Four year Bachelor of Technology (BTech) Degree Program **in** *Electronics and Communication Engineering (ECE)*

by

Department of Electrical Engineering Department
Indian Institute of Technology Patna
Bihta, Patna-801106

Bachelor of Technology (B.Tech.) in Electronics and Communication Engineering (ECE)

Academic Program: Bachelor of Technology (B.Tech.) in Electronics and Communication Engineering (ECE)

Program Learning Objectives: 1. Develop a solid foundation in electronics and communication engineering principles, including circuit analysis, electronic devices, signal processing, microprocessor/microcontroller systems, analog communication systems, digital communication, and RF circuits etc. 2. Develop electronics and communication project management skills, including the ability to plan, execute, and complete within specified timelines and budgets. 3. Work collaboratively in multidisciplinary teams, demonstrating effective teamwork and communication to solve complex engineering problems. 4. Recognize the importance of ongoing professional development, engaging in activities such as certifications, workshops, and conferences to stay updated of industry trends.	**Program Learning Outcomes:** The graduates of this program will have 1. a successful career in an Academia/Industry/Entrepreneur. 2. strong fundamentals in electronics and communications engineering. 3. ability to design prototypes for real world problems related to electronics, communications and interdisciplinary fields. 4. ability to develop soft skills such as effective communications in both verbal and written forms, body language, time management, problem-solving, leadership, work in both team as well as individual in a professional manner.
Program Goal 1: Academic excellence by providing a curriculum that aligns with industry standards and encourages critical thinking in the field of electronics and communication engineering.	**Program Learning Outcome 1a:** Highly skilled market ready man power to serve the emerging electronic sectors **Program Learning Outcome 1b:** Skilled Human resource to cater the needs of next generation communication sectors
Program Goal 2: A culture of research and innovation by promoting faculty and student involvement in cutting-edge projects in electronic and communication technologies.	**Program Learning Outcome 2a:** Trained researchers for implementing research projects in line with national priorities such as CPS, Semiconductors, Clean Energy, Green Technologies **Program Learning Outcome 2b:** Design and develop innovative smart electronics products as per the societal need
Program Goal 3:. To design dynamic and flexible course structures for UG and PG programs as per the changing requirement of the industries	**Program Learning Outcome 3a:** Industry relevant UG, PG, and research programs **Program Learning Outcome 3b:** Trained manpower as per the industry requirement
Program Goal 4: To promote entrepreneurship among the students in the field of electronics and communication engineering	**Program Learning Outcome 4a:** Realization of working prototype towards product development **Program Learning Outcome 4b:** Promotion of in house technology based ventures catering societal needs
Program Goal 5: Equip students with strong communication skills, enabling them to articulate technical concepts clearly and effectively in both written and oral forms.	**Program Learning Outcome 5a:** Man power with enhanced soft skills to support the vision of developed India **Program Learning Outcome 5b:** Responsible citizen for the holistic growth of the country

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Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	MA1101	Mathematics I (Calculus and Linear Algebra)	3	1	0	4
2.	CS1101	Foundations of Programming	3	0	3	4.5
3.	PH1101/ PH1201	Physics	3	1	3	5.5
4.	CE1101/ CE1201	Engineering Graphics	1	0	3	2.5
5.	EE1101/ EE1201	Electrical Sciences	3	0	3	4.5
6.	HS1101	English for Professionals	2	0	1	2.5
TOTAL			15	2	13	23.5

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MA1201	Mathematics II (Probability and ODE)	3	1	0	4
2.	CS1201	Data Structure	3	0	3	4.5
3.	CH1201/ CH1101	Chemistry	3	1	3	5.5
4.	ME1201/ ME1101	Workshop Practice	0	0	3	1.5
5.	ME1202/ ME1102	Engineering Mechanics	3	1	0	4
6.	IK1101	Indian Knowledge System (IKS)	3	0	0	3
TOTAL			15	3	9	22.5

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	EE2101	Measurements and Instrumentation	3	0	2	4
2.	EE2102	Network Analysis and Synthesis	3	0	0	3
3.	EC2101	Analog Circuits	3	0	2	4
4.	EC2102	Signals and Systems	3	1	0	4
5.	EC2103	Semiconductor Devices	3	0	2	4
6.	HS21PQ	HSS Elective I	3	0	0	3
TOTAL			18	1	6	22
1.	EC2102	Minor I	3	1	0	4

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	EC2201	Digital Electronics	3	0	2	4
2.	EC2202	Microprocessor	2	0	2	3
3.	EE2201	Control Systems	3	0	2	4
4.	EC2203	Computer Organization and Architecture	3	0	0	3
5.	EC2204	Internet of Things	3	0	0	3
6.	XX22PQ	IDE I	3	0	0	3
TOTAL			17	0	6	20
2.	EC2201	Minor II	3	0	2	4

Sl. No.	Subject Code	SEMESTER V	L	T	P	C
1.	EC3101	Microcontroller and Embedded System	3	0	2	4
2.	EE3102	VLSI Design	3	0	2	4
3.	EC3103	Analog Communication	3	0	2	4
4.	EC3104	Engineering Electromagnetics	3	0	0	3
5.	EC3105	Random Signals and Stochastic Processes	3	0	0	3
6.	XX31PQ	IDE II	3	0	0	3
TOTAL			18	0	6	21
3.	EC3103	Minor III	3	0	2	4

Sl. No.	Subject Code	SEMESTER VI	L	T	P	C
1.	EC3201	Digital Communication	3	0	2	4
2.	EC3202	Digital Signal Processing	3	0	2	4
3.	EC3203	Introduction to AI/ML	3	0	0	3
4.	EC3204	Low Power MOSFETs Design and Modeling	3	0	0	3
5.	EC3205	Introduction to Wireless Communications	3	0	0	3
6.	EC3206	RF Systems	3	0	0	3
TOTAL			18	0	4	20
4.	EC3201	Minor IV	3	0	2	4

Sl. No.	Subject Code	SEMESTER VII	L	T	P	C
1.	EC41XX	Department Elective I	3	0	0	3
2.	EC41XX	Department Elective II	3	0	0	3
3.	XX41PQ	IDE III	3	0	0	3
4.	HSXXXX	HSS Elective II	3	0	0	3
5.	EC4198	Summer Internship*	0	0	12	3
6.	EC4199	Project – I	0	0	12	6
TOTAL			12	0	24	21

Sl. No.	Subject Code	SEMESTER VIII	L	T	P	C
1.	EC42XX	Department Elective III	3	0	0	3
2.	EC42XX	Department Elective IV	3	0	0	3
3.	EC42XX	Department Elective V	3	0	0	3
4.	EC4299	Project – II	0	0	16	8
TOTAL			9	0	16	17
GRAND TOTAL						167

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Minor in Communication
Minor I
EC2102 Signals and Systems
Minor II
EC2201 Digital Electronics
Minor III
EC3103 Analog Communication
Minor IV
EC3201 Digital Communication

List of department electives

Department Elective I	**Department Elective II**
EC4101 Introduction to Quantum Computing	EC4104 Introduction to Information Theory
EC4102 Deep Learning for Video Surveillance Systems	EC4105 Digital Image Processing
EC4103 FPGA based System Design	EC4106 Graph Signal Processing

