Revised

M. Tech. Syllabus

[Communication Engineering 2022]

Electronics & Communication Engineering,

North-Eastern Hill University,

Shillong - 793 022

Meghalaya

Table of Contents

1. Syllabus Scheme

1.1 Semester: I

Branch: *Electronics & Communication Engineering* **Year:** I **Semester:** I

Sl. No.	Course Code	Course Name	Periods (Contact Hours)			Evaluation Scheme (Distribution of Marks)					**Credits**
Papers			**L**	**T**	**P**	**TA**	**CT**	**ST**	**ESE**	**TOT**	
1	EC-CC-500	Advanced Signal Processing	3	1	0	10	15	25	75	100	4
2	EC-CC-501	Machine Learning	3	1	0	10	15	25	75	100	4
3	EC-DSEC-502xx	Discipline Specific Elective Course Elective - I	3	1	0	10	15	25	75	100	4
4	EC-DSEC-503xx	Discipline Specific Elective Course Elective - II	2	0	4	10	15	25	75	100	4
5	EC-GEC-504xx	Generic Elective Course (Multidisciplinary)	3	1	0	10	15	25	75	100	4
		Total	**14**	**4**	**4**	50	75	**125**	**375**	**500**	20

L - Lecture **T -** Tutorial **P -** Practical **TA -** Assesment by Teacher
CT - Class Test **ST -** Sub-Total **ESE -** End Semester Evaluation **TOT -** Total

Contact Hours: *22* **Total Marks:** *500* **Total Credits:** *20*

DSEC : Elective - I

1. EC-DSEC-50201 Advanced Wireless Communication
2. EC-DSEC-50202 Microwave Theory and Techniques
3. EC-DSEC-50203 Silicon Photonics
4. EC-DSEC-50204 Digital IC Design

DSEC : Elective - II

1. EC-DSEC-50301 FPGA Implementation Practices
2. EC-DSEC-50302 IoT Sensors and Devices
3. EC-DSEC-50303 Advanced Communication Practices

Generic Elective Course (Multidisciplinary)

1. EC-GEC-50401 Biosensors and Applications
2. EC-GEC-50402 Fabrication Techniques for MEMs-based Sensors: Clinical Perspective
3. EC-GEC-50403 Biomedical Instrumentation

1.2 Semester: II

Branch: *Electronics & Communication Engineering* **Year:** I **Semester:** II

Sl. No.	Course Code	Course Name	Periods (Contact Hours)			Evaluation Scheme (Distribution of Marks)					Credits
Papers			**L**	**T**	**P**	**TA**	**CT**	**ST**	**ESE**	**TOT**	
1	EC-CC-506	Next Generation Communication Techniques	3	1	0	10	15	25	75	100	4
2	EC-CC-507	Modern Digital Control Systems	3	1	0	10	15	25	75	100	4
3	EC-DSEC-508xx	Discipline Specific Elective Course Elective - III	3	1	0	10	15	25	75	100	4
4	EC-DSEC-509xx	Discipline Specific Elective Course Elective - IV	2	0	4	10	15	25	75	100	4
5	EC-RM-510	Research Methodology and Proposal Writting	2	2	0	10	15	25	75	100	4
6	EC-SEC-511xx	Skill Enhancement Course (SEC)	3	1	0	10	15	25	75	100	4
		Total	**16**	**6**	**4**	60	90	**150**	**450**	**600**	24

L - Lecture **T -** Tutorial **P -** Practical **TA -** Assesment by Teacher
CT - Class Test **ST -** Sub-Total **ESE -** End Semester Evaluation **TOT -** Total

Contact Hours: *26* **Total Marks:** *600* **Total Credits:** *24*

DSEC : Elective - I

1. EC-DSEC-50801 Antenna Analysis and Design
2. EC-DSEC-50802 VLSI Devices and Modeling
3. EC-DSEC-50803 Photonic Integrated Circuits

DSEC : Elective - II

1. EC-DSEC-50901 Advanced Practices in VLSI Devices and RF Circuits
2. EC-DSEC-50902 Advanced Practices in Machine Learning

Skill Enhancement Course (SEC)

1. EC-SEC-51101 Advanced Data Visualization and Analytics
2. EC-SEC-51102 Development of MOOC Courses
3. EC-SEC-51103 Project Management for Managers

1.3 Semester: III

Branch: *Electronics & Communication Engineering* **Year:** II **Semester:** III

Sl. No.	Course Code	Course Name	Periods (Contact Hours)			Evaluation Scheme (Distribution of Marks)					**Credits**
Papers			**L**	**T**	**P**	**TA**	**CT**	**ST**	**ESE**	**TOT**	
1	EC-CC-600	Advanced Digital Communication	3	1	0	10	15	25	75	100	4
2	EC-CC- 601	Millimeter-wave and Terahertz Techniques	3	1	0	10	15	25	75	100	4
3	EC-CC-602	Minor Project	0	0	8	10	15	25	75	100	4
4	EC-DSEC-603xx	Discipline Specific Elective Course : Elective - V	3	1	0	10	15	25	75	100	4
5	EC-DSEC-604xx	Discipline Specific Elective Course : Elective - VI	3	1	0	10	15	25	75	100	4
6	EC-DSEC-605xx	Discipline Specific Elective Course : Elective - VII	3	1	0	10	15	25	75	100	4
		Total	**15**	**5**	**8**	60	90	**150**	**450**	**600**	24

L - Lecture **T -** Tutorial **P -** Practical **TA -** Assesment by Teacher
CT - Class Test **ST -** Sub-Total **ESE -** End Semester Evaluation **TOT -** Total

Contact Hours: *28* **Total Marks:** *600* **Total Credits:** *24*

DSEC : Elective - V

1. EC-DSEC-60301 Analog IC Design
2. EC-DSEC-60302 Speech Processing

DSEC : Elective - VI

1. EC-DSEC-60401 Image Processing for Computer Vision
2. EC-DSEC-60402 Social Robotics

DSEC : Elective - VII

1. EC-DSEC-60501 Spoken Language Identification Techniques
2. EC-DSEC-60502 Embedded System Design with ARM

1.4 Semester: IV

Branch: *Electronics & Communication Engineering* **Year:** II **Semester:** IV

Sl. No.	Course Code	Course Name	Periods (Contact Hours)			Evaluation Scheme (Distribution of Marks)					**Credits**
Papers			**L**	**T**	**P**	**TA**	**CT**	**ST**	**ESE**	**TOT**	
1	EC-DSEC- 606	Major Project	-	-	40	50	75	125	375	500	20
		Total			**40**	**50**	**75**	**125**	**375**	**500**	**20**

L - Lecture **T -** Tutorial **P -** Practical **TA -** Assesment by Teacher
CT - Class Test **ST -** Sub-Total **ESE -** End Semester Evaluation **TOT -** Total

Contact Hours: *40* **Total Marks:** *500* **Total Credits:** *20*

The Project evaluation will be done based on the following components:

1. Problem Identification and Review of Related Literature
2. Proposal Writing and Presentation
3. Data Collection
4. Data Analysis, Interpretation and Discussion
5. Report Writing
6. Viva Voce

Students can also select MOOCs courses of equivalent credit under SWAYAM plateform against Discipline Specific Elective Courses and Research Methodology (Applicable to Semester I, II & III.)

L - T - P
3 - 1 - 0 = 4

2. M. Tech. Syllabus

2.1 First Semester

2.1.1 EC-CC-500 Advanced Signal Processing

Course Code	:	$EC - CC - 500$
Course Name	:	*Advanced Signal Processing.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To describe the multirate systems and filter banks. The paper at last focusses various wavelet transforms.

Objectives: On completion of the paper, students should

- CO1: Understand various forms of sampling alteration devices
- CO2: Understand filter banks and their significance
- CO3: Understand Hilbert and wavelet transforms

Unit I
Multirate Signal Processing: Sampling Rate Conversion; Decimation and Interpolation; Time and Frequency Domain Characterization; Filters in Sampling Rate Alteration Systems; Multirate Design of Decimator and Interpolator; Poly-phase Techniques; Poly-phase Down-sampler and Interpolator; Poly-phase Filter Design.

Unit II
Filter Banks: Two-channel QMF Banks, Alias free FIR and IIR QMF Banks; Perfect Reconstruction Two-channel FIR Filter Banks; M-Channel Filter Banks Design; Cosine-Modulated M-Channel Filter Banks Design

Unit III
Discrete Hilbert Transforms: Real and Imaginary Part, Sufficiency of the FT for Causal Sequences, Sufficiency Theorems for Finite length Sequences, Relationship between Magnitude and Phase, HT Relation for Complex Sequences.

Unit IV
Wavelet Transforms: Fourier Transform and Its limitations, Short-Time Fourier Transform, Continuous Wavelet Transform, Discretization of the Continuous Wavelet Transform, Multiresolution Approximations; Wavelet and Scaling Function Coefficients, Harr Wavelets, The Daubechies Wavelets Construction, Fast Wavelet Transform and Image Compression, Denoising using Wavelets, Perfect Reconstruction Filter bank design using Wavelets.

Text Books:

1. S. K. Mitra, *Digital Signal Processing: A Computer Based Approach*, 4/e, TMH, 2013.
2. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, 4/e, Pearson Education Inc., 2007.
3. M. Vetterli and J. Kovacevic, *Wavelets and Subband Coding*, CreateSpace Independent Publishing Platform, 2013.
4. G. Strang and T. Nguyen, *Wavelets and Filter Banks*, Wellesley Cambridge Press, 1996.

Reference Books:

1. A.V. Oppenheim and R. W. Schafer, *Discrete – Time Signal Processing*, 3/e, Prentice-Hall, 2009.
2. R. E. Crochiere and L. R. Rabiner, *Multirate Digital Signal Processing*, Prentice-Hall Inc., 1983.
3. C.K.Chui, *Wavelets: A tutorial in Theory and Applications*, Academic Press.
4. C. S. Burrus, R. A. Gopinath and H. Guo, *Introduction to Wavelets and Wavelets Transforms*, Prentice Hall Inc., 1997.

L	-	T	-	P		
3	-	1	-	0	=	4

2.1.2 EC-CC-501 Machine Learning

Course Code	:	$EC - CC - 501$
Course Name	:	*Machine Learning*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To obtain a broad overview of existing machine learning methods, and to understand their motivations and main ideas from a variety of perspectives.

Objectives: On completion of this paper, students should

- CO1: Understand fundamentals of machine learning
- CO2: Have thorough grounding in the methodologies, technologies, mathematics and algorithms of machine learning
- CO3: To mathematically analyse various machine learning approaches and paradigms

Unit I
Supervised Learning (Regression/Classification): Basic methods: Distance-based methods, Nearest-Neighbours, Decision Trees, Nave Bayes; Linear models: Linear Regression, Logistic Regression, Generalized Linear Models; Support Vector Machines, Nonlinearity and Kernel Methods;Beyond Binary Classification: Multi-class/Structured Outputs, Ranking.

Unit II
Unsupervised Learning:
Clustering: K-means/Kernel K-means; Hidden Markov Models; Dimensionality Reduction: PCA and kernel PCA; Matrix Factorization and Matrix Completion;Generative Models (mixture models and latent factor models).

