Semester I Courses

Course Title	Mathematical Foundations of ESD	**Course Number**	EC501T
Department	Electronics and Communication Engineering	**Structure (IPC)**	3-0-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Nil	**Effective from**	July 2020
Course Aim	This course's objective is to provide a good understanding in thetime complexity analysis of any arithmetic operation, Galois filed theory of any crypto operation, estimation theory, linear programming, and multivariate analysis.		
Course Outcomes	At the end of this course, the students will be able to 1. Simulate appropriate application/distribution problems. 2. Obtain the value of the point estimators using the method of moments and method of maximum likelihood. 3. Apply the concept of various test statistics used in hypothesis testing for mean and variances of large and small samples. 4. Get exposure to the principal component analysis of random vectors and matrices. 5. Analyse the time complexity of the operation of the digital operations. 6. Apply Galois Field theory in the cryptography applications.		
Contents of the course	SPECIAL FUNCTIONS: Bessel's equation – Bessel function – Recurrence relations - Generating function and orthogonal property for Bessel functions of first kind – Fourier-Bessel expansion. LINEAR PROGRAMMING: Formulation – Graphical solution – Simplex method – Two phase method –Transportation and Assignment Problems. SIMULATION: Discrete Event Simulation – Monte – Carlo Simulation – Stochastic Simulation – Applications to real time problems. ESTIMATION THEORY: Estimators: Unbiasedness, Consistency, Efficiency and Sufficiency – Maximum Likelihood Estimation – Method of moments. MULTIVARIATE ANALYSIS: Random vectors and Matrices – Mean vectors and Covariance matrices – Multivariate Normal density and its properties – Principal components: Population principal components – Principal components from standardized variables.		

	COMPLEXITY ANALYSIS: Introduction to time complexity of an algorithm or operation (worst case, average case, and best case), SAT problems, NP hard and NP complete problems. ABSTRACT ALGEBRA: Introduction to Group, Ring, and Fields, Prime/Polynomial field representation, Irreducible polynomial, primitive polynomial, minimal polynomial, Galois field (GF) addition, GF multiplication, GF exponentiation, and GF multiplicative inverse.
References	1. Jay L. Devore, “Probability and Statistics for Engineering and the Sciences”, Cengage Learning, 9th Edition, Boston, 2016. 2. Johnson, R.A, Irwin Miller and John Freund., “Miller and Freund’s Probability and Statistics for Engineers”, Pearson Education, 9th Edition, New York, 2016. 3. Johnson, R.A., and Wichern, D.W., “Applied Multivariate Statistical Analysis”, Pearson Education, Sixth Edition, New Delhi, 2013. 4. Ross. S.M., “Probability Models for Computer Science”, Academic Press, SanDiego, 2002. 5. Taha H.A. “Operations Research: An Introduction”, Prentice Hall of India Pvt. Ltd. 10th Edition, New Delhi, 2017. 6. Winston, W.L., “Operations Research”, Thomson – Brooks/Cole, Fourth Edition, Belmont, 2003. 7. Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, “Introduction to Algorithms”, MIT Press, 2009. 8. Ralph P. Grimaldi, "Discrete and combinatorial Mathematics", Pearson Education, 5th Edition, New Jersey, 2004. 9. Erwin Kreyszig. “Advanced Engineering Mathematics”, John Wiley & Sons, 10th Edition, New York, 2010.

Course Title	Product Design and Development	**Course Number**	EC502T
Department	Electronics and Communication Engineering	**Structure (IPC)**	3-0-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Nil	**Effective from**	July 2020
Course Aim	1. The course comprises theoretical sessions that are supplemented with practice sessions. 2. The students will be given an overview of systematic approach used during product design and development. 3. The course will highlight the methods for need identification, techniques for creative thinking, concept generation, concept selection, product architecture, aesthetics, ergonomics etc. 4. The students will realize the design through models of using suitable materials		
Course Outcomes	1. The students will be able to understand the need of a customer and use the creative thinking to conceptualize designs. 2. The students will also be able to quickly visualize the concepts using models.		
Contents of the course	Introduction: Importance of engineering design, types of design, total life cycle- types of products, Phases of product development process, product and process cycles. (10 hours) Problem Definition & Need Identification: Identifying customer needs, gathering information classifying customer requirements, engineering characteristics, competitive benchmarking, QFD, product design specification. (10 hours) Conceptual Design: Creativity in design, creativity and problem solving, creative thinking methods, conceptual decomposition morphological methods-TRIZ and contradiction, Bio and Shape mimicry techniques, Decision making and concept selection-decision theories-concept screening and scoring. (8 hours) Embodiment Design: Product architecture, steps in developing product architecture, industrial design human factors design, Nostalgia and Design, Environment factors. (8 hours) Design Profile Preparation (4 hours)		
Textbooks	1. K. Otto, Product Design, Pearson Education, 1st edition, 2011, ISBN: 8177588214. 2. U. Karl and S. Eppinger, Product Design and Development, McGraw-Hill Education, 6th edition, 2015, ISBN: 0078029066.		
References	1. C. A. Harper, Handbook of Materials for Product Design, McGraw-Hill Professional, 1st edition, 2001, ISBN: 0071354069.		

	2. R. Stuer and K. Eissen, Sketching: Drawing Techniques for Product Designers, Thames & Hudson, 1st edition, 2007, ISBN: 9063691718. 3. B. Hallgrimsson, Prototyping and Modelmaking for Product Design, Laurence King Publishing, 1st edition, 2012, ISBN: 9781856698764

Course Title	Product Design and Development Practice	**Course Number**	EC502P
Department	Electronics and Communication Engineering	**Structure (IPC)**	0-3-2
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Nil	**Effective from**	July 2020
Course Aim	1. The course comprises theoretical sessions that are supplemented with practice sessions. 2. The students will be given an overview of systematic approach used during product design and development. 3. The course will highlight the methods for need identification, techniques for creative thinking, concept generation, concept selection, product architecture, aesthetics, ergonomics etc. 4. The students will realize the design through models of using suitable materials		
Course Outcomes	1. The students will be able to understand the need of a customer and use the creative thinking to conceptualize designs. 2. The students will also be able to quickly visualize the concepts using models.		
Contents of the course	Method of Expressing and communicating and documenting technical ideas through sketches. Clay, Foam, Wood modelling and modern 3D printing. Problem Definition and Need Identification. Conceptual design: Morphological charts, TRIZ and Contradiction, Bio and Shape mimicry, Concept selection, Screening. Embodiment Design: Product Architecture, Human Factors, Aesthetics, Nostalgia and Environmental factors. Design Profile presentation.		
Textbooks	1. K. Otto, Product Design, Pearson Education, 1st edition, 2011, ISBN: 8177588214. 2. U. Karl and S. Eppinger, Product Design and Development, McGraw-Hill Education, 6th edition, 2015, ISBN: 0078029066.		
References	1. C. A. Harper, Handbook of Materials for Product Design, McGraw-Hill Professional, 1st edition, 2001, ISBN: 0071354069. 2. R. Stuer and K. Eissen, Sketching: Drawing Techniques for		

	Product Designers, Thames & Hudson, 1st edition, 2007, ISBN: 9063691718. 3. B. Hallgrimsson, Prototyping and Modelmaking for Product Design, Laurence King Publishing, 1st edition, 2012, ISBN: 9781856698764

Course Title	Digital VLSI System Design	**Course Number**	EC503T
Department	Electronics and Communication Engineering	**Structure (IPC)**	3-0-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Digital Logic Design, VLSI Design	**Effective from**	July 2020
Course Aim	The aim of this course is to introduce architecture and design concepts underlying the modern complex VLSI circuits/systems.		
Course Outcomes	At the end of this course, the students will be able to 1. Design digital system using HDL and CMOS transistors. 2. Analyse the circuit/system performance, area, and power dissipation. 3. Implement the low power and high throughput techniques on digital integrated circuits. 4. Develop the Custom IPs to integrate into Digital Systems		
Contents of the course	1. Introduction to Digital design: timing issues, pipelining, folding/ unfolding, resource sharing, metastability, synchronization, clock skew, setup/hold time of flip-flops, synchronization between multiple clock domains using FIFO, PLL, and DLL, reset – recovery/removal time, false path. (5 hours) 2. Digital Systems Design with ASICs: PLDs, Semi/full custom ASIC designs, Emphasis on the synthesis based approach to VLSI Design. Relevant issues related to physical design automation such as partitioning, floor planning, power planning, placement & routing, Algorithms for VLSI Physical Design, IO pads, electro static discharge. (5 hours) 3. Digital Systems Design with FPGAs: Hardware-Software Co-design, Custom IP Development, High level synthesis (HLS), Efficient Coding Techniques in High Level Language for HLS, Partial Reconfiguration. (4 hours) 4. Hardware Verification and Testing Equivalence/model check based formal hardware verification, Binary decision/moment diagram, flexible/vector hardware designs, VLSI testing, logical fault models, fault equivalence, fault dominance, fault collapsing, double/triple modular redundancy, fault simulation, test pattern generation, Built-in-self test, Scan chain based test, fault tolerant designs. (7 hours) 5. CMOS Transistor Logic: I-V characteristics, Short channel		

