronics Systems, Sensors' Swarm, Printed Electronics, IoT Generation Roadmap.	8 Hours
Module-3	IoT Reference Model: Domain, information, functional and communication models; Application Protocols for IoT: UPnP, CoAP, MQTT, XMPP. REST API, AMSP, DDS, Web Socket; IP-based protocols: 6LoWPAN, RPL; Authentication Protocols; IEEE 802.15.4.	8 Hours
Module-4	Embedded Systems: Application Areas, Categories of embedded systems, Overview of embedded system architecture, Hardware architecture, Software architecture, Application Software, Communication Software.	8 Hours
Module-5	ARM Architecture: Architecture Versions, Processor Naming, Instruction Set Development, Thumb-2 and Instruction Set Architecture. Cortex-M3 Basics: Registers, General Purpose Registers, Operation Mode, Exceptions and Interrupts, Vector Tables, Stack Memory Operations, Reset Sequence. CortexM3Instruction Sets, Instruction Descriptions.	8 Hours
Total		42 Hours

Text Books:

- T1. A. Bahaga and V. Madiseti, *Internet of Things: A Hands-on Approach*, 1st Edition, University Press, 2014.
- T2. J. Yiu, *The Definitive Guide to the ARM Cortex-M3*, 2nd Edition, Elsevier, 2010.

Reference Books:

- R1. O. Hersent, D. Boswarthick, O. Elloumi, *The Internet of Things - Key Applications & Protocols*, Student Edition, Wiley, 2015.
- R2. S.Furber, *ARM System-on-Chip Architecture*, 2nd Edition, Pearson Education, 2015.

Online Resources:

1. <https://nptel.ac.in/courses/106/105/106105195/>: by Prof. S. Misra, IIT Kharagpur.
2. <https://nptel.ac.in/courses/108/108/108108098/>: by Prof. T. V. Prabhakar, IISc Bangalore

3. <https://nptel.ac.in/courses/106/105/106105166/>: by Prof. S. Misra, IIT Kharagpur
4. <https://nptel.ac.in/courses/108/102/108102169/>: by Prof. D. V. Gadre and Prof. B. N. Subudhi, IIT Jammu
5. <https://nptel.ac.in/courses/106/105/106105193/>: by Prof. I. Sengupta and Prof. K. Datta, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the different designs of IoT and their levels of deployment.
CO2	Explain the different industrial sensors and their applications.
CO3	Articulate the IoT reference model and application protocols.
CO4	Describe the application areas of embedded systems and their architectures.
CO5	Explain the different versions of ARM processors architecture and instructions.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	3	2						1	2	2
CO2	3	3	2	2	2						3	3	3
CO3	2	2	3	2	2						3	2	2
CO4	3	2	2	3	2						1	2	2
CO5	3	3	2	2	2						3	3	3

Type	Code	IC Fabrication Technology	L-T-P	Credits	Marks
PE	MTEC-T-PE-001		3-0-0	0	100

Objectives	The objective of this course is to understand and explore the fabrication flow and IC integration processes of semiconductor devices and semiconductor ICs.
Pre-Requisites	Basic knowledge on semiconductor devices and digital VLSI design is desired.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: Moore's Law and material processing, Defects in crystals, Eutectic phase diagram, Solid solubility, Homogeneous nucleation, Heterogeneous Nucleation; Growth Processes: Crystal Growth-Necking and dislocation free CZ crystal growth, Segregation of impurities along length and diameter, Defects in CZ crystals, FZ Crystal growth; Epitaxy: Vapor phase epitaxy, LPE, MBE, CVD deposition of Polysilicon, SILOX Process.	9 Hours
Module-2	Diffusion: Constant & limited source diffusion, Concentration dependent diffusion, Field assisted diffusion, Junction depth, Open and closed tube diffusion, Diffusion sources; Ion Implantation: Basic process, Ion Implantation Systems, Ion penetration & profile, Ion Implantation Damage.	8 Hours
Module-3	Annealing Oxidation: Purpose, Dry and wet oxidation, Deal-Grove model, Oxidation system, Properties of oxides - Masking and charges in oxides; Deposition Processes: Fundamentals of vacuum systems, Vacuum evaporation of thin films, DC and RF Sputtering of thin films, Interconnects, Contacts and dielectrics in IC Fabrication, Deposition of Silicon Nitride, Silicides and insulating layers.	9 Hours
Module-4	Lithography: Pattern generation and mask making, Optical Lithography - Contact, Proximity and Projection Printing, Photoresists - Negative, Positive, Lift-off process, Electron beam and X-ray lithographic techniques; Etching: Wet Etching, Isotropic and Anisotropic Etching, Plasma Etching, Reactive Ion Beam Etching.	8 Hours
Module-5	IC Process Integration: Bipolar Transistor Fabrication, Isolation techniques, P-MOS, N-MOS and C-MOS processes, IC Fabrication Process Integration, IC Process Yield and Reliability.	8 Hours
Total		42 Hours

Text Books:

- T1. S. K. Gandhi, *VLSI Fabrication Principles: Silicon and Gallium Arsenide*, 2nd Edition, Wiley, 1994.
- T2. S. M. Sze, *VLSI Technology*, 2nd Edition, McGraw-Hill Education, 2017.

Reference Books:

- R1. J. Plummer, M. Deal, and P. Griffin, *Silicon VLSI Technology: Fundamentals, Practice, and Modeling*, Prentice Hall, 2000.
- R2. M. J. Madou, *Fundamentals of Micro Fabrication: The Science of Miniaturization*, 2nd Edition, CRC Press, 2002.
- R3. S. Mahajan, *Principles of Growth and Processing of Semiconductors*, McGraw-Hill Education, 1999.
- R4. S. A. Campbell, *The Science & Engineering of Microelectronics Fabrication*, 2nd Edition, Oxford University Press, 2001.

Online Resources:

1. <https://nptel.ac.in/courses/108101089/>: by Prof. A. N. Chandorkar, IIT Bombay
2. <https://nptel.ac.in/courses/113106062/>: by Prof. P. Swaminathan, IIT Madras
3. <https://nptel.ac.in/courses/103106075/>: by Dr. S. Ramanathan, IIT Madras
4. <https://ocw.mit.edu/courses/6-780-semiconductor-manufacturing-spring-2003/>
5. <https://nptel.ac.in/courses/117/106/117106093/>: by Dr. N. Dasgupta, IIT Madras

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain basic concepts IC fabrication like crystal growth and epitaxy.
CO2	Describe the diffusion and ion implantation process for IC fabrication.
CO3	Explain annealing oxidation and other material deposition processes.
CO4	Analyze & articulate lithography process and various etching processes.
CO5	Analyze and explain IC fabrication process integration.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	2	1		2								1
CO2	2	2	2								1	1	1
CO3	2	2	2								2	1	1
CO4	1	3	3							1	1	2	1
CO5	2	3	3							1	1	2	1

Type	Code	Smart Sensors for IoT Applications	L-T-P	Credits	Marks
PE	MTEC-T-PE-002		3-0-0	3	100

Objectives	The objective of this course is to study the design and implementation of IoT applications using Smart Sensors, Protocols and IoT infrastructure for various applications by using sensors.
Pre-Requisites	Basic knowledge of sensors, transducer and protocols is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on examples & case studies.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Smart Sensor Basics: Introduction, Mechanical-Electronic Transitions in Sensing, Nature of Sensors, Integration of Micromachining and Microelectronics.	7 Hours
Module-2	Sensor Outputs: Introduction, Sensor Output Characteristics, Other Sensing Technologies: Capacitive, Piezoelectric, Hall Effect, Chemical Sensors, Improving Sensor Characteristics; Digital Output Sensors: Incremental Optical Encoders, Digital Techniques, Noise/Interference Aspects; Low-Power, Low-Voltage Sensors: Impedance; Analysis of Sensitivity Improvement: Thin Diaphragm, Increased Diaphragm Area.	10 Hours
Module-3	Interfacing Mechanism: Introduction, Amplification and Signal Conditioning: Instrumentation Amplifiers, SLEEPMODE Operational Amplifier, Rail-to-Rail Operational Simplifiers, Switched-Capacitor Amplifier, Barometer Application Circuit, 4-20 mA Signal Transmitter, Schmitt Trigger, Inherent Power-Supply Rejection; Separate Versus Integrated Signal Conditioning: Integrated Passive Elements, Integrated Active Elements; Digital Conversion.	9 Hours
Module-4	Communications for Smart Sensors: Introduction, Standards, Automotive Protocols: SAE J1850, CAN Protocol, Other Protocols; Industrial Networks, Protocols in Silicon: MCU With Integrated SAE J1850 and CAN, Neuronfi Chips and LonTalk Protocol, MI-Bus, Other MCUs and Protocols; Other Aspects of Network Communications: MCU Protocols, Transition Between Protocols and Systems, Protocol as a Module.	9 Hours
Module-5	Case Study: Biomimetic Materials and Structures for Sensor Applications; Smart Sensor Microsystems: Application-Dependent Design and Integration Approaches; Significance of IoT in the Agricultural Sector; Precision Agriculture Using Advanced Technology of IoT, Unmanned Aerial Vehicle, Augmented Reality and Machine Learning.	7 Hours
Total		42 Hours

Text Books:

T1. R. Frank, *Understanding Smart Sensors*, 3rd Edition, Artech House, 2013.

- T2. C. M. Kyung, H. Yasuura, Y. Liu, and Y-L. Lin, *Smart Sensors and Systems: Innovations for Medical, Environmental, and IoT Applications*, Springer, 2017.
- T3. D. Gupta, V. C. de Albuquerque, A. Khanna, and P. L. Mehta, *Smart Sensors for Industrial Internet of Things: Challenges, Solutions and Applications*, Springer, 2021.

Reference Books:

- R1. K. Iniewski, *Smart Sensors: For Industrial Applications*, CRC Press, 2013.
- R2. V. K. Awaar, P. Jugge, and P. Nayak, *Significance of Smart Sensors in IoT Applications*, 1st Edition, CRC Press, 2021.
- R3. H. Yasuura, C. M. Kyung, Y. Liu, and Y. L. S. Lin, *Smart Sensors at the IoT Frontier*, Springer, 2017.

Online Resources:

1. <https://nptel.ac.in/courses/108106165>: by Prof. S. Talukder, IISER Bhopal
2. <https://nptel.ac.in/courses/108108147>: by Prof. H. J. Pandya, IISc Bangalore

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the basics of smart sensors and integration mechanisms.
CO2	Analyze various sensing principles and characteristics of smart sensing technologies.
CO3	Articulate sensor interfacing schemes for designing smart applications.
CO4	Explain different communication protocols for smart sensors with MCUs.
CO5	Analyze and implement smart sensor applications in the real-world.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2	2	1		1		2	1	2	1	1
CO2	3	2	3	1	2		1		1	2	3	2	3
CO3	3	2	3	2	3				1	3	2	3	2
CO4	3	2	3	2	3				2	3	3	3	3
CO5	3	3	2	2	2				2	3	2	2	3

Type	Code	Information Theory & Coding	L-T-P	Credits	Marks
PE	MTEC-T-PE-003		3-0-0	3	100

Objectives	The objective of this course is to study the fundamentals of information theory like information measure in source, encoding of source output, modeling of communication channels, error control coding and convolutional code.
Pre-Requisites	Basic knowledge of probability theory, random variables, random processes, and digital communication is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours		
Module-1	Information Theory: Introduction, Measure of information, Information content of message, Average Information content of symbols in Long Independent sequences, Average Information content of symbols in Long dependent sequences, Mark-off Statistical Model for Information Sources, Entropy and Information rate of Mark off Sources.	8 Hours		
Module-2	Source Coding: Encoding of the Source Output, Shannon's Encoding Algorithm Shannon-Fano Encoding Algorithm, Source coding theorem, Prefix Codes, Kraft McMillan Inequality property (KMI), Huffman Codes, Arithmetic Coding, The Lempel-Ziv Algorithm.	9 Hours		
Module-3	Information Channels: Communication Channels, Discrete Communication channels and Channel Matrix, Joint probability Matrix, Binary Symmetric Channel, differential entropy, mutual Information, Channel Capacity, Channel Capacity of Binary Symmetric Channel, Channel capacity Theorem.	8 Hours		
Module-4	Error Control Coding: Introduction, Examples of Error control coding, methods of Controlling Errors, Types of Errors, types of Codes, Linear Block Codes: matrix description of Linear Block Codes, Error detection & Correction capabilities of Linear Block Codes, Single error correction Hamming code. Binary Cyclic Codes: Algebraic Structure of Cyclic Codes, Encoding using an (n-k) Bit Shift register, Syndrome Calculation, BCH codes.	9 Hours		
Module-5	Convolution Codes: Convolution Encoder, Time domain approach, Transform domain approach, Code Tree, Trellis and State Diagram, The Viterbi Algorithm.	8 Hours		
Total				42 Hours

Text Books:

- T1. R. Bose, *Information Theory, Coding and Cryptography*, 3rd Edition, Tata McGraw-Hill, 2016.
- T2. T. K. Moon, *Elements of Information Theory*, 2nd Edition, Wiley Interscience, 2006.