Unit III
Probabilistic Models: Evaluating Machine Learning algorithms and Model Selection, Introduction to Statistical machine learning (Maximum Likelihood Estimation, MAP, Bayes Classifiers Naive Bayes; Bayes optimal classifiers; Minimum description length principle; Bayesian Networks, Inference in Bayesian Networks, Bayes Net Structure Learning).

Unit IV
Recent Trends: Sparse Modeling and Estimation, Modeling Sequence/Time-Series Data, Deep Learning and Feature Representation Learning; Recent trends in various learning techniques of machine learning

Text Books:

1. Tom M. Mitchell, *Machine Learning*, 2/e, McGraw Hill, 2010.
2. Alpaydin Ethem, *Introduction to Machine Learning*, 2/e, MIT Press, 2010.
3. Christopher M. Bishop, *Pattern Recognition and Machine Learning*, Sringer, 2007.
4. Duda R. O., Hart P.E. and Stork D.G., *Pattern Classification*, 2/e, Wiley & Sons, 2006.
5. Murphy Kavin. P., *Machine Learning: A Probabilistic Perspective*, The MIT Press, 2012.
6. Trevor Hastie, Robert Tibshirani, Jerome Friedman, *The Elements of Statistical Learning*, Springer 2009.

Reference Books:

1. P. Flach, *Machine Learning: The Art and Science of Algorithms that Make Sense of Data*, Cambridge University Press, 2012.

2. David J. C. MacKay, *Information Theory, Inference, and Learning Algorithms*, the South Asia Edition, Foundation Books, 2003.
3. S. J. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, 3/e, Pearson Education, 2015.
4. Mohri M., Rostamizadeh A. and Talwalkar A., *Foundations of Machine Learning* the MIT Press, 2012.
5. Ball Rasmussen C. E. and Williams C. K. I., *Gaussian Processes for Machine Learning*, the MIT Press,2006.

L	-	T	-	P		
3	-	1	-	0	=	4

2.1.3 EC-DSEC-50201 Advanced Wireless Communication

Course Code	:	*EC − DSEC − 50201*
Course Name	:	*Advanced Wireless Communication.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To get a well-defined apprehension of modern wireless communication system which will help the students to design and evaluate wireless system theoretically.

Course Outcomes:

- CO1: To introduce the concepts of wireless communication.
- CO2: To make the students to know about the various propagation methods, Channel models, capacity calculations multiple antennas and multiple user techniques used in the mobile communication.

Unit I
Introduction to Cellular Communication: History of cellular communication, Frequency reuse, multiple access technologies, Channel assignment strategies, Handoff strategies, Interference and system capacity, Trunking and grade of services, Trends in cellular radio and personal communication.

Unit II
Sources and Transmitters: Slow and Fast Fading Wireless Channel Modeling, Rayleigh/Ricean Fading Channels, BER Performance in Fading Channels.

Unit III
Diversity techniques: Diversity techniques for Wireless Communications, Basic methods of diversity combining, BER Performance Improvement with diversity, Types of Diversity - Frequency, Time, Space.

Unit IV
Advanced Techniques for Digital Communication: Model of spread spectrum digital communication system, Direct sequence spread spectrum signals, Frequency Hopped spread spectrum signals, other types of spread spectrum signals, Introduction to MIMO, MIMO Channel Capacity SVD and Eigenmodes of the MIMO Channel, Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues - PAPR.

Text Books:

1. T. S. Rappaport, *Wireless Communication Principle and Practice*, Prentice-Hall of India, 2007.
2. Andreas Molisch, *Wireless Communications*, Wiley IEEE Press. 2007.
3. S. Haykin, *Communication Systems*, Wiley India, 2006.
4. Arogyaswami Paulraj, *Introduction to Space-Time Wireless Communications*, Cambridge University Press, 2006.

Reference Books:

1. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press. 2005.
2. David Tse and Pramod Viswanath, *Fundamentals of Wireless Communications*, Cambridge University Press, 2005.
3. Mischa Schwartz, *Mobile Wireless Communications*, Cambridge University Press 2005.
4. J. G. Proakis and M. Salehi, *Digital Communications*, 5/e, McGraw-Hill International Edition, 2008.

2.1.4 EC-DSEC-50202 Microwave Theory and Technique

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC – DSEC – 50202*
Course Name	:	*Microwave Theory and Techniques*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: (To understand the significance of microwave theory and to design modern microwave components.)

Objective: On completion of this paper, students should be able to

- CO1: develop the concept of microwave transmission line and networks.
- CO2: design matching circuits and other planar microwave components.
- CO3: design filters for modern communication systems

Unit I
Transmission Line and Networks : Review of electromagnetic field equations, The wave equation, Solution of wave equations, Radio Frequency Transmission Line Theory, Telegrapher's Equations, Concept of Voltage and Current Wave in a Line, Characteristics impedance and characteristics admittance, Power Flow in a Transmission Line , Terminated Lines: Short circuited line, Open Circuited Line, Matrix Representation of network: The impedance matrix, The admittance matrix, ABCD matrix, Matching of Transmission Lines: The Quarterwave Transformer matching , Stub Matching. Introduction to left handed transmission lines.

Unit II
Planar Transmission Lines: Micro-strip Line: EM field distribution in a Micro-strip Line, Effective Dielectric Constant, Characteristic impedance, Coplanar waveguide, Stripline, Microwave resonators: series and parallel resonant circuits, transmission line resonator, Dielectric resonators.

Unit III
Microwave Passive Components : Planar Power divider, T-junction power divider, Wilkinson power divider, Directional coupler: 90 degree Hybrid, 180 degree Hybrid coupler, Lange Coupler, Ferrimagnetic Components, Ferrite Phase Shifter, Ferrite Isolator, Ferrite Circulator

Unit IV
Microwave filters : Periodic structures, Filter Design by the Insertion Loss Method, Maximally Flat and Chebyshev Filter design, stepped impedance lowpass filter, Band Pass and High Pass Filters, Filter using coupled line resonators. Multiband and broad banding techniques in modern filter applications.

Text Books:

1. D. M. Pozar, Microwave Engineering, 4/e, John Wiley, 2011.
2. Peter A. Rizzi, Microwave Engineering: Passive Circuits, 1/e, Prentice Hall, 1987.
3. C. Caloz, T. Itoh, Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, John Wiley and Sons, 2006.
4. S. M. Liao, Microwave Devices and Circuits, 3/e, Pearson Education, 2003.
5. Jia-Sheng Hong, Microstrip Filters for RF/Microwave Applications, 2/e, John Wiley and Sons, 2011

Reference Books:

1. R. E. Collin, Foundations for Microwave Engineering, 2/e, Wiley-IEEE Press, 2000.
2. R. Ludwig and G. Bogdanov, RF Circuit Design: Theory and Applications, 2/e, Prentice Hall, 2008.

2.1.5 EC-DSEC-50203 Silicon Photonics

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − DSEC − 50203*
Course Name	:	*Silicon Photonics.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To design Silicon Photonics (SiPh) technology-based Interferometer (MZI/MRR/Michelson) with suggested specifications for data-center interconnect and communication applications.

Objectives: On completion of this course, students should be able

- CO1: To recognize and explain Silicon Photonics (SiPh) as an emerging technology to meet the explosive bandwidth demand and computationally efficient systems
- CO2: To Model SiPh technology-based passive photonic devices such as strip waveguide, Y-branch, directional couplers, etc.
- CO3: To design the Layout of passive photonic devices on an open-source GDS-II platform, i.e., KLayout using SiEPIC tools and pdks
- CO4: To evaluate the performance of MZI/MRR/Michelson interferometers for interconnects and PIC applications with given specifications

Unit I
Introduction to Silicon Photonics (SiPh): SiPh as the next fabless semiconductor industry, application of SiPh in data center and communication, technical challenges and state of the art, Opportunities in SiPh engineer as a career

Unit II
Modeling and Design approaches: Introduction to Mode solvers, Physical Layout: different physical layout tools, Introduction and application of KLayout (open-source) for GDS-II design. Introduction to Design workflow. Optical materials and waveguides: SoI, waveguides-slab waveguide, 1-D and 2-D mode profile calculations, compact models for waveguides, and waveguide loss.

Unit III
SiPh-based Passive Devices: Design of Y-branch, strip waveguide grating, Directional Coupler, MZI, MRR, Bragg gratings filters, Lattice filter, Multiplexer/Demultiplexer

Unit IV
Design of SiPh-based Circuits on SoI: Optical Input/output Devices: Grating and edge couplers, Lattice filter, Multiplexer/Demultiplexer using SiEPIC pdk on KLayout, DRC, Circuit simulation and characterization

Text Books:

1. Lukas Chrostowski and Michael Hochberg, Silicon Photonics Design: from Devices to Systems, 1/e, 2016, Cambridge University Press, University Printing House, Cambridge CB2 8BS, UK

2. Slawomir Sujecki, Photonics Modeling and Design, 1/e, 2015 CRC Press, Taylor and Francis Group, 6000 Broken Soud Parkway, NW, Suit 300.

3. Daryl Inniss and Roy Rubenstein, Silicon Photonics-Fuelling the Next Information Revolution, 1/e, 2016, Morgan Kaufmann, USA

4. David J. Lockwood, Lorenzo Pavesi, Silicon Photonics IV: Innovative Frontiers, 1/e, 2021, Springer Cham

Reference Books:

1. Lorenzo Pavesi, David J. Lockwood, *Silicon Photonics, Topics in Applied Physics (TAP, volume 94)*, 1/e, 2004, Springer Berlin, Heidelberg.
2. Graham T. Reed and Andrew P. Knights, *Silicon Photonics: An Introduction*, 1/e, 2004, Wiley.
3. S. J. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, 3/e, Pearson Education, 2015.
4. David J. Lockwood and Lorenzo Pavesi., *Silicon Photonics II: Components and Integration: 119 (Topics in Applied Physics)* 1/e, 2010, Springer.
5. Murphy Kavin. P., *Machine Learning: A Probabilistic Perspective*, The MIT Press, 2012.
6. IEEE Journals of Photonics Technology Letters, JLT, Sec. Topics in Quantum Electrons etc
7. Tools: Matlab ,Comsol Multiphysics(https://www.istem.gov.in/rd-infrastructure-map/software-through-istem, visited 26.08.2022), Ansys Lumerical
8. Tools: Python, KLayout, SiEPIC tools, and pdk (https://github.com/SiEPIC, visited 26.08.2022)

2.1.6 EC-DSEC-50204 Digital IC Design

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − DSEC − 50204*
Course Name	:	*Digital IC Design.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To get understanding of Synthesis, Optimization, Verification and Testing of Digital Circuits.

Objectives: On completion of this course, students should be able

- CO1: Understand the Digital Design Flow.
- CO2: Discuss the techniques for the Synthesis of digital circuits.
- CO3: To understand the Testing of digital circuits.
- CO4: To understand the Verification of digital circuits.

Unit I
CAD tool Flow: Introduction to Digital VLSI Design Flow Specification, High level Synthesis, RTL Design, Logic Optimization, Verification and Test Planning, Design Representation, Hardware Specific Transformations.

Unit II
High Level Synthesis: Scheduling, Allocation and Binding: Problem Specification(Scheduling, Allocation and Binding), Basic Scheduling Algorithms (Time constrained and Resource Constrained), Allocation Steps: Unit Selection, Functional Unit Binding, Storage Binding, Interconnect Binding, Allocation Techniques: Clique Partitioning, Left-Edge Algorithm, Iterative Refinement.