Department Elective III	**Department Elective IV**	**Department Elective V**
EC4201 Mobile Communications	EC4203 Introduction to Optical Communications	EC4205 Biomedical Signal Processing
EC4202 Opto Electronic Devices	EC4204 Low Power Circuits	EC4206 High Power Semiconductor Devices
EE4203 Introduction to Energy Storage Techniques	EE4206 Fundamentals of Electrical Vehicle Technology	EC4207 Biomedical Instrumentation

Course Number	EE1101/EE1201
Course Credit	3-0-3-4.5
Course Title	Electrical Sciences
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of all B. Tech programmes. The course aims at giving an overview of the entire electrical engineering domain from the concepts of circuits, devices, digital systems and magnetic circuits.
Course Outline	Circuit Analysis Techniques, Circuit elements, Simple RL and RC Circuits, Kirchoff's law, Nodal Analysis, Mesh Analysis, Linearity and Superposition, Source Transformations, Thevenin's and Norton's Theorems, Time Domain Response of RC, RL and RLC circuits, Sinusoidal Forcing Function, Phasor Relationship for R, L and C, Impedance and Admittance, Instantaneous power, Real, reactive power and power factor. Semiconductor Diode, Zener Diode, Rectifier Circuits, Clipper, Clamper, UJT, Bipolar Junction Transistors, MOSFET, Transistor Biasing, Transistor Small Signal Analysis, Transistor Amplifier and their types, Operational Amplifiers, Op-amp Equivalent Circuit, Practical Op-amp Circuits, Power Opamp, DC Offset, Constant Gain Multiplier, Voltage Summing, Voltage Buffer, Controlled Sources, Instrumentation Amplifier, Active Filters and Oscillators. Number Systems, Logic Gates, Boolean Theorem, Algebraic Simplification, K-map, Combinatorial Circuits, Encoder, Decoder, Combinatorial Circuit Design, Introduction to Sequential Circuits. Magnetic Circuits, Mutually Coupled Circuits, Transformers, Equivalent Circuit and Performance, Analysis of Three-Phase Circuits, Power measurement in three phase system, Electromechanical Energy Conversion, Introduction to Rotating Machines (DC and AC Machines). Laboratory: Experiments to verify Circuit Theorems; Experiments using diodes and bipolar junction transistor (BJT): design and analysis of half -wave and full-wave rectifiers, clipping and clamping circuits and Zener diode characteristics and its regulators, BJT characteristics (CE, CB and CC) and BJT amplifiers; Experiment on MOSFET characteristics (CS, CG, and CD), parameter extraction and amplifier; Experiments using operational amplifiers (op-amps): summing amplifier, comparator, precision rectifier, Astable and Monostable Multivibrators and oscillators; Experiments using logic gates: combinational circuits such as staircase switch, majority detector, equality detector, multiplexer and demultiplexer; Experiments using flip-flops: sequential circuits such as non-overlapping pulse generator, ripple counter, synchronous counter, pulse counter and numerical display; Power Measurement by two Wattmeter method; Open and Short Circuit Tests of Transformer.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Texts/References** 1. C. K. Alexander, M. N. O. Sadiku, Fundamentals of Electric Circuits, 3rd Edition, McGraw-Hill, 2008. 2. W. H. Hayt and J. E. Kemmerly, Engineering Circuit Analysis, McGraw-Hill, 1993. 3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 6th Edition, PHI, 2001. 4. M. M. Mano, M. D. Ciletti, Digital Design, 4th Edition, Pearson Education, 2008. 5. Floyd, Jain, Digital Fundamentals, 8th Edition, Pearson. 6. David V. Kerns, Jr. J. David Irwin, Essentials of Electrical and Computer Engineering, Pearson, 2004. 7. Donald A Neamen, Electronic Circuits; analysis and Design, 3rd Edition, Tata McGraw-Hill Publishing Company Limited. 8. Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, 5th Edition, Oxford University Press, 2004. 9. A. E. Fitzgerald, C. Kingsley Jr., S. D. Umans, Electric Machinery, 6th Edition, Tata McGraw-Hill, 2003. 10. D. P. Kothari, I. J. Nagrath, Electric Machines, 3rd Edition, McGraw-Hill, 2004. 11. Del Toro, Vincent. "Principles of electrical engineering." (No Title) (1972).

Course Number	EE2101
Course Credit	3-0-0-3
Course Title	Measurements and Instrumentation
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of construction, operation and modelling of transformer and DC machines. Transformer and DC machines will be discussed.
Course Outline	Definition of instrumentation. Static characteristics of measuring devices. Error analysis, standards and calibration. Dynamic characteristics of instrumentation systems. Electromechanical indicating instruments: ac/dc current and voltage meters, ohmmeter; loading effect. Measurement of power and energy; Instrument transformers. Measurement of resistance, inductance, capacitance. ac/dc bridges. Measurement of non-electrical quantities: transducers classification; measurement of displacement, strain, pressure, flow, temperature, force, level and humidity. Signal conditioning; Instrumentation amplifier, Isolation amplifier, and other special purpose amplifiers. EMI and EMC, shielding, earthing and grounding. Signal recovery, data transmission and telemetry. Data acquisition and conversion. Modern electronic test equipment: oscilloscope, DMM, frequency counter, wave/ network/ harmonic distortion/ spectrum analyzers, logic probe and logic analyzer. Data acquisition system; PC based instrumentation. Programmable logic controller: ladder diagram. Computer controlled test systems, serial and parallel interfaces, Field buses. Smart sensors (Voltage, Current and Temperature sensors). Laboratory: Experiments on displacement, temperature, strain, flow, acceleration measurements, AC bridges, PLC, instrumentation amplifier, encoder, Measurement of capacitance, inductance and resistance.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	Texts/References 1. A. D. Helfrick and W. D. Cooper, Modern Electronic Instrumentation and Measuring Techniques, Pearson Education, 1996. 2. M. M. S. Anand, Electronic Instruments and Instrumentation Technology, PHI, 2006. 3. E. O. Deobelin, Measurement Systems - Application and Design, Tata McGraw-Hill, 1990. 4. B. E. Jones, Instrumentation, measurement, and Feedback, Tata McGraw-Hill, 2000. 5. R. P. Areny and T. G. Webster, Sensors and Signal Conditioning, John Wiley, 1991. 6. B. M. Oliver and J. M. Cage, Electronic Measurements and Instrumentation, McGraw-Hill, 1975. 7. C. F. Coombs, Electronic Instruments Handbook, McGraw-Hill, 1995. 8. R. A. Witte, Electronic Test Instruments, Pearson Education, 1995. 9. B. G. Liptak, Instrument Engineers' Handbook: Process Measurement and Analysis, Chilton Book, 1995.

Course Number	EE2102
Course Credit	3-0-0-3
Course Title	Network Analysis and Synthesis
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving detail of network theorems, graph theory and analysing and designing electrical circuits.
Course Outline	Overview of network analysis techniques, network theorems, transient and steady state sinusoidal response. Graph theory: basic definitions of loop (or tie set), cut-set, mesh matrices and their relationships, applications of graph theory in solving network equations. Two-port and *N*-Port networks, *Z, Y, h, g* and transmission parameters, combination of two ports, Analysis of common two port networks, pie and t-networks. Network functions, parts of network functions, obtaining a network function from a given part. Network transmission criteria; delay and rise time. Elements of network synthesis techniques, Cauer and Foster forms, Butterworth and Chebyshev Approximation.
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments, and Exams
Suggested Reading	**Texts/ References:** 1. F. F. Kuo, Network Analysis and Synthesis, John. Wiley, 2006. 2. M. E. V. Valkenburg, Network Analysis 3rd Edition 3. R. J. Trudeau, Introduction to graph theory. Courier Corporation, 2013.