	effects, Mobility degradation & velocity saturation, channel length modulation, body effect, drain induced barrier lowering, leakage, RC delay model, logical effort, clock gating, dynamic voltage scaling, power gating, glitch free circuits, dual-edge triggering, static CMOS, ratioed circuits, dynamic CMOS, domino logic, pass transistor logic, CMOS latches, CMOS flipflops, dual edge triggered flipflops, synchronizers, arbiters, wave pipelining. (15 hours) 6. Memory Designs: SRAM, DRAM, ROM, PROM, EPROM, EEPROM, Flash, CAM (5 hours)
Evaluation Pattern	The end-sem exam will have at least 50% of weightage. The remaining weightage comprises Minor-1, Minor-2, and projects (or assignments).
Textbooks	1. Neil H.E. Westte and David Money Harris: CMOS VLSI Design : A Circuits and Systems Perspective, Addison Wesley, 4th Edn, 2011.
References	1. Wakerly, J. F., Digital Design: Principles and Practices, 4th Edition, Pearson, 2008 2. Miron Abramovici, Melvin A Breuer, and Arthur D Friedman: Digital Systems Testing and Testable Designs, Wiley-IEEE Press, 1994. 3. N. A. Sherwani, Algorithms for VLSI Physical Design Automation, Bsp Books Pvt. Ltd., 3rd edition, 2005. 4. Samir Palnitkar: Verilog HDL - Guide to Digital design and synthesis, Pearson Education, 3rd Edn, 2003.

Course Title	Digital VLSI System Design Practice	**Course Number**	EC503P
Department	Electronics and Communication Engineering	**Structure (IPC)**	0-3-2
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Digital Logic Design, VLSI Design	**Effective from**	July 2020
Course Aim	The lab course is intended to give exposure to the design of different functional components of digital integrated circuits using FPGA development boards and VLSI CAD tools respectively.		
Course Outcomes	At the end of this course, the students will be able to 1. Design the RTL based digital circuits using HDL. 2. Develop the hardware-software co-design using VLSI CAD tool. 3. Develop the custom IP using RTL design and/or high level synthesis 4. Design the digital system with low power and high throughput VLSI techniques 5. Implement the fault tolerant hardware design and formal hardware verification using HDL		
Contents of the course	1. Introduction to RTL Design**:** Basic combinational (half adder, full adder, multiplexer, decoder, and so on) and sequential circuits design (Flip-flops and counters) using HDL with commercial VLSI CAD tools or open source compilers. 2. Familiarity of Datapath elements**:** 32-bit Ripple carry adder, recursive doubling based carry look ahead adder, Braun multiplier, Wallace tree multiplier, non restoring based division, IEEE-754 floating point adder/Subtractor/multiplier/divider, CORDIC, modular multiplier, modular multiplicative inverse, modular exponentiator, cross-bar switch, Banyan switch, Batcher switch, digital FIR filter. 3. Advanced VLSI circuit design concepts**:** Pipelining, clock gating to reduce the switching power dissipation, hardware reuse strategy (folded hardware) to reduce the area, fault tolerant digital circuit design, formal hardware verification using equivalence check, high level synthesis with EDA, performance analysis of RTL design & high level synthesis based digital system using EDA, partial reconfiguration using EDA. 4. Hardware-Software Co-design**:** Design flow of hardware-software co-design using FPGA evaluation board with EDA, Custom IP design (arithmetic circuits as mentioned above), hardware-software partitioning, and performance analysis of various hardware-software co-design techniques.		

	5. Digital Circuits Design using CMOS**:** logic gates, combinational logic circuits, low power CMOS circuits using VLSI CAD tool. 6. Project Work (Individual): Basic 32-bit Processor Design (Harvard Architecture with Microprogramming based Controller) that includes the functional units such as logic unit, fixed/floating point adder, multiplier, and divider. Here, two separate memories are used for data and instruction.
Textbooks	1. Neil H.E. Westte and David Money Harris: CMOS VLSI Design : A Circuits and Systems Perspective, Addison Wesley, 4th Edn, 2011.
References	1. Wakerly, J. F., Digital Design: Principles and Practices, 4th Edition, Pearson, 2008 2. Miron Abramovici, Melvin A Breuer, and Arthur D Friedman: Digital Systems Testing and Testable Designs, Wiley-IEEE Press, 1994. 3. N. A. Sherwani, Algorithms for VLSI Physical Design Automation, Bsp Books Pvt. Ltd., 3rd edition, 2005. 4. Samir Palnitkar: Verilog HDL - Guide to Digital design and synthesis, Pearson Education, 3rd Edn, 2003.

Course Title	Embedded System Design Practice	**Course Number**	EC503I
Department	Electronics and Communication Engineering	**Structure (IPC)**	1-3-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Microprocessors and Microcontrollers	**Effective from**	July 2020
Course Aim	To provide a hands-on introduction to design of embedded systems with hardware/software and interfacing in real-time to networked cyber-physical systems and real time systems using the microcontrollers.		
Course Outcomes	At the end of this course, the students will be able to 1. Understand the basic elements of embedded systems such as I/O and interfaces. 2. Understand embedded system design using the ARM Cortex-M microcontroller with the Launch pad IDE in C. 3. Develop the rapid prototype of embedded systems using open source microcontrollers and microcomputers such as Arduino, Raspberry Pi, BeagleBone Black, and Intel Edison/Galileo. 4. Build wireless networked embedded systems using Arduino shields and modules (e.g., GPS, GSM/GPRS, Bluetooth, RFID, and ZigBee). 5. Exploit the advanced concepts such as networking and wireless communications, real-time operating systems and control, and Internet of Things in the real time embedded systems. 6. Develop the hardware-software co-design with parallel threads using Xilnx Vivado. 7. Conduct experiments in Internet of Things (e.g., using Arduino Yun, Intel and Microsoft Developer Kits)		
Contents of the course	**Detailed Theory syllabus** 1. Elements of embedded systems (such as microcontrollers, GPIO, communication, interrupts, ADC, and DAC); overview of microcontroller; Comparison between Hardware, Software, and Firmware; Comparison between Hard, Soft, Firm, and Hybrid real time systems; applications of embedded systems; classification of embedded systems; characteristics of embedded systems; hardware-software partitioning; 2. Software aspects of embedded systems; Real-time operating system (RTOS) - mutual exclusion using semaphore; deadlock; critical section; event-driven scheduling; time sharing; earliest		

	deadline first scheduling; pre-emptive scheduling; non-pre-emptive scheduling; multi-tasking; multi-threading; inter-process communication using mboxes, and pipes; priority inversion; 3. Rapid prototyping of embedded systems with advanced microcontroller boards; Basic elements of IoT; IoT systems design using advanced microcontroller boards; **Detailed Syllabus for Lab Practice** 1. Experiments in GPIO such as switches, LEDs, LCD, Key pad, Seven Segment Display, Buzzer, and relay; 2. Serial and parallel interfacing; data acquisition with ADC, audio, and video; timer interrupts; Various bus intereconnects such as I2C, UART, SPI, and so on; 3. DAC Experiments in control of RC servos, stepper motors, and DC motors; 4. Data acquisition and real-time control with TIVA boards, LPC2148 trainer board, FPGA boards, Arduino, Raspberry Pi, and BeagleBone Black microcontrollers; 5. Add-on boards Experiments in wireless networked systems with GPS, GSM/GPRS, ZigBee, Bluetooth, and RFID; 6. Hardware-software co-design experiments using FPGA boards. 6. Experiments in IoT for smart automation using sensors, microcontrollers, and cloud. 7 Free RTOS based applications using TIVA board.
References	1. J. W. Valavano, Embedded Systems: Introduction to Arm Cortex-M Microcontrollers, 2nd edition, Create Space, 2012. ISBN: 978-1477508992. 2. J. W. Valavano, Embedded Systems (Vol-2): Real-Time Interfacing to ARM Cortex-M Microcontrollers, 2nd edition, Create Space, 2011, ISBN: 978-1463590154. 3. J. W. Valavano, Embedded Systems (Vol-3): Real-Time Operating Systems for Arm Cortex M Microcontrollers, 2nd edition, Create Space, 2012. ISBN: 978-1466468863. 4. A. McEwen and H. Cassimally, Designing the Internet of Things, 1st edition, Wiley, 2013. ISBN: 978-8126556861. 5. D. Gajski, F. Vahid, S. Narayan, and J. Gong.Specification and Design of Embedded Systems,Prentice Hall.