Unit III
Gate Level Synthesis and Optimization.: Logic Optimization and Synthesis: Heuristic Minimization of Two-Level Circuits: Espresso, Finite State Machine Synthesis, Multi-Level Logic Synthesis, Multi-Level Minimization, Technology Mapping, Binary Decision Diagram: Introduction and construction, Reduction rules and Algorithms, ROBDDs, Operation on BDDs and its Algorithms, Representation of Sequential Circuits.

Unit IV
Verification and Testing.: Model Checking:Introduction to Verification, Specification and Modelling, Model Checking Algorithm, Symbolic Model Checking, Automata and its use in Verification, Automata Theoretic Model Checking. Introduction to Digital Testing, Fault Simulation and Testability Measures, Combinational Circuit Test Pattern Generation, Sequential Circuit Testing and Scan Chains, Built in Self test (BIST).

Text Books:

1. LG. De Micheli, Synthesis and optimization of digital circuits, Tata McGraw-Hill Education, 2003.
2. D. D. Gajski, N. D. Dutt, A. C.-H. Wu and S .Y.-L. Lin, High-Level Synthesis: Introduction to Chip and System Design, 1e, Springer, 1992.
3. M. Huth and M. Ryan, Logic in Computer Science modeling and reasoning about system, 2e, Cambridge University Press, 2004.

Reference Books:

1. Bushnell and Agrawal, Essentials of Electronic Testing for Digital, Memory and Mixed-Signal Circuits, Kluwer Academic Publishers, 2000.

L	-	T	-	P		
2	-	0	-	4	=	4

2.1.7 EC-DSEC-50301 FPGA Implementation Practices

Course Code	:	*EC – DSEC – 50301*
Course Name	:	*FPGA Implementation Practices*
Contact Hours per Week	:	*2(two) Hours Lecture & 4(four) Practical*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Three.(Theory) & Eight (Practical)*
Questions to be Answered	:	*Any two from theory and one from Practical*
Duration of End Semester Examination	:	*1.5 hours (Theory) & 3 hours (Practical).*

Aim: The main aim of this course is to give in depth understanding of the Digital Designs in an FPGA.

Course Outcomes: On completion of this paper, students would be able to:

- CO1: Implement arbitrary Logic Implementation over FPGA.
- CO2: Synthesize High Level Algorithms for Production.
- CO3: Learn to produce Digital IP for Consumer Applications.

Unit I
FPGA Architectures: What is FPGA, FPGA Architectures, CPLD vs FPGA, SoC FPGAs

Unit II
FPGA Design and Applications: FPGA Design Cycle, FPGA Uses: An Attractive Choice for Certain Applications..

Unit III
Hands-on/ Laboratory/ Practicals:

1. Simple Combinational Logic implementation in FPGA.
2. Multi-Function Gate implementation in FPGA.
3. Three-Bit Binary Adder implementation in FPGA.
4. Multiplexers in Combinational logic implementation in FPGA.
5. Decoder and Demultiplexer implementation in FPGA.
6. Random Access Memory implementation in FPGA.
7. Flip-Flop implementation in FPGA.
8. Designing with D-Flip flops.
9. Shift Register and Sequence Counter implementation in FPGA.
10. State Machine Implementation implementation in FPGA.
11. Implement IP Cores in an FPGA.
12. Translation of High Level Codes for FPGA.
13. FPGA System Emulation.

Text Books:

1. Donald Thomas, Logic Design and Verification Using System Verilog, 2016
2. Frank Bruno, FPGA Programming for Beginners, Springer, 2021.
3. Justin Rajewski,Learning FPGAs, Springer, 2017.

L	-	T	-	P		
2	-	0	-	4	=	4

2.1.8 EC-DSEC-50302 IoT Sensors and Devices

Course Code	:	*EC − DSEC − 50302*
Course Name	:	*IoT Sensors and Devices*
Contact Hours per Week	:	*2(two) Hours Lecture & 4(four) Practical*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Three.(Theory) & Eight (Practical)*
Questions to be Answered	:	*Any two from theory and one from Practical*
Duration of End Semester Examination	:	*1.5 hours (Theory) & 3 hours (Practical).*

Aim: The paper is designed to equip students with basics of Internet of Things (IoT) and its applications. It provides theoretical and practical aspects of interfacing with sensors and actuators, communication modes and software models to build real-time IoT-based solutions.

Objectives: On completion of this paper, students would be able to:

- CO1: Learn basic electronics design and embedded controllers needed in IoT systems.
- CO2: Identify the devices needed for different IoT solutions eg. sensors.
- CO2: Understand, design and build an IoT system incorporating specific devices.
- CO4: Understand various communication protocols used in IoT.
- CO5: Apply various IOT technologies in real-life applications.

Unit I
Fundamentals of IoT: Introduction, working principles, properties, IoT ecosystem, IoT decision framework, IoT solution, architecture models, and applications. Sensors and actuators, basic understanding of microcontrollers/Raspberry/Arduino. Setting Up Raspberry/Arduino to Create Solutions: Exploring and setting up, showing working of Raspberry Pi using SSH Client and Team Viewer, Understand Sensing actions, Understand Actuators and MEMS.

Unit II
Communication Protocols of IoT: Types of wireless communication, Major wireless Short-range communication devices, properties, comparison of these devices (Bluetooth, WIFI, ZigBee, 6LoWPAN), Major wireless Long-range communication devices, properties, comparison of these devices (Cellular IoT, LPWAN).
Sensors and their Applications: Google Maps, Waze, WhatsApp, Ola Positioning sensors: encoders and accelerometers; Image sensors: cameras, Global positioning sensors: GPS, GLONASS, IRNSS, Galileo and indoor localization systems; Motion & Orientation Sensors: Accelerometer, Magnetometer, Proximity Sensor, Gyroscope Calibration, noise modeling and characterization and noise filtering and sensor data processing. Privacy & Security.

Unit III
Hands-on/ Laboratory/ Practicals: To interface and perform actions in various IoT based projects:

1. To familiarization with Arduino/Raspberry pi and necessary software installation.
2. Interface with various sensors with Arduino/Raspberry Pi and to write program to perform indicated actions.
3. Experiment on application framework and embedded software agents for IoT Toolkit.

Text Books:

1. Vijay Madisetti and Arshdeep Bahga, *Internet of Things (A Hands-on Approach)*, 1st Edition, VPT, 2014.
2. CunoPfister, Getting Started with the Internet of Things, O Reilly Media, 2011.
3. Kyung, C.-M., Yasuura, H., Liu, Y., Lin, Y.-L., Smart Sensors and Systems, Springer International Publishing, 2015.

4. Raj Pethuru, Raman Anupama C., *The Internet of Things. Enabling Technologies, Platforms, and Use Cases*, CRC Press, 2017.
5. Cirani S., Ferrari G., Picone M., Veltri L., *Internet of Things: Architectures, Protocols and Standards*, Wiley Press, 2018.

Reference Books:

1. Francis da Costa, Rethinking the Internet of Things: A Scalable Approach to Connecting Everything, 1stEdition, Apress Publications, 2014.
2. Singh R., Gehlot A., *Internet Of things With Raspberry Pi And Arduino*, CRC Press/Taylor & Francis Group, 2019.
3. Xiao P., *Designing Embedded Systems and the Internet of Things (IoT) with the ARM Mbed*, Wiley Press, 2018.
4. Hu F., *Security and Privacy in Internet of Things (IoTs): Models, Algorithms, and Implementations*, CRC Press, 2016.

L	-	T	-	P		
2	-	0	-	4	=	4

2.1.9 EC-DSEC-50303 Advanced Communication Practices

Course Code	:	*EC − DSEC − 50303*
Course Name	:	*Advanced Communication Practices*
Contact Hours per Week	:	*2(two) Hours Lecture & 4(four) Practical*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Three.(Theory) & Eight (Practical)*
Questions to be Answered	:	*Any two from theory and one from Practical*
Duration of End Semester Examination	:	*1.5 hours (Theory) & 3 hours (Practical).*

Aim: To develop a communication engineer who can model and design the laboratory based prototype communication devices, circuit and system as per given specifications.

Course Outcomes: On completion of this paper, students would be able to:

- CO1: Estimate the path loss in the communication channel
- CO2: Compute BER and analyse Eye diagram for given modulation scheme
- CO3: Model and Design of passive Silicon Photonic based Devices
- CO4: Model and Design of Photonic Circuits (MZI/MRR)
- CO5: Develop software based complete Communication link and analyze performance in terms of Bit rate, SNR and power.
- CO6: Study the characteristics of a microsrtrip antenna and development of microwave passive circuits.

Unit I
Silicon Photonic based Devices and Circuits: Modeling and design of strip waveguide on SoI for TETM for Photonic Integrated circuit using effective index method.Design of uniform Bragg grating with a central wavelength of 1550 nm. Calculation of free spectral rang of Mach-Zehnder Interferometer (MZI)Micro-Ring Resonator (MRR).

Unit II
Microwave Antenna and Circuits: Unknown impedance measurement, Microstrip patch antenna: circular, rectangular patch, Microwave filters. Slow and fast fading wireless channel modelling, Rayleigh/Rician Fading channels, BER performance in fading channels.

Unit III
Hands-on/ Laboratory/ Practicals:

1. Develop software to get the free space path loss propagation by varying the distances between the transmitter & receiver and Compare the result graphically, using the Matlab.
2. Develop software to get the different pattern of Rayleigh function by using the Matlab.
3. Find out the BER of BPSK and higher modulation scheme over Rayleigh and Rice fading channels using Monte-carlo simulation.
4. Find out the BER of BPSK and higher modulation scheme with selection diversity over Rayleigh and Rice fading channels using Monte-carlo simulation.
5. Analytic calculation of 1D2D strip waveguide mode parameters and effective index
6. To design a uniform Bragg grating with given specifications
7. To design Mach-Zehnder Interferometer (MZI) using SiEPIC tools and pkd on KLayout /matlab for a given specification
8. To design Micro-Ring Resonator (MRR) using SiEPIC tools and pkd on KLayout /matlab for a given specification
9. Measurement of impedance of an unknown load.

10. Design and simulation of microstrip antenna.
11. Design and simulation of microwave filters.
12. Study the characteristics of a microsrtrip antenna using advance microstrip antenna trainer kit.

Text Books:

1. Lukas Chrostowski and Michael Hochberg, Silicon Photonics Design: from Devices to Systems, 1e, 2016, Cambridge University Press, University Printing House, Cambridge CB2 8BS, UK
2. Slawomir Sujecki, Photonics Modeling and Design, 1e, 2015 CRC Press, Taylor and Francis Group, 6000 Broken Soud Parkway, NW, Suit 300.
3. Lorenzo Pavesi, David J. Lockwood, Silicon Photonics, Topics in Applied Physics (TAP, volume 94), 1e, 2004, Springer Berlin, Heidelberg
4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, 1e, 2004, Wiley
5. David J. Lockwood and Lorenzo Pavesi, Silicon Photonics II: Components and Integration: 119 (Topics in Applied Physics), 1e, 2010, Springer
6. Morris Tischler, Optoelectronics: TextbookLaboratory Manual, McGraw-Hill Inc., 1990.
7. V. Protopopov, Practical Opto-Electronics: An Illustrated Guide for the Laboratory, Springer; 2014.
8. M. L. Sisodia, G. S. Raghuvanshi, Basic Microwave Techniques and Lab. Manual , New Age Int., 1987,
9. J. D. Kraus, Antennas, 3e, McGraw Hill Book Co., 2001.
10. C. A. Balanis, Antenna Theory: Analysis and Design, 3e, John Wiley Sons, 2009.