P.T.O

Reference Books:

- R1. S. Haykin, *Digital Communications*, Student Edition, Wiley India, 2008.
 R2. N. N. Rao, *Error Correction Coding*, Student Edition, Wiley India, 2006.

Online Resources:

1. <https://nptel.ac.in/courses/117101053>: by Prof. S. N. Merchant, IIT Bombay
2. <https://nptel.ac.in/courses/108108168>: by Prof. H. Tyagi, IISc Bangalore
3. <https://nptel.ac.in/courses/108102117>: by Prof. R. Bose, IIT Delhi
4. <https://nptel.ac.in/courses/117108097>: by Prof. P. S. Nuggehalli, IISc Bangalore

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the concepts of dependent & independent sources, measure of information, entropy, rate of information and order of a source.
CO2	Analyze the source information using different source coding techniques and different inequality schemes.
CO3	Represent the model of discrete communication channels using input, output and joint probabilities.
CO4	Design the encoding and decoding circuits for Linear Block codes, cyclic codes and BCH.
CO5	Analyze convolutional codes and apply Viterbi algorithm for determining a code word comprising of the check bits computed convolutional code.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	1	1						2		1	1
CO2	3	2	2	1						3	1	1	1
CO3	2	2	1	2						1	1	1	1
CO4	3	1	2	1						2	2	2	2
CO5	2	2	2	1						2	1	2	2

Type	Code	Research Methodology & IPR	L-T-P	Credits	Marks
MC	MTBS-T-MC-005		2-0-0	0	100

Objectives	The objective of this course is to introduce the principles and practices involved in conducting scientific research. The course is designed to cover three broad areas - The Scientific Method and Hypothesis Testing, Review of Literature and writing Technical Reports, and the elements of Intellectual Property Rights (IPR).
Pre-Requisites	Basic knowledge of probability & statistics will be helpful.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving & examples.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction to research, its significance and meaning; Types of research - fundamental, pure, theoretical, applied and experimental; Identification of the research problem and formulation of hypothesis; Research design and errors in research, error analysis; The Scientific Method as the established way of doing research; Data collection, measurement and scaling techniques.	8 Hours
Module-2	Meaning and need for hypothesis, Types of hypothesis, Functions and characteristics of a good hypothesis; Statistical testing of hypothesis – T-test, Chi-squared test; Sampling methods, Types of sampling, Probability and non-probability sampling; One-sample and two-sample tests, Correlation and regression analysis.	8 Hours
Module-3	Literature - types and review; Literature survey using the web, Search engines; Journal, report and thesis writing; Types of reports, Structure of the research report and presentation of results.	7 Hours
Module-4	Code of ethics in research - Intellectual Property Rights; Details of patents, Copyrights, Trademarks and Trade Secrets.	5 Hours
Total		28 Hours

Text Books:

- T1. C. R. Kothari & G. Garg, *Research Methodology: Methods and Techniques*, 2nd Edition, New Age International Publishers, 2004.
- T2. D. Chawla & N. Sodhi, *Research Methodology: Concepts and Cases*, 2nd Edition, Vikas Publishing, 2016.

Reference Books:

- R1. E. L. Lehman & J. P. Romano, *Testing Statistical Hypothesis*, 3rd Edition, Springer, 2008.
- R2. R. Panneerselvam, *Research Methodology*, 2nd Edition, Prentice Hall India, 2013.

P.T.O

Online Resources:

1. <https://nptel.ac.in/courses/127106227>: by Prof. S. Banerjee, IIT Madras
2. <https://nptel.ac.in/courses/109105115>: by Prof. A. Malik, IIT Kharagpur
3. <https://nptel.ac.in/courses/109105112>: by Prof. T. K. Bandyopadhyay, IIT Kharagpur
4. <https://ocw.mit.edu/courses/sloan-school-of-management/15-347-doctoral-seminar-in-research-methods-i-fall-2004/readings/>: MIT Open Courseware (MIT-OCW).

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Disseminate the scientific method as a structured way of conducting scientific research.
CO2	Apply statistical principles for conducting hypothesis testing.
CO3	Conduct effective review of literature and write technical reports.
CO4	Acquire knowledge of the various intellectual property rights.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	1	1	1					1	1	1	2
CO2	2	2	1	1	1					1		1	1
CO3					3				2	1		1	2
CO4								3		1		1	2

Type	Code	Advanced Semiconductor Devices Lab	L-T-P	Credits	Marks
PC	MTEC-P-PC-002		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide hands-on exposure on the characteristics of different semiconductor devices used in modern electronics equipment.
Pre-Requisites	Knowledge of physics of semiconductor devices and topics taught in the theory class are required.
Teaching Scheme	Regular laboratory experiments executed under the supervision of teachers. Demonstration on theoretical concepts and TCAD tool shall be given.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test/ Mini Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Design of MOSFET (channel length $1\mu\text{m}$) and study of its characteristics ($V_{GS} \sim ID$) and ($V_{DS} \sim ID$).
2	Design of a MOSFET and extraction of analog/RF performance parameters from the characteristic curves.
3	Design of a MOSFET and extraction of linearity performance parameters from the characteristic curves.
4	Study of the effect of gate oxide scaling and channel length scaling on the characteristic of MOSFETs.
5	Design of MOSFET using different High-K materials and comparison of their characteristics.
6	Design and study the characteristics of heterojunction MOSFET.
7	Design of a Tunnel FET and extraction of analog/RF performance parameters from the characteristic curves.
9	Design of SOI FinFET and extraction of its analog/RF performance parameters from the characteristic curves.
10	Design of Gate all-around (GAA) MOSFET and extraction of its analog/RF performance parameters from the characteristic curves.
11	Study and analysis of short channel effect in nanoscale devices.
12	Design and study the sensitivity characteristics of MOSFET as a biosensor.
13	Study of linearity performance of advanced nanoscale devices (FinFET/TFET/GAA FET).

Text Books:

- T1. D. A. Neamen, *Semiconductor Physics and Devices*, 4th Edition, McGraw-Hill, 2012.
- T2. S. M. Sze and K. N. Kwok, *Physics of Semiconductor Devices*, 3rd Edition, John Wiley & Sons, 2006.
- T3. A. Sarkar, S. De, and C. K. Sarkar, *VLSI Design and EDA Tools*, 1st Edition, SciTech, 2013.

Reference Books:

- R1. G. Streetman and S. K. Banerjee, *Solid State Electronic Devices*, 7th Edition, Pearson, 2014.

- R2. C. C. Hu, *Modern Semiconductor Devices for Integrated Circuits*, 1st Edition, Pearson, 2010.
 R3. R. S. Muller and T. I. Kamins, *Device Electronics for Integrated Circuits*, 3rd Edition, Wiley, 2007.
 R4. Y. Tsididis and M. Colin, *Operation & Modelling of MOS Transistor*, 3rd Edition, Oxford Univ. Press, 2011.
 R5. C. K. Maiti, S. Chattopadhyay, and L. K. Bera, *Strained-Si Heterostructure Field Effect Devices*, 1st Edition, CRC Press, Taylor & Francis Group, 2007.

Online Resources:

1. <https://nptel.ac.in/courses/108108122/>: by Prof. D. N. Nath, IISc Bangalore
2. <https://nptel.ac.in/courses/117108047/>: by Dr. N. Bhat and others, IISc Bangalore
3. <https://www.digimat.in/nptel/courses/video/108107129/L01.html>
4. <https://www.digimat.in/nptel/courses/video/117107149/L42.html>
5. <http://www.digimat.in/nptel/courses/video/117108047/L17.html>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the MOS transistor structure and its characteristics.
CO2	Extract the parameters for linearity and RF performance measurement of a MOSFET.
CO3	Understand the limitations of down scaling the size of MOS transistor.
CO4	Realize the importance of High-K gate dielectrics for advanced CMOS design.
CO5	Investigate the characteristic of hetero-junction MOSFET structures for advanced CMOS technology nodes.
CO6	Explore multi-gate CMOS structures and evaluate their performance.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3		3	3		2			1	3	3	3
CO2	3	2		3	3		2			2	3	3	3
CO3	3	3		3	3		2			2	3	2	3
CO4	3	3		3	2		2			1	3	3	2
CO5	3	3		3	2		3			2	3	3	3
CO6	3	3		2	3		3			2	3	2	3

Type	Code	Modern Communication Systems Lab	L-T-P	Credits	Marks
PC	MTEC-P-PC-003		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide in-depth practical exposure on digital communication systems with TDM, FDM, Pulse modulations, Digital modulation techniques, audio, video as well as spreading and dispreading concepts.
Pre-Requisites	Knowledge of analog & digital communication and topics taught in the theory class are required.
Teaching Scheme	Regular Laboratory experiments executed under supervision of the teacher with the help of hardware and simulation through software.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test/ Mini Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Hardware/Simulation of the Pulse Code Modulation (PCM) and demodulation Technique using MATLAB Simulink.
2	Hardware/Simulation of Time division multiplexing (TDM) using MATLAB Simulink.
3	Hardware/Simulation of frequency division multiplexing (FDM) and frequency division de-multiplexing using MATLAB Simulink.
4	Hardware/Simulation of generation and reception of signals in Amplitude Shift Keying (ASK) using MATLAB Simulink.
5	Hardware/Simulation of generation and reception of signals in Frequency Shift Keying (FSK) using MATLAB Simulink.
6	Hardware/Simulation of generation and reception of signals in Phase Shift Key (PSK) using MATLAB Simulink.
7	Hardware/Simulation of generation and reception of signals in Quadrature Phase Shift Key (QPSK) using MATLAB Simulink.
8	Simulation of M-ary Phase Shift Keying (M-ary PSK) using MATLAB.
9	Simulation of M-ary Quadrature Amplitude Modulation (M-ary QAM) using MATLAB.
10	Study of Performance Analysis of different digital modulation techniques by using MATLAB.
11	Simulation of Direct Sequence Spread Spectrum (DS-SS) using MATLAB.
12	Multiplexing of signals using OFDM

Text Books:

- T1. H. Taub, D. L. Schilling, and G. Saha, *Principles of Communication Systems*, 4th Edition, Tata McGraw-Hill, 2013.
- T2. B. P. Lathi and Z. Ding, *Modern Digital and Analog Communication Systems*, 4th Edition, Oxford University Press, 2010.

Reference Books:

- R1. L. W. Couch-II, *Digital and Analog Communication System*, 8th Edition, Pearson Education, 2013.
 R2. B. Sklar, *Digital Communications - Fundamentals and Applications*, 2nd Edition, Pearson Education, 2009.

Online Resources:

1. <https://nptel.ac.in/courses/117101051>: by Prof. B. K. Dey, IIT Bombay
2. <https://nptel.ac.in/courses/117104115>: by Prof. A. K. Jagannatham
3. <https://freevideolectures.com/course/2314/communication-engineering/32>
4. <https://www.digimat.in/nptel/courses/video/117105136/L39.html>
5. <https://freevideolectures.com/course/4701/nptel-principles-communication-systems-i/51>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Convert analog to digital signal and vice-versa.
CO2	Transmit multiple signals using Time Division Multiplexing.
CO3	Realize different digital modulation schemes and their effect in communications with the help of spectrum analyzer.
CO4	Explain spreading concepts and methods to spread and disspread the given signals.
CO5	Describe multiplexing of signals using OFDM.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	1	2				2	1	2	2	1
CO2	2	2	2	2					2	1	2	2	1
CO3	3	3	2	3	2				2	1	3	2	1
CO4	3	2	2	1					1	1	2	1	2
CO5	3	2	3	2	3				2	1	3	2	1

Type	Code	IoT & Embedded Systems Lab	L-T-P	Credits	Marks
PC	MTEC-P-PC-004		0-0-2	1	100

Objectives	The objective of this laboratory course is to provide practical exposure on concepts of Arduino board, GSM module, use of sensors and web server for design of IoT and Embedded systems.
Pre-Requisites	Knowledge on concepts of microcontrollers and sensors is required.
Teaching Scheme	Regular Laboratory experiments executed under supervision of the teacher with focus on designing of IoT and Embedded systems for real world applications with the help of hardware and software.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test/ Mini Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	Introduction to Different Internet Protocols like HTTP, TCP/IP etc.
2	Introduction to Arduino MEGA 2560 and Interfacing Push Button, LED, LDR, Potentiometer, Buzzer and Relay with Arduino MEGA 2560.
3	Interfacing below sensors with Arduino MEGA 2560 LM35 (Temperature Sensor), DHT11 (Temperature and Humidity Sensor), PIR (Passive Infrared Sensor), DS18B20 (One Wire Temperature Sensor), HC-SR04 (Ultrasonic Sensor).
4	Interfacing Display Devices (Liquid Crystal Display) to display the sensor output.
5	Wireless Transceiver (NRF24L01) interfacing with Arduino UNO to wirelessly transmit sensor output value.
6	Controlling Sensors with DTMF Technology using GSM Module SIM900A.
7	Uploading Sensor Data wirelessly to Thing Speak cloud using GSM Module SIM900A.
8	Front End Designing with Node-RED.
9	Web Service Development for IoT based applications (Database and their Management).
10	Using ESP8266/ESP32 as a WiFi Client to upload sensor data to Thing Speak API.
11	Configuring ESP8266 as a Web Server.
12	Interfacing of Bluetooth with Arduino/Raspberry Pi to send sensor data to smart phone using Bluetooth.