Course Number	EC2101
Course Credit	3-0-2-4
Course Title	Analog Circuits
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1 and 2
Course Description	The course deals with various analog sub circuits including analog circuits such as amplifiers, differential amplifiers, filters and oscillators. It also focuses on design and implementation of various analog circuits like amplifiers - single transistor amplifiers, cascode amplifiers, differential amplifiers, filters and oscillators.

Course Outline	**CMOS realizations:** current source, sink and mirrors, differential amplifiers, multistage amplifiers; **Differential amplifiers:** DC and small signal analysis, CMRR, current mirrors, active load and cascode configurations; **Frequency response of amplifiers:** high frequency device models, frequency responses of various amplifiers, GBW, methods of short circuit and open circuit time constants, dominant pole approximation; **Analog subsystems:** analog switches, voltage comparator, voltage regulator, switching regulator, bandgap reference voltage source, analog multiplier, **Filter approximations**: Butterworth, Chebyshev, first order and second order passive/active filter realizations of LPF, HPF, BPF. **Signal generation and waveform shaping:** Schmitt trigger, relaxation oscillators, sinusoidal oscillators – RC, LC, and crystal oscillator; **Feedback amplifiers:** basic feedback topologies and their properties, analysis of practical feedback amplifiers, stability; **Power amplifiers:** efficiency of class A, B, AB, C, D stages, output stages, short circuit protection, power transistors and thermal design considerations; **Case study:** 741 op-amp - DC and small signal analysis, frequency response, frequency compensation, GBW, phase margin, slew rate, offsets; **Laboratory** Experiments on advanced applications of BJTs- and FETs-based circuits, Op-amps and other integrated circuits, Multistage amplifiers, Automatic gain controlled amplifiers, programmable gain amplifiers, Frequency response of amplifiers; waveform generators, Active filters, Feedback circuits and analysis, Current mirroring, 555 timer-based circuit design.
Learning Outcomes	Complies with PLO 1a, 2a, 2b
Assessment Method	Quiz, Experiments and Exams
Suggested Reading	**Textbooks:** 1. A. S. Sedra and K. C. Smith, Microelectronics Circuits, 5th Edition, 2005, Oxford University Press. 2. P. Gray, P. Hurst, S. Lewis and R. Meyer, Analysis & Design of Analog Integrated Circuits, 4th Edition, 2001, Wiley. 3. B. Razavi, Fundamental of Microelectronics, 1st Edition, 2009, Wiley. 4. A. Malvino and D. Bates, Electronic Principles, 7th Edition, 2017, McGraw-Hill. 5. R. A. Gayakwad, Op-Amps and Linear Integrated Circuit, 4th Edition, 2002, Prentice Hall. **Reference Books:** 1. B. Carter and R. Mancini, Op Amaps for Everyone, 3rd Edition, 2009, Texas Instruments. 2. D. Johns, T. C. Carusone and K. Martin, Analog Integrated Circuit Design, 2nd Edition, 2011, Wiley. 3. R. A. Gayakwad, Op-Amps and Linear Integrated Circuit, 4th Edition, 2002, Prentice Hall. 4. P. E. Allen and D. R. Holberg, CMOS Analog Circuit Design, 2nd Edition, 1997, Oxford University Press.

Course Number	EC2102
Course Credit	3-1-0-4
Course Title	Signals and Systems
Learning Mode	Lectures and Tutorials
Learning Objectives	Complies with Program Goal 1 and 2
Course Description	The course deals with fundamental concepts of signals and systems including its application, analysis of impulse response of systems and frequency response using transforms such as CTFT, Laplace, DTFT, ZT, DFT.

Course Outline	Signals: classification of signals; signal operations: scaling, shifting and inversion; signal properties: symmetry, periodicity and absolute integrability; elementary signals. Systems: classification of systems; system properties: linearity, time/shift-invariance, causality, stability; continuous-time linear time invariant (LTI) and discrete-time linear shift invariant (LSI) systems: impulse response and step response; Response to an arbitrary input: convolution; system representation using differential and difference equations; Eigenfunctions of LTI/ LSI systems, frequency response and its relation to the impulse response. Signal representation: signal space and orthogonal bases; Fourier series representation of continuous-time and discrete-time signals; continuous-time Fourier transform and its properties; Parseval's relation, time-bandwidth product; discrete-time Fourier transform and its properties; relations among various Fourier representations. Sampling: sampling theorem; aliasing; signal reconstruction: ideal interpolator, zero-order hold, first-order hold; discrete Fourier transform and its properties. Laplace transform and Z-transform: definition, region of convergence, properties; transform-domain analysis of LTI/LSI systems, system function: poles and zeros; stability.
Learning Outcomes	Complies with PLO 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. 1. A.V. Oppenheim, A.S. Willsky and H.S. Nawab, Signals and Systems, 2nd Edition, 2006, Prentice Hall.. 2. 2. S. Haykin and B. V. Veen, Signals and Systems, 2nd Edition, 1998, John Wiley and Sons. **Reference Books:** 1. B. P. Lathi, Signal Processing and Linear Systems, 1998, Oxford University Press.

Course Number	EC2103
Course Credit	3-0-2-4
Course Title	Semiconductor Devices
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with major properties of semiconductor materials, explains energy band diagrams and connections with the device structures and properties. It also focuses on basic equations to analyze semiconductor devices and design semiconductor devices and estimate device characteristics.
Course Outline	Energy bands; semiconductors; charge carriers: electrons and holes, effective mass, doping. Carrier concentration: Fermi level, temperature dependence of carrier concentration. Drift and diffusion of carriers: excess carriers; recombination and lifetime P-N Junction: depletion region, forward and reverse- bias, depletion and diffusion capacitances, switching characteristics; breakdown mechanisms; SPICE model. Metal-semiconductor junctions: rectifying and Ohmic contacts. BJT: carrier distribution; current gain, transit time, secondary effects MOSFET: MOS capacitor; C-V and I-V characteristics; threshold voltage; Short-channel effects. Body effect in MOSFET, Other Semiconductor Devices: MESFET: Working mechanism, I-V characteristics, HEMT: Working mechanism, I-V characteristics, Tunnel Diode: Working mechanism, I-V characteristics, Introduction to Power Semiconductor Devices (diode, IGBT and MOSFETs) **Laboratory:** Characterization and parameter extraction of various diodes Measurement and h parameter extraction of BJTs CV characteristics of MOS Capacitor Measurement and parameter extraction of MOSFETs

	TCAD Simulation of semiconductor devices
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. S. M. Sze and M. K. Lee, Semiconductor Devices: Physics and Technology, 3rd Edition, 2013, Wiley. 2. A. K. Dutta, Semiconductor Devices and Circuits, Illustrated Edition, 2008, Oxford University Press. **Reference Books:** 1. J. Millman, C. C. Halkias and S. Jit, Electronics Devices and Circuits, 4th Edition, 2015, McGraw-Hill. 2. A. S. Sedra and K. C. Smith, Microelectronics Circuits, 5th Edition, 2005, Oxford University Press. 3. B. Streetman and S. Banerjee, Solid State Electronic Devices, 7th Edition, 2015, Pearson Education Limited. 4. D. A. Neamen, Semiconductor Physics and Devices, 4th Edition, 2011, McGraw-Hill.