Reference Books:

1. Casimer DeCusatis, Handbook of Fiber Optic Data Communication: A Practical Guide to Optical Net-working), 3e, Academic Press; 2008.

2.1.10 EC-GEC-50401 Biosensors and Applications

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − GEC − 50401*
Course Name	:	*Biosensors and Applications.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination =75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: This course is designed with an aim of educating students in microtechnology and its use to fabricate sensors and systems.

Course Outcomes:

- CO1:To understand how to fabricate some of the sensors. To have an exposure towards how to fabricate the sensors and its application in real world.
- CO2: To understand and learn modern day microsensors and micro actuators,
- CO3: To simulate some of the sensors and characterise before fabricating it.

Unit I
Basics of Energy Transformation: Transducers, Sensors and Actuators: Introduction To Sensors, Fabrication of Sensors and Actuators, Techniques and cleanroom protocols, Basics of Microsensor Fabrication and illustration of sensor interfacing for various applications, Silicon as a substrate, Arduino Interfacing for Sensors and Actuators,DC Motor as an actuator.

Unit II
Introduction to COMSOL Multiphysics and Gas Sensor Demonstration: Surface Profilometry and Physical Vapour Deposition Techniques, Introduction to COMSOL Multiphysics and Modelling Examples, Thermal Actuators using COMSOL, Gas sensor using Arduino.

Unit III
Basics of Photolithography, Signal conditioning circuit for temperature sensors: Photolithography, Signal Conditioning Circuit for Temperature Sensors, Microheaters in COMSOL Multiphysics, Introduction to Cleanroom facilities for biomedical applications.

Unit IV
Recent trends in biosensors and 3D Printing: Biosensors for Electrothermal sensor, MEMS based sensor for catheter contact force measurement, Microfluidics based Drug Screening, Basic aspects of 3D Printing, 3D Printing Materials and Demonstration of Remote 3D Printing.

Text Books:

1. Hardik J. Pandya, *Sensors and Actuators*, IISc Bangalore, 2022.

2.1.11 EC-GEC-50402 Fabrication Techniques for MEMs-based Sensors: Clinical Perspective

L - T - P
3 - 1 - 0 = 4

Course Code	:	*EC − GEC − 50402*
Course Name	:	*Fabrication Techniques for MEMs-based Sensors: Clinical Perspective.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To comprehend area of microtechnology and its use to fabricate sensors and systems with special reference to clinical perspective

Objectives: On completion of this paper, students should

- CO1: To understand microfabrication process Understand sensors used in electronics and biomedical areas Understand Clean Room (Class 1 to Class 10000)
- CO2: To understand Microengineering Technology Design the process flow for fabricating microheater required in gas sensors.
- CO3: To design the process flow for fabricating forces sensors for biomedical application
- CO4: To understand fabrication of microfluidic platforms, micro-cantilevers, flexible force sensors, inter-digitated electrodes, polymer-glass bonding etc. for clinical research

Unit I
Introduction to microengineering devices and its applications: Clean room, contaminants, wafer cleaning processes (DI water, RCA, metallic impurities, etc.). Introduction to the microheater, force sensors, microfluidic devices, its specifications, and applications.

Unit II
Masks: Types of masks, Types of Photoresists, Spin Coaters Lithography process: optical lithography, x-ray, and e-beam lithography, lift-off techniques, soft lithography, Use of resists (spin coating, positive and negative photoresists), photoresist pre-baking, exposure, and development. Etching: Isotropic/anisotropic, selectivity, wet and plasma-assisted etching.

Unit III
Types of wafers and orientations: Techniques of metallization: PVD [(Sputtering – DC, RF, and Magnetron), thermal evaporation, e-beam evaporation]. Chemical Vapor Deposition: Dielectric films (Plasma Enhance Chemical Vapor Deposition (PECVD)), Atomic Layer Deposition. Understanding and designing the process flow for fabricating microengineering devices. Process flow for microheater, force sensors, and microfluidic devices. Wafer dicing and bonding techniques. Microfluidic Chips

Unit IV
Process Flow for Fabricating: Flexible Force Sensors and Force Sensors on Silicon, Process Flow for Fabricating VOC sensors, Biochips, Clinical Research: Problems and Solutions using Microengineering Device

Text Books:

1. J.D. Plummer, M.D. Deal, P.G. Griffin, *Silicon VLSI Technology*, Pearson Education, 2001.
2. S.A. Campbell, *The Science and Engineering of Microelectronic Fabrication*, Oxford University Press, 2001.
3. S.M. Sze (Ed), *VLSI Technology*,2nd Edition, McGraw Hill, 1988
4. Stephen D. Senturia *Microsystem Design*, Kluwer Academic Publisher, 2001.

Reference Books:

1. Gad-el-Hak, M., Ed. *The MEMS Handbook*, CRC Press: New York, NY, 2002.
2. Marc Madou, *Fundamentals of Microfabrication*,CRC Press, 1997.

2.1.12 EC-GEC-50403 Biomedical Instrumentation

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC – GEC – 50403*
Course Name	:	*Biomedical Instrumentation*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional = 25, End Semester = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To obtain a broad overview of various methods applied to Biomedical Instrumentation useful for healthcare .

Course outcomes:

- CO1: To understand anatomy and physiology of the human body and its response to various equipments when interfaced
- CO2: To analyse the scope for measurement of bio-electric potential and various learn about instruments associated to it
- CO3: To investigate about invasive and non-invasive measurements with their merits and demerits
- CO4: To categorise medical various imaging systems with emphasis to justification as per their use for layout design of hospital facilities

Unit I
Physiological systems and signals: Biology of human heart, circulatory and respiratory systems, fundamentals of human brain and nervous system, origin of bio-electric signals, electrocardiogram(ECG), electroencephalogram(EEC), electromyogram(EMG)

Unit II
Transducers and signal conditioners : Electrodes for ECG, EEG, EMG, Micro-electrodes, different types of transducers and their selection for Bio-medical applications, pre-amplifiers, instrumentation amplifier, biomedical filters, recorders for ECG, EEG and EMG systems

Unit III
Instrumentation for clinical Laboratory: Measurement of pH value of blood, Hemoglobin measurement, oxygen and carbon-dioxide measurement, design of therapeutic equipments like cardiac pacemaker, cardiac defibrillator, ventilators, hemodialysis machine.

Unit IV
Medical imaging and patient monitoring systems: X-ray imaging, Computed tomography, Ultrasonic imaging, Magnetic resonance imaging, Intensive cardiac care, patient monitoring through bio-telemetry, bedside and central monitoring systems

Text Books:

1. Cromwell, L., Weibell, F. J., Pfeiffer, E. A., and Usselman, L. B. (1973). Biomedical instrumentation and measurements Englewood Cliffs, N. J., Prentice-Hall

Reference Books:

1. Khandpur, R. S. (2014). Handbook of Biomedical Instrumentation. McGraw-Hill Education.
2. Venkatraman, S. S. (2001). Introduction to Biomedical Engineering J. Enderle, S. Blanchard, J. Bronzino, Academic Press

2.2 Second Semester

L	-	T	-	P		
3	-	1	-	0	=	4

2.2.1 EC-CC-506 Next Generation Communication Techniques

Course Code	:	*EC − CC − 506*
Course Name	:	*Next Generation Communication Techniques.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works =25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: The field of wireless communications has witnessed revolutionary technology developments in the last decade. Several radical wireless technologies have been developed to enable broadband wireless access with high data rates. This course will present an elaborate introduction to the principles and performance of the fundamental 3G/ 4G/ 5G wireless technologies.

Course Outcomes:

- CO1: To understand the development in the field of wireless communications.
- CO2: To understand wireless technologies such as CDMA, OFDM, MIMO.
- CO3: To understand the principle of 3G/4G/5G wireless communication systems.
- CO4: To analyse the performance of the fundamental 3G/ 4G/5G wireless technologies.

Unit I
Introduction to Wireless Systems: Evolution of Wireless Communication Technologies, Modeling Wireless Channel, Wireless Fading Channel Model, Fading Channel Distribution, Rayleigh Fading Channel, Bit Error Rate (BER) Performance, Deep Fade Analysis of Wireless Communication, Principle of Diversity, Maximal-Ratio Combining.

Unit II
Multiple Antenna Wireless Systems and Wireless Channel Characterization: BER of Multiple Antenna Wireless Systems, Deep Fade in Multi Antenna Systems, Intuition for Deep Fade in Multi-Antenna System, Definition of Diversity Order, Max Delay Spread, RMS Delay Spread, Delay Spread and Inter Symbol Interference, Coherence Bandwidth of Wireless Channel, Mobility and Doppler Effect in Wireless Channels.

Unit III
Principles of CDMA Wireless Communication: Introduction to Code Division Multiple Access (CDMA), Chip Time and Bandwidth Expansion in CDMA, Code Generation for CDMA, CDMA Codes: Properties of PN Sequences, BER of CDMA Systems. Analysis of Multi-user CDMA, Multipath Diversity in CDMA Systems, Near-Far Problem in CDMA.

Unit IV
Principles of MIMO, OFDM Wireless Communication: Multiple Input Multiple Output (MIMO) Systems, MIMO Receivers, Transmit Beamforming in MISO Systems, Alamouti Code and Space-Time Block Codes, Singular Value Decomposition (SVD), SVD in MIMO, Orthogonal Frequency Division Multiplexing (OFDM), Transmission in Multicarrier Systems, FFT/IFFT Processing in OFDM, Cyclic Prefix in OFDM Systems, Schematic Representation of OFDM Transmitter and Receiver.

Text Books:

1. David Tse, Pramod Viswanath, *Fundamentals of Wireless Communication*, Cambridge University Press, 2005.
2. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.

Reference Books:

1. T. S. Rappaport, *Wireless Communications*, 2/e, Pearson, 2010.

2.2.2 EC-CC-507 Modern Digital Control System

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − CC − 507*
Course Name	:	*Modern Digital Control Systems.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To understand the concept of discrete-time system and to apply the theoretical concepts for designing digital control system through different techniques.

Objectives:

- CO1: To develop the knowledge of sample and hold circuits and pulse transfer function.
- CO2: To design the digital controllers and to evaluate the stability of the system.
- CO3: To analyze and design the digital control system using state space representation.

Unit I
Introduction to Discrete Time Control System: Basic building blocks of discrete-time control system, Quantization and error effects, Data acquisition, conversion and distribution systems, Z transform, Inverse Z transform, Z transform method for solving differential equations, Digital control of processes.

Unit II
Z-Plane Analysis of Discrete-Time Control Systems: Impulse sampling and data hold, Zero Order Hold (ZOH) and First Order Hold (FOH), Determination of pulse transfer function for: cascaded elements, closed loop digital control system and digital PID controller. Realization of digital controllers and digital filters: Direct programming, Standard Programming, Series and parallel programming.