Text Books:

- T1. A. Bahaga and V. Madiseti, *Internet of Things: A Hands-on Approach*, 1st Edition, University Press, 2014.
- T2. J. Yiu, *The Definitive Guide to the ARM Cortex-M3*, 2nd Edition, Elsevier, 2010.

Reference Books:

- R1. O. Hersent, D. Boswarthick, O. Elloumi, *The Internet of Things - Key Applications & Protocols*, Student Edition, Wiley, 2015.
- R2. S.Furber, *ARM System-on-Chip Architecture*, 2nd Edition, Pearson Education, 2015.

Online Resources:

1. <https://nptel.ac.in/courses/108/108/108108098/>:by Prof. T. V. Prabhakar,IISc Bangalore
2. <https://nptel.ac.in/courses/106/105/106105195/>:by Prof. S. Misra, IIT Kharagpur.
3. <https://nptel.ac.in/courses/106/105/106105166/>:by Prof. S. Misra, IIT Kharagpur
4. <https://nptel.ac.in/courses/106/106/106106182/>:by Prof. S. Iyengar, IIT Madras
5. <https://nptel.ac.in/courses/115/104/115104095/>:by Prof. M. Verma, IIT Kanpur
6. <https://nptel.ac.in/courses/106/104/106104189/>:by Dr. R. Misra, IIT Patna

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain different IoT protocols.
CO2	Interface external devices using Arduino board, sensors, display devices etc.
CO3	Interface wireless transceiver for different applications.
CO4	Develop wireless sensor data control using GSM module.
CO5	Design and develop web service for IoT applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	3	2						1	2	2
CO2	3	3	2	2	2						3	3	3
CO3	2	2	3	2	2						3	2	2
CO4	3	2	2	3	2						1	2	2
CO5	3	3	2	2	2						3	3	3

Type	Code	Advanced Digital Signal Processing	L-T-P	Credits	Marks
PC	MTEC-T-PC-005		3-0-0	3	100

Objectives	The objectives of this course is to study the mathematical modeling of discrete time random signals, choose appropriate filter structures, estimation, prediction and filtering techniques, and develop DSP based real-time data processing systems for high speed applications.
Pre-Requisites	Knowledge of Signals & Systems and Digital Signal Processing is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours			
Module-1	Review of Discrete Time Systems: Design of FIR Digital filters - Window method, Park-McClellan's method; Design of IIR Digital Filters - Butterworth and Chebyshev; Lowpass, Bandpass, Bandstop and High pass filters.	8 Hours			
Module-2	Multirate Signal Processing: Basic multirate operations, Up-sampling and down sampling, Time domain and frequency domain analysis, Identities of multirate operations, Efficient transversal structure, Rate conversion, Polyphase representation, Multirate filter banks.	9 Hours			
Module-3	Linear Estimation and Prediction: Representations of a stationary random process, Forward and backward linear prediction, AR Lattice structure, ARMA processes & Lattice - Ladder Filters, Wiener filters.	9 Hours			
Module-4	Parametric and Non-parametric Spectral Estimation: Estimation of spectra from finite duration observations of a signal - Periodogram, Use of DFT in power spectrum estimation, Non-parametric spectral estimation, Parametric spectral estimation.	9 Hours			
Module-5	Adaptive systems: Adaptive linear combiner: the performance function, gradient and minimum mean square error. Adaptive algorithms: LMS and RLS, Applications.	7 Hours			
Total					42 Hours

Text Books:

- T1. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithm and Applications*, 4th Edition, Prentice Hall, 2007.
- T2. A. V. Oppenheim and R. W. Schaffer, *Discrete-Time Signal Processing*, 3rd Edition, Pearson Education, 2004.
- T3. B. Widrow and S. D. Stearns, *Adaptive Signal Processing*, edn1, Pearson Education, 2002.

Reference Books:

- R1. L. R. Rabiner and B. Gold, *Theory and Application of Digital Signal Processing*, 2nd Edition, Prentice Hall India, 1992.
- R2. J. R. Johnson, *Introduction to Digital Signal Processing*, 2nd Edition, Prentice Hall India, 1992.

- R3. A. N. Kani, *Digital Signal Processing*, 2nd Edition, McGraw-Hill Education, 2017.
 R4. P. R. Babu, *Digital Signal Processing*, 4th Edition, Scitech Publication, 2011.
 R5. A. . Ambaradar, *Analog and Digital Signal processing*, 2nd Edition, CL Engineering, 1999.

Online Resources:

1. <https://nptel.ac.in/courses/108/106/108106151/>: by Prof. C. S. Ramalingam, IIT Madras
2. <https://nptel.ac.in/courses/117102060/>: by Prof. S. C. Dutta Roy, IIT Delhi
3. <https://nptel.ac.in/courses/117104070/>: by Prof. T. K. Basu, IIT Kharagpur
4. <https://nptel.ac.in/courses/117101001/>: by Prof. V. M. Gadre, IIT Bombay

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Design IIR and FIR filters using various techniques.
CO2	Explain the concepts of multirate signal processing.
CO3	Analyze the linear estimation and prediction.
CO4	Estimate power spectrum of signals using different techniques.
CO5	Describe the concepts of adaptive systems.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2		3		1				2	2	1
CO2	2	3	2		2		2				2	1	1
CO3	3	2	1		3		1				2	1	2
CO4	3	2	3		3		2				3	1	1
CO5	3	2	1		2		2				2	1	2

Type	Code	VLSI System Design & Verification	L-T-P	Credits	Marks
PC	MTEC-T-PC-006		3-0-0	3	100

Objectives	The objective of this course is to provide in-depth knowledge on the Verilog HDL and System Verilog HDL techniques for digital VLSI system design and verification.
Pre-Requisites	Knowledge of digital electronic circuits and MOSFET is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: Evolution of Logic Design, System and Logic Design Abstractions, Integrated Circuit Design and Methodologies, Verilog Design Description, Concept of Concurrency; Verilog Operators: Arithmetic, Logical, Equality and Inequality, Bitwise, Relational, Reduction, and Shift.	8 Hours
Module-2	Verilog Constructs and Combinational Design: The Role of Constructs, Logic Gates and Synthesizable RTL, Tristate Logic, Arithmetic Circuits, Procedural Block, Multi-bit Adders and Subtractors.	8 Hours
Module-3	Multiplexers: Multiplexer as Universal logic, the if...else and case Construct, 4:1 MUX Using if...else and case, Design Combinational Logic Using Multiplexers; Decoders and Encoders: 1:2 Decoders, 2:4 Decoder, Test bench of Decoder, Priority Encoders, Test bench of Encoder.	8 Hours
Module-4	Sequential Design Using Verilog: Sequential Logic, Flip-Flop, Positive and negative Edge-Triggered D Flip-Flop, Synchronous and Asynchronous Reset; Synchronous Counter Design Using Synthesizable Constructs: Synchronous Counters, Gray Counters, BCD Up-Down Counter; Finite State Machines Using Verilog: Moore Versus Mealy Machines, Level to Pulse Converter, FSM Encoding Styles, One-Hot Encoding, Sequence Detectors Using FSMs.	10 Hours
Module-5	System Verilog for Verification: Verification Guidelines, Process, and Methodology, Basic Test bench Functionality, Directed Testing, Methodology Basics, Constrained-Random Stimulus, Functional Coverage, Test bench Components, Layered Test bench, Building a Layered Test bench, Simulation Environment Phases, Maximum Code Reuse.	8 Hours
Total		42 Hours

Text Books:

- T1. S. Palnitkar, *Verilog HDL : A Guide to Digital Design and Synthesis*, 2nd Edition, Pearson Education, 2003.
- T2. C. Spear and G. Tumbush, *System Verilog for Verification: A Guide to Learning the Testbench Language Features*, 3rd Edition, Springer, 2012.

Reference Books:

- R1. K. Mishra, *Advanced Chip Design: Practical Examples in Verilog*, 1st Edition. Create Space Independent Pub, 2013.
- R2. V. Taraate, *Digital Logic Design Using Verilog*, 2nd Edition, Springer, 2016.
- R3. C. H. Roth Jr., L. K. John, B. K. Lee, *Digital Systems Design Using Verilog*, 1st Edition, Cengage Learning, 2015.
- R4. D. E. Thomas, P. R. Moorby, *The Verilog Hardware Description Language*, 5th Edition, Kluwer Academic Publishers, 2002.

Online Resources:

1. <https://nptel.ac.in/courses/108103179>: by Prof. S. R. Ahamed, IIT Guwahati
2. http://www.ece.uah.edu/~gaede/cpe526/SystemVerilog_3.1a.pdf
3. <https://www.chipverify.com/verilog/verilog-tutorial>
4. <https://www.javatpoint.com/verilog>
5. <https://www.edaplayground.com/>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the basic concepts, constructs and syntax of Verilog HDL.
CO2	Analyze, design and test combinational logic circuits using dataflow, gate level, structural, behavioral and switch level modeling.
CO3	Analyze, design and test combinational logic circuits using multiplexer as universal logic and design different types of decoders & encoders.
CO4	Analyze, design and verify sequential logic circuits & FSMs through Verilog HDL using synthesizable constructs.
CO5	Develop procedure to carry out design verification using System Verilog HDL.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1			1						1			1
CO2	3	3	3	2						1	2	2	1
CO3	3	3	3	2						1	2		1
CO4	3	3	3	2						1	1	2	1
CO5	1	2	2	2						1	1	2	1

Type	Code	Soft Computing	L-T-P	Credits	Marks
PC	MTEC-T-PC-007		3-0-0	3	100

Objectives	The objective of this course is to study the concepts of various soft computing techniques like fuzzy logic, neural networks etc., along with optimization & evolutionary computation, and their applications in communication engineering.
Pre-Requisites	Knowledge of engineering mathematics and basics of programming is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on theory and programming activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Basic Tools of Soft Computing: Evolution of Computing - Soft Computing constituents, Neural Network Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks.	10 Hours
Module-2	Fuzzy Logic: Basic concepts of fuzzy logic, Fuzzy sets and Crisp sets, membership functions, Fuzzy set theory and operations, Extension principle of fuzzy set, fuzzy inference, Fuzzy implications, fuzzy relation, fuzzy reasoning, fuzzy c-means clustering, Defuzzification techniques.	8 Hours
Module-3	Artificial Neural Networks: Early neural network architectures - Rosenblatt's Perceptron, ADALINE network, MADALINE network, Examples & applications of neural networks; Unsupervised Learning Neural Networks: Hopfield neural network, Competitive learning, Self-organizing feature map, Reinforcement learning: Q-learning, Temporal difference learning.	7 Hours
Module-4	Training of ANN: Generalized delta rule, Hebbian rule; Back propagation algorithm, Effect of tuning parameters of the back propagation algorithm; Radial Basis Function networks & Least Square training algorithm; Kohonen self-organizing map and learning vector quantization networks; Recurrent neural networks, Simulated annealing neural networks; Adaptive neurofuzzy inference systems (ANFIS).	9 Hours
Module-5	Evolutionary Computing Fundamentals of genetic algorithms: Encoding, Fitness functions, Reproduction Genetic Modeling: Cross cover, Inversion and deletion, Mutation operator, Bit-wise operators, Bitwise operators used in GA. Convergence of Genetic algorithm. GA as an alternative to back propagation, Applications of GA in navigational planning of robots, Particle swarm optimization, ant-colony optimization, Bee colony optimization.	8 Hours
Total		42 Hours

Text Books:

- T1. J. S. R. Jang, C. T. Sun, and E. Mizutani, *Neuro-Fuzzy & Soft Computing - A Computational Approach to Learning and Machine Intelligence*, 1st Edition, PHI Learning, 2015.

- T2. S. Rajasekaran and G. A. V. Pai, *Neural Networks, Fuzzy Systems and Evolutionary Algorithms: Synthesis and Applications*, 2nd Revised Edition, PHI Learning, 2017.