Semester II Courses

Course Title	Circuits for Electronic System Design	**Course Number**	EC504T
Department	Electronics and Communication Engineering	**Structure (IPC)**	3-0-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Analog and Digital Electronics	**Effective from**	July 2020
Course Aim	The aim of offering this course is to provide a proficiency in designing circuits for electronics system design..		
Course Outcomes	1. Apply concepts of Analog circuits for signal conditioning, signal processing, controller circuits, and driver circuits for power electronic circuits. 2. Design transformer and different power sources for various applications 3. Understand the interface of various modules to microcontroller and learn various communication protocols 4. Perform descriptive error analysis for the circuits 5. Demonstrate key concepts in electronics circuit design, including tools, approaches, and application scenarios		
Contents of the course	1. Introduction to Op-Amps: Op-amp Characteristics, Negative feedback, Gain of the Op-Amp 2. Analog Signal conditioning circuits**:** Buffering, scaling, level translation, filtering applications, Analog math circuits - arithmetic circuits, log circuits, trigonometric circuits and applications Timer circuits, pulse width modulation circuits, P, PI and PID controller circuits, protection circuits, base and gate drive circuits for power transistors, MOSFETs and IGBTs, relay and contactor drive circuits. Design and error budget analysis of signal conditioners for low level AC and DC applications. Error Analysis. 3. Power supply circuits: Board level power supply circuits to generate +/-12V, 5V, 3.3V, 1.8V. Linear regulators, low drop out regulators, charge pumps, switched mode power converters. 4. Interfacing circuits**:** A to D, D to A, A to A and D to D interfaces, serial and parallel DACs, sampling, RS-232, USB, I2C, LCD, serial memory, SPI, CAN, wireless (RF, WiFi) Ethernet, RFID, SD card, SIM card, GPS, Touchscreen interfaces. 5. Digital circuit essentials**:**Digital filters, moving average, numeric formats, scaling, normalizing, arithmetic, log, exponential, square root, cube root, hypotenuse, sine, 3 phase waves, PWM etc.		
References	1. Franco, S., Design with operational amplifiers and analog		

	integrated circuits. Mc. Graw Hill book Co. 1988. 2. Horowitz, P., and Hill, W., The art of electronics (2nd edition), Cambridge University Press. 1992. 3.Abraham Pressman, Keith Billings, Taylor Morey, Switching Power Supply Design, McGraw-Hill Education, 2009 4. Warwick A. Smith, ARM Microcontroller Interfacing: Hardware and Software, Elektor Electronics Publishing, 2010 5. Datasheets and Application notes of different Integrated circuits

Course Title	Circuits for Electronic System Design Practice	**Course Number**	EC504P
Department	Electronics and Communication Engineering	**Structure (IPC)**	0-3-2
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Analog and Digital Electronics	**Effective from**	July 2020
Course Aim	The aim of offering this laboratory course is to acquire knowledge and proficiency in design circuits for electronics system design.		
Course Outcomes	1. Design and build circuits using OPAMPS 2. Design and develop different power supplies 3. Design and develop signal conditioning circuits for resistive, capacitive, inductive, current current, and voltage-based sensors 4. Analysis of various communication protocols		
Contents of the course	1. Design and build circuits using OPAMPS (summer, integrator, differentiators, and Instrumentation amplifier) 2. Design and build the power supply circuits such as linear power supply, LDO, and DC-DC converter 3. Design and develop the signal conditioning circuits for resistive (RTD), capacitive, inductive (LVDT), current (Photodiode) and voltage based sensors (Thermocouple) 4. Analysis of communication protocols (SPI, CAN, I2C)		
References	1. Franco, S., Design with operational amplifiers and analog integrated circuits. Mc. Graw Hill book Co. 1988. 2. Horowitz, P., and Hill, W., The art of electronics (2^{nd} edition), Cambridge UniversityPress. 1992. 3. Abraham Pressman, Keith Billings, Taylor Morey, Switching Power Supply Design, McGraw-Hill Education, 2009 4. Warwick A. Smith, ARM Microcontroller Interfacing: Hardware and Software, Elektor Electronics Publishing, 2010		

Course Title	Electronic Systems Packaging	**Course Number**	EC505T
Department	Electronics and Communication Engineering	**Structure (IPC)**	3-0-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Basics of Electrical & Electronics Engineering	**Effective from**	July 2020
Course Aim	The course will sensitize the participants to the fundamentals of electronics systems packaging. The course is multidisciplinary in nature. Today products in electronics industry need to be packaged to current state-of-art if it has to be in the leading edge market.		
Course Outcomes	1. Understands the electronics packaging including package styles or forms, hierarchy and methods of packaging necessary for various environments. 2. Provides industry perspective in the electronics packaging 3. Ability to distinguish between engineering performance and economic considerations to develop cost-efficient and high performance packaging approaches. 4. Predict the reliability of electronic components and structures.		
Contents of the course	Module 1: Overview of Electronic Systems Packaging: Definition of a system and history of semiconductors, Products and levels of packaging, Packaging aspects of handheld products, Definition of PWB, Basics of Semiconductor and Process flowchart, Wafer fabrication, inspection and testing, Wafer packaging; Packaging evolution; Chip connection choices, Wire bonding, TAB and flip chip. Module 2 Electronic systems and needs, physical integration of circuits, packages, boards and complete electronic systems; system applications like computer, automobile, medical and consumer electronics with case studies and packaging levels. Module 3: Electrical design considerations - power distribution, signal integrity, RF package design and Power-delivery in systems. CAD for Printed Wiring Boards (PWBs) and Design for Manufacturability (DFM). PWB Technologies, Single-chip (SCM) and Multi-chip modules (MCM), flex circuits. Recent trends in manufacturing like microvias, sequential build-up circuits and high-density interconnect structures. Module 4: Materials and processes in electronics packaging, joining methods in electronics; lead-free solders. Surface Mount Technology - design, fabrication and assembly, embedded passive components.		

	Module 5: Thermal management of IC and PWBs, Cooling Requirements, Electronic cooling methodsthermo-mechanical reliability, design for reliability, electrical test and green packaging issues, Design for Reliability – Fundamentals, Induced failures. Electrical Testing – System level electrical testing, Interconnection tests, Active Circuit Testing, Design for Testability. Trends in packaging.
References	1. Rao R. Tummala, Fundamentals of Microsystems Packaging, McGraw Hill, NY, 2001, 2. Rao R Tummala& Madhavan Swaminathan, Introduction to System-on-Package, McGraw Hill, 2008, 3. R S Khandpur, Printed Circuit Boards, McGraw Hill, 2006 4.Richard K. Ulrich &William D. Brown Advanced Electronic Packaging - 2nd Edition : IEEEPress, 2006

Course Title	Electronic Systems Packaging Practice	**Course Number**	EC505P
Department	Electronics and Communication Engineering	**Structure (IPC)**	0-3-2
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	NIL	**Effective from**	July 2020
Course Aim	To understand the manufacturing and assembling aspects of Electronic components in systems.		
Course Outcomes	1. Expected to design optimized layout for printed circuits boards. 2. Exposed to multi-layer PCB design 3. To develop Prototype circuits		
Contents of the course	PCB design flow- Schematic -layout - PCB design using created library -PCB printing using PCB prototyping machine-Testing and debugging of PCB Familiarization of different components and chip packages PCB Design for manufacturability PCB Design consideration for special circuits Design and development of PCBs using different simulator tools and prototyping. Hands-on lab sessions for board manufacturing and assembly. Thermal and Heat Sink Design Electrical Testing and Active Circuit Testing		
References	1. Jan Axelson, Making Printed Circuit Boards, TAB/McGraw Hill, 1993 2. J. Varteresian, Fabricating Printed Circuit Boards. 3. Ronald A. Reis, Electronic project design and fabrication, 6/E, Prentice Hall, 2005. 4. Complete PCB Design Using OrCad Capture and Layout Kraig Mitzner, Elsevier		

Course Title	Digital Signal Processing and Architectures	**Course Number**	EC506T
Department	Electronics and Communication Engineering	**Structure (IPC)**	3-0-3
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Digital Signal Processing, Digital Logic Design	**Effective from**	July 2020
Course Aim	The goal of this course is to provide a good understanding of the principles and their corresponding hardware designs of various Digital Signal Processing operations.		
Course Outcomes	At the end of this course, the students will be able to 1. Understand the concepts of digital signal processing : Filtering Techniques and Orthogonal Transformations. 2. Develop the hardware designs of various Digital Filtering Techniques and Orthogonal Transformations.		
Contents of the course	1. Arithmetic Circuits: Fixed point number representation, barrel shifter, logarithmic shifter, ripple carry adder, carry select adder, carry skip adder, carry save adder, recursive doubling based carry look ahead adder, Booth algorithm, Carry save array multiplier, Wallace tree multiplier, distributed arithmetic based multiplication, fixed point multiply accumulate circuit design, restoring/non restoring division techniques, IEEE-754 floating point representation, floating point addition/subtraction, floating point multiplication/division, floating point multiply accumulate circuit design, and CORDIC. (8 hours) 2. Digital filter design: Basics of folded/parallel design, FIR/IIR filter design, steepest- descent LMS algorithm, adaptive FIR filter design, multirate signal processing, polyphase decomposition, and filter banks. (8 hours) 3. Discrete wavelet transform: Haar wavelet, 1D/2D/3D-Convolution based discrete wavelet transform architecture, 1D/2D/3D- (5,3) and (9,7) lifting based discrete wavelet transform architecture. (4 hours) 4. FFT architectures: radix-2/4 SDF, MDC, parallel FFT architectures. (4 hours) 5. HEVC architectures: introduction to DCT, integer DCT architectures, and discrete Hadamard transform architectures. (4 hours)		