Unit III
Design of Discrete-Time Control System: Mapping between S plane and Z plane, Stability analysis of closed-loop systems in Z-plane, Jury stability criterion, Transient and steady state response analysis, Design based on root-locus method: Root locus diagrams of digital control systems, Effect of sampling period on transient response characteristics, Design based on frequency response method: Bilinear transformation and w plane, Bode diagrams, Compensator design.

Unit IV
State Space Analysis, Pole placement and Observer design: State space representation of discrete-time systems, Solving discrete-time state space equations, State transition matrix (STM), Computation of STM by Z transformation method Pulse transfer function matrix, Discretization of continuous-time state space equations, Liapunov stability analysis of discrete-time systems, Controllability and observability, Design via pole placement, State observers

Text Books:

1. K. Ogata, *Discrete Time Control System*, 2/e, Pearson Education, 2007.
2. M. Gopal, *Digital Control & State Variable Methods*, 3/e, Tata McGraw Hill, 2003.
3. Gene F. Franklin, Abbas Emami-Naeini and J. David Powell, *Feedback Control of Dynamic Systems*, 5/e, Pearson Education Inc., 2008.
4. R. G. Jacquot, *Modern Digital Control Systems*, 2/e, Routledge, 2019.

Reference Books:

1. B. C. Kuo, *Digital Control Systems*, Oxford University Press, 2/e, 2003.
2. Riachrd H. Middleton and Graham C. Goodwin, *Digital Control and Estimation: A Unified Approach*, Prentice Hall Inc., 1990

2.2.3 EC-DSEC-50801 Antenna analysis and Design

L - T - P
3 - 1 - 0 = 4

Course Code	:	*EC − DSEC − 50801*
Course Name	:	*Antenna Analysis and Design.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To develop RF engineers who can design variety of antennas for a wide range of applications.

Objective: On completion of this paper, students should

- CO1: understand the radiation mechanism and different parameters of an antenna
- CO2: analyze and design the antenna arrays.
- CO3: design various antenna for different applications.
- CO4: understand the concept of smart antenna.

Unit I
Review on Antenna Fundamentals : Solution of Maxwell's Equations for Radiation Problems, Ideal Dipole, Radiation pattern, Beam solid angle, Directivity, Gain, Input impedance, Polarization, Bandwidth, Reciprocity, Equivalence of Radiation patterns, Antenna element design and characterization.

Unit II
Antenna Arrays: Array factor for linear arrays, uniformly excited, equally spaced Linear arrays, pattern multiplication, directivity of linear arrays, nonuniformly excited -equally spaced linear arrays, Mutual coupling, multidimensional arrays, phased arrays, feeding techniques, perspective on arrays.

Unit III
Microstrip antenna : Operating principle, modes of operation, field patterns, Impedance, Feeding techniques, polarization, design of rectangular and circular patch antennas, Arrays and feed network.

Unit IV
Concept of smart antenna : Need for Smart Antennas, Smart Antenna Configurations, Beamforming Fundamentals, Adaptive beamforming, Space Division Multiple Access (SDMA), Architecture of a Smart Antenna System.

Text Books:

1. J. D. Kraus, Antennas, 3/e, McGraw Hill Book Co., 2001.
2. C. A. Balanis, Antenna Theory: Analysis and Design, 3/e, John Wiley Sons, 2009.
3. Thomas A. Milligan, Modern Antenna Design, 2/e, Wiley-IEEE Press, 2005.
4. Ahmed El Zooghby, Smart Antenna Engineering, Artech HouseM.J. Bronzel, Smart Antennas, John Wiley, 2004

Reference Books:

1. Jordan and Balmain, Electromagnetic Wave and Radiating Systems, John Wiley, 2002
2. Yi Huang and Kevin Boyles, Antennas: From Theory to Practice, Wiley-IEEE Press, 2008.

2.2.4 EC-DSEC-50802 VLSI Devices and Modeling

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − DSEC − 50802*
Course Name	:	*VLSI Devices and Modeling*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional = 25, End Semester = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: The reader will get acquainted with the modeling techniques of different VLSI Devices.

Course outcomes:

- CO1: To study the basic device physics required to understand the working of the MOS Devices
- CO2: To understand the concept of modeling of new device structure.
- CO3: Implantation of acquired knowledge to overcome the small dimensional effects.

Unit I
Basic Device Physics: Two terminal MOS Transistor model: Flat-band voltage, Potential balance and charge balance, Effect of Gate-substrate voltage on surface condition, Inversion, Small signal capacitance; Three Terminal Transistor MOS model: Contacting the inversion layer, Body effect, Regions of inversion, Pinch-off voltage.

Unit II
Four Terminal MOS Transistor model: Transistor regions of operation, general charge sheet models, regions of inversion in terms of terminal voltage, strong inversion, weak inversion, moderate inversion, effective mobility, temperature effects, temperature effects, breakdown p - channel MOSFET, enhancement and depletion type, model parameter values, model accuracy etc;

Unit III
Small Dimension Effects:: channel length modulation, barrier lowering, two-dimensional charge sharing and threshold voltage, punch - through, carrier velocity saturation, hot carrier effects, scaling, effects of surface and drain series resistance, effects due to thin oxides and high doping. Sub threshold regions.

Unit IV
CMOS Device Design: Scaling, Threshold voltage, MOSFET channel length; CMOS Performance Factors: Basic CMOS circuit elements; parasitic elements; sensitivity of CMOS delay to device parameters, performance factors of advanced CMOS devices.

Text Books:

1. Yuan Taur and Tak. H. Ning, Fundamentals of Modern VLSI Devices, 2/e, Cambridge University Press (2013).
2. Yannis Tsividis, Operation and Modeling of the MOS Transistor, 2/e, Oxford University Press, 2003.

Reference Books:

1. S. M. Sze, Physics of Semiconductor Devices, Wiley India Private Limited, 3/e 2008.
2. Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, 2/e, Oxford University Press, 2002.

2.2.5 EC-DSEC-50803 Photonic Integrated Circuits

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC – DSEC – 50803*
Course Name	:	*Photonic Integrated Circuits.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To design Photonic Integrated Circuit with suggested specifications for data-centre interconnect and communication applications.

Objectives: On completion of this course, students should be able

- CO1: To recognize and explain Photonic Integrated Circuits on SoI along with electronics as an emerging technology to meet the explosive bandwidth demand and computationally efficient systems
- CO2: To Model Passive and Active PICs on SOI platform using SiPh technology
- CO3: To design the Layout of passive and active photonic devices on an open-source GDS-II platform, i.e., KLayout using SiEPIC tools and pdks
- CO4: To evaluate the performance of PIC for data center and communication applications with given specifications

Unit I
Introduction to Photonic Integrated Circuits (PICs): Review of SiPh technology and role of PIC along with Integrated electronic Circuits, Planar Waveguide and its types on SoI, Waveguide design, calculation of the effective index, compact model of a slap-waveguide.

Unit II
Fundamental Building Blocks of PICs: Design of Y-branch, Directional Couplers, Grating, and Edge Couplers, Taper, bend waveguide.

Unit III
Functional Device and Circuits for PICs: MZI: Derivation of Transfer Function of MZI, Michelson Interferometer, Derivation of FSR, Application of MZIs; Microring Resonator (MRR): Transfer Function of MRR, Michalson, Derivation of FSR, Application of MRRs; Plasma-dispersion effect and pn-junction phase shifter, photo-detector on SoI

Unit IV
Introduction to SIEPIC tools and PDKs: CMOS fabrication steps for passive PICs, GDS-II Layout on KLayout design platform, interface with SiEPIC tools, Process Design kits (pdk) associated with e-beam pdk, application of e-beam pdk in designing MZI, MRR and other functional Devices. Design rule check and simulation. SiPh-based Transceiver.

Text Books:

1. Lukas Chrostowski and Michael Hochberg, *Silicon Photonics Design: from Devices to Systems*, 1/e, 2016, Cambridge University Press, University Printing House, Cambridge CB2 8BS, UK, 2016.
2. Richard Osgood jr.,Xiang Meng, *Principles of Photonic Integrated Circuits: Materials, Device Physics, Guided Wave Design*, 1/e, 2021, Springer.
3. José Capmany; Daniel Pérez, *Programmable Integrated Photonics*, 1/e, 2020, Oxford University Press.
4. David J. Lockwood and Lorenzo Pavesi., *Silicon Photonics III: Components and Integration: 119 (Topics in Applied Physics)*, 1/e, 2018, Springer.

Reference Books:

1. . Lorenzo Pavesi, David J. Lockwood, *Silicon Photonics, Topics in Applied Physics (TAP, volume 94)*, 1/e, 2004, Springer Berlin, Heidelberg.
2. Graham T. Reed and Andrew P. Knights, *Silicon Photonics: An Introduction*, 1/e, 2004, Wiley
3. David J. Lockwood and Lorenzo Pavesi, *Silicon Photonics II: Components and Integration: 119 (Topics in Applied Physics)*, 1/e, 2010, Springer
4. IEEE Journals of Photonic Technology Letters, JLT, Sec. Topics in Quantum Electrons etc. 2012.
5. Tool, *Matlab ,Comsol Multiphysics(https://www.istem.gov.in/rd-infrastructure-map/software-through-istem, visited 26.08.2022), Ansys Lumerical*
6. Tools: *Python, KLayout, SiEPIC tools, and pdk (https://github.com/SiEPIC, visited 26.08.2022)*

2.2.6 EC-DSEC-50901 Advanced Practices in VLSI Devices and RF Circuits

L	-	T	-	P		
2	-	0	-	2	=	4

Course Code	:	$EC - DSEC - 50901$
Course Name	:	*Advanced Practices in VLSI Devices and RF Circuits*
Contact Hours per Week	:	*2(two) Hours Lecture & 4(four) Practical*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Three.(Theory) & Eight (Practical)*
Questions to be Answered	:	*Any two from theory and one from Practical*
Duration of End Semester Examination	:	*1.5 hours (Theory) & 3 hours (Practical).*

Aim: The main aim of this course is to produce world class professionals with wide knowledge in high speed semiconductor devices and to enhance their skills in designing of various modern electronic circuits.

Objective: On completion of this paper, students should

- CO1: understand and model advanced nano scaled VLSI devices.
- CO2: design new architectures of the new MOS devices.
- CO3: to understand the behaviour of microwave semiconductor devices
- CO4: design and verify the characteristics of MESFET and HEMT
- CO5: design and simulate various modern electronic circuits

Unit I
Advance MOS Devices: (Introduction to the Field Effect Nano Devices, gradual channel approximation, source/drain resistances, High-k dielectrics, High Field effects CMOS leakage current Introduction to Electrostatic Integrity, Fin FETs and other Multi Gate Transistors, CNTFET, TFT and Accumulation-mode Transistors.

Unit II
Microwave semiconductor devices and circuits: (Metal-Semiconductor Field-Effect Transistors (MESFETs): Physical Structures, Principles of Operation, Equivalent Circuit, Cutoff Frequency and Maximum Oscillation Frequency; High Electron Mobility Transistors (HEMTs): Physical Structure, Operational Mechanism, Performance Characteristics; Microwave amplifier design: Stability circle, Tests for unconditional stability, Design for maximum gain, low-noise amplifier design, Oscillator design: General Analysis, Oscillator using FET, Mixers: mixer characteristics, single-ended mixer, balanced mixer.)