Reference Books:

- R1. F. O. Karry and C. De Silva, *Soft Computing and Intelligent Systems Design - Theory, Tools and Applications*, 1st Edition, Pearson Education, 2009.
 R2. S. Haykin, *Neural Networks : A Comprehensive Foundation*, —edn2, Pearson Education, 1997.

Online Resources:

1. <https://nptel.ac.in/courses/127/105/127105006/>: by Prof. D. K. Pratihar, IIT Kharagpur
2. <https://nptel.ac.in/courses/106/105/106105173/>: by Prof. D. Samanta, IIT Kharagpur
3. <https://nptel.ac.in/courses/117/105/117105084/>: by Prof. S. Sengupta, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the basics of soft computing techniques and their applicability.
CO2	Describe fuzzy principles & inference and defuzzification methods.
CO3	Apply different types of neural networks algorithms for engineering problems.
CO4	Analyze effectiveness of neural networks for solving complex engineering problems.
CO5	Use evolutionary computation with optimization algorithms in real world applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	1	1						3	2	2
CO2	3	2	2	2	2						3	2	2
CO3	2	3	3	3	2						3	2	1
CO4	2	3	3	3	2						3	3	3
CO5	2	2	3	2	3						2	3	2

Type	Code	Analog & Mixed Signal Design	L-T-P	Credits	Marks
PE	MTEC-T-PE-004		3-0-0	3	100

Objectives	The objective of this course is to study, analyze, and build analog integrated circuits for various applications, apply Op-Amp circuits for designing the comparators, frequency compensation techniques for amplifiers and analyze operations of VCOs & different types of PLLs and design them.
Pre-Requisites	Knowledge of analog electronic circuits and electrical network analysis is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Analog Design: General Concepts, Levels of Abstraction, Robust Analog Design; Single-Stage Amplifiers: Basic Concepts, Common-Source Stage, Common-Source Stage with Resistive Load, CS Stage with Diode-Connected Load, CS Stage with Current-Source Load, CS Stage with Triode Load, CS Stage with Source Degeneration, Source Follower, Common-Gate Stage, Cascode Stage, Folded Cascode.	8 Hours
Module-2	Differential Amplifiers: Single-Ended and Differential Operation, Basic Differential Pair, Qualitative Analysis, Quantitative Analysis, Common-Mode Response, Differential Pair with MOS Loads, Gilbert Cell.	8 Hours
Module-3	Passive and Active Current Mirrors: Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors, Large-Signal Analysis, Small-Signal Analysis, Common-Mode Properties; Bandgap References: General Considerations, Supply-Independent Biasing, Temperature-Independent References, Negative-TC Voltage, Positive-TC Voltage, Bandgap Reference.	9 Hours
Module-4	Operational Amplifiers: General Considerations, Performance Parameters, One-Stage Op Amps, Two-Stage Op Amps, Gain Boosting, Comparison, Common-Mode Feedback, Input Range Limitations, Slew Rate, Power Supply Rejection.	8 Hours
Module-5	Frequency Response of Amplifiers: General Considerations, Miller Effect, Association of Poles with Nodes, Common-Source Stage, Source Followers, Common-Gate Stage, Cascode Stage, Differential Pair; Phase-Locked Loops-Concept of Voltage controlled Oscillator, Phase locked loop terminologies, Types of PLL, PFD/CP non-idealities, Jitter, Delay Locked Loop, Applications.	9 Hours
Total		42 Hours

Text Books:

T1. B. Razavi, *Design of Analog CMOS Integrated Circuits*, Tata McGraw-Hill, 2002.

T2. P. E. Allen and D. R. Holberg, *CMOS Analog Circuit Design*, 3rd Edition, Oxford University Press, 2013.

Reference Books:

- R1. P. R. Gray, P. J. Hurst, S. H. Lewis, and R. G. Meyer, *Analysis and Design of Analog Integrated Circuits*, 5th Edition, John Wiley & Sons, 2009.
- R2. B. Razavi, *Fundamentals of Microelectronics*, 1st Edition, John Wiley & Sons, 2008.
- R3. T. C. Carusone, D. Johns, and K. Martin, *Analog Integrated Circuit Design*, 2nd Edition, Wiley India, 2012.
- R4. K. R. Laker and W. M. C. Sansen, *Design of Analog Integrated Circuits and Systems*, McGraw-Hill Education, 1994.

Online Resources:

1. <https://nptel.ac.in/courses/117/101/117101105/>: by Prof. A. N. Chandorkar, IIT Bombay
2. <https://nptel.ac.in/courses/117106030/>: by Dr. N. Krishnapura, IIT Madras
3. <https://nptel.ac.in/courses/108/106/108106105/>: by Prof. S. Aniruddhan, IIT Madras
4. <https://nptel.ac.in/courses/108/106/108106068/>: by Prof. K. R. Rao, IIT Madras
5. <https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-374-analysis-and-design-of-digital-integrated-circuits-fall-2003/>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Analyze and design single-stage amplifiers for various applications.
CO2	Compute the performance parameters and design single-stage amplifiers for various applications.
CO3	Design passive and active current mirrors and band-gap reference circuits.
CO4	Design Op-Amps to meet required performance metrics for specific applications.
CO5	Analyze and design different types of Phase-Locked Loops.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	1		2						1	1	1
CO2	3	3	2	1	2						1	1	2
CO3	3	3	2	2	3					1	2	1	2
CO4	3	3	3	2	3					1	2	1	2
CO5	3	3	2	2	2					1	2	1	2

Type	Code	IoT Protocols & Architecture	L-T-P	Credits	Marks
PE	MTEC-T-PE-005		3-0-0	3	100

Objectives	The objective of this course is to study the design and implementation of IoT applications that manage big data using Smart Objects, protocols and study IoT infrastructure for popular applications.
Pre-Requisites	Basic knowledge of system architecture and protocols is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on theory and programming activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Fundamentals of IoT: Evolution of Internet of Things, Enabling Technologies, IoT Architectures: one M2M, IoT World Forum (IoTWF) and Alternative IoT models, Simplified IoT Architecture and Core IoT Functional Stack, Fog, Edge and Cloud in IoT, Functional blocks of an IoT ecosystem, Sensors, Actuators, Smart Objects and Connecting Smart Objects.	10 Hours
Module-2	IoT Protocols: IoT Access Technologies: Physical and MAC layers, topology and Security of IEEE 802.15.4, 802.15.4g, 802.15.4e, 1901.2a, 802.11ah and LoRaWAN, Zigbee protocol, Network Layer: IP versions, Constrained Nodes and Constrained Networks, Optimizing IP for IoT: From 6LoWPAN to 6Lo, Routing over Low Power and Lossy Networks, Application Transport Methods: Supervisory Control and Data Acquisition, Application Layer Protocols: CoAP and MQTT	8 Hours
Module-3	Design and Development: Design Methodology, Embedded computing logic, Microcontroller, System on Chips, IoT system building blocks, Arduino-Board details, IDE programming, Raspberry Pi and Interfaces.	7 Hours
Module-4	Data Analytics and Supporting Services: Structured Vs Unstructured Data and Data in Motion Vs Data in Rest, Role of Machine Learning-No SQL Databases, Hadoop Ecosystem, Apache Kafka, Apache Spark, Edge Streaming Analytics and Network Analytics, Xively Cloud for IoT, Python Web Application Framework, Django, AWS for IoT, System Management with NETCONF-YANG, Kibana, Faulttolerant data processing on devices.	9 Hours
Module-5	Case Studies & Industrial Applications: Cisco IoT system, IBM Watson IoT platform, Manufacturing, Converged Plantwide Ethernet Model (CPwE), Power Utility Industry, GridBlocks Reference Model, Smart and Connected Cities: Layered architecture, Smart Lighting, Smart Parking Architecture and Smart Traffic Control.	8 Hours
Total		42 Hours

Text Books:

- T1. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, and J. Henry, *IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things*, 1st Edition, Pearson Education, 2017.

T2. A. Bahaga and V. Madiseti, *Internet of Things: A Hands-on Approach*, 1st Edition, University Press, 2014.

Reference Books:

- R1. O. Hersent, D. Boswarthick, and O. Elloumi, *The Internet of Things : Key Applications and Protocols*, Student Edition, John Wiley & Sons, 2016.
- R2. V. Tsiatsis, S. Karnouskos, J. Holler, D. Boyle, and C. Mulligan, *From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*, Elsevier, 2014.
- R3. D. Uckelmann, M. Harrison, and F. Michahelles, *Architecting the Internet of Things*, Springer, 2011.

Online Resources:

1. <https://nptel.ac.in/courses/106/105/106105195/>:by Prof. S. Misra, IIT Kharagpur.
2. <https://nptel.ac.in/courses/108/108/108108098/>:by Prof. T. V. Prabhakar, IISc Bangalore
3. <https://nptel.ac.in/courses/106/105/106105166/>:by Prof. S. Misra, IIT Kharagpur
4. <https://nptel.ac.in/courses/108/105/108105064/>:by Prof. A.Barua, IIT Kharagpur
5. <https://nptel.ac.in/courses/106/106/106106182/>:by Prof. S. Iyengar, IIT Madras
6. <https://nptel.ac.in/courses/115/104/115104095/>:by Prof. M. Verma, IITKanpur
7. <https://nptel.ac.in/courses/106/104/106104189/>:by Dr. R. Misra, IIT Patna

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the fundamental and architecture of IOT and its components.
CO2	Articulate the architecture of different IoT protocol layers.
CO3	Interface external devices using Arduino board, Raspberry pi interfaces and programming to create products and solutions for real life applications.
CO4	Study data analytics and support services using SQL database, Hadoop, Python web application, and AWS etc.
CO5	Design, formulate and implement different Industrial applications in real time scenario.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	2	1	1						1	2	2
CO2	3	2	2	2	2						3	2	2
CO3	2	3	3	3	2						3	3	3
CO4	2	3	3	3	2						3	3	3
CO5	2	2	3	2	3						2	3	2

Type	Code	Digital Speech & Video Processing	L-T-P	Credits	Marks
PE	MTEC-T-PE-006		3-0-0	3	100

Objectives	The objective of this course is to study motion estimation, motion segmentation, tracking, motion compensated filtering, video compression, extract speech signal features, speech compression, and recognition techniques.
Pre-Requisites	Knowledge of digital signal processing, image processing, convolution, 1-D and 2-D filters, and Fourier transform is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours		
Module-1	Speech Signal Characteristics and Analysis: Introduction, Speech production process, Representation of Speech in time and frequency domains, Short-Time Analysis of Speech, Short-Time Energy and Zero-Crossing Rate, Short-Time Autocorrelation Function, Short-Time Fourier Transform (STFT), Speech Spectrum, Cepstrum, Mel-Frequency Cepstrum Coefficients (MFCC).	9 Hours		
Module-2	Speech Compression and Recognition: Sampling and Quantization of Speech using PCM, Vector Quantization- Linear predictive coding (LPC), LPC for speech recognition, Hidden Markov Model (HMM), Training procedure for HMM, Sub-word unit model based on HMM, Language models for large vocabulary speech recognition, Overall recognition system based on sub-word units.	8 Hours		
Module-3	2-D Motion Estimation: Introduction to video processing, Motion estimation, Occlusion and aperture problem, 2-D motion field models, Methods using optical flow, Block based methods, Block-motion model, Phase Correlation method, Block-matching, Generalized block-motion estimation.	8 Hours		
Module-4	Motion Segmentation and Tracking: Direct methods, Optical flow segmentation, Motion and structure from stereo, Motion tracking; Video Filtering and Restoration: Motion compensated filtering, Filtering along with motion trajectories, Motion adaptive filtering, Multi-frame restoration, Cross-correlated multi-frame filter, Motion compensated multi-frame filter.	9 Hours		
Module-5	Video Compression: Video coding, Inter-frame redundancy, Elements of video encoder and decoder, Wavelet video compression, Object based video coding, Video coding standards - MPEG and H.26X.	8 Hours		
Total				42 Hours

Text Books:

- T1. L. Rabiner, B-H. Juang, and B. Yegnanarayana, *Fundamentals of Speech Recognition*, 1st Edition, Pearson Education, 2009.
- T2. A. M. Tekalp, *Digital Video Processing*, 2nd Edition, Pearson Education, 2015.

Reference Books:

- R1. A. L. Bovik, *Handbook of Image and Video Processing*, 3rd Edition, Academic Press, 2017.
 R2. L. R. Rabiner and R. W. Schafer, *Introduction to Digital Speech Processing, Foundations and Trends in Signal Processing*, Now Publishers, 2007.