	6. Hardware/software co-design: Analogous between ASIC/FPGA/hardware-software co-designs, need for digital signal processing accelerators (or coprocessors), and hardware/software partitioning based digital signal processing architectures, (4 hours) 7. Digital signal processor design: basics of Von-Neumann, Harvard, Modified Harvard, and super Harvard architectures, hazards, hazard resolution techniques, instruction and data level parallelism. (8 hours)
Text Books	1. S. K. Mitra, Digital Signal Processing: A computer base approach, Third edition, Mc Graw Hill Higher Education, 2006. 2. Y.T. Chan, Wavelet Basics, Kluwer Publishers, Boston, 1993. 3. Simon Haykin, Adaptive filter theory, Pearson Education, Fifth edition, 2014. 4. Carl Hamacher, Zvonko Vranesic, Safwat Zaky, and Naraig Manjikian, Computer Organization and Embedded Systems, McGraw Hill Publications, Sixth Edition, 2012.
References	1. A. V. Oppenheium, R. W. Schafer, Discrete-time signal processing, Second edition, Prentice Hall, 1999. 2. Moris M. Mano, Computer System Architecture, Third Edition, Pearson Publication, 2007. 3. John L. Hannessey and David A. Patterson, Computer Architecture: A Quantitative Approach, Fourth Edition, Elsevier, Morgan Kaufmann Publishers, 2007. 4. Research articles on VLSI for Signal Processing

Course Title	Digital Signal Processing and Architectures Practice	**Course Number**	EC506P
Department	Electronics and Communication Engineering	**Structure (IPC)**	0-3-2
Offered to	M.Tech. ESD	**Status (Core/ Elective)**	Core
Prerequisite	Digital Signal Processing, Digital Logic Design	**Effective from**	July 2020
Course Aim	The goal of this course is to provide a good understanding of the principles and their corresponding hardware designs of various Digital Signal Processing operations.		
Course Outcomes	At the end of this course, the students will be able to 1. Denoise the signals. 2. Compress the audio, image, and video signals 3. Develop the RTL designs of various signal processing elements such as compressor and filter.		
Contents of the course	1. Hardware/software co-design of signal processing operations 2. Digital Signal Co-processor design 3. Digital Filter Designs – FIR, IIR, Adaptive filters 4. Discrete Orthogonal Transform Designs – FFT, integer DCT, DHT, DWT 5. Experiments using TMS320 trainer kit.		
Text Books	1. S. K. Mitra, Digital Signal Processing: A computer base approach, Third edition, Mc Graw Hill Higher Education, 2006. 2. Y.T. Chan, Wavelet Basics, Kluwer Publishers, Boston, 1993. 3. Simon Haykin, Adaptive filter theory, Pearson Education, Fifth edition, 2014. 4. Carl Hamacher, Zvonko Vranesic, Safwat Zaky, and Naraig Manjikian, Computer Organization and Embedded Systems, McGraw Hill Publications, Sixth Edition, 2012.		
References	1. A. V. Oppenheium, R. W. Schafer, Discrete-time signal processing, Second edition, Prentice Hall, 1999. 2. Moris M. Mano, Computer System Architecture, Third Edition, Pearson Publication, 2007. 3. John L. Hannessey and David A. Patterson, Computer Architecture: A Quantitative Approach, Fourth Edition, Elsevier, Morgan Kaufmann Publishers, 2007. 4. Research articles on VLSI for Signal Processing		

Electives

Course Title	Course Code	Structure (I-P-C)		
Antenna Design	**EC511**	**3**	**0**	**3**

Pre-requisite, if any: Engineering Electromagnetics

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

CO1	Analyse a given Antenna
CO2	Measure a given Antenna
CO3	Design standard antennas
CO4	Develop new antenna structures with desired specifications

Syllabus:

Fundamental Concepts: Physical concept of radiation, Radiation pattern, near-and far-field regions, reciprocity, directivity and gain, effective aperture, polarization, input impedance, efficiency, Friis transmission equation, radiation integrals and auxiliary potential functions.

Radiation from Wires and Loops: Infinitesimal dipole, finite-length dipole, linear elements near conductors, dipoles for mobile communication, small circular loop.

Aperture and Reflector Antennas: Huygens' principle, radiation from rectangular and circular apertures, design considerations, Babinet's principle, Radiation from sectoral and pyramidal horns, design concepts, parabolic reflector and cassegrain antennas.

Broadband Antennas: Log-periodic and Yagi antennas, frequency independent antennas, Helical and Biconical antenna broadcast antennas, Spiral antenna.

Microstrip Antennas: Radiation mechanism, parameters and applications of microstrip antennas, feeding methods, methods of analysis, design of rectangular and circular patch antennas. Impedance matching of microstrip antenna.

Antenna systems and measurements: Receiving properties of antenna, Antenna noise and temperature, Gain measurement, polarization measurement, field intensity measurement, Antenna range Introduction and concept of antenna arrays. Case study on practical microstrip patch antenna for personal wireless communications consistent with the frequencies assigned by FCC.

Text Book(s):

1. C. A. Balanis, "Antenna Theory and Design", 3rd Ed., John Wiley & Sons., 2005.
2. W. L. Stutzman, and G. A. Thiele, "Antenna Theory and Design", 2nd Ed., John Wiley & Sons., 1998.

References & Web Resources:

1. R. E. Collin, "Antennas and Radio Wave Propagation", McGraw-Hill., 1985.
1. F. B. Gross, "Smart Antennas for Wireless Communications", McGraw-Hill., 2005
2. R. S. Elliot, "Antenna Theory and Design", Revised edition, Wiley-IEEE Press., 2003
3. J. D. Kraus and R. J. Marhefka, “Antennas for All Applications,” Third Edition, 2002.
4. S. R. Saunders, “Antennas and Propagation for Wireless Communication Systems,” John Wiley & Sons, 1999.

Course Title	Course Code	Structure (I-P-C)		
Analog and Mixed Signal Circuit Design	**EC512**	**3**	**0**	**3**

Pre-requisite, if any: Analog Circuits

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

CO1	Design and analyze complex analog integrated circuits using industry level analog IC Design tools
CO2	Design and analyze ADC and DAC using EDA tools
CO3	Design and analyze various MOSFET based arithmetic circuits.
CO4	Learn the various method of power optimization in analog circuits.

Syllabus:

Introduction: Review of single state MOS amplifiers, current mirrors, cascode current mirrors, active current mirrors, biasing techniques.

Op-amp design: Differential pair with current mirror load, single stage op-amp characteristics, single stage op-amo tradeoffs, telescopic cascode op-amp, folded cascode op-amp, two stage op-amp, fully differential single stage op-amp.

Data converter fundamentals: Analog versus digital (or discrete time) signals, converting analog signals to data signals, sample and hold circuits, sample and hold characteristics, switched capacitor circuits, DAC specifications, ADC specifications.

Data converters: DAC architectures – digital input code, R-2R ladder networks, current steering, charge scaling DACs, cyclic DAC, pipeline DAC, ADC architectures – flash ADC, 2-step flash ADC, pipeline ADC, integrating ADC, successive approximation ADC.

Phase locked loop: simple PLL, frequency/phase detectors, charge pump PLL, application as frequency multiplier.

Text Book(s):

1. Behzad Razavi, Design of Analog CMOS Integrated Circuits McGraw-Hill International Edition 2016.
2. Baker, R. Jacob, CMOS: Circuit design, Layout, and Simulation. John Wiley & Sons, 2019.

References & Web Resources:

1. Phillip E. Allen and Douglas R. Holberg, CMOS Analog Circuit Design, Oxford University Press, 2003.
2. Behzad Razavi, Fundamentals of Microelectronics, Second edition, Wiley, 2013
3. P. R. Gray, P. J. Hurst, S. H. Lewis and R. G. Meyer, Analysis And Design Of Analog Integrated Circuits, 5th edition, John Wiley & Sons, Inc., 2009.

Course Title	Course Code	Structure (I-P-C)		
Testing and Testability	**EC513**	**3**	**0**	**3**

Pre-requisite, if any: Digital Logic Design

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

CO1	Identify the significance of testable design
CO2	Understand the concept of yield and identify the parameters influencing the same
CO3	Specify fabrication defects, errors and faults.
CO4	Implement combinational and sequential circuit test generation algorithms
CO5	Identify techniques to improve fault coverage

Syllabus:

Role of testing in VLSI Design flow, Testing at different levels of abstraction, Fault error, defect, diagnosis, yield, Types of testing, Rule of Ten, Defects in VLSI chip. Modelling basic concepts, Functional modelling at logic level and register level, structure models, logic simulation, delay models.

Various types of faults, Fault equivalence and Fault dominance in combinational sequential circuits. Fault simulation applications, General fault simulation algorithms- Serial, and parallel, Deductive fault simulation algorithms. Combinational circuit test generation, Structural Vs Functional test, ATPG, Path sensitization methods.