Unit III
List of the Experiments:

1. Implementing MOSFET compact model in SPICE.
2. TCAD simulation process of semiconductor devices.
3. Design and verification of HEMT.
4. Design of the A/D converter using CMOS logic.
5. Design and development of an oscillator.
6. Design and development of a mixer.

Text Books:

1. Donald Neamen, Semiconductor physics and Devices, McGraw-Hill, 3rd edition.
2. J.-P. Colinge and C.A. Colinge Physics of Semiconductor Devices, Springer, 2002.
3. Jean-Pierre Colinge ,FinFETs and other multi-gate transistors, Springer, 2008.
4. B.G.Streetman and S.Banerjee ,Solid State Electronic Devices , Prentice Hall India.
5. Guillermo Gonzalez, Foundations of Oscillator Circuit Design, Artech House, INC.
6. Stephen A. Maas, Nonlinear Microwave and RF Circuits, Artech House, INC.
7. Paolo Antognetti and Giuseppe Massobrio, Semiconductor device modelling with SPICE, McGraw – Hill Inc., US.

2.2.7 EC-DSEC-50902 Advanced Practices in Machine Learning

L	-	T	-	P		
2	-	0	-	4	=	4

Course Code	:	*EC – DSEC – 50902*
Course Name	:	*Advanced Practices in Machine Learning*
Contact Hours per Week	:	*2(two) Hours Lecture & 4(four) Practical*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Three.(Theory) & Eight (Practical)*
Questions to be Answered	:	*Any two from theory and one from Practical*
Duration of End Semester Examination	:	*1.5 hours (Theory) & 3 hours (Practical).*

Aim: The main aim of this course is to provide the fundamentals of deep learning and the main research activities in this field. Further, to learn the architectures and optimization methods for deep neural network training along with applications.

Course Outcomes: On completion of this paper, students would be able to:

- CO1: Understand the fundamentals of deep learning and its main research activities..
- CO2: Understand the architectures and optimization methods for deep neural network training
- CO3: Implement, apply and test relevant learning algorithms in TensorFlow/Pytorch etc.

Unit I
Fundamentals of Deep Learning: History and Fundamental concepts of Deep Learning, Multilayer Perceptrons (MLPs), Representation Power of MLPs, Sigmoid Neurons, Feed Forward Neural Networks, Backpropagation. Activation functions and parameters : Gradient Descent (GD), Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, Principal Component Analysis; Singular Value Decomposition; Parameters and Hyper-parameters.

Unit II
Deep Learning Models and Applications: CNN: Architecture, layers and Applications; LeNet; AlexNet; VGGNet; GoogLeNet; ResNet; RNNs and Transformer.DL Applications in Image Processing, Natural Language Processing, Speech recognition, Video Analytics.

Unit III
Hands-on/ Laboratory/ Practicals: Implementation of following deep learning algorithms in various projects using Python:

1. Simple implementation of Artificial Neural Network.
2. Implementation Convolution Neural Network using Python, AlexNet, VGGNet, RNN etc.
3. Project work involving applications of Deep Learning like image processing, NLP, speech recognition, video analysis.

Text Books:

1. Chollet, Francois. *Deep learning with Python.* Simon and Schuster, 2021.
2. Rajiv Chopra, *Deep Learning*, Khanna Book Publishing, Delhi 2020.
3. Ian Goodfellow, Yoshua Bengio, Aaron Courville, *Deep Learning*, 2016.
4. https://nptel.ac.in/courses/106/106/106106184/

Reference Books:

1. Bengio, Yoshua. *Learning deep architectures for AI.* Foundations and trends in Machine Learning 2.1, Now Publishers, 2009.
2. Michael Nielsen, *Neural Networks and Deep Learning*, 2016.
3. https://www.coursera.org/specializations/deep-learning.

2.2.8 EC-RM-510 Research Methodology and Proposal Writing

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − RM − 510*
Course Name	:	*Research Methodology and Proposal Writing.*
Contact Hours per Week	:	*3(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Five.*
Questions to be Answered	:	*Any 3(Three).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To understand how to find research problem and its solution; and how to communicate reaserch findings.

Objectives: On completion of this course, students will be able to

- CO1: Understand research problem formulation.
- CO1: Analyze research related information.
- CO1: Write a research proposal.

Unit I
Research Problem: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.

Unit II
Solution Approaches: Approaches of investigation to solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.
Unit III
Literature survey and ethics: Effective literature studies approaches, analysis, Plagiarism, Research ethics.

Unit IV
Writing Research Proposal: Effective technical writing, how to write report, Paper. Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Text Books:

1. Ranjit Kumar, 2nd Edition, *Research Methodology: A Step by Step Guide for beginners.*

Reference Books:

1. Stuart Melville and Wayne Goddard, *Research methodology: an introduction for science & engineering students.*
2. Wayne Goddard and Stuart Melville, *Research Methodology: An Introduction.*

2.2.9 EC-SEC-51101 Advanced Data Visualization and Analytics

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	$EC - SEC - 51101$
Course Name	:	*Advanced Data Visualization and Analytics.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: The aim of this course is to provide knowledge on data visualization design principles and deciding the type of visualization chart to choose, creating simple to advanced chart types using python modules and libraries, and giving exposure for exploring, visualizing and analyzing various types of data sets using various visualization tools used in data analytics.

Objective: On completion of this paper, students should

- CO1: Understand the importance of data visualization.
- CO2: Learn to create basic charts by applying visualization design principles.
- CO3: Learn to create advanced visualization charts and analysis.
- CO4: Explore and Analyse Time series, Geospatial and multimodal data.
- CO5: Learn to build interactive/animated dashboards and construct data stories.

Unit I
Overview of Data Visualization: Importance and benefits of good data visualization; Design principles; Introduction to python libraries for visualization: seaborn, plotly express, pygal; Exploring Data; Reduce Items and Attributes: Filter and Aggregate; Creation of basic visualization: Histogram, Bar and Line Chart, Box plot, Scatter plot; Color palettes – Creation of 3D Charts; Creation of Advanced Visualization: Heat Map– Facet Grid.

Unit II
Visualization of Time Series Data: Summary statistics and plotting aggregated views; Visualization of seasonality, trends and noise; working with multiple time series data. Some case studies.

Unit III
Data Analytics Overview: Introduction, benefits, types of data analytics; some data analytics real-world case studies; tools and techniques.

Unit IV
Business Analytics and Visualization Tools: Tableau, PowerBI, Creating Interactive Dashboards and charts to organize data using visualization principles; Data Storytelling.

Text Books:

1. Wes McKinney, "*Python for Data Analysi*, O'Reilly Media, 2012.
2. Tamara Munzner, *Visualization Analysis and Design, A K Peters Visualization Series*, CRC Press, 2014.
3. Scott Murray, *Interactive Data Visualization for the Web*, O'Reilly, 2013.
4. Vander Plas , *Python data science handbook: essential tools for working with data*, O'Reilly Media. Inc", 2016

Reference Books:

1. Alberto Cairo, *The Functional Art: An Introduction to Information Graphics and Visualization*, New Riders, 2012.
2. Nathan Yau, *Visualize This: The Flowing Data Guide to Design, Visualization and Statistics*, John Wiley & Sons, 2011.

2.2.10 EC-SEC-51102 Development of MOOC Courses

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC – SEC – 51102*
Course Name	:	*Development of MOOC Courses.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To develop Massive Open Online Courses (MOOCs) that have become a popular avenue for diverse learners to upgrade their knowledge and skills.

Course Outcomes:

- CO1: To be aware of the technology affordances.
- CO2: To focus on the pedagogy of how to use the MOOC features effectively to foster student engagement and learning.
- CO3: To know a set of design principles and guidelines to create a learner-centric and effective MOOCs.

Unit I
The LCM model: Perceptions of MOOC, Learner Expectation, Learner Engagement, Course Introduction, Evolution of MOOCs, Known Challenges, Why LCM? The LCM Model.

Unit II
Creating LeDs: : What is an LeD?, Chunking a Lecture into LeD, Introducing Reflection Spot, Making Your Own LeD, LeDs Takeaway, Reflection Spot.

Unit III
Creating LbDs and LxTs: What is an LbD? Creating LbDs, Constructive Customized Feedback in LbDs, Giving Feedback for Open Ended Questions, Recommendations for effective LbDs, What is an LxT? Creating LxTs, Creating an Assimilation Quiz.

Unit IV
LxIs and Orchestration: What is an LxI?, Creating LxIs with Reflection Quiz, LxI- Sharing Experiences, LxI- How to Achieve Learner-Learner Interaction?, LxI- Types of focus questions, Orchestrating your MOOC, Orchestration Dynamics in LCM, Assessment, From Regular course to LCM, Course Design in MOOC, Maintaining Learner Connect, Implementing the Learner-Centric Approach.

Text Books:

1. Sridhar Iyer, Sahana Murthy, Jayakrishnan M, Sameer Sahasrabudhe, *Designing Learner-Centric MOOCs*, IIT Bombay, 2022.

2.2.11 EC-SEC-51103 Project Management for Managers

		L	-	T	-	P		
		3	-	1	-	0	=	4

Course Code	:	*EC − SEC − 51103*
Course Name	:	*Project Management for Managers*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To develop essential skills required to manage projects and managerial knowledge and competencies.

Objectives: On completion of this paper, students should be able

- CO1: To describe project life cycles, types, and methods of selecting a project
- CO2: To explain the various risk management techniques and methods and plant capacity analysis
- CO3: To elaborate on project team building, HRM issues, and time management in the project
- CO4: To describe Time and Cost relationship, quality management, and project termination

Unit I
Project Management Fundamentals: Introduction to Project Management, Project Success, Types of Structure Organizations, Project Management Office; Project life cycle analysis: Types of Projects and Project Life Cycle, Methods of Project Selection; Project selection methods: Methods of Project Selection, Market and Demand Analysis, Financial Analysis

Unit II
Capital Budgeting Techniques: Financing of Projects, Risk Management; Risk Management (Control and Documentation); Stand Alone Risk Analysis, Hillier Model, Simulation Analysis; Decision Tree Analysis, Abandonment Analysis, Technical Analysis, Product Mix and Plant Capacity Analysis.

Unit III
Project Team Building: Conflict and Negotiation, HRM Issues and Time Management, Project Time Management- Introduction, Project Time Management (Project Scheduling), Numbering of Nodes, PERT Networks, Laddering in PERT/CPM, Probability Models in Networks.

Unit IV
Time and Cost Relationship: Crashing of Networks, Introduction to Project Cost Management and estimation, Introduction to Quality Management, Quality Management (Source of variability and Six Sigma), Procurement Management and Project Termination.

Text Books:

1. Roderick A. Munro and Govindarajan Ramu and Daniel J. Zrymiak, *The certified six sigma Green Belt Handbook*, ASQ Quality Press and Infotech Standards India Pvt. Ltd. 2017.
2. S.A. Campbell, *The Certified Six Sigma Black Belt Handbook*, Pearson Publication. 2018.
3. Forrest W. Breyfogle III, *Implementing Six Sigma,*, John Wiley & Sons, INC. 2003
4. Evans, J R and W M Lindsay *An Introduction to Six Sigma and Process Improvement*, CENGAGE Learning.2014

Reference Books:

1. Howard S. Gitlow and David M. Levine *Six Sigma for Green Belts and Champions*, Pearson Education, Inc. 2004.
2. Montgomery, D C, *Design and Analysis of Experiments*,10th Edi. Wiley. 2019.
3. Mitra, Amitava, *Fundamentals of Quality Control and Improvement*,3rd edi. Wiley India Pvt Ltd, 2013.
4. Montgomery, D C, *FStatistical Quality Control: A modern introduction*,7th Edi. Wiley. 2013.