Online Resources:

1. <https://nptel.ac.in/courses/117105145/>: by Prof. S. K. Das Mandal, IIT Kharagpur
2. <https://nptel.ac.in/courses/117104020/>: by Prof. S. Gupta, IIT Kanpur
3. <https://nptel.ac.in/courses/117105135/>: by Prof. P. K. Biswas, IIT Kharagpur
4. <https://nptel.ac.in/courses/106105032/>: by Dr. G. Harit, IIT Kharagpur
5. <https://nptel.ac.in/courses/117/104/117104069/>: by Prof. S. Gupta, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Analyze speech signals and extract the features from speech signals.
CO2	Design speech compression techniques and configure speech recognition techniques.
CO3	Utilize motion estimation and block matching techniques for video processing.
CO4	Analyze motion segmentation using optical flow and motion tracking in videos.
CO5	Apply motion compensated filtering and video compression techniques.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	1	2	1	1	1				1		1	1
CO2	1	2	1	1	2	1				1	1	1	1
CO3	1	1	1	2	2	1				1	1	1	1
CO4	2	1	2	2	2	1				1	2	2	2
CO5	2	1	1	2	1	1				2	1	2	2

Type	Code	Digital Integrated Circuit Design	L-T-P	Credits	Marks
PE	MTEC-T-PE-007		3-0-0	3	100

Objectives	The objective of this course is to provide in-depth knowledge of MOSFET, its manufacturing process including analysis and design of digital integrated circuits & systems using state-of-the-art technology.
Pre-Requisites	Knowledge of digital electronic circuits and MOSFET is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: Historical Perspective, Issues in Digital Integrated Circuit Design, Quality Metrics of a Digital Design, Cost of an Integrated Circuit, Functionality & Robustness, Performance, Power & Energy Consumption; Manufacturing Process: Introduction, Manufacturing CMOS Integrated Circuits, The Silicon Wafer, Photolithography, Some Recurring Process Steps, Simplified CMOS Process Flow, Design Rules - The Contract between Designer & Process Engineer, Packaging Integrated Circuits, Package Materials, Interconnect Levels, Thermal Considerations in Packaging.	8 Hours
Module-2	The Devices: The MOS(FET) Transistor, A First Glance, MOS Transistor under Static Conditions, Dynamic Behavior, Actual MOS Transistor - Some Secondary Effects, SPICE Models for the MOS Transistor; The Wire: Introduction, First Glance, Interconnect Parameters - Capacitance, Resistance, and Inductance, Electrical Wire Models, The Ideal Wire, Lumped Model, Lumped RC model, Distributed rc Line, Transmission Line.	8 Hours
Module-3	The CMOS Inverter : Introduction, Static CMOS Inverter - An Intuitive Perspective, Evaluating the Robustness of the CMOS Inverter: Static Behavior, Switching Threshold, Noise Margins, Robustness Revisited, Performance of CMOS Inverter: Dynamic Behavior, Computing the Capacitances, Propagation Delay: First-Order Analysis, Propagation Delay from a Design Perspective, Power, Energy, and Energy-Delay, Dynamic Power Consumption, Static Consumption, Putting It All Together.	9 Hours
Module-4	Designing Combinational Logic Gates in CMOS: Introduction, Static CMOS Design, Complementary CMOS, Ratioed Logic, Pass-Transistor Logic, Dynamic CMOS Design, Dynamic Logic: Basic Principles, Speed and Power Dissipation of Dynamic Logic, Issues in Dynamic Design, Cascading Dynamic Gates.	8 Hours

Cont'd...

Module-#	Topics	Hours
Module-5	Designing Sequential Logic Circuits : Introduction, Timing Metrics for Sequential Circuits, Classification of Memory Elements, Static Latches and Registers, Bistability Principle, Multiplexer-Based Latches, Master-Slave Edge-Triggered Register, Low-Voltage Static Latches, Static SR Flip-Flops—Writing Data by Pure Force, Dynamic Latches and Registers, Dynamic Transmission-Gate Edge-triggered Registers, C2MOS-A Clock-Skew Insensitive Approach, True Single-Phase Clocked Register (TSPCR), Pipelining: An approach to optimize sequential circuits, Latch- vs. Register-Based Pipelines, NORA-CMOS-A Logic Style for Pipelined Structures.	9 Hours
Total		42 Hours

Text Books:

- T1. J. P. Rabaey, A. P. Chandrakasan, and B. Nikolić, *Digital Integrated Circuits: A Design Perspective*, 2nd Edition, Pearson Education India, 2016.
- T2. S. M. Kang, Y. Leblebici, and C. Kim, *CMOS Digital Integrated Circuits - Analysis and Design*, 4th Edition, McGraw-Hill, 2019.

Reference Books:

- R1. N. H. E. Weste, D. Harris, and A. Banerjee, *CMOS VLSI Design - A Circuits and Systems Perspective*, 4th Edition, Pearson Education, 2010.
- R2. R. J. Baker, *CMOS Circuit Design, Layout & Simulation*, 3rd Edition, John Wiley & Sons, 2010.
- R3. D. A. Pucknell and K. Eshraghian, *Basic VLSI Design*, 3rd Edition, PHI Learning, 1995.
- R4. D. A. Hodges, H. G. Jackson, and R. Saleh, *Analysis and Design of Digital Integrated Circuits in Deep Sub-Micron Technology*, 3rd International Edition, McGraw-Hill Education, 2004.

Online Resources:

1. <https://nptel.ac.in/courses/117/106/117106092/>: by Prof. S. Srinivasan, IIT Madras
2. <https://nptel.ac.in/courses/117/106/117106093/>: by Dr. N. Dasgupta, IIT Madras
3. <https://nptel.ac.in/courses/117101058/>: by Prof. A. N. Chandorkar, IIT Bombay
4. <https://nptel.ac.in/courses/108/107/108107129/>: by Prof. S. Dasgupta, IIT Roorkee
5. <https://nptel.ac.in/courses/106/105/106105161/>: by Prof. I. Sengupta, IIT Kharagpur
6. <https://ocw.mit.edu/courses/6-374-analysis-and-design-of-digital-integrated-circuits-fall-2003/pages/lecture-notes/>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand different methods of designing integrated circuits and systems using modern tools by following appropriate design flow and fabrication steps.
CO2	Acquire in-depth knowledge of the structure and operational analysis of MOSFET and electrical model of wire used in integrated circuits.
CO3	Design application specific CMOS inverter with optimal performance by considering its static and dynamic behavior.
CO4	Design and analyze combinational logic circuits using static and dynamic design styles.
CO5	Design and analyze sequential logic circuits using various state of the art design styles.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.

Cont'd...

PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	1									1	1
CO2	3	1	2							1		1	1
CO3	3	3	2	2						1	2	1	2
CO4	3	3	2	2						1	2	1	2
CO5	3	3	2	2						1	2	1	2

Type	Code	Embedded Systems for Wireless Communication	L-T-P	Credits	Marks
PE	MTEC-T-PE-008		3-0-0	3	100

Objectives	The objective of this course is to study the concepts of embedded processors, memory management techniques, I/O operations, multitasking, task scheduling mechanisms, and 6LoWPAN-based wireless communication for popular applications.
Pre-Requisites	Knowledge of microprocessors, microcontrollers, and operating systems is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on theory and programming activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Embedded Core: Introduction, Embedded system Design Process, Modeling, Design and Analysis; Types of Processors: Microcontrollers and DSP Processors, Graphics Processors; Parallelism: Parallelism vs. Concurrency, Pipelining, Instruction-Level Parallelism, Multicore Architectures.	8 Hours
Module-2	Memory Technologies: Introduction, RAM, Non-Volatile Memory; Memory Hierarchy: Memory Maps, Register Files, Scratchpads and Caches; Memory Models: Memory Addresses, Stacks, Memory Protection Units, Dynamic Memory Allocation, Memory Model of C.	8 Hours
Module-3	I/O Hardware: Introduction, Pulse Width Modulation, General-Purpose Digital I/O, Serial Interfaces, Parallel Interfaces, Buses; Sequential Software: Timers, Interrupts and Exceptions, Atomicity, Interrupt Controllers, Modeling Interrupts.	8 Hours
Module-4	Multitasking: Imperative Programs, Threads: Creating Threads, Implementing Threads, Mutual Exclusion, Deadlock, Memory Consistency Models, Problem with Threads; Processes and Message Passing; Scheduling: Scheduling Decisions, Task Models, Implementation of a Scheduler; Scheduling and Mutual Exclusion, Multiprocessor Scheduling.	9 Hours
Module-5	Wireless Embedded Internet: 6LoWPAN and its Applications, 6LoWPAN Architecture, protocol stack, Link layers for 6LoWPAN, Addressing, Header format and Bootstrapping, Mesh topologies, Internet integration; 6LoWPAN Solutions: Chip Solutions, Protocol Stacks and Application Development, Edge Router Integration.	9 Hours
Total		42 Hours

Text Books:

- T1. E. A. Lee and S. A. Seshia, *Introduction to Embedded Systems - A Cyber-Physical Systems Approach*, 2nd Edition, MIT Press, 2017.
- T2. Z. Shelby and C. Bormann, *6LoWPAN: The Wireless Embedded Internet*, Wiley, 2009.

Reference Books:

- R1. F. Eady, *Implementing 802.11 with Microcontrollers: Wireless Networking for Embedded Systems Designers*, Elsevier, 2005.
- R2. R. A. Santos and A. E. Block, *Embedded Systems and Wireless Technology*, CRC Press, 2013.
- R3. P. Stavroulakis, *Interference Analysis & Reduction for Wireless Systems*, Artech House, 2003.

Online Resources:

1. <https://nptel.ac.in/courses/106105159>: by Prof. A. Basu, IIT Kharagpur
2. <https://nptel.ac.in/courses/117106112>: by Prof. H. M. Madhukeshwara, IIT Madras
3. <https://nptel.ac.in/courses/108102169>: by Prof. D. V. Gadre and Prof. B. N. Subudhi, IIT Jammu
4. <https://nptel.ac.in/courses/108105057>: by Prof. R. Mall, Prof. A. Patra, and Prof. A. Routray, IIT Kharagpur
5. <https://cseweb.ucsd.edu/classes/wi19/cse190-a/>: Prof. A. Schulman, UC San Diego

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the fundamental concepts of Embedded systems and processors.
CO2	Articulate the memory technologies and models in embedded processors for real-time design.
CO3	Analyze the I/O interfacing schemes in Embedded System Design.
CO4	Realize the in-depth concepts of Multitasking and Scheduling in Embedded System Design.
CO5	Design, formulate and implement Wireless Embedded Internet-based applications using 6LoWPAN technologies.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2		1	2	1		1		1	1	1
CO2	3	2	3		2	3	1		1		3	1	3
CO3	3	3	3		3	3	2		2	2	3	2	3
CO4	3	3	3		3	3	2		2	2	3	3	3
CO5	3	3	3		3	3	2	1	2	2	3	3	3

Type	Code	Image Processing & Computer Vision	L-T-P	Credits	Marks
PE	MTEC-T-PE-009		3-0-0	3	100

Objectives	The objective of this course is to study the fundamentals, transformation, filtering, restoration, compression, segmentation, description and recognition of images and their applications in various real life problems.
Pre-Requisites	Knowledge of digital signal processing, matrices, convolution, 1-D filters, and Fourier transform is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Image Fundamentals: Steps in digital image processing, sampling and quantization, relationship between pixels, imaging geometry; Image Enhancement: Some basic gray level transformations, Histogram equalization and matching; Filtering in spatial domain, Smoothing and sharpening spatial filters.	8 Hours
Module-2	Filtering in frequency domain: Preliminary concepts, 2D DFT and its properties, basic filtering in the frequency domain, smoothing and sharpening frequency domain filters, Homomorphic filtering; Image Restoration: Noise models, Restoration in the presence of noise only-spatial filtering, Estimating the degradation functions, Inverse filtering.	8 Hours
Module-3	Color Image Processing: Color fundamentals, Color models, Color conversions, Pseudo-color processing Wavelets and Multi-resolution Processing: Multi-resolution expansions, wavelet transforms in one and two dimension.	8 Hours
Module-4	Image Compression: Image compression models, Some basic compression methods, Loss-less and Lossy compression; Morphological Image Processing: Dilation and erosion, Opening and closing, Some basic morphological algorithms; Image Segmentation: Detection of discontinuities, Point line and edge detection, Thresholding, Region based segmentation.	9 Hours
Module-5	Representation and Description: Chain codes, Signatures, Skeletons, Boundary descriptors, Shape numbers, Fourier descriptors, Regional descriptors, Principal components for description; Object Recognition: Recognition based on decision-theoretic methods, matching, Optimum statistical classifiers, Bayes classifier, Perceptron for two pattern classes (linearly and nonlinearly separable).	9 Hours
Total		42 Hours

Text Books:

- T1. R. C. Gonzalez, *Digital Image Processing*, 3rd Edition, Pearson Education, 2008.
- T2. S. Sridhar, *Digital Image Processing*, 2nd Edition, Oxford University Press, 2014.