Course Number	EC2201
Course Credit	3-0-2-4
Course Title	Digital Electronics
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the fundamental concepts used in digital electronics, analyzing and designing of various combinational and sequential circuits, identifying the basic requirements for a design application with focus on a cost effective solution, understanding the digital signals, and developing skills for designing combinational and sequential logic circuits and their practical implementation on breadboard.
Course Outline	Introduction to digital circuits: Logic families (RTL, TTL, ECL and MOS), Integer and floating point representation. Logic gates representation and combinational circuit realization, Boolean functions and simplification. Karnaugh Maps and logic optimization. Macro level combinational circuits and their realization: Multiplexers, Code converters, Decoders, parity Generators, 7-segment display decoder; Digital Arithmetic Circuits: Adders, Subtractor, BCD adders. Introduction to sequential elements (Latches and Flip-flops) and sequential circuit design, State machines. Finite state machines and examples: shift registers and counters. Introduction to memory circuits: RAM, ROM, EEPROM Introduction to programmable and reconfigurable devices. Digital logic realization using programmable Logic devices. **Laboratory:** To set up circuits for Bipolar (RTL, DTL, TTL) and Unipolar (MOS, CMOS) Logic families, Logic Gate verification Introduction to Combinational circuits, Realization of Decoder, Design and realization of a Multiplexer and Magnitude Comparator Verification of basic Flip Flops using 74XXICS, Implementation of basic Latches, Asynchronous Counters, Synchronous Counters, Pattern Generation and Detection
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a

Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. D. P. Leach, A. P. Malvino and G. Saha, Digital Principal and Applications, 2nd Edition, 2006, McGraw-Hill. 2. J. F. Wakerly, Digital Design Principles and Practices, 4th Edition, 2006, Pearson Education. 3. M. Mano and M. D. Ciletti, Digital Design, 4th Edition, 2008, Pearson Education. 4. C. H. Roth, Fundamentals of Logic Design, 5th Edition, 2004, Cengage Learning. 5. N. Wirth, Digital Circuit Design: An Introductory Textbook, 1st Edition, 1995, Springer. 6. D. P. Leach, A. P. Malvino and G. Saha, Digital Principal and Applications, 2nd Edition, 2006, McGraw-Hill. **Reference Books:** 1. D. J. Corner, Digital Logic and State Machine Design, 3rd Edition, 2012, Oxford University Press. 2. H. Taub and D. Schilling, Digital Integrated Electronics, Illustrated Edition, 1977, McGraw-Hill.

Course Number	EC2202
Course Credit	2-0-2-3
Course Title	Microprocessor
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with architecture & organization of 8085 & 8086 Microprocessor, classification of the instruction set of 8086 microprocessor and distinguishing the use of different instructions and applying it in assembly language programming. It also focuses on realization of the Interfacing of memory & various I/O devices with 8086 Microprocessor, familiarization of the architecture and operation of Programmable Interface Devices and realization of the programming & interfacing of it with 8086 Microprocessor. The course covers hands-on experiments on emulators and hardware kits and gives exposure to advanced microprocessor architectures.
Course Outline	Introduction to Microprocessor and Microcomputer, Introduction to 8-bit microprocessor: Internal architecture of Intel 8085 microprocessor Introduction to 8086: Block diagram, Registers, Internal Bus Organization, Functional details of pins, Control signals, External Address / Data bus multiplexing, Demultiplexing. 8086 Architecture: Addressing Modes, Instruction Set Architecture, Instruction Coding Format, Instruction Description and Assembler directives, Standard program Structure, Assembly Language Programming, Strings, Procedures, Macros,. Pinouts: minimum mode and maximum mode configurations, Bus structure, bus buffering, latching, system bus timing with diagram, Interrupt Controller. Timing, I/ O mapped I/ O, and memory mapped I/ O techniques. I/O and memory interfacing using 8086: Memory interfacing and I/O interfacing with 8086, Parallel communication interface (8255), Timer (8253 / 8254) , Keyboard / Display controller (8279), Priority Interrupt controller (8259) , DMA controller (8257). Coprocessor (8087) architecture and interfacing with 8086 Microprocessor Introduction to advanced Microprocessors (X86). **Laboratory:** Hands-on laboratory experiment based on assembly language to program microprocessor using emulator/hardware kit to implement various algorithms and applications along with peripherals.
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams

Suggested Reading	**Textbooks:** 1. R. S. Gaonkar, Microprocessor – Architecture, Programming and Applications with the 8085, 6th Edition, 2013, Penram International Publisher. 2. D. V. Hall, Microprocessors and Interfacing, 2nd Edition, 2012, McGraw-Hill. **Reference Books:** 1. B. B. Brey, The INTEL Microprocessors – 8086 / 8088, 80186 / 80188, 80286, 80386, 80486 Pentium and Pentium pro processor, Pentium II, Pentium III and Pentium IV - Architecture, Programming and Interfacing, 8th Edition, 2012, Pearson Education.

Course Number	EE2201
Course Credit	3-0-2-4
Course Title	Control Systems
Learning Mode	Lectures and Experiments
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	This course gives the idea of classical methods of Control Systems to be useful in Engineering applications. The prerequisite for this course is signal and systems.
Course Outline	Basic concepts: Notion of feedback, open- and closed-loop systems; Modeling and representations of control systems: Ordinary differential equations, Transfer functions, Block diagrams, Signal flow graphs, State-space representations; Performance and stability: Time-domain analysis, Second-order systems, Characteristic-equation and roots, Routh-Hurwitz criteria; Frequency-domain techniques: Root-locus methods, Frequency responses, Bode-plots, Gain-margin and phase-margin, Nyquist plots; Compensator design: Proportional, PI and PID controllers, Lead-lag compensators; State-space concepts: Controllability, Observability, pole placement result, Minimal representations; Introduction to nonlinear control. <u>Laboratory:</u> To Study the DC Modular Servo System and to obtain the characteristics of the constituent components. Also, to set up a closed loop position control system and study the system performance; Controller design for position and velocity control of servo motors; Modeling and analysis of Magnetic Levitation System; Design a PD/PID controller for the Magnetic Levitation System; Determine the transfer function of black box from the Bode plot Level control of three/ four coupled tanks; Study and design of controller for Inverted Pendulum System; Introduction to Matlab and analysis of basic control theory in Matlab; Linearisation and Simulation of Nonlinear Ship Roll Dynamics Twin rotor control using PI/PID controller
Learning Outcomes	Complies with PLO 1a, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/References** 1. N. S. Nise, Control Systems Engineering, 4th edition, New York, John Wiley, 2003. (Indian edition) 2. G. Franklin, J.D. Powell and A. Emami-Naeini, Feedback Control of Dynamic Systems, Addison Wesley, 1986. 3. I. J. Nagrath and M. Gopal, Control System Engineering, 2nd Edn.Wiley Eastern, New Delhi, 1982. 4. C. L. Phillips and R.D. Harbour, Feedback Control Systems, Prentice Hall, 1985 5. B.C. Kuo, Automatic Control Systems, 4th Edn. Prentice Hall of India, New Delhi, 1985. 6. K. Ogata, Modern control systems. Prentice Hall, 1997.