L	-	T	-	P		
3	-	1	-	0	=	4

2.3 Third Semester

2.3.1 EC-CC-600 Advanced Digital Communication

Course Code	:	$EC - CC - 600$
Course Name	:	*Advanced Digital Communication.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To develop a clear understanding of modern communication system (wire and wireless) based on which student can model their own system and evaluate the performance mathematically.

Course Outcomes:

- CO1: To understand the basics of signal space analysis and digital transmission.
- CO2: To understand the coherent and noncoherent receivers and its impact on different channel characteristics.
- CO3:To understand the different block coded and convolutional coded digital communication systems.
- CO4: To understand the different wireless channel models and their performance.

Unit I
Signal space representation and its use on modulation: Geometric representation of signals, Linear modulation technique: Coherent Phase-Shift Keying, QPSK, offset QPSK, Constant envelop technique: MSK, GMSK, Linear and Constant envelop modulation technique advantages and disadvantages, M-ary PSK, M-ary QAM.

Unit II
Spread spectrum techniques: Spread spectrum system, DS-Spread spectrum and frequency Hopped spread spectrum, Pseudo noise sequences, Performance of DS-SS, Frequency Hopping systems, Error performance for Binary signal in AWGN.

Unit III
Band limited channels and equalizers: Band Limited Channels, ISI, Nyquist Criterion, Controlled ISI, Linear equalizer Equalization, Adaptive equalizer, Adaptive Equalization algorithms, Linear Equalizer,Nonlinear Equalizer Maximum likelihood sequence estimation (MLSE) equalizer.

Unit IV
Coding techniques and introduction to wireless channels: Architecture and performance: Binary block codes, Orthogonal, Biorthogonal, Transorthogonal, Fading channels and its modeling: Rayleigh fading, Ricean fading distribution, Diversity receivers, Performance evaluation of diversity receivers over fading channels.

Text Books:

1. Stephen G. Wilson, *Digital Modulation and Coding*, Pearson Education, 1996.
2. T. S. Rappaport, *Wireless Communications*, 2/e, Pearson, 2010.
3. S. Hykin, *Digital Communication*, Wiley Student Edition, 2006.

Reference Books:

1. J. G. Proakis and M. Salehi, *Digital Communication*, 5/e, McGraw Hill Publication, 2008.

2.3.2 EC-CC-601 Millimeter-wave and Terahertz Techniques

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	$EC-CC-601$
Course Name	:	*Millimeter-wave and Terahertz Techniques*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: The aim of the course is to provide students with a wide introduction to millimeter and sub-millimeter (Terahertz) technology for industrial, radio astronomy, environmental science and other applications.

Objective: On completion of this paper, students should

- CO1: understand the characteristics of mm-wave and THz communication technologies.
- CO2: explain and model different mm-wave semiconductor devices.
- CO3: design and develop mm-wave and THz Communication devices and circuits

Unit I
Introduction to mm-wave and THz Technology : mm-Wave and THz wave Characteristics, Regulation, Propagation at mm-Waves, THz Propagation and Channel Modeling.

Unit II
mm-wave semiconductor devices: Transient and ac behaviour of P-N junctions, PIN diode, varactor diode and its applications; Schottky effect, Schottky barrier diode and its applications; Heterojunctions, high electron mobility transistor.

Unit III
mm-wave and THz components and circuits : mm-Wave and THz Integrated Passive Components, Circuits and Interconnects, Millimetre-wave design considerations, mm-Wave and THz component packaging.

Unit IV
mm-wave and THz Communication : Advanced beam steering technology, Advanced beamforming technology, Advanced antenna ID technology, Millimeter- Wave MIMO: Spatial diversity of antenna arrays.

Text Books:

1. Duixian Liu, Brian Gaucher, Ulrich Pfeiffer and Janusz Grzyb, Advanced Millimeter-wave Technologies Antennas, Packaging and Circuits, John Wiley Sons Ltd, United Kingdom, 2009.
2. Kao-Cheng Huang, Zhaocheng Wang, Millimeter wave communication systems, John Wiley Sons, Inc., Hoboken, New Jersey 2011.
3. S. Ahmad, Microwave and Millimeter Wave Semiconductor Materials Technology, Tata McGraw Hill.
4. Wolf W., Modern VLSI Design System on Silicon, 2nd Edition, Pearson Education, 2000.
5. Thomas Kurner, Daniel M. Mittleman and Tadao Nagatsuma, THz Communications. Springer Series in Optical Sciences, vol 234. Springer, Cham.

Reference Books:

1. D. M. Pozar, Microwave Engineering, 4 e, John Wiley, 2011.
2. Peter A. Rizzi, Microwave Engineering: Passive Circuits, 1 e, Prentice Hall, 1987.

2.3.3 EC-CC-602 Minor Project

L	-	T	-	P		
0	-	0	-	8	=	4

Course Code	:	$EC - CC - 602$
Course Name	:	*Minor Project*
Contact Hours per Week	:	*8(Eight) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	
Questions to be Answered	:	.
Duration of End Semester Examination	:	

The Project evaluation will be done based on the following components:

1. Problem Identification and Review of Related Literature
2. Proposal Writing and Presentation
3. Data Collection
4. Data Analysis, Interpretation and Discussion
5. Report Writing
6. Viva Voce

L	-	T	-	P		
3	-	1	-	0	=	4

2.3.4 EC-DSEC-60301 Analog IC Design

Course Code	:	*EC − DSEC − 60301*
Course Name	:	*Analog IC Design*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional = 25, End Semester = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: Learn the Basic Approach to Design CMOS Based Analog Building Blocks.

Course outcomes:

- CO1: Learn the various topologies of Analog Design blocks.
- CO2: Complete Design of CMOS based OPAMP for a desired target specification.
- CO3: Approach to design of specialized circuit architectures for High-speed and Low-power.

Unit I
Introduction to MOS and Basic Building Blocks: Introduction to Analog Design, Basic MOS Device Physics, MOS Device models. Short Channel Effects and Device Models. Single Stage Amplifiers – Basic Concepts, Common Source Stage, Source Follower, Common Gate Stage, Cascode Stage.

Unit II
CMOS Amplifier Design: Differential Amplifiers – Single Ended and Differential Operation, Basic Differential Pair, Common Mode Response, Differential Pair with MOS loads, Gilbert Cell. Passive and Active Current Mirrors – Basic Current Mirrors, Cascode Current Mirrors, Active Current Mirrors.

Unit III
Feedback Amplifiers:: Frequency Response of Amplifier, Stability and frequency compensation, Comparators: Characterization of a Comparator, Operational Amplifiers – General Considerations, One Stage Op Amps, Two Stage Op Amps, Gain Boosting, Common–Mode Feedback, Input Range limitations, Slew Rate, Power Supply Rejection, Noise in Op Amps. Stability and Frequency Compensation Techniques.

Unit IV
Low-Power and High-Speed Circuits: Bandgap References, Introduction to Switched-Capacitor Circuits, Nonlinearity and Mismatch.

Text Books:

1. B. Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill, 2000.
2. Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, 3/e, Oxford University Press, 2011.
3. Randall L. Geiger, Phillip E. Allen and Noel Strader, VLSI Design Techniques for Analog and Digital Circuits, McGraw-Hill, 2010.
4. R. Jacob Baker, CMOS Circuit Design, Layout, and Simulation, 3/e, Wiley-IEEE Press, 2010.

Reference Books:

1. Yannis Tsividis and Colin McAndrew, The MOS Transistor, 3/e, Oxford University Press, 2013.
2. R. Jacob Baker, CMOS Mixed-Signal Circuit Design, 2/e, Wiley-IEEE Press, 2009.

2.3.5 EC-DSEC-60302 Speech Processing

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − DSEC − 60302*
Course Name	:	*Speech Processing*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional works = 25, End Semester examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To obtain an overview speech signal processing techniques with an application to speaker recognition

Course outcomes:

- CO1: To understand speech production system and its digital model
- CO2: To analyse speech signal using digital signal processing techniques
- CO3: To measure various parameters useful for speech recognition
- CO4: To investigate the application of speech processing for speaker recognition

Unit I
Fundamentals of speech: Production and classification of speech sounds, Acoustic phonetics, Speech production mechanism and its digital models

Unit II
Measurement of speech parameters: Feature extraction and digital representation of speech, distortion measurements, Log spectral and Cepstral distances, Likelihood distortions

Unit III
Speech recognition : Pattern comparison techniques, Spectral distortion using warped frequency scale, dynamic time warping, introduction to deep learning based methods

Unit IV
Speaker recognition: Basics of speaker recognition, feature selection, hyperparameter optimization, building state of art speaker recognition systems

Text Books:

1. Jurafsky, D., & Martin, J. H. Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition.
2. Rabiner, L. (2003). Biing-hwang Juang'"Fundamentals of speech recognition", Low Price Edition.
3. Quatieri, T. F. (2006). Discrete-time speech signal processing: principles and practice. Pearson Education India.

Reference Books:

1. Deller Jr, J. R. (1993). Discrete-time processing of speech signals. In Discrete-time processing of speech signals (pp. 908-908).
2. Rabiner, L. R. (1978). Digital processing of speech signals. Pearson Education India.

2.3.6 EC-DSEC-60401 Image Processing for Computer Vision

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − DSEC − 60401*
Course Name	:	*Image Processing for Computer Vision*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional works = 25, End Semester examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To get an in-depth understanding of various Image Processing algorithms with applications

Course outcomes:

- CO1: To understand transforms for image analysis
- CO2: To learn image restoration and segmentation
- CO3: To get an overview of Image reconstruction from projections
- CO4: To understand applications to computer vision

Unit I
Introduction to Image transforms: Review of digital images, 2-D signals and systems, 2-DFT, Cosine and Hadmard transform, Transform operations, Image smoothing and sharpening using frequency domain filters.

Unit II
Image restoration and segmentation : Image restoration techniques, noise models and filter types, geometric transforms, image segmentation, classification techniques.

Unit III
Image Compression and reconstruction: Compression and standards, image reconstruction from projections, back projection operator, projection theorem.

Unit IV
Image recognition applications for computer vision: Artificial Neural Network for Pattern Classification, Convolutional Neural Networks, Motion Estimation and Object Tracking.

Text Books:

1. Jain, A. K. (1989). Fundamentals of digital image processing. Prentice-Hall, Inc..
2. Prince, S. J. (2012). Computer vision: models, learning, and inference. Cambridge University Press.
3. Gonzalez, R. C. (2009). Digital image processing. Pearson education india.

Reference Books:

1. Joshi, M. A. (2018). Digital image processing: An algorithmic approach. PHI Learning Pvt. Ltd..
2. Szeliski, R. (2010). Computer vision: algorithms and applications. Springer Science & Business Media.