Difference between combinational and sequential circuit testing, five and eight valued algebra, and Scan chain based testing method. D-algorithm procedure, Problems, PODEM Algorithm, Problems on PODEM Algorithm. FAN Algorithm, Problems on FAN algorithm, Comparison of D, FAN and PODEM Algorithms. Design for Testability, Ad-hoc design, Generic scan based design.

Classical scan based design, System level DFT approaches, Test pattern generation for BIST, and Circular BIST, BIST Architectures, and Testable memory design-Test algorithms-Test generation for Embedded RAMs.

Fault Diagnosis Logic Level Diagnosis - Diagnosis by UUT reduction - Fault Diagnosis for Combinational Circuits - Self-checking design - System Level Diagnosis.

Text Book(s):

1. M. Abramovici, M. Breuer, and A. Friedman, “Digital Systems Testing and Testable Design, IEEE Press, 1990

2. Stroud, “A Designer’s Guide to Built-in Self-Test”, Kluwer Academic Publishers, 2002

References & Web Resources:

1. M. Bushnell and V. Agrawal, “Essentials of Electronic Testing for Digital, Memory & Mixed-Signal VLSI Circuits”, Kluwer Academic Publishers, 2000
2. V. Agrawal and S.C. Seth, Test Generation for VLSI Chips, Computer Society Press.1989.
3. M. Abramovici, M.A. Breuer and A.D. Friedman, "Digital Systems and Testable Design", Jaico Publishing House.
4. M.L. Bushnell and V.D. Agrawal, "Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits", Kluwer Academic Publishers.
5. P.K. Lala, "Digital Circuit Testing and Testability", Academic Press, 2002.
6. A.L. Crouch, "Design Test for Digital IC's and Embedded Core Systems", Prentice Hall International.

Course Title	Course Code	Structure (I-P-C)		
Reliable Digital Communication System Design	**EC514**	**3**	**0**	**3**

Pre-requisite, if any: Communication Systems, Digital Logic Design

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

CO1	Learn the functional behaviour of various cryptography, intrusion detection, and error correction algorithms.
CO2	Learn to develop hardware architectures of various cryptography, intrusion detection, and error correction algorithms.
CO3	Develop the countermeasure prototypes of adversary attacks
CO4	Develop the crypto co-processors using FPGA.

Syllabus:

Information theory, Entropy, Properties of Entropy

Goals of Relilable Digital Communication: first level of defense (integrity, confidentiality, authenticity, and availability) and second level of defense (resilience to attacks).

Galois Field Arithmetic: Introduction to Group, Ring, and Fields, Prime/Polynomial field representation, Irreducible polynomial, primitive polynomial, minimal polynomial, Galois field addition, LSB first/MSB first/Montgomery Galois field multiplication architectures-bit serial, bit parallel, digit serial, systolic, and scalable architectures, Modular exponentiators-Square-multiply algorithm and Montgomery Ladder algorithm, Extended Euclidean algorithm/Fermat's little theorem based multiplicative inverse architectures.

Symmetric Encryption/Decryption Architectures: DES, 3-DES, and AES (fully folded, parameterized parallel, and fully parallel architectures).

Asymmetric Encryption/Decryption Architectures: ECC (right-to-left, left-to-right, Montgomery based scalar multiplication in affine/projective co-ordinates) and RSA.

HASH architectures: SHA512 and SHA3.

Key exchange protocols: Diffie Helmen, Elgamal, Neuro crypto key exchange protocol.

Authentication schemes: Yang Shieh and Eiji Okamato.

Pseudo random number generators, Stream ciphers.

Physical unclonable functions: RO PUF, larger decoder memory based PUF, and XOR PUF.

Intrusion Detection: Universal HASH functions, Cuckoo hashing, and Bloom filter.

Error detection codes: CRC, LRC, and parity check, Error correction codes-Hamming, BCH, Reed Solomon, LDPC, Convolutional, Turbo product, and concatenated codes, Hardware/software co-design analogous between ASIC/FPGA/hardware-software co-designs, need for crypto accelerators (or coprocessors), and hardware/software partitioning based AES/ECC architectures.

Side channel analysis: Power attack, Bit masking, and Cache template attack.

Text Book(s):

1. Doug R. Stinson , Cryptography Theory and Practice, Third Edition, CRC Press, 2006.

2. Shu Lin and Daniel J Castello, Error Control Coding, Second Edition, Printice Hall, 2004.

3. Haykin, An Introduction to Analog and Digital Communications, wiley Vol

2, 2008.

References & Web Resources:

1. A. J. Menezes, P. C. van Oorshot, and S. A. Vanstone, Handbook of Applied Cryptography, CRC Press, 1996.
2. Jonathan Katz and Yehuda Lindell, Introduction to Modern Cryptography, CRC Press, 2015.
3. Debdeep Mukhopadhyay and Rajat Subhra Chakraborty, Hardware Security: Design, Threats and Safeguards, CRC Press, 2014.

Course Title	Course Code	Structure (I-P-C)		
Satellite Communication	**EC515**	**3**	**0**	**3**

Pre-requisite, if any: Signals and Systems, Analog and Digital, Wireless Communication Techniques.

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

CO1	Understand the satellite communication.
CO2	Understand the rrbits and space of satellite communication.
CO3	Understand the optical communication.
CO4	Develop the packet switched networks.

Syllabus:

OVERVIEW OF SATELLITE SYSTEMS, ORBITS AND LAUNCHING METHODS: Introduction, Frequency Allocations for Satellite Services, Intelsat, U. S. Domsats Polar Orbiting Satellites, Problems, Kepler's First Law, Kepler's Second Law, Kepler's Third Law, Definitions of Terms for Earth-orbiting Satellites, Orbital Elements, Apogee and Perigee Heights, Orbital Perturbations, Effects of a Non-spherical Earth, Atmospheric Drag, Inclined Orbits, Calendars, Universal Time, Julian Dates, Sidereal Time, The Orbital Plane, The Geocentric, Equatorial Coordinate System, Earth Station Referred to the IJK Frame, The Top centric-Horizon Co-ordinate System, The Sub-satellite Point, Predicting Satellite Position.

GEOSTATIONARY ORBIT & SPACE SEGMENT: Introduction, Antenna Look Angels, The Polar Mount Antenna , Limits of Visibility , Near Geostationary Orbits, Earth Eclipse of Satellite, Sun Transit Outage, Launching Orbits, Problems, Power Supply, Attitude Control, Spinning Satellite Stabilization, Momentum Wheel Stabilization, Station Keeping, Thermal Control, TT&C Subsystem , Transponders, Wideband Receiver, Input De-multiplexer, Power Amplifier, Antenna Subsystem, Morelos, Anik-E, Advanced Tiros-N Spacecraft.

OPTICAL NETWORK ARCHITECTURES: Introduction to Optical Networks; Layered Architecture- Spectrum partitioning, Network Nodes, Network Access Stations, Overlay Processor, Logical network overlays, Connection Management and Control; Static and Wavelength Routed Networks; Linear Light wave networks; Logically Routed Networks; Traffic Grooming; The Optical Control Plane- Architecture, Interfaces, Functions; Generalized Multiprotocol Label Switching – MPLS network and protocol stack, Link management, Routing and Signaling in GMPLS.

OPTICAL PACKET SWITCHED NETWORKS: Network Architectures- Unbuffered Networks, Buffering Strategies; OPS enabling technologies, Test beds; Optical Burst Switching, Switching protocols, Contention Resolution, Optical Label Switching, OLS network test beds, Control and Management – Network management functions, Configuration management, Performance management, Fault management, Optical safety, Service interface; network Survivability- Protection in SONET / SDH and IP Networks, Optical layer Protection, Interworking between layers.

FREE SPACE OPTICAL COMMUNICATION: Analog and digital FSOC data link, atmospheric attenuation, scattering, scintillation index, beam wandering, beam wave front aberration, adaptive optics, active optics, deformable mirror control, RoFSO, atmospheric channel models, estimation of refractive index, modulation and demodulation techniques, error control techniques.

Text Book(s):

1. Satellite Communications, Dennis Roddy, McGraw-Hill Publication Third edition2001
2. Satellite Communications – Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003.

References & Web Resources:

1. Timothy Pratt – Charles Bostian & Jeremy Allmuti, Satellite Communications, John Willy & Sons (Asia) Pvt. Ltd. 2004
2. Wilbur L. Pritchars Henri G. Suyder Hond Robert A. Nelson, Satellite Communication Systems Engineering, Pearson Education Ltd., Second edition 2003.
3. Satellite Communications: Design Principles – M. Richharia, BS Publications, 2nd Edition, 2003.
4. J. Gower, “Optical Communication System”, Prentice Hall of India, 2001
5. Rajiv Ramaswami, “Optical Networks “, Second Edition, Elsevier, 2004.
6. Satellite Communications Engineering – Wilbur L. Pritchard, Robert A Nelson and Henri G. Suyderhoud, 2nd Edition, Pearson Publications, 2003.
7. Optical Fiber Communication – John M. Senior – Pearson Education – Second Edition. 2007
8. Optical Fiber Communication – Gerd Keiser – Mc Graw Hill – Third Edition. 2000

Course Title	Course Code	Structure (I-P-C)		
Design of IoT System	**EC516**	**3**	**0**	**3**

Pre-requisite, if any: Microprocessors and Microcontrollers.