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Course Number	EC2203
Course Credit	3-0-0-3
Course Title	Computer Organization and Architecture
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	This course introduces the basic organization and architecture of computing systems, various CPU architectures and peripherals, and designing of both programmable and reconfigurable architecture. It also covers the state of art embedded processor architecture and their applications.
Course Outline	**Introduction:** Evolution of computing systems and applications, Introduction to computing system, top level view of computer function and interconnection, computing performances and measures, Register transfer and micro-operations, Basic Computer Arithmetic architectures. **Basic CPU architecture:** Data Path and Control Path, hardwired and microprogrammed control architecture, Timing of control units, Basic CPU Design using HDL. **General purpose CPU organization and architecture:** CISC and RISC features, Processor structure and function, Instruction Set Architecture, Addressing Mode, RTL representation of Instructions, Assembly Language and Programming, Introduction to Assembler. **Memory Organization and Architecture:** Types of memory and interfacing, Virtual memory, paging, Cache Memory. **I/O and peripheral organization and architecture:** programmable I/O architecture, Programmable Timers, Interrupts and exception handling, Priority Interrupt Controller, DMA Controller **Introduction to high performance computing architecture:** pipeline architecture, Pipeline hazard, Hazard control unit. **Embedded and reconfigurable computing architecture:** Embedded CPU organization and architecture, RISC ISA, Embedded CPU programming, Assembly Language, Embedded Bus protocol and architecture, FPGA Architecture, FPGA programming, Implementation and prototype methods: Case studies, IP and its reuse, **Introduction to Operating System:** Embedded Operating System and RTOS.
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. M Morris Mano, Computer System Architecture, 3rd Edition, 2017, Prentice Hall. 2. J. Hayes, Computer Architecture and Organization, 3rd Edition, 2017, McGraw Hill. 3. W. Stallings, Computer Architecture and Organization, 3rd Edition, 2013, Pearson Education. **Reference Books:** 1. D. V. Hall and S.S.S.P. Rao, Microprocessors and Interfacing, 3rd Edition, 2017, McGraw Hill. 2. R. Kamal, Embedded Systems: Architecture, Programming and Design, 3rd Edition, 2017, McGraw Hill.. 3. M. A. Mazidi, R. D. Mckinlay and D. Causey, PIC Microcontroller and Embedded Systems, 1st Edition, 2008, Pearson Education. 4. S. Palnitkar, VerilogHDL, 2nd Edition, 2003, Pearson Education. 5. F. Bruno, FPGA Programming for Beginners, 1st Edition, 2021, Packt Publishing. 6. P. P. Chu, FPGA Prototyping by VerilogHDL examples, 1st Edition, 2008, Wiley.

Course Number	EC2204
Course Credit	3-0-0-3
Course Title	Internet of Things (IoT)
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with fundamental building blocks of the Internet of Things components and its underlying concepts. It also covers the design aspect of various IoT applications.
Course Outline	Motivation, Applications and Objectives of Internet of Things (IoT), Cyber-Physical Systems and Wireless Sensor Networks. Sensors and Actuators, Sensor Types, Sensor Characteristics, Actuator Types, Controlling IoT Devices. Radio Frequency Identification (RFID) Technology, Connectivity Protocols in IoT: Bluetooth Low Energy, ZigBee, and LoRa. Data messaging Protocols in IoT: Message Queue Telemetry Transport (MQTT), Hyper-Text Transport Protocol (HTTP), Constrained Application Protocol (CoAP). Localization in IoT: Localization using Received Signal Strength (RSS), Time and Time difference of arrival (ToA/TdoA) and Angle based Localization. Sensor Fusion, Fog Computing and Edge Computing, Task Offloading. Security in IoT Networks. Use Cases of IoT for Smart Environments: Healthcare, Agriculture, and Smart City
Learning Outcomes	Complies with PLO 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Raj, P., and Raman A.C., The Internet of Things: Enabling Technologies, Platforms, and Use Cases, 1st Edition, 2017, Auerbach Publications. 2. Rayes, A., and Salam, S., Internet of Things from Hype to Reality: The Road to Digitization, 2nd Edition, 2018, Springer. 3. Kumar S., Fundamentals of Internet of Things, 1st Edition, 2021, CRC Press. **Reference Books:** 1. Song H. et al., Cyber-Physical Systems: Foundations, Principles and Applications, 1st Edition, 2016, Academic Press Inc. 2. Yan, L., et al., The Internet of Things: From RFID to the Next-Generation Pervasive Networked Systems, 1st Edition, 2008, CRC Press. 3. Waher, P. , Learning Internet of Things, 2015, Packt Publishing Ltd.

Course Number	EC3101
Course Credit	3-0-2-4
Course Title	Microcontroller and Embedded Systems
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the fundamentals as well as advanced concepts in microcontroller and embedded systems. This also focuses on writing assembly and high level programs on real-time microcontrollers, developing the optimized embedded systems, and applying the ideas in different applications. Further it covers hands on experiments on commercially available embedded kits and components.

Course Outline	Introduction to microcontroller and embedded system, Introduction to CISC and RISC microcontroller, Registers, Pin diagram, I/O ports functions, 16-bits microcontroller architecture, Addressing modes, Internal memory organization, External memory (ROM & RAM) interfacing. Instruction set Architecture Data Transfer instructions, Arithmetic instructions, Logical instructions, Branch instructions, Bit manipulation instructions. Peripherals: Timers and Counters, PWM, Interrupts, communication protocols: UART, SPI. Embedded System Interfacing: ADC, DAC, Sensors, Display, keyboard. Embedded system models and development cycle, Embedded system components, Embedded processor and memory architecture. Hierarchical state machine, Embedded OS and RTOS, Scheduling, Multi-tasking. Experiments on microcontrollers: Programming and interfacing. **Lab**: PIC Microcontroller-Based Experiments: 1. Write and implement a program to read input through a momentary switch and toggle the ON/OFF of led blinking. 2. Write and implement a program to realize a simple calculator. 3. Write and implement a program to generate precise delay and pulse by using TIMER 4. Write and implement a program to interface a seven segment display and scroll the roll number on single/multiple seven segment display. 5. Write and implement a program to interface both keyboard and LCD display. 6. Write and implement a program to interface a ADC peripheral and control LED brightness depending on ADC value. 7. Write and implement a program to interface 16×2 LCD display and display the ADC value 8. Write and implement a program to use microcontroller as function generator and interface DAC to display generated signals in DSO. 9. Write and implement a program to generate PWM and controlling a lightweight DC Motor 10. Write and implement a program to control speed and direction of the stepper Motor and use it as Clock. Arduino/Raspberry-Pi/Galileo-based Experiments: 1. Write and implement a program to interface I2C IMU sensor and display over LCD display. 2. Write and implement a program to interface blue tooth and Wi-Fi Devices
Learning Outcomes	Complies with PLO 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. M. A. Mazidi, R. D. McKinlay, D. Causey, PIC Microcontroller and Embedded Systems, 1st Edition, 2008, Pearson Education. 2. P. Marvedel, Embedded System Design, 4th Edition, 2021, Springer. **Reference Books:** 1. R. Kamal, Embedded Systems: Architecture, Programming and Design, 3rd Edition, 2017, McGraw Hill.