Reference Books:

- R1. A. K. Jain, *Fundamentals of Digital Image Processing*, 2nd Edition, Prentice Hall, 2004.
 R2. A. L. Bovik, *Handbook of Image and Video Processing*, 3rd Edition, Academic Press, 2017.

Online Resources:

1. <https://nptel.ac.in/courses/117105079/>: by Prof. P. K. Biswas, IIT Kharagpur
2. <https://nptel.ac.in/courses/117105135/>: by Prof. P. K. Biswas, IIT Kharagpur
3. <https://nptel.ac.in/courses/106105032/>: by Dr. G. Harit, IIT Kharagpur
4. <https://nptel.ac.in/courses/117/104/117104069/>: by Prof. S. Gupta, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Analyze image acquisition and perform basic image processing operations.
CO2	Apply image enhancement in both spatial and frequency domains for noise removal and better quality improvement.
CO3	Analyze color imaging, color models, color image processing and multi-resolution processing.
CO4	Apply image compression techniques for storage and transmission purpose.
CO5	Interpret Image segmentation and its use in object detection and recognition.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	1	1	1	1	1				1	1		
CO2	2	1	1	1	2	1				1	1	1	1
CO3	1	1	2	1	2	1				1	2	2	1
CO4	1	2	2	2	1	1				1	2	1	1
CO5	1	2	2	1	2	1				2	2	2	2

Type	Code	English for Research Paper Writing	L-T-P	Credits	Marks
MC	MTBS-T-MC-009		2-0-0	0	100

Objectives	The objective of this course is to give learners an exposure to different aspects of research related technical writing and to help them write such matter effectively through practice.
Pre-Requisites	Basic knowledge of English grammar and the ability to read and write using the English language.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on technical writing activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Technical Communication: Differentiating between general and technical writing, purpose of writing, plain English, mechanics of writing, elements of style. Essentials of English Grammar: basic word order, tense forms, reported speech, use of passives, conditionals, concord, clauses, common errors.	9 Hours
Module-2	Elements of Writing: Process writing, developing an effective paragraph, qualities of a paragraph, structuring a paragraph, types of essays, writing reports.	5 Hours
Module-3	Key Reading Skills: sub-skills of reading, local and global comprehension, types of technical texts, critical analysis of technical texts, note-making, the purpose and importance of literature review, evaluating literature.	5 Hours
Module-4	Developing Writing Skills: writing abstracts, technical letters, project reports, elements of proposal writing.	6 Hours
Module-5	Research and Writing: The research paper as a form of communication, Writing a review of Literature, developing a hypothesis, formulating a thesis statement, plagiarism issues.	3 Hours
Total		28 Hours

Text Books:

- T1. C. Ellison, *McGraw-Hill's Concise Guide to Writing Research Papers*, McGraw-Hill, 2010.
- T2. A. Wallwork, *English for Writing Research Papers*, Springer, 2011.
- T3. R. A. Day, *How to Write and Publish a Scientific Paper*, 7th Edition, Greenwood, 2011.

Reference Books:

- R1. R. Goldbort, *Writing for Science*, Yale University Press, 2006.
- R2. N. J. Higham, *Handbook of Writing for the Mathematical Sciences*, 2nd Edition, SIAN, 1998.
- R3. C. R. Kothari & G. Garg, *Research Methodology: Methods and Techniques*, 2nd Edition, New Age International Publishers, 2014.

P.T.O

Online Resources:

1. <https://msu.edu/course/be/485/bewritingguideV2.0.pdf>: Michigan State University Press, USA, Technical Writing Guide, 2007.
2. <http://web.mit.edu/me-ugoffice/communication/technical-writing.pdf>: Sentence Structure of Technical Writing, Nicole Kelley, MIT, USA, 2006.
3. http://www.inf.ed.ac.uk/teaching/courses/pi/2017_2018/slides/Technical-Writing-Basics.pdf: Notes from Pocketbook of Technical Writing for Engineers and Scientists by Leo Finkelstein, NY, 2007.
4. https://www.shs-conferences.org/articles/shsconf/pdf/2016/04/shsconf_erp2016_01090.pdf: A need analysis of technical writing skill of engineering students in India, JCK Evangeline & K. Ganesh, DOI: 10.1051/shsconf/20162601090, 2016

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Understand the importance and application of technical communication and apply essentials of English grammar to make research writing effective.
CO2	Apply the elements of technical writing to produce effective research papers.
CO3	Develop critical reading and analysis skills of technical research papers and texts.
CO4	Develop the ability to write technical articles and effectively present the ideas.
CO5	Develop research acumen by understanding the key skills of research.

Program Outcomes Relevant to the Course:

PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO8	Understand intellectual property rights and overall professional & ethical responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1						3	1	1	3	3	1	2	3
CO2						3			3	3	1	2	3
CO3						3	1	1	3	3	2	2	3
CO4						2		1	3	3	2	2	3
CO5						2	1	3	3	3	2	2	3

Type	Code	VLSI System Design & Verification Lab	L-T-P	Credits	Marks
PC	MTEC-P-PC-006		0-0-1	1	100

Objectives	The objective of this course is to provide practical experience to analyze & design digital VLSI systems for real-world applications through Verilog HDL, and to make the students ready for the VLSI industry.
Pre-Requisites	Knowledge of digital electronics and digital VLSI is required.
Teaching Scheme	Regular Laboratory classes with use of ICT as and when required, practicals are planned to be interactive with focus on problem solving activities and real time applications with the help of software, FPGA and other peripherals.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test/ Mini Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
<i>All experiments will be carried out using Verilog HDL</i>	
1	Introduction to EDA Tools for simulation and synthesis.
2	Design and verification of simple logic gates and its verification through test-bench.
3	Design and verification of combinational circuit using dataflow model.
4	Design and verification of combinational circuit using Behavioural model.
5	Design and verification of combinational circuit using Gate level model.
6	Design and verification of combinational circuit (Full Adder) using structural model.
7	Design and verification of combinational circuit (Full Subtractor) using structural model.
8	Design and verification of 4:1 Mux using vector.
9	Design and verification of combinational circuit using Mux.
10	Design and verification of positive & negative level sensitive Latches.
11	Design and verification of positive & negative edge triggered Flip Flops.
12	Design and verification of JK-Flip Flop using other Flip Flops.
13	Design and verification of asynchronous up/down counter using T-Flip Flop.
14	Design and verification of synchronous up/down counter using T-Flip Flop.
15	Design and verification of Melay based Finite State Machine.
16	Design and verification of Moore based Finite State Machine.

Text Books:

- T1. S. Palnitkar, *Verilog HDL : A Guide to Digital Design and Synthesis*, 2nd Edition, Pearson Education, 2003.
- T2. C. Spear and G. Tumbush, *System Verilog for Verification: A Guide to Learning the Testbench Language Features*, 3rd Edition, Springer, 2012.

P.T.O

Reference Books:

- R1. K. Mishra, *Advanced Chip Design: Practical Examples in Verilog*, 1st Edition. Create Space Independent Pub, 2013.
- R2. V. Taraate, *Digital Logic Design Using Verilog*, 2nd Edition, Springer, 2016.
- R3. C. H. Roth Jr., L. K. John, B. K. Lee, *Digital Systems Design Using Verilog*, 1st Edition, Cengage Learning, 2015.
- R4. D. E. Thomas, P. R. Moorby, *The Verilog Hardware Description Language*, 5th Edition, Kluwer Academic Publishers, 2002.

Online Resources:

1. <https://nptel.ac.in/courses/108103179>: by Prof. S. R. Ahamed, IIT Guwahati
2. http://www.ece.uah.edu/~gaede/cpe526/SystemVerilog_3.1a.pdf
3. <https://www.chipverify.com/verilog/verilog-tutorial>
4. <https://www.javatpoint.com/verilog>
5. <https://www.edaplayground.com/>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Use different EDA Tools for design, synthesis and verification of digital circuits.
CO2	Understand different abstraction levels of Verilog HDL.
CO3	Implement various combinational circuits and analyze their behavior.
CO4	Design several synchronous and asynchronous sequential circuits.
CO5	Analyze and construct different Finite State machines.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	1	1	3	3							2	1
CO2	1	2	2	3	3						1	2	2
CO3	2	3	3	3	3						2	3	2
CO4	1	2	3	3	3						2	2	2
CO5	1	3	3	3	3						3	3	2

Type	Code	VLSI System Design & Verification Lab	L-T-P	Credits	Marks
PC	MTEC-P-PC-008		0-0-1	1	100

Objectives	The objective of this laboratory course is to provide practical exposure on latest & advanced tools & technologies of current demand in various electronics & communication engineering domains so as to make the students adapt to the fast-changing world of technology and make them ready for the industry.
Pre-Requisites	Knowledge of subjects taught in previous semester is required. Additional topics (if any) required for conducting the experiments shall be taught in the lab.
Teaching Scheme	Regular laboratory experiments to be conducted under the supervision of the teacher. Demonstration will be given for each experiment.

Evaluation Scheme

Attendance	Daily Performance	Lab Record	Lab Test/ Mini Project	Viva-voce	Total
10	30	15	30	15	100

Detailed Syllabus

Experiment-#	Assignment/Experiment
1	To interface ADC with ARM-7.
2	To interface ZIGBEE with ARM-7 to control more external device.
3	To interface RFID module with ARM-7.
4	To interface OLED with Arduino/RaspberryPi and write a program to print temperature and humidity readings on it.
5	To interface Bluetooth with Arduino/RaspberryPi and write a program to send sensor data to smart phone using Bluetooth.
6	To interface Bluetooth with Arduino/RaspberryPi and write a program to send sensor data to smart phone using Bluetooth.
7	Write a program on Arduino/RaspberryPi to upload temperature and humidity data to thing speak cloud.
8	Write a program on Arduino/RaspberryPi to retrieve temperature and humidity data from thing speak cloud.
9	To install MySQL data base on RaspberryPi and perform basic SQL queries.
10	Write a program on Arduino/RaspberryPi to publish temperature data to MQTT broker.
11	Write a program on Arduino/RaspberryPi to subscribe to MQTT broker for temperature data and print it.
12	Write a program to create TCP server on Arduino/RaspberryPi and respond with humidity data to TCP client when requested.
13	Write a program to create UDP server on Arduino/RaspberryPi and respond with humidity data to UDP client when requested.
14	Sending message to PC through serial port by three different tasks on priority Basis.
15	Write simple applications using RTX (ARM Keil's real time operating system, RTOS).

P.T.O

Text Books:

- T1. K. V. Shibu, *Introduction to Embedded Systems*, 2nd Edition, McGraw-Hill Education, 2017.
- T2. R. Kamal, *Embedded Systems - Architecture, Programming and Design*, 12th Reprint, Tata McGraw-Hill, 2007.
- T3. A. Bahga and V. Madiseti, *Internet of Things : A Hands-On Approach*, 1st Edition, Universities Press, 2014.
- T4. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, and J. Henry, *IoT Fundamentals : Networking Technologies, Protocols, and Use Cases for the Internet of Things*, 1st Edition, Pearson Education, 2017.

Reference Books:

- R1. D. E. Simon, *An Embedded Software Primer*, Addison Wesley, 1999.
- R2. D. Kellmerit and D. Obodovski, *The Silent Intelligence: The Internet of Things*, 1st Edition, Lightning Source, 2014.
- R3. M. Schwartz, *Internet of Things with Arduino Cook book*, Packt Publishing, 2016.