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

CO1	Understand the networking with IoT, its enabling technologies, and explore a young, but rich, body of exciting ideas, solutions, and paradigm shifts.
CO2	Understand the potential of IoT devices, support for networking according to the protocol standards, and being able to program them, would be useful for real time applications.
CO3	Develop the rapid prototypes of IoT based embedded systems using sensors, cloud.
CO4	Develop the IoT system using Arduino, Raspberry Pi, BeagleBone Black, and Intel Edison/Galileo.

Syllabus:

Introduction to IoT: Definition, Trend, IoT applications, Sensing and Actuation, IoT Devices and deployment models, Power awareness of IoT, LDO in IoT.

IoT Networking: Basic IoT Components, Interdependencies, Service Oriented Architecture.

IoT Data Protocols: MQTT, SMQTT, CoAP, XMPP, AMQP.

IoT Communication Protocols and their applications: IEEE 802.15.4, ZigBee6LoWPAN, Wireless HART, Z-Wave, ISA 100, Bluetooth, and Bluetooth low energy (BLE), NFC, RFID, WiFi for IoT communications.

Data Handling, Analytics, Data management for IoT: Data cleaning and processing, Data storage models, Searching in IoT, Deep Web Semantic Sensor Web, Semantic web data management, Real-time and Big data analytics for IoT, High-dimensional data processing, Parallel and Distributed data processing.

Interoperability in IoT: Low power Interoperability for IPV6 IoT.

Cloud-Centric IoT: Architecture, Open Challenges, Energy efficiency, QoS, QoE.

Industrial IoT (IIoT): Industrial IoT and its benefits, Future of IIoT, Challenges, Examples.

IoT System Management and Virtualization: IoT environment management over Cloud computing framework, Fog Computing paradigm for IoT with case studies, Softwarized control and virtualization technologies for IoT network and computation resource managements.

Case Studies: Sensor body-area-network, Smart cities and Smart homes, Agriculture.

IoT Network Framework: Wireless Network Fundamental for IoT communication tutorials with demonstrations and hands-on: 802.11 and 802.15.4 MAC Fundamentals, Management Operations, Security Overview, Network Core Protocols, Tizen Network Stack Architecture, Introduction, CAPI Architecture Overview, Sync/Async Operation Sequence, Interaction of Network Core Components, P2P Core Component Overview, OEM Layer, Supplicant Plugin Architecture overview.

Text Book(s):

1. The Internet of Things: Enabling Technologies, Platforms, and Use Cases, by EethurumRaj and Anupama C. Raman (CRC Press).

2. Internet of Things: A Hands-on Approach, by ArshdeepBahga and Vijay Madisetti (Universities Press).

References & Web Resources:

1. AdrianMcEwen, HakimCassimally, Designing the Internet of Things,Wiley,Nov 2013, (1st edition)
2. Martin Charlier, Alfred Lui, Claire Rowland, Elizabeth Goodman, Ann Light, Designing Connected Products, May 2015, O'Reilly Media.

Course Title	Course Code	Structure (I-P-C)		
Data Communication and Networking	**EC517**	**3**	**0**	**3**

Pre-requisite, if any: Computer Networks, C Programming

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

CO1	Understand a transmission of a data in a network
CO2	Acquire knowledge of various OSI layers.
CO3	Understand topologies for specific networks.
CO4	Understand the basics of cryptography.

Syllabus:

Overview of Data Communication and Networking: Introduction; Data communications: components, data representation (ASCII, ISO etc.), direction of data flow (simplex, half duplex, full duplex); network criteria, physical structure (type of connection, topology), categories of network (LAN, MAN, WAN); Internet: brief history, Protocols and standards; Reference models: OSI reference model, TCP/IP reference model, their comparative study.

Physical Layer: Overview of data (analog & digital), signal (analog & digital), transmission (analog & digital) & transmission media (guided & unguided); Circuit switching: time division & space division switch, TDM bus; Telephone Network; ATM, B-ISDN.

Data link Layer: Types of errors, framing (character and bit stuffing), error detection & correction methods; Flow control; Protocols: Stop & wait ARQ, Go-Back- N ARQ, Selective repeat ARQ, HDLC.

Medium Access sub layer: Point to Point Protocol, LCP, NCP, Token Ring; Reservation, Polling, Multiple access protocols: Pure ALOHA, Slotted ALOHA, CSMA, CSMA/CD, CSMA/CA Traditional Ethernet, fast Ethernet (in brief).

Network layer: Internetworking & devices: Repeaters, Hubs, Bridges, Switches, Router, Gateway; Addressing: IP addressing, subnetting; Routing: techniques, static vs. dynamic routing, Unicast Routing Protocols: RIP, OSPF, BGP; Other Protocols: ARP, IP, ICMP, IPV6.

Transport layer: Process to Process delivery; UDP; TCP; Congestion Control: Open Loop, Closed Loop choke packets; Quality of service: techniques to improve QoS: Leaky bucket algorithm, Token bucket algorithm.

Application Layer: Introduction to DNS, SMTP, SNMP, FTP, HTTP & WWW; Security: Cryptography (Public, Private Key based), Digital Signature, Firewalls.

Text Book(s):

1. B. A. Forouzan, Data Communications and Networking, 4th edition, Tata McGraw Hill 2012, ISBN: 0072967757

2. A. S. Tanenbaum, Computer Networks, 4^{th} edition, Pearson, 2013, ISBN: 978-0132126953

References & Web Resources:

1. W. Stallings, Data and Computer Communications, 5th edition, Pearson, 5th edition, 2013, ISBN: 978-0133506488.

Course Title	Course Code	Structure (I-P-C)		
Numerical Techniques in Electromagnetics	**EC521**	**3**	**0**	**3**

Pre-requisite, if any: Engineering Electromagnetics

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

CO1	Understand various computational techniques and their pros and cons.
CO2	Understand which software works best in terms of speed, and accuracy for analysing a given structure
CO3	Develop codes to analyze the EM structures.
CO4	Develop EM simulation software tools

Syllabus:

Review of vector calculus, Overview of computational electromagnetics, Review of Maxwell's equations.
Analytical techniques in Electromagnetics.
Finite Difference Time Domain methods: Analysis, convergence, accuracy and numerical dispersion,incorporating dielectric and dispersive materials, absorbing boundary conditions, perfectly matched layers (PML), sources.

Moment Methods: Integral equations (EFIE,MFIE), Green's Functions, MOM.

Finite element methods: Formulation and Absorbing boundary conditions (FEM).

Applications of computational electromagnetics: Specific Absorption Rate, Radar RCS, Periodic structures, Eddy current calculations, capacitance and inductance calculations, Microwave inverse imaging, Antenna radiation problems, Calculating the modes of a waveguide structure using the integral equation method.

Text Book(s):

1. Numerical Techniques in Electromagnetics, Second Edition Hardcover – Import, 12 July 2000, by Matthew N.O. Sadiku
2. Analytical and Computational Methods in Electromagnetics, Artech House Electromagnetic Analysis, 30 September 2008, by Ramesh Garg, Raj Mittra

References & Web Resources:

1. Computational Electromagnetics for RF and Microwave Engineering, 28 October 2010, by David B. Davidson
2. Advanced Engineering Electromagnetics Paperback - 8 October 2008, by Constantine A. Balanis
3. Computational Methods for Electromagnetics: 4 (IEEE Press Series on Electromagnetic Wave Theory) Hardcover – Import, 12 December 1997, by Andrew F. Peterson, Scott L. Ray, Raj Mittra

Course Title	Course Code	Structure (I-P-C)		
RF and Microwave Integrated Circuits	**EC522**	**3**	**0**	**3**

Pre-requisite, if any: Engineering Electromagnetics

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

CO1	Analyse high frequency filters, couplers, amplifier, oscillators and mixer circuits.
CO2	Design high frequency filters, couplers, amplifiers.
CO3	Develop RFICs.
CO4	Develop MMICs.

Syllabus:

Electromagnetic Theory Review: Maxwell's Equations, Fields in Media and Boundary Conditions, The Wave Equation, General Plane Wave Solutions, Energy and Power, Transmission lines and waveguide solutions.

Transmission Line Theory: The Lumped-Element Circuit Model for a Transmission Line, Field Analysis of Transmission Lines, The Terminated Lossless Transmission Line, The Smith Chart, The Quarter-Wave Transformer, Generator and Load Mismatches, Lossy Transmission Lines, Transients on Transmission Lines.

Microwave Network Analysis: Impedance and Equivalent Voltages and Currents, Impedance and Admittance Matrices, The Scattering Matrix, The Transmission (ABCD) Matrix.

Impedance matching and tuning, Microwave filter design.

Noise and nonlinear distortion, active rf and microwave devices.

Microwave Power Amplifier, Low Noise Amplifier, Oscillator and Mixer Design.

Introduction to microwave systems.