Course Number	EC3102
Course Credit	3-0-2-4
Course Title	VLSI Design
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the design and implementation methods of VLSI Chip starting from full custom circuit to semi-custom architecture, FPGA and ASIC Architectures, and basic VLSI testing and validation methodologies. The course also covers various EDA tools and soft skills for designing VLSI Chip, full custom circuit simulation

	and verification, design and simulation of digital VLSI Systems using HD, synthesis and physical design along with analysis and FPGA implementation and prototype of digital VLSI systems.
Course Outline	Introduction to CMOS Technology, VLSI Design Flow, ASIC and FPGA Design Approaches. CMOS Process Flow, Design Rules, Layout and Stick Diagram. Design matrices: Area, Power and Performance Optimization, CMOS Inverter, Static and Dynamic of Inverter, Inverter Sizing. Speed and Power Dissipation: Static and Dynamic Power Consumption, Static CMOS Design, and different CMOS Logic Design approaches. Wire Delay model, Elmore Delay Model, CMOS Logic Sizing, Worst-case and Best-case Delays, Pass Transistors and Transmission Gates. Dynamic Logic, Domino Logic, Sequential Circuits, Latches and Flip-flops Arithmetic and Logic Circuits : Pipelining and Adders, Carry Save Adder & Multipliers. Memories: Working and Design aspects of DRAM, SRAM, and Flash memories, Design and Implementation of Digital Subsystems: Case Studies such as Neuromorphic Computing, In-memory Computing, and AI/Cryptographic Accelerators **Laboratory:** Introduction to the Cadence VLSI EDA software, develop schematics for NMOS/PMOS as pass gates, INV, NAND, and NOR as logic gates. Design and analyse the inverter and the universal gates (NAND and NOR). Design and analyse the sequential circuits, such as D-latch/flip-flop using transmission gates and other building blocks (library cells developed in this lab) and their behavior characterization Design of simplified state machines that generates a sequence of patterns
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. W. Wolf, Modern VLSI Design - System on Chip design, 3rd Edition, 2004, Pearson Education. 2. J. M. Rabaey, A. Chandrakasan and B. Nikolic, Digital Integrated Circuits- A Design Perspective, 2nd Edition, 2003, Prentice Hall of India. 3. N. Weste and D. Harris, CMOS VLSI Design: A Circuits and Systems Perspective, 3rd Edition, 2007, Pearson Education India. 4. Kang, Sung Mo, and Yusuf Leblebici. *CMOS digital integrated circuits*. New York, NY, USA: MacGraw-Hill, 2003. 5. M. H. Rashid, Introduction to PSpice Using OrCAD for Circuits and Electronics, 3rd Edition, 2005, Prentice Hall. 6. C. H. Roth Jr., Digital systems Design Using VHDL, 8th Edition, 2006, Thomson Learning Inc. **Reference Books:** 1. M. J. S. Smith, Application Specific Integrated Circuit, 1st Edition, Pearson India. 2. R. J. Baker, CMOS Circuit Design, Layout and Simulation, 1st Edition, 2009, Wiley. 3. S. M. Kang and Y. Leblevici, CMOS Digital Integrated Circuits Analysis and Design, 3rd Edition, 2003, McGraw Hill. 4. J. P. Uyemura, Introduction to VLSI Circuits and Systems, 2002, John Wiley & Sons. 5. C. H. Roth Jr., Fundamentals of Logic Design, 5th Edition, 2007, Thomson Learning Inc. 6. J. M. Rabaey, A. Chandrakasan and B. Nikolic, Digital Integrated Circuits- A Design Perspective, 2nd Edition, 2003, Pearson Education. 7. P. E. Allen and D. R. Holberg, CMOS Analog Circuit Design, 2nd Edition, 1997, Oxford University Press.

Course Number	EC3103
Course Credit	3-0-2-4
Course Title	Analog Communications
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course focuses on building blocks of communication systems, and different modulation formats; their usage along with their advantages and limitations. In particular, it covers design and performance analysis of analog communication systems, design of transmitter and receivers for different analog modulation formats from scratch using both discrete. component and software configurable system. The focus would be on understanding of baseband, passband modulation and demodulation techniques using experiments, advantages and disadvantages of various modulation and demodulation techniques and encoding and decoding using self-made hardware system and estimate their performance.
Course Outline	Review of Fourier Series and Transforms. Hilbert Transforms, Band pass signal and System Representation. Random Processes, Stationarity, Power Spectral Density, Gaussian Process, Noise. Amplitude Modulation, DSBSC, SSB, VSB: Signal Representation, Generation and Demodulation. Frequency Modulation: Signal Representation, Generation, and Demodulation. Mixing, Super-heterodyne Receiver, Phase Recovery with PLLs. Noise in AM Receivers using Coherent Detection, in AM Receivers using Envelope Detection, in FM Receivers. Fidelity of AM and FM Receivers. Sampling, Pulse-Amplitude Modulation. Quantization, Pulse-Code Modulation. Noise considerations in PCM, Time Division Multiplexing, Delta Modulation, DPCM and ADPCM. Inter symbol Interference **Laboratory:** Amplitude modulation and demodulation (AM with carrier & DSB-SC AM); Frequency modulation and demodulation (using VCO & PLL); automatic gain control (AGC); Pulse amplitude modulation (PAM): Natural Sampling and Flat Top Sampling; Pulse Code Modulation (PCM); Pulse Width Modulation and Demodulation; Pulse Position Modulation and Demodulation. Delta Modulation and DPCM Transmitter & Receiver.
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. H. Taub and D. L. Schilling, Principles of Communication Systems, 2nd Edition, 1986, McGraw Hill. 2. S. Haykin, Digital Communications, Student Edition, 2004, Wiley. 3. B. P. Lathi, Modern Analog and Digital Communication Systems, 3rd Edition, 1998, Oxford University Press. 4. H. Taub and D. L. Schilling, Principles of Communication Systems, 4th Edition, 2017, McGraw-Hill. 5. W. Tomasi, Electronic Communications Systems - Fundamentals Through Advanced, 4th Edition, 2003, Pearson. 6. S. Haykin and M. Moher, An Introduction to Analog and Digital Communication Systems, 2nd Edition, 2012, Wiley. **Reference Books:** 1. K. S. Sanmugan, Digital and Analog Communication Systems, Student Edition, 2006, John Wiley & Sons 2. L. W. Couch, Digital and Analog Communication Systems, 8th Edition, 2012, Pearson