Online Resources:

1. <https://nptel.ac.in/courses/106105159/>: by Prof. A. Basu, IIT Kharagpur
2. <https://nptel.ac.in/courses/106/105/106105195/>: by Prof. S. Misra, IIT Kharagpur.
3. <https://nptel.ac.in/courses/108/108/108108098/>: by Prof. T. V. Prabhakar, IISc Bangalore
4. <https://nptel.ac.in/courses/108/105/108105064/>: by Prof. A. Barua, IIT Kharagpur
5. <https://nptel.ac.in/courses/106/104/106104189/>: by Dr. R. Misra, IIT Patna

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the pin diagram of the ARM7 processor.
CO2	Realize and conceive different applications using the ARM7 processor.
CO3	Develop expertise on designing systems with Arduino/RaspberryPi.
CO4	Use Arduino/RaspberryPi for different practical applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	3	1	2	1					1	2	1	1
CO2	3	3	2	1						1	2	1	1
CO3	3	2	2	2	1					1	2	2	1
CO4	3	2	2	1						1	2	1	2

Part II

2nd Year M.Tech. (ECE)

Curriculum Structure

Semester III								
Type	Code	Course Title	WCH L-T-P			Credits L-T-P		
THEORY								
PE		Professional Elective - IV	3	0	0	3	0	0
PE		Professional Elective - V	3	0	0	3	0	0
OO		MOOC	0	0	0	3	0	0
PRACTICAL								
PJ		Thesis (Part - I) & Seminar	0	0	12	0	0	6
PJ		Summer Internship	0	0	0	0	0	1
		<i>SUB-TOTAL</i>	6	0	12	9	0	7
		<i>TOTAL</i>	18			16		

Semester IV								
Type	Code	Course Title	WCH L-T-P			Credits L-T-P		
PRACTICAL								
PJ	MTEC-P-PJ-003	Thesis (Part - II) & Seminar	0	0	28	0	0	14
MC	MTBS-P-MC-001	Yoga/NCC/NSS	0	0	2	0	0	0
		<i>SUB-TOTAL</i>	0	0	30	0	0	14
		<i>TOTAL</i>	30			14		

		<i>GRAND TOTAL (4 SEMESTERS)</i>	96			68		
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Note:

1. MOOC - Massive Open Online Course.
2. Approved list of courses for MOOC (self study) shall be published by the department.
3. Courses offered under each elective are given in "List of Electives" on Page 54.

List of Electives

Code	Elective # and Subjects
<i>Professional Elective - IV</i>	
MTEC-T-PE-010	Low Power VLSI Design
MTEC-T-PE-011	Industrial IoT
MTEC-T-PE-012	Optical Communication
<i>Professional Elective - V</i>	
MTEE-T-PE-014	Machine Learning
MTEC-T-PE-013	IC Design Testing
MTEC-T-PE-014	Advanced Mobile Communication

Type	Code	Low Power VLSI Design	L-T-P	Credits	Marks
PE	MTEC-T-PE-010		3-0-0	3	100

Objectives	The objective of this course is to understand the need of low power design, model power consumption and apply various techniques to design low power digital VLSI circuits & systems.
Pre-Requisites	Knowledge of Digital Electronic Circuits and Digital VLSI Design is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: Need for low power VLSI chips, Sources of Dissipation in Digital Integrated Circuits, Degrees of freedom, Emerging Low Power Approaches - Overview; Device & Technology Impact on Low Power Electronics: Introduction, Dynamic Dissipation in CMOS, Effects of & on Speed, Constraints on Reduction, Transistor Sizing & Optimal Gate Oxide Thickness, Impact of Technology Scaling, Technology and Device Innovations.	8 Hours
Module-2	Low Power Circuit Techniques: Introduction, Power Consumption in Circuits, Flip-flops and Latches, Logic, High Capacitance Nodes; Energy-Recovery CMOS: A Simple Example, A look at some practical details, Retractable Logic, Reversible Pipelines, High-Performance Approaches.	8 Hours
Module-3	Low Power Clock Distribution: Power Dissipation in Clock Distribution, Single Driver vs. Distributed Buffers, Buffer and Device Sizing under Process Variations, Zero Skew vs. Tolerable Skew, Chip and Package Co-Design of Clock Network.	9 Hours
Module-4	Logic Synthesis for Low Power: Introduction, Power Estimation Techniques, Power Minimization Techniques. Low Power Arithmetic Components; Introduction, Circuit Design Style, Adders, Multipliers, Division.	9 Hours
Module-5	Low Power Memory Design: Introduction, Sources and Reductions of Power Dissipation in Memory Subsystem, Sources of Power Dissipation in DRAM and SRAM, Low Power DRAM Circuits, Low Power SRAM Circuits.	8 Hours
Total		42 Hours

Text Books:

- T1. J. M. Rabaey and M. Pedram, *Low Power Design Methodologies*, Springer India, 2009.
- T2. G. K. Yeap, *Practical Low Power Digital VLSI Design*, Kluwer Academic Publishers 1998.

Reference Books:

- R1. K. Roy and S. C. Prasad, *Low-Power CMOS VLSI Circuit Design*, Wiley India, 2009.
- R2. A. P. Chandrakasan and R. W. Brodersen, *Low Power Digital CMOS Design*, Kluwer Academic Publishers, 2012.

- R3. A. Bellaouar and M. Elmasry, *Low-Power Digital VLSI Design: Circuits and Systems*, Kluwer Academic Publishers, 2012.
- R4. K. S. Yeo, S. S. Rofail, and W-L. Goh, *CMOS/BiCMOS ULSI Low Voltage Low Power*, 1st Indian Edition, Pearson Education, 2002.

Online Resources:

1. <https://nptel.ac.in/courses/106105034>: by Prof. A. Pal, IIT Kharagpur
2. <http://www.ocw.titech.ac.jp/index.php?module=General&action=T0300&JWC=201820800&lang=EN&vid=03>

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the need of the low power VLSI design and device and technology impact on low power electronics.
CO2	Explain low power circuit design techniques and energy recovery CMOS circuit method.
CO3	Analyze and design low power clock distribution network for VLSI chips.
CO4	Perform logic synthesis for low power systems and design low power arithmetic components.
CO5	Design low power memory circuits like DRAM and SRAM.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	1	2		1						1			1
CO2	2	2	2	2						1	1	2	1
CO3	3	3	3	2						1	2	2	1
CO4	3	3	3	2						1	1	2	1
CO5	3	3	3	2						1	1	2	1

Type	Code	Industrial IoT	L-T-P	Credits	Marks
PE	MTEC-T-PE-011		3-0-0	3	100

Objectives	The objective of this course is to study the design and implementation of IoT applications, industrial automation, and automation environments through a network by connecting the sensors to the cloud network and extracting data from the cloud to the connected devices.
Pre-Requisites	Knowledge of knowledge of IoT protocols and architecture is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on on theory and programming activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Technical Requirements of Industrial IoT: IoT Background, IoT key technologies, What is the I-IoT? Use cases of the IIOT, IoT and IIoT Similarities and difference, IoT Analytics and AI, Industry environments and scenarios covered by IIoT.	8 Hours
Module-2	Industrial Process and Devices Technical requirements: The Industrial Process, The CIM Pyramid, The I-IoT data flow.	7 Hours
Module-3	Industrial Data Flow and Devices Technical requirements: The I-IoT data flow in the factory Measurements and the actuator chain, Controllers, Industrial Protocols, SCADA, ERP and MES.	8 Hours
Module-4	Implementing the Industrial IoT Data Flow Discovering OPC: OPC Classic, OPC UA. Understanding the I-IoT edge, Implementing the IIoT data flow.	9 Hours
Module-5	Implementing a Cloud Industrial IoT solution with AWS Technical requirements: AWS Architecture, Registering for AWS, IoT Core, Storing Data, AWS analytics; Understanding Diagnostics, Maintenance, and Predictive Analytics: Technical Requirements, The different classes of analytics, I-IoT analytics technologies, Building I-IoT analytics, Understanding the role of the infrastructure Deploying analytics.	10 Hours
Total		42 Hours

Text Books:

- T1. G. Veeneri and A. Capasso, *Hands-On Industrial Internet of Things*, 1st Edition, Packt Publishing, 2018.
- T2. I. Butun, *Industrial IoT*, 1st Edition, Springer, 2020.
- T3. A. Suresh, M. nandagopal, P. Raj, E. A. Neeba, and J-W. Lin, *Industrial IoT Application Architectures and Use Cases*, 1st Edition, CRC Press, 2020.

Reference Books:

- R1. O. Hersent, D. Boswarthick, and O. Elloumi, *The Internet of Things - Key applications & Protocols*, Wiley, 2012.
- R2. A. Gichrist, *Industry 4.0: The Industrial Internet of Things*, 1st Edition, Apress, 2017.

Online Resources:

1. <https://nptel.ac.in/courses/106105195/>: by Prof. S. Misra, IIT Kharagpur.
2. <https://nptel.ac.in/courses/106/105/106105166/>: by Prof. S. Misra, IIT Kharagpur
3. <https://nptel.ac.in/courses/108/105/108105064/>: by Prof. A. Barua, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain the fundamental components and technologies of Industrial IoT.
CO2	Analyze the Industrial process and devices.
CO3	Design network protocols & software layers for data flow in an industrial set up.
CO4	Implement data flow from the edge to the cloud by means of OPC UA and Node-Red.
CO5	Develop IIoT solutions on cloud and perform data analytics for real life applications.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	2	2	2		1						1	1	1
CO2	3	2	3		2						3	1	3
CO3	3	3	3		3				2	2	3	2	3
CO4	3	3	3		3				2	2	3	3	3
CO5	3	3	3		3				1	2	3	3	3

Type	Code	Optical Communication	L-T-P	Credits	Marks
PE	MTEC-T-PE-012		3-0-0	3	100

Objectives	The objective of this course is to study the design and analysis of modern optical communication systems for providing worldwide connectivity.
Pre-Requisites	Knowledge of physics, electronics, and networks is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required; sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Introduction: The basic communications system, Nature of light, Advantages of fibers, Applications of Fiber optic communications; Optical Fibers and Connection losses: Terminology of light, Classification of fibers, SI fibers: NA and Multipath dispersion, Attenuation and Dispersion, Graded index fiber, V-number, Connector and splice, Losses during coupling between source to fiber, fiber to fiber.	9 Hours
Module-2	Optical sources and Amplifiers: LEDs, LED operating characteristics, LASER principles, LASER diodes and operating Characteristics, Fiber Lasers, Optical Amplifiers; Light Detectors: Principles of Photo detection, Photomultiplier, Optical Detectors, PIN photodiode and Avalanche Photodiode.	9 Hours
Module-3	Distribution Networks and Components: Distribution Networks, Directional Couplers, Star couplers, Switches, Optical Isolator, WDM, Fiber Bragg Gratings, Arrayed-waveguide Gratings, MEMs Switches, Attenuator, Circulator, Polarization Controller.	8 Hours
Module-4	Modulation: LED Modulation and circuits, LASER-Diode Modulation and circuits, Analog-Modulation formats, Digital modulation formats, Electro-absorption modulators, Optic-Heterodyne Receivers.	8 Hours
Module-5	Optical Fiber Transmitters and Receivers: Introduction, Direct intensity modulation, Direct optical modulation, Digital communication system, Basic components of a digital fiber optic communication receiver, Coherent optical fiber detection system; System Design: Design of analog systems, Design of digital systems.	8 Hours
Total		42 Hours

Text Books:

- T1. J. C. Palais, *Fiber Optic Communications*, 5th Edition, Pearson Education, 2013.
- T2. S. C. Gupta, *Textbook on Optical Fiber Communication and its Applications*, PHI Learning, 2012.

Reference Books:

- R1. R. P. Khare, *Fiber Optics and Optoelectronics*, Oxford University Press, 2008.
- R2. G. Keiser, *Optical Fiber Communications*, 4th Edition, Tata McGraw-Hill, 2013.

R3. J. M. Senior, *Optical Fiber Communication: Principles and Practice*, 3rd Edition, Pearson Education, 2013.

R4. H. Kolimbris, *Fiber Optics Communications*, Pearson Education, 2006.

Online Resources:

1. <https://nptel.ac.in/courses/108/104/108104113/>: by Dr. P. Kumar, IIT Kanpur
2. <https://nptel.ac.in/courses/117/101/117101002/>: by Prof. R. K. Shevgaonkar, IIT Bombay
3. <https://nptel.ac.in/courses/117104127/>: by Dr. P. Kumar, IIT Kanpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe the concepts of fiber optic communications, optical fiber classifications, attenuation, dispersion, and connection losses.
CO2	Explain and design different types of optical sources, amplifiers, and detectors.
CO3	Describe and analyze distribution networks and its various components.
CO4	Analyze the performance of modulation process, circuits for analog and Digital OFC systems.
CO5	Design optical transmitters and receivers as per application requirements.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2	1	1		1				1	1	1
CO2	3	3	2	2	2		1			1	2	2	2
CO3	3	3	2	2	2		1		1	1	2	2	2
CO4	3	3	2	3	2		1			2	2	2	2
CO5	3	3	3	1	2		1		2	2	2	2	2

Type	Code	Machine Learning	L-T-P	Credits	Marks
PE	MTEE-T-PE-014		3-0-0	3	100

Objectives	The objective of this course is to learn patterns and concepts from data using various machine learning techniques focusing on recent advances. Students will explore supervised & unsupervised learning paradigms, deep learning technique and various feature extraction strategies.
Pre-Requisites	Knowledge of algorithms, optimization, and matrix theory is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving and real-life examples.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Linear Methods for Regression and Classification: Overview of supervised learning, Linear regression models and least squares, Multiple linear and polynomial regression, Ridge regression, Least angle regression and Lasso, Elastic Net, Linear Discriminant Analysis.	8 Hours
Module-2	Dimensionality Reduction: Principal Components, Kernel PCA, Independent Component Analysis, LLE, Feature Selection.	8 Hours
Module-3	Model Assessment and Selection: Bias, Variance, and Model Complexity, Bias-variance trade-off, Optimism of the training error rate, Estimate of in-sample prediction error, Cross-validation.	9 Hours
Module-4	Neural Networks: Model of a neuron, LMS, Perceptron and its learning algorithm, MLP and Back Propagation algorithm, Heuristics for improving performance of BPA, Higher order convergence methods for BPA (Newton method, Conjugradient method); Radial Basis Function Networks, Self-Organizing Maps.	11 Hours
Module-5	Support Vector Machines (SVM) and Others: SVM for classification and Novelty detection (1-class classification), Reproducing Kernels, SVM for Regression.	6 Hours
Total		42 Hours

Text Books:

- T1. T. Hastie, R. Tibshirani, and J. Friedman, *The Elements of Statistical Learning: Data Mining, Inference and Prediction*, 2nd Edition, Springer Verlag, 2009.
- T2. S. Haykin, *Neural Networks: A Comprehensive Foundation*, 2nd Edition, Pearson Education, 1999.