Text Book(s):

1. David M Pozar, Microwave Engineering, 4th Edition, Wiley, 2013.

References & Web Resources:

1. Robert E Collin, Foundations for Microwave Engineering, 2nd Edition, Wiley, 2007.

2. Behzad Razavi, RF Microelectronics, 2nd Edition, Pearson, 2011.

3. I.D. Robertson , S. Lucyszyn, RFIC and MMIC Design and Technology: 13 (Materials, Circuits and Devices), Institution of Engineering and Technology, 2001.

Course Title	Course Code	Structure (I-P-C)		
Electromagnetic Interference and Compatibility	**EC523**	**3**	**0**	**3**

Pre-requisite, if any: Engineering Electromagnetics

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

CO1	Gain knowledge to understand the concept of EMI / EMC related to product design.
CO2	Diagnose and solve various electromagnetic compatibility problems.
CO3	Understand the sources of EMI and various coupling methods.
CO4	Learn the various method of doing the pre compliance measurement techniques.

Syllabus:

Introduction to EMI and EMC: Various EMC requirements and standards-Need for EMC and its importance in electronic product design - sources of EMI - few case studies on EMC.

Conducted and radiated emission: power supply line filters-common mode and differential mode current-common mode choke- switched mode power supplies.

Shielding techniques: shielding effectiveness-shield behavior for electric and magnetic field - aperture-seams-conductive gaskets- conductive coatings.

Grounding techniques: signal ground-single point and multi point grounding-system ground common impedance coupling -common mode choke-Digital circuit power distribution and grounding.

Contact protection: arc and glow discharge-contact protection network for inductive loads-C, RC, RCD protection circuit- inductive kick back.

RF and transient immunity: transient protection network- RFI mitigation filter-power line disturbance- ESD- human body model- ESD protection in system design.

PCB design for EMC compliance: PCB layout and stack up- multi layer PCB objectives Return path discontinuities-mixed signal PCB layout.

EMC pre compliance measurement: conducted and radiated emission test-LISN- Anechoic chamber.

Text Book(s):

1. H. W. Ott, Electromagnetic Compatibility Engineering, 2nd edition, John Wiley & Sons, 2011, ISBN: 9781118210659.

2. C. R. Paul, Introduction to Electromagnetic Compatibility, 2nd edition, Wiley India, 2010, ISBN: 9788126528752.

References & Web Resources:

1. K. L. Kaiser, Electromagnetic Compatibility Handbook, 1st edition, CRC Press, 2005. ISBN: 9780849320873.

Course Title	Course Code	Structure (I-P-C)		
Software Defined Radio	**EC524**	**3**	**0**	**3**

Pre-requisite, if any: Signals and Systems, Analog and Digital, Wireless Communication Techniques.

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

CO1	Understand the SDR, CR, and their applications.
CO2	Understand the signal processing architectures used in the SDR.
CO3	Develop the FPGA based SDR.
CO4	Develop microcontroller based SDR.

Syllabus:

INTRODUCTION TO SDR: What is Software-Defined Radio, The Requirement for Software-Defined Radio, Legacy Systems, The Benefits of Multi-standard Terminals, Economies of Scale, Global Roaming, Service Upgrading, Adaptive Modulation and Coding, Operational Requirements, Key Requirements, Reconfiguration Mechanisms, , Handset Model, New Base-Station and Network, Architectures, Separation of Digital and RF, Tower-Top Mounting, BTS Hoteling, Smart Antenna Systems, Smart Antenna System Architectures, Power Consumption Issues, Calibration Issues, Projects and Sources of Information on Software Defined Radio.

BASIC ARCHITECTURE OF A SOFTWARE DEFINED RADIO: Software Defined Radio Architectures, Ideal Software Defined Radio Architecture, Required Hardware Specifications, Digital Aspects of a Software Defined Radio, Digital Hardware, Alternative Digital Processing Options for BTS Applications, Alternative Digital Processing Options for Handset Applications, Current Technology Limitations, A/D Signal-to-Noise Ratio and Power 343 Consumption, Derivation of Minimum Power Consumption, Power Consumption Examples, ADC Performance Trends, Impact of Superconducting Technologies on Future SDR Systems.

SIGNAL PROCESSING DEVICES AND ARCHITECTURES: General Purpose Processors, Digital Signal Processors, Field Programmable Gate Arrays, Specialized Processing Units, Tilera Tile Processor, Application-Specific Integrated Circuits, Hybrid Solutions, Choosing a DSP Solution. GPP-Based SDR, Non real time Radios, High-Throughput GPP-Based SDR, FPGA-Based SDR, Separate Configurations, Multi-Waveform Configuration, Partial Reconfiguration, Host Interface, Memory-Mapped Interface to Hardware, Packet Interface, Architecture for FPGA-Based SDR, Configuration, Data Flow, Advanced Bus Architectures, Parallelizing for Higher Throughput, Hybrid and Multi-FPGA Architectures, Hardware Acceleration, Software Considerations, Multiple HA and Resource Sharing, Multi-Channel SDR.

COGNITIVE RADIO : TECHNIQUES AND SIGNAL PROCESSING History and background, Communication policy and Spectrum Management, Cognitive radio cycle, Cognitive radio architecture, SDR architecture for cognitive radio, Spectrum sensing Single node sensing: energy detection, cyclostationary and wavelet based sensing- problem formulation and performance analysis based on probability of detection vs SNR. Cooperative sensing: different fusion rules, wideband spectrum sensing- problem formulation and performance analysis based on probability of detection vs SNR.

COGNITIVE RADIO: HARDWARE AND APPLICATIONS: Spectrum allocation models. Spectrum handoff, Cognitive radio performance analysis. Hardware platforms for Cognitive radio (USRP, WARP), details of USRP board, Applications of Cognitive radio.

Text Book(s):

1. "RF and Baseband Techniques for Software Defined Radio" Peter B. Kenington, ARTECH HOUSE, INC © 2005.
2. "Implementing Software Defined Radio", Eugene Grayver, Springer, New York Heidelberg Dordrecht London, ISBN 978-1-4419-9332-8 (eBook) 2013.

References & Web Resources:

1. "Cognitive Radio Technology", by Bruce A. Fette, Elsevier, ISBN 10: 0-7506-7952-2, 2006.
2. "Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems", Hüseyin Arslan, Springer, ISBN 978-1-4020-5541-6 (HB), 2007.

Course Title	Course Code	Structure (I-P-C)		
Cognitive Communication Networks	**EC525**	**3**	**0**	**3**

Pre-requisite, if any: Signals and Systems, Analog and Digital, Wireless Communication Techniques.

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

CO1	Understand the Cognitive Communication and networking as per applications.
CO2	Detect the desired signal in scrambled spectrum.
CO3	Understand algorithms for of cognitive networks.
CO4	Understand the MAC protocols in cognitive networks.

Syllabus:

Introduction to Cognitive Radio: Introduction –Software Defined Radio: Architecture–Digital Signal Processor and SDR Baseband architecture – Reconfigurable Wireless Communication Systems – Digital Radio Processing –Cognitive Radio: Cognitive radio Framework – Functions – Paradigms of Cognitive Radio.

Spectrum Sensing: Introduction –Spectrum Sensing – Multiband Spectrum Sensing – Sensing Techniques – Other algorithms – Comparison – Performance Measure & Design Trade-Offs: Receiver operating characteristics – Throughput Performance measure –Fundamental limits and trade-offs.

Cooperative Spectrum Acquisition: Basics of cooperative spectrum sensing–Examples of spectrum acquisition techniques – cooperative transmission techniques – sensing strategies– Acquisition in the Presence of Interference: Chase combining HARQ –Regenerative cooperative Diversity– spectrum overlay– spectrum handoff.

MAC Protocols and Network Layer Design: Functionality of MAC protocol in spectrum access –classification –Interframe spacing and MAC challenges – QOS – Spectrum sharing in CRAHN –CRAHN models – CSMA/CA based MAC protocols for CRAHN – Routing in CRN– Centralized and Distributed protocols – Geographical Protocol.

Text Book(s):

1. Mohamed Ibnkahla, “Cooperative Cognitive Radio Networks:The complete Spectrum Cycle” I edition.
2. AhamedKhattab, Dmitri Perkins,BagdyByoumi,“Cognitive Radio Networks from Theory to practice” 2013th edition.

References & Web Resources:

1. Kwang-Cheng Chen and Ramjee Prasad, “Cognitive Radio Networks, Wiley Publications
2. Alexander M.Wyglinski,MaziarNekovee, ThomasHou,” Cognitive Radio Communications and Networks”. I edition.

Course Title	Course Code	Structure (I-P-C)		
MIMO Communication Systems	**EC526**	**3**	**0**	**3**

Pre-requisite, if any: Signals and Systems, Analog and Digital, Wireless Communication Techniques.

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

CO1	Understand the concept of MIMO communication techniques, Channel Capacity, MIMO algorithms.
CO2	Understand power allocation strategies for practical MIMO systems.
CO3	Design algorithms of MIMO to improve the bit rate.
CO4	Understand MIMO in 5G communication.

Syllabus:

Introduction: Diversity-multiplexing trade-off, transmit diversity schemes, advantages and applications of MIMO systems.

Analytical MIMO channel models: Uncorrelated, fully correlated, separately correlated and keyhole MIMO fading models, parallel decomposition of MIMO channel.