Course Number	EC3104
Course Credit	3-0-0-3
Course Title	Engineering Electromagnetics
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with frequency dependent circuit designs, and various aspects of wave propagation and mechanism. The focus would be on visualizing various field interactions and phenomena and hands-on with several electromagnetic simulators and components.
Course Outline	An overview of electrostatics, electromagnetic fields, and vector calculus. Time-varying EM fields: Maxwell's equations, wave equation, and plane waves: Helmholtz wave equation, Solution to wave equations and plane waves, wave polarization, Poynting vector and power flow in EM fields. Wave Propagation: Wave propagations in unbounded & moving medium. boundary conditions, reflection, and refraction of plane waves. Transmission Lines: distributed parameter circuits, traveling and standing waves, impedance matching, Smith chart, stub matching. Introduction to antenna, Dipole antenna. Radio-wave propagation: ground-wave, sky-wave, and space-wave. Diversity techniques. Assignments on numerical methods using computational tools: FDTD, FEM.
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** **1.** M. N. O. Sadiku, Elements of Electromagnetics, 3rd Edition, 2000, Oxford University Press. **2.** R. F. Harrington, Time-Harmonic Electromagnetic Fields, 2nd Edition, 2001, Wiley-IEEE Press. **3.** J. Griffiths, Introduction to Electrodynamics, 3rd Edition, 1999, Pearson Education. 4. E. C. Jordan and K. G. Balmain, Electromagnetic Waves and Radiating Systems, 2nd Edition, 2016, Pearson **Reference Books:** 1. K. E. Lonngren and S. V. Savov, Fundamentals Electromagnetics with MATLAB, 1st Edition, 2005, Pearson Education. 2. D. K. Cheng, Field and Wave Electromagnetics, 2nd Edition, 2001, Pearson Education. 3. N. Ida, Engineering Electromagnetics, 1st Edition, 2000, Springer. 4. W. H. Hayt Jr, J. A. Buck and M. J. Akhtar, Engineering Electromagnetics, 9th Edition, 2020, McGraw Hill.

Course Number	EC3105
Course Credit	3-0-0-3
Course Title	Random Signals & Stochastic Processes
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with frequently encountered random variables, mathematical tools to analyze random process and development of analytical skills to model systems exhibiting random behavior
Course Outline	Random process: Concept of random process, ensemble, mathematical tools for studying random process, correlation function, stationarity, ergodicity, a few known stochastic processes: random walk, Poisson process, Gaussian random process, Markov chains, Brownian motion etc., pseudorandom process, nonlinear transformation of random process. Random process in frequency domain: Peridogram and power spectral density, Weiner-Khintchine-Einstein Theorem, concept of bandwidth, spectral estimation. Linear system: Discrete time and continuous time LTI system, concept of convolution, system described in frequency domain, state space description of the system. Linear systems with random inputs: Linear system fundamentals, response of a linear system, convolution, mean, autocorrelation and cross correlation function in LTI system, power spectral density in LTI, cross power spectral density in LTI. Processing of random signals: Noise in systems, noise bandwidth, SNR, bandlimited random process, noise reduction, matched filter, Wiener filter, Kalman filter, extended Kalman filter. Engineering examples.
Learning Outcomes	Complies with PLO 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/Reference Books:** 1. Miller, Scott, and Donald Childers, "Probability and random processes: with applications to signal processing and communications", Academic Press, 2012. 2. Wim C. van Etten, "Introduction to random signals and Noise", Chichester, England: Wiley, 2005. 3. Peyton Z. Peebles, "Probability, random variables, and random signal principles". McGraw Hill Book Company, 1987. 4. Geoffrey R. Grimmett, and David Stirzaker, "Probability and random processes", Oxford university press, 2001. 5. Alberto Leon-Garcia, "Probability, statistics, and random processes for Electrical engineering", Upper Saddle River, NJ: Pearson/Prentice Hall, 2008. 6. Grewal, Mohinder, and Angus P. Andrews, "Kalman filtering: theory and practice with MATLAB", John Wiley & Sons, 2014.

Course Number	EC3201
Course Credit	3-0-2-4
Course Title	Digital Communications
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the fundamentals as well as advanced concepts in digital communications such as modulation, demodulation, detection, channel estimation and equalization. It also covers the implementation of various digital communications techniques. comparison of different techniques and apply for different applications, and design of transmitter and receivers for different digital modulation formats from scratch using both discrete component and software configurable system

Course Outline	Overview of Random Variables, Random Processes and Linear Algebra: Signal Space Concepts, Orthogonal Representation of Signals, Gram-Schmidt Procedure and Karhunen-Loeve (KL) Expansion. Communication Channel Models, Bandpass & Lowpass Signals Digital Modulation Schemes and their Performance Analysis: Memoryless and with Memory Modulation Methods, Pulse Amplitude Modulation (PAM), Phase Modulation, Quadrature Amplitude Modulation (QAM), Continuous-Phase Frequency-Shift Keying (CPFSK), and Continuous-Phase Modulation (CPM) Optimum Receiver in Presence of Additive White Gaussian Noise: Maximum a Posteriori Probability (MAP) and Maximum Likelihood (ML) Receivers, Coherent versus Non-coherent Detection, Binary Signal Detection in AWGN, M-ary Signal Detection in AWGN. Probability of Error Analysis Introduction to Receiver Synchronization **Laboratory:** Pseudo-random (PN) sequence generation; Amplitude shift keying (ASK) Generation and Detection; Frequency shift keying (FSK) Generation and Detection; Binary phase shift keying (BPSK) Generation and Detection; binary frequency shift keying (BFSK) Generation and Detection; Quadrature phase shift keying (QPSK) Generation and Detection; Orthogonal frequency division multiple access; Code division multiple access (CDMA) and direct sequence spread spectrum (DSSS) system.
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. J. G. Proakis, M. Salehi, Digital Communications, 5th Edition, 2008, McGraw Hill. 2. R. G. Gallager, Principles of Digital Communication, 2009, Cambridge University Press. 3. S. S. Haykin, Digital Communications, 2001, Wiley-India. 4. B.P. Lathi, Zhi Ding, and Hari Mohan Gupta, Modern Digital And Analog Communication Systems, 4th Edition, 2017, Oxford University Press. 5. W. Tomasi, Electronic Communications Systems - Fundamentals through advanced, 4/e, Pearson, 2003. 6. S.S. Haykin, An Introduction to Analog and Digital Communication Systems, Wiley Eastern 1989. **Reference Books:** 1. P. B Crilly, A. B. Carlson, Communication Systems, 5th Edition, 2011, Tata McGraw-Hill Education. 2. U. Madhow, Fundamentals of Digital Communication, 2008, Cambridge University Press. 3. J.M Wozencraft, I.M. Jacobs, Principles of Communication Engineering, 1965, JohnWiley. 4. A. Glover, P. M. Grant, Digital Communications, 5th Impression, 2012, Pearson. 5. P. Z. Peeples, Digital Communication Systems, 1987, Prentice Hall International.

Course Number	EC3202
Course Credit	3-0-2-4
Course Title	Digital Signal Processing
Learning Mode	Lectures and Labs
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the illustration of digital signals, systems and their significance. understanding of the analytical tools such as Fourier transforms, Discrete Fourier transforms, Fast Fourier Transforms and Z-Transforms required for digital signal processing. It also covers the design and development of the basic digital system, familiarization with various structures of IIR and FIR systems, design and realization of various digital filters for digital signal processing, interpretation of the finite word length effects on functioning of digital filters. Experimental concepts of DSP and its applications using MATLAB Software is also included.
Course Outline	Review of discrete time signals, systems and transforms and sampling theorems (bandlimited and bandpass signals) Discrete Fourier Transform (DFT): Computational problem, DFT relations, DFT properties, fast Fourier transform (FFT) algorithms (radix-2, decimation-in-time, decimation-in-frequency), Goertzel algorithm, linear convolution using DFT. Frequency selective filters: Ideal filter characteristics, lowpass, highpass, bandpass and bandstop filters, Paley-Wiener criterion, digital resonators, notch filters, comb filters, all-pass filters, inverse systems, minimum phase, maximum phase and mixed phase systems.