2.3.7 EC-DSEC-60402 Social Robotics

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	*EC − DSEC − 60402*
Course Name	:	*Social Robotics*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional works = 25, End Semester examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To get an in-depth understanding of various challenges and opportunities of social robots alongwith theirs with applications

Course outcomes: On completion of this paper, students should able

- CO1: To analyze the main challenges and opportunities of social robots.
- CO2: To develop the ability to analyze the need of the social robots in different scenarios.
- CO3: To predict the possible consequences of social interaction between the human and the robots.

Unit I
Introduction to Social Robotics: How is it different from traditional robotics and its applications; Embodiment and Design: To be able to understand by humans.

Unit II
Social Robots Skill Set: To understand humans (Social Emotional Intelligence and Socio-Cognitive Skills); Social Robots and Communication Skills: To be able to interact with humans

Unit III
Design Methodology : Involving Humans in HRI Studies.

Unit IV
Case Studies: Kids with Autism Spectrum Disorder (ASD), Individuals with Intellectual Disability (ID), Elderly People. Ethical Issues: Ethical, legal and Social Implications of Social Robotics.

Text Books:

1. Breazeal, Cynthia. *Designing sociable robots.* MIT press, 2004.
2. Bartneck, Christoph, et al. *Human-robot interaction: An introduction.* Cambridge University Press, 2020.
3. Kanda, Takayuki, and Hiroshi Ishiguro. *Human-robot interaction in social robotics.* CRC Press, 2017

Reference Books:

1. Jones, Raya. *Personhood and Social Robotics: A psychological consideration.* Routledge, 2015.
2. https://link.springer.com/book/10.1007/978-3-030-62056-1

2.3.8 EC-DSEC-60501 Spoken Language Identification Techniques

L	-	T	-	P		
3	-	1	-	0	=	4

Course Code	:	$EC - DSEC - 60501$
Course Name	:	*Spoken Language Identification Techniques*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional works = 25, End Semester examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: To get an in-depth understanding of various spoken language identification techniques.

Course outcomes:

- CO1: To understand structures of spoken languages
- CO2: To analyse speech signal for language recognition
- CO3: To understand various pattern recognition techniques
- CO4: To investigate language models and use them for spoken language recognition

Unit I
Spoken Language Structure: Sound production and human speech system, phonetics and phonology, syllables and words, syntax and semantics.

Unit II
Review of speech processing for language recognition : Short term Fourier transform, acoustic model of speech production, cepstral processing,perceptually motivated representations (MFCC, PLP).

Unit III
Pattern recognition basics: Bayes' decision theory, construction of classifiers, supervised and unsupervised estimation methods

Unit IV
Language and Statistical Models: Acoustic and language models, introduction to HMM, isolated word recognition, introduction to shallow and deep features for language recognition.

Text Books:

1. Jurafsky, D., & Martin, J. H. Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition.
2. Rabiner, L. (2003). Biing-hwang Juang Fundamentals of speech recognition, Low Price Edition.
3. Huang, X., Acero, A., Hon, H. W., & Reddy, R. (2001). Spoken language processing: A guide to theory, algorithm, and system development. Prentice hall PTR.

Reference Books:

1. Deller Jr, J. R. (1993). Discrete-time processing of speech signals. In Discrete-time processing of speech signals (pp. 908-908).
2. Rabiner, L. R. (1978). Digital processing of speech signals. Pearson Education India.
3. Quatieri, T. F. (2006). Discrete-time speech signal processing: principles and practice. Pearson Education India.

2.3.9 EC-DSEC-60502 Embedded System Design with ARM

L - T - P

3 - 1 - 0 = 4

Course Code	:	*EC − DSEC − 60502*
Course Name	:	*Embedded System Design with ARM Microcontroller.*
Contact Hours per Week	:	*4(Four) Hours.*
Marks Distribution	:	*Sessional Works = 25, End Semester Examination = 75.*
Questions to be Set	:	*Eight.*
Questions to be Answered	:	*Any 5(Five).*
Duration of End Semester Examination	:	*3(Three) Hours.*

Aim: This course will discuss about the basic concepts of embedded system design, with particular emphasis on system design using ARM microcontrollers.

Course Outcomes:

- CO1: To familiarize with the concepts of embedded system designs and the system design using ARM microcontrollers.
- CO2: This course will also help to understand the developmental aspects of Internet of Things (IoT) based designs.
- CO3: To understand various interfacing issues with sensors and actuators.
- CO4: To be able to carry out application based experiments with microcontroller development boards.

Unit I
Introduction to embedded systems and ARM microcontrollers: Introduction To Embedded Systems, Design Considerations Of Embedded Systems, Microprocessors And Microcontrollers, Architecture Of ARM Microcontroller.Instruction set and assembly language programming

Unit II
D/A and A/D converter, sensors, actuators and their interfacing: Instruction set of ARM microcontroller, and assembly language programming, Digital To Analog Converter interfacing, Analog To Digital Converter interfacing, sensors, actuators and their interfacing.

Unit III
Microcontroller development boards and embedded programming platforms: Microcontroller Development Boards, Embed C Programming Environment, Interfacing With Stm32f401 Board, Interfacing With Arduino Uno, Interfacing 7-Segment Led And Lcd Displays.

Unit IV
Object tracking using GPS, GSM and Introduction to Internet of Things: Introduction To Internet Of Things, GSM And Bluetooth, Design Of A Home Automation System, Design Of A Simple Alarm System Using Touch Sensor. motion sensing using accelerometer, control of appliances over SMS.

Text Books:

1. F. Vahid and T. Givargis, *Embedded System Design: A Unified Hardware/Software Introduction*, , Wiley India Pvt. Ltd., 2002.
2. A.N. Sloss, D. Symes and C. Wright, *ARM System Developer's Guide: Design and Optimizing System Software*, Morgan Kaufman Publishers, 2004.

Reference Books:

1. W. Wolf *Computers as Components: Principles of Embedded Computing System Design*, Morgan Kaufman Publishers, 2008.

2.4 Fourth Semester

2.4.1 EC-DSEC- 606 Major Project

Aim: The aim of Dissertation work for M. Tech (ECE) is to obtain an understanding of how to define, plan, undertake and report on an open-ended piece of supervised research or design work.

2.4.1.1 Introduction

The aim of Dissertation work for M. Tech (ECE) is to obtain an understanding of how to define, plan, undertake and report on an open-ended piece of supervised research or design work. Students will discuss the Dissertation topic with the supervisor(s) and generate a suitable Dissertation research plan with proposed outcomes. They will then conduct a literature survey and background research. Students are asked to write a detailed report on a major research or design project. Some projects will be experimental in nature, others may involve computer-based simulation, feasibility studies or the design, construction and testing of equipment. In the normal course of events some or all of the theoretical, developmental and experimental aspects of design or research work will be covered in this unit of study. These aspects may be either directed by the supervisor or be of an original nature, but in any event the student is responsible for the execution of his or her practical work and the general layout and content of the Dissertation document. During the course of this unit of study, the students will learn how to examine published and experimental data, set objectives, organize a program of work and analyze results. They will also be expected to evaluate these results in relation to existing knowledge. The Dissertation will be judged on the extent and quality of the student's original work and particularly how critical, perceptive and constructive he or she has been in assessing his/her work and that of others. Students will also be required to present the results of their findings to their peers and supervisors in seminar.

2.4.1.2 Learning Outcomes

Learning outcomes are the key abilities and knowledge that will be assessed in this Dissertation. Outcomes are listed according to the Dissertation goals that they support.

Engineering/IT Specialization (Level 5)

1. Development of a higher level of research skills and expertise in the specific area(s)
2. Implementation of the research plan.
3. Ability to plan and undertake major research or design project
4. Ability to design and conduct experiments or tests and to analyze and interpret data from those experiments or tests.
5. Ability to work independently on a substantial project.

Information Seeking (Level 4)

1. Literature survey and in-depth review

Communication (Level 4)

7. Preparation and submission of a dissertation detailing the context of the problem, relevant back ground research and results of the investigation.
8. Development of seminar presentation skills

Professional Conduct (Level 4)

1. Understanding in research ethics, intellectual properties and commercialization potential

2.4.1.3 Assessment Tasks

Assesment Summary

Sl. No.	Assesment Name	Weight	Due	Learning Outcomes
1	Progress Report	$5\% + 5\% = 10\%$	March & June	2, 6
2	Presentation/Seminar	$10 + 10 + 10 = 30\%$	March, April & May	3, 6, 8
3	Thesis	60	June	1, 2, 3, 4, 5, 6, 7, 8, 9

2.4.1.4 Assessment Description

Progress Report: A progress report should include literature review, research plan, and intermediate outcomes in a format developed by department of ECE on sixth monthly basis.
Presentation/Seminar: An open seminar presentation will be given in Semester 3 and 4thof 20 minute presentation plus 5 minute questions/answers.
There shall be minimum three seminars (ppt presentation) to assess the entire M. Tech (ECE) student's dissertation work regularly on individual basis i.e. (1st Seminar in 2nd week of Nov., before End Semester Practical Exam; 2nd Seminar in 1/2nd Week of April (during University Week) and 3rd Seminar in 1st Week of June every year).
Thesis/Dissertation: A research dissertation will be submitted to cover (a) Literature review, (b) Methods and materials, (c) Results, (d) Discussion and (e) Conclusion, plus list of references and appendices.

2.4.1.5 Attributes Developed

Sl. No.	Attribute	Method
1	Engineering Specialization (Level 5)	Students are expected to demonstrate initiative and ingenuity in research, pointed and critical analysis of material, thoroughness of design, and innovative interpretation of evidence.
2	Information Seeking (Level 4)	The results presented and conclusions drawn are to be presented in the appropriate literature context. Students are expected to seek out information efficiently and effectively and to evaluate the relevance of this information and its sources to their project.
3	Communication (Level 4)	Written communication will be exercised through the generation of the Progress Report and Thesis. The Seminar will give students an opportunity to practice their oral communication and presentation skills.
4	Professional Conduct (Level 4)	A particular emphasis of Research Dissertation is the student's ability to value their own engineering judgments through the process of engineering design. Students should demonstrate an understanding of the ethical, social and professional implications of the work they are undertaking.

Text Books:

1. Mark Breach, *Dissertation Writing for Engineers and Scientists* , Prentice Hall (UK); Student edition (January 31, 2009)
2. Derek Swetnam, *Writing Your Dissertation*, Publisher:How To Books; 3 edition (April 1, 2000)
3. Evelyn Hunt Ogden, *Complete Your Dissertation or Thesis in Two Semesters or Less*, Rowman & Littlefield Publishers; 3 edition (December 21, 2006)
4. Carol M. Roberts, *The Dissertation Journey*, Corwin; Second Edition edition (August 23, 2010)

Reference Books:

1. Tonette S. Rocco, Tim Hatcher, *The Handbook of Scholarly Writing and Publishing* , Jossey-Bass; 1 edition (March 22, 2011)
2. Lawrence (Larry) A. (Anthony) Machi, Brenda T. (Tyler) McEvoy *The Literature Review: Six Steps to Success*,Corwin; Second Edition edition (June 8, 2012)
3. E. (Emily) Alana James, Tracesea H. (Heather) Slater, *Writing Your Doctoral Dissertation or Thesis Faster: A Proven Map to Success*, SAGE Publications, Inc; 1 edition (November 7, 2013).