Reference Books:

- R1. C. Bishop, *Pattern Recognition and Machine Learning*, 1st Edition, Springer, 2007.
- R2. T. Mitchel, *Machine Learning*, 1st Edition, McGraw-Hill Education, 1997.
- R3. G. James, D. Witten, T. Hastie, and R. Tibshirani, *An Introduction to Statistical Learning with Applications in R*, 7th Edition, Springer, 2013.
- R4. K. P. Murphy, *Machine Learning: A Probabilistic Perspective*, 4th Edition, MIT Press, 2012.

Online Resources:

1. <https://nptel.ac.in/courses/106/106/106106202/>: by Prof. C. G. Jansson, IIT Madras
2. <https://nptel.ac.in/courses/106/105/106105152/>: by Prof. S. Sarkar, IIT Kharagpur
3. <https://github.com/josephmisiti/awesome-machine-learning>: An exhaustive index of machine learning concepts and programming materials.
4. <http://mlss.cc/>: Machine Learning Summer School Study Material

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Formulate and solve machine learning problems using linear models of regression and classification.
CO2	Explain unsupervised learning models of dimensionality reduction and factor analysis.
CO3	Analyze the building blocks of probabilistic model assessment and selection.
CO4	Understand neural networks and their applications to real-world problems.
CO5	Apply the tools in cluster analysis, support vector machines and K-nearest neighbors.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	3	2		1	2			1	1	3	3	2
CO2	3	3	2		1	2			1	1	3	3	2
CO3	3	3	2		1	2			1	1	3	3	2
CO4	3	3	2		2	2			1	1	3	3	2
CO5	3	3	2		2	2			1	1	3	3	2

Type	Code	IC Design Testing	L-T-P	Credits	Marks
PE	MTEC-T-PE-013		3-0-0	0	100

Objectives	The objective of this course is to study the VLSI testing techniques for the design and analysis of digital VLSI circuits & systems.
Pre-Requisites	Knowledge on digital electronic circuits, MOSFET, and digital VLSI is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Fault Modeling: Defects, Errors, and Faults, Functional Versus Structural Testing, Levels of Fault Models, Different Fault Models, Single Stuck-at Fault, Fault Equivalence, Equivalence of Single Stuck-at Faults, Fault Collapsing, Fault Dominance and Checkpoint Theorem.	8 Hours
Module-2	Combinational Circuit Test Generation: Algorithms and Representations, Structural vs. Functional Test, Definition of Automatic Test-Pattern Generator, Search Space Abstractions, Algorithm Completeness, ATPG Algebras, Algorithm Types, Redundancy Identification (RID), Testing as a Global Problem, Definitions, Significant Combinational ATPG Algorithms, D-Calculus and D-Algorithm (Roth), PODEM (Goel), FAN (Fujiwara and Shimino), Test Generation Systems.	9 Hours
Module-3	Sequential Circuit Test Generation : ATPG for Single-Clock Synchronous Circuits, A Simplified Problem, Time-Frame Expansion Method, Use of Nine-Valued Logic, Development of Time-Frame Expansion Methods, Approximate Methods, Implementation of Time-Frame Expansion Methods, Complexity of Sequential ATPG, Cycle-Free Circuits, Cyclic Circuits, Clock Faults and Multiple-Clock Circuits, Asynchronous Circuits, Simulation-Based Sequential Circuit ATPG, CONTEST Algorithm.	8 Hours
Module-4	I_{DDQ} Test: Motivation, Faults Detected, Testing Methods, Fault Coverage Metrics, Test Vector Selection from Stuck-Fault Vector Sets, Instrumentation Problems, Current Limit Setting, Testing Effectiveness, Limitations, Delta I_{DDQ} Testing, I_{DDQ} Built-In Current Testing, I_{DDQ} Design for Testability.	8 Hours
Module-5	Design for Testability: Digital DFT and Scan Design - Ad-Hoc DFT Methods, Scan Design, Scan Design Rules, Tests for Scan Circuits; Built-in Self-Test - The Economic Case for BIST, Chip/Board Area Cost vs. Tester Cost & System Downtime Cost, Random Logic BIST Definitions, BIST Process, BIST Pattern Generation (Pseudo-Random Pattern Generation-LFSR), BIST Response Compaction (Transition Count Response Compaction, LFSR for Response Compaction, Modular LFSR Response Compaction), Built-in Logic Block Observers, Test-Per-Clock BIST Systems, Test-Per-Scan BIST Systems.	9 Hours
Total		42 Hours

Text Books:

- T1. M. L. Bushnell and V. D. Agarwal, *Essentials of Electronic Testing for Digital, Memory and Mixed Signal VLSI Circuits*, Kluwer Academic Publishers, 2004.
- T2. Z. Navabi, *Digital System Test & Testable Design: Using HDL Model & Architecture*, Springer, 2010.

Reference Books:

- R1. M. Abramovici, M. A. Breuer, and A. D. Friedman, *Digital Systems and Testable Design*, Jaico Publishing House, 2001.
- R2. L-T. Wang, C-W. Wu, X. Wen, *VLSI Test Principles and Architectures*, Morgan Kaufmann, 2006.
- R3. P. K. Lala, *Digital Circuit Testing and Testability*, Academic Press, 2002.
- R4. N. K. Jha and S. G. Gupta, *Testing of Digital Systems*, Cambridge University Press, 2003.

Online Resources:

1. <https://nptel.ac.in/courses/117105137>: by Prof. S. Chattopadhyay, IIT Kharagpur
2. <https://nptel.ac.in/courses/117103125>: by Dr. S. Biswas and others, IIT Guwahati
3. <https://ocw.tudelft.nl/courses/vlsi-test-technology-reliability/>
4. http://www.ee.ncu.edu.tw/~ares/course_VLSI_Testing.htm

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Explain fault modeling of VLSI circuits and systems.
CO2	Design various testing techniques of combinational VLSI circuits.
CO3	Design various testing technique of sequential VLSI circuits.
CO4	Analyze and design I _{DDQ} testing method for different VLSI circuits.
CO5	Design VLSI circuits for testability using BIST and scan-based techniques.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO2	Identify, formulate and solve engineering problems in the broad areas like Systems Design using communication, VLSI, Embedded Platforms and tools.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3	2	1	1	1								1
CO2	2	3	3	2	3	1					2	1	1
CO3	2	2	3	2	2	1					2	1	1
CO4	3	3	3	3	2	1				1	2	1	2
CO5	3	3	3	2	3	1				1	2	1	1

Type	Code	Advanced Mobile Communication	L-T-P	Credits	Marks
PE	MTEC-T-PE-014		3-0-0	0	100

Objectives	The objective of this course is to study advanced wireless communications, signal processing and state-of-the-art techniques of mobile communications networks.
Pre-Requisites	Knowledge of wireless communication systems and mobile communication is required.
Teaching Scheme	Regular classroom lectures with use of ICT as and when required, sessions are planned to be interactive with focus on problem solving activities.

Evaluation Scheme

Teacher's Assessment			Written Assessment		Total
Quiz	Surprise Test(s)	Assignment(s)	Mid-Term	End-Term	
05	05	05	25	60	100

Detailed Syllabus

Module-#	Topics	Hours
Module-1	Wireless Communications and Diversity: Fast Fading Wireless Channel Modeling, Rayleigh/Ricean Fading Channels, BER Performance in Fading Channels, Diversity modeling for Wireless Communications, BER Performance Improvement with diversity, Types of Diversity - Frequency, Time, Space; Broadband Wireless Channel Modeling: WSSUS Channel Modeling, RMS Delay Spread, Doppler Fading, Jakes Model, Autocorrelation, Jakes Spectrum.	11 Hours
Module-2	Cellular Communications: Introduction to Cellular Communications, Frequency reuse, Multiple Access Technologies, Cellular Processes - Call Setup, Handover, Tele-traffic Theory.	7 Hours
Module-3	OFDM: Introduction to OFDM, Principles of OFDM Wireless Communication, Channel Estimation, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues - PAPR Frequency and Timing Offset Issues, OFDMA, SCFDMA.	8 Hours
Module-4	MIMO: Introduction, Principles of MIMO Wireless Communication, MIMO Channel Capacity, SVD and Eigen modes of the MIMO Channel, MIMO Spatial Multiplexing - BLAST, MIMO Diversity - Alamouti, OSTBC, MRT, MIMO - OFDM, Introduction to Massive MIMO.	8 Hours
Module-5	UWB (Ultrawide Band): UWB Definition and Features, UWB Wireless Channels, UWB Data Modulation, Uniform Pulse Train, Bit-Error Rate Performance of UWB; 5G Technology: Introduction to 5G, 5G air interface requirements, Overview of antenna technologies used in 5G, Overview resource allocation in 5G networks.	8 Hours
Total		42 Hours

Text Books:

- T1. T. Rappaport, *Wireless Communications: Principles and Practice*, 2nd Edition, Prentice Hall, 2009.
- T2. E. Biglieri, *MIMO Wireless Communications*, 3rd Edition, Cambridge University Press, 2010.

Reference Books:

- R1. D. Tse and P. Viswanath, *Fundamentals of Wireless Communications*, Cambridge University Press, 2005.

- R2. A. Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.
 R3. F. Monserrat and P. Marsch, *5G Mobile and Wireless Communications Technology*, Cambridge University Press, 2016.
 R4. A. Paulraj, *Introduction to Space-Time Wireless Communications*, Cambridge University Press, 2003.
 R5. J. G. Proakis, *Digital Communications*, 5th Edition, McGraw-Hill, 2008.

Online Resources:

1. <https://nptel.ac.in/courses/117104115>: by Prof. A. K. Jagannatham, IIT Kanpur
2. <https://nptel.ac.in/courses/106106167>: by Prof. R. D. Koilpillai, IIT Madras
3. <https://nptel.ac.in/courses/108105134>: by Prof. S. S. Das, IIT Kharagpur
4. <https://nptel.ac.in/courses/108105179>: by Prof. A. K. Dutta, IIT Kharagpur

Course Outcomes: *At the end of this course, the students will be able to:*

CO1	Describe current and upcoming technologies wireless communications for broadband wireless networks.
CO2	Explain the fundamentals of cellular communication systems.
CO3	Enhance OFDM performance using MIMO and OFDMA techniques.
CO4	Explore the use of MIMO in 5G and its techniques for mobile communication.
CO5	Apply OFDM-based standards such as 4G LTE, 5G, and Wi-Fi in the real world.

Program Outcomes Relevant to the Course:

PO1	Apply the knowledge of science and mathematics in analyzing and designing electronic & communication equipment for various industrial and domestic applications.
PO3	Develop robust and problem specific algorithms for processing, analysis, synthesis of signals, and exploring recent developments in the field of advanced communication engineering.
PO4	Understand and use different software tools for design, analysis and verification in the domain of communication, VLSI and signal processing through design, synthesis, functional, and timing simulation.
PO5	Design and conduct experiments, analyze and interpret data, utilize programming skills for development of simulation experiments.
PO6	Function effectively as an individual or as a member of a multidisciplinary team with sense of ethics, integrity and social responsibility.
PO7	Understand the impact of electronics & communications in an economic, social and environment context.
PO9	Communicate effectively in a technically sound manner with a wide range of audience.
PO10	Continue to learn independently and engage in life-long learning.

Mapping of COs to POs and PSOs (1: Low, 2: Medium, 3: High)

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PSO1	PSO2	PSO3
CO1	3		2	2	1	1	1		1	1	1	2	3
CO2	2		3	2	1	1	2		1	1	1	2	3
CO3	3		3	2	2	1	1		1	1	2	2	3
CO4	3		3	2	2	1	1		1	1	2	2	3
CO5	2		3	2	1	1	1		1	1	1	2	3



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