	Structures for discrete-time systems: Signal flow graph representation, basic structures for FIR and IIR systems (direct, parallel, cascade and polyphase forms), transposition theorem, ladder and lattice structures. Design of FIR and IIR filters: Design of FIR filters using windows, frequency sampling, Remez algorithm and least mean square error methods; Design of IIR filters using impulse invariance, bilinear transformation and frequency transformations. **Laboratory** DSK6713 Signal Processing Kit and MATLAB are used for the experiments: 1. Familiarization with Kits and MATLAB 2. Linear and Circular Convolution 3. Z Transform 4. Discrete Fourier Transform & Fast Fourier Transform 5. IIR Filter Design – Analog Filter 6. Filter Design using Windowing Techniques
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. S. K. Mitra, Digital Signal Processing: A computer-Based Approach, TMH, 2/e, 2001. 2. A. V. Oppenheim and R. W. Shafer, Discrete-Time Signal Processing, PHI, 2/e, 2004. 3. J. G. Proakis and D. G. Manolakis, Digital Signal Processing: Principles, Algorithms and Applications, PHI, 1997 4. TMS320C6XXX CPU and Instruction Set Reference Guide, Texas Instruments, 2000 (www.ti.com) 5. V. K. Ingle and J. G. Proakis, Digital signal processing using MATLAB, Thompson Brooks/Cole, Singapore, 2007. 6. MATLAB and Signal Processing Toolbox User's Guide (www.mathworks.com) **Reference Books:** 1. L. R. Rabiner and B. Gold, Theory and Application of Digital Signal Processing, Prentice Hall India, 2005. 2. A. Antoniou, Digital Filters: Analysis, Design and Applications, Tata McGraw-Hill, New Delhi, 2003.

Course Number	EC3203
Course Credit	3-0-0-3
Course Title	Introduction to AI/ ML
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1,2 and 4
Course Description	The course deals with the comprehension of AI to analyze and map real world problem. and identification of electrical engineering problems (communication, power, control, signal processing) that is solved by AI techniques. It also focuses on different learning techniques and program/code in AI languages
Course Outline	Introduction: Foundations of Artificial Intelligence, Definitions; Problem solving: Problem-Solving Agents, Searching for Solutions, Uninformed Search, Breadth-first search, Depth-first search, Heuristic Search, Domain Relaxations, Local Search, Adversarial Search, Greedy best-first search; Logic and reasoning: Knowledge-Based systems, Propositional Logic, Reasoning Patterns in Propositional Logic, Resolution, Forward and Backward chaining, Syntax and Semantics of First-Order Logic, Using First-Order Logic, Propositional vs. First-Order Inference, Unification and Lifting, Forward Chaining, Backward Chaining, Resolution; Machine Learning: kNN, SVM, PCA, ICA, Clustering and ANN algorithms. Applications of AI in healthcare, communication, speech processing, electrical power and control engineering
Learning Outcomes	Complies with PLO 1b, 2a and 4a

Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Patrick Henry Winston, *Artificial Intelligence*, Third Edition, Addison-Wesley Publishing Company, 2004. 2. Nils J Nilsson, *Principles of Artificial Intelligence*, Illustrated Reprint Edition, Springer Heidelberg, 2014 3. Duda, Richard O., and Peter E. Hart. *Pattern classification*. John Wiley & Sons, 2006 **Reference Books:** 1. Stuart Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd Edition, PHI 2009.

Course Number	EC3204
Course Credit	3-0-0-3
Course Title	Low Power MOSFETs Design and Modeling
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with Low-Power Design Principles for MOSFETs, design of Low-Power MOSFET Architectures, modelling and simulation of Low-Power MOSFET Devices and implementation and validation of compact models for Low-Power MOSFETs:
Course Outline	**Overview of Low-Power Design:** Importance of low-power MOSFETs in modern electronics, Concepts of Power Consumption, Static power vs. dynamic power, Sources of power dissipation: Leakage currents, switching power, short-circuit power **Fundamentals of MOSFET Operation:** Structure and operation principles, Key parameters: Threshold voltage, mobility, subthreshold slope, Short-channel effects and their impact on power consumption, Quantum mechanical effects at nanoscale dimensions **Design Techniques for Low-Power MOSFETs:** Techniques for adjusting threshold voltage, Impact of threshold voltage on power and performance, Strained silicon and other materials for mobility enhancement, Use of high-k/metal gate stacks to reduce leakage, **Leakage Reduction Techniques,** Power gating and sleep modes, Use of multiple threshold voltages (Multi-Vth), Dynamic Power Reduction**,** Voltage scaling and Dynamic Voltage and Frequency Scaling (DVFS), Clock gating and its impact on dynamic power **Advanced Low-Power MOSFET Architectures:** FinFETs and Multi-Gate MOSFETs and their Structure, operation, and benefits for low-power applications, Design, considerations and modeling techniques, **Tunnel FETs (TFETs):**Principles of operation and advantages for low-power design, Design challenges and modeling approaches, **Negative Capacitance FETs (NC-FETs):** Concept of negative capacitance and its impact on power consumption, Integration with existing MOSFET technology **Compact Modeling of Low-Power MOSFETs: Introduction to Compact Models,** Importance of compact models for circuit simulation, Key parameters and their significance, **BSIM Models,** Overview of BSIM models for traditional and advanced MOSFETs, Parameter extraction and fitting techniques **Compact Models for Advanced MOSFETs:** BSIM-CMG for FinFETs, Models for TFETs and NC-FETs, Custom models for emerging low-power MOSFETs **Numerical Simulation Techniques:** TCAD Simulation Tools, Overview of TCAD tools (e.g., Synopsys Sentaurus, Silvaco ATLAS), Setting up simulations for low-power MOSFETs, Process Simulation, Simulation of fabrication processes and their impact on device performance, Analyzing process variations and their effect on power consumption, Device Simulation, Electrical characterization and parameter extraction, Analyzing simulation results for low-power performance
Learning Outcomes	Complies with PLO 1b, 2a, 2b and 4a
Assessment Method	Quiz, Assignments and Exams

Suggested Reading	**Textbooks:** 1. Roy, Kaushik, and Sharat C. Prasad. Low-power CMOS VLSI circuit design. John Wiley & Sons, 2009. 2. Taur, Yuan, and Tak H. Ning. Fundamentals of modern VLSI devices. Cambridge university press, 2021. **Reference Books:** 1. Saha, Samar K. Compact models for integrated circuit design: conventional transistors and beyond. Taylor & Francis, 2015.

Course Number	EC3205
Course Credit	3-0-0-3
Course Title	Introduction of Wireless Communications
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the basic concepts of radio wave propagation, channel models and fading, effect of fading on data transmission and understanding of the modern communication technologies
Course Outline	Wireless Transmission, Radio wave propagation issues in wireless systems, Path Loss and Shadowing: Radio Wave Propagation, Transmit and Receive Signal Models, Free-Space Path Loss, Ray Tracing Models, Different Propagation models, Shadow Fading, Combined Path Loss and Shadowing. Multipath Fading and Time-Varying Channel Impulse Response, Narrowband and Wideband Fading Models. Capacity in AWGN and Fading Channels. Performance of different modulation over Wireless