Power allocation in MIMO systems:Uniform, adaptive and near optimal power allocation.

MIMO channel capacity: Capacity for deterministic and random MIMO channels, Capacity of i.i.d., separately correlated and keyhole Rayleigh fading MIMO channels.

Space-Time codes: Advantages, code design criteria, Alamouti space-time codes, SER analysis of Alamouti space-time code over fading channels, Space-time block codes, Space-time trellis codes, Performance analysis of Space-time codes over separately correlated MIMO channel, Space-time turbo codes.

MIMO detection: ML, ZF, MMSE, ZF-SIC, MMSE-SIC, LR based detection.

Advances in MIMO wireless communications: Spatial modulation, MIMO based cooperative communication and cognitive radio, multiuser MIMO, cognitive-femtocells and large MIMO systems for 5G wireless.

Text Book(s):

1. R. S. Kshetrimayum, Fundamentals of MIMO Wireless Communications, Cambridge University Press, 2017.
2. A. Chokhalingam and B. S. Rajan, Large MIMO systems, Cambridge University Press, 2014.

References & Web Resources:

1. B. Kumbhani and R. S. Kshetrimayum, MIMO Wireless Communications over Generalized Fading Channels, CRC Press, 2017
2. T. L. Marzetta, E. G. Larsson, H. Yang and H. Q. Ngo, Fundamentals of Massive MIMO, Cambridge University Press, 2016.

Course Title	Course Code	Structure (I-P-C)		
Detection and Estimation Theory	**EC527**	**3**	**0**	**3**

Pre-requisite, if any: Signals and Systems, Random Process, Communication Systems

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

CO1	Understand the discrete-time and continuous-time signal theory for finding unknown signal parameters.
CO2	Extract useful information from random observations in communications.
CO3	Design and analyze optimum detection schemes.
CO4	Estimate the error in wireless communication.

Syllabus:

Detection Theory: Detection Theory in Signal Processing; the Detection Problem; the Mathematical Detection Problem; Hierarchy of Detection Problems; Role of Asymptotics.

Statistical Detection Theory: Neyman-Pearson Theorem , Receiver Operating Characteristics, Minimum Probability of Error, Multiple Hypothesis Testing, Minimum Bayes Risk Detector - Binary Hypothesis.

Deterministic Signal: Matched Filters – Development of Detector, Performance of Matched Filter; Multiple Signals – Binary case, Performance of Binary Case, M-ary case.

Random Signals: Estimator-Correlator – Energy Detector; Linear Model - Rayleigh Fading Sinusoid, Incoherent FSK for a Multipath Channel.

Estimation Theory: Estimation in Signal Processing; Mathematical Estimation Problem; Assessing Estimator Performance.

Minimum Variance Unbiased Estimation: Unbiased Estimators; Minimum Variance Criterion; Existence of the Minimum Variance Unbiased Estimator; Finding the Minimum Variance Unbiased Estimator. Estimator Accuracy Considerations; Cramer-Rao Lower Bound; General CRLB for Signals in AWGN.

Estimation Techniques: Linear Model, General Minimum Variance Unbiased Estimation, Best Linear Unbiased Estimators, Maximum Likelihood Estimation, Least Squares, Estimation.

Text Book(s):

1. Steven M. Kay, Fundamentals of Statistical signal processing, volume-1: Estimation theory. Prentice Hall 2011.
2. Steven M. Kay, Fundamentals of Statistical signal processing, volume-2: Detection theory, Prentice Hall 2011.

References & Web Resources:

1. Harry L. Van Trees, Detection, Estimation, and Modulation Theory, Part I, John Wiley & Sons, Inc. 2011.
2. A. Papoulis and S. Unnikrishna Pillai, Probability, Random Variables and stochastic processes, 4e. The McGraw-Hill 2010.

Course Title	Course Code	Structure (I-P-C)		
Electric Vehicle Technology	**EC528**	**3**	**0**	**3**

Pre-requisite, if any: Basic Electrical and Electronics Engineering, Electric Drives

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

CO1	To understand about basics of electric vehicle
CO2	To understand about drives and control.
CO3	Select battery, battery indication system for EV applications
CO4	Design battery charger for an EV

Syllabus:

Introduction to Electric Vehicle : Review of Conventional Vehicle: Introduction to Electric Vehicles: Types of EVs, Electric Drive-train, Tractive effort in normal driving.

Electric Drives : Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis. Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Energy Storage : Introduction to Energy Storage Requirements in Electric Vehicles: - Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices. Sizing the drive system, Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems.

Energy Management System : Energy Management Strategies, Automotive networking and communication, EV charging standards, V2G, G2V, V2B, V2H. Business: E-mobility business, electrification challenges, Business- E-mobility business, electrification challenges.

Mobility and Connectors : Connected Mobility and Autonomous Mobility- case study E-mobility Indian Roadmap Perspective. Policy: EVs in infrastructure system, integration of EVs in smart grid, social dimensions of EVs. Connectors- Types of EV charging connector, North American EV Plug Standards, DC Fast Charge EV Plug Standards in North America, CCS (Combined Charging System), CHAdeMO, Tesla, European EV Plug Standards.

Text Book(s):

1. Emadi, A. (Ed.), Miller, J., Ehsani, M., “Vehicular Electric Power Systems” Boca Raton, CRC Press, 2003

2. Husain, I. “Electric and Hybrid Vehicles” Boca Raton, CRC Press, 2010.

References & Web Resources:

1. Larminie, James, and John Lowry, “Electric Vehicle Technology Explained” John Wiley and Sons, 2012
2. Tariq Muneer and Irene IllescasGarcía, “The automobile, In Electric Vehicles: Prospects and Challenges”, Elsevier, 2017
3. 5. Sheldon S. Williamson, “Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles”, Springer, 2013
4. Patents of TESLA

Course Title	Course Code	Structure (I-P-C)		
Navigation System	**EC529**	**3**	**0**	**3**

Pre-requisite, if any: Nil

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

CO1	Understand the concept of GNSS, AGNSS, Radio Positioning and Integration of Navigation technique.
CO2	Analyze navigation in various terrestrial situations.
CO3	Find the exact location of an object in navigation system.
CO4	Design precision navigation systems.

Syllabus:

INTRODUCTION TO NAVIGATION: What Is Navigation, Position Fixing, Dead Reckoning, Inertial Navigation, Radio and Satellite Navigation, Terrestrial Radio Navigation, Satellite Navigation, Feature Matching, The Complete Navigation System.

NAVIGATION MATHEMATICS: Coordinate Frames, Kinematics, and the Earth: Coordinate Frames, Kinematics, Earth Surface and Gravity Models, Frame Transformations, Coriolis force.

INERTIAL NAVIGATION: Inertial-Frame Navigation Equations, Earth-Frame Navigation Equations, Local-Navigation-Frame Navigation Equations, Navigation Equations Precision, Initialization and Alignment, INS Error Propagation, Platform INS, Horizontal-Plane Inertial Navigation.

PRINCIPLES OF RADIO POSITIONING: Radio Positioning Configurations and Methods, Positioning Signals, User Equipment, Propagation, Error Sources, and Positioning Accuracy.

GNSS: FUNDAMENTALS, SIGNALS, AND SATELLITES: Fundamentals of Satellite Navigation, The Systems: Global Positioning System, GLONASS, Galileo, Beidou, REGIONAL NAVIGATION SYSTEMS: Beidou and Compass, QZSS, IRNSS, GNSS INTEROPERABILITY: Frequency Compatibility, User Competition, Multistandard User Equipment Augmentation Systems, System Compatibility, GNSS Signals, Navigation Data Messages.

ADVANCED SATELLITE NAVIGATION: Differential GNSS, Carrier-Phase Positioning and Attitude, Poor Signal-to-Noise Environments, Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking.

TERRESTRIAL RADIO NAVIGATION: Point-Source Systems, Loran, Instrument Landing System, Urban and Indoor Positioning, Relative Navigation, Tracking, Sonar Transponders. (

FEATURE MATCHING: Terrain-Referenced Navigation, Sequential Processing, Batch Processing, Performance, Laser TRN, Barometric TRN, Sonar TRN, Image Matching, Scene Matching by Area Correlation, Continuous Visual Navigation, Map Matching, Other Feature-Matching Techniques, Stellar Navigation, Gravity Gradiometry, Magnetic Field Variation. (6 hours)

INS/GNSS Integration: Integration Architectures, System Model and State Selection, Measurement Models, Advanced INS/GNSS Integration.

Text Book(s):

1. Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Paul D. Groves Artech House, 2008 and 2013 Second Edition.
2. B.Hofmann Wollenhof, H.Lichtenegger, and J.Collins, "GPS Theory and Practice", Springer Wien, new York, 2000.

References & Web Resources:

1. Pratap Misra and Per Enge, "Global Positioning System Signals, Measurements, and Performance," Ganga-Jamuna Press, Massachusetts, 2001.
2. Ahmed El-Rabbany, "Introduction to GPS," Artech House, Boston, 2002.
3. Bradford W. Parkinson and James J. Spilker, "Global Positioning System: Theory and Applications," Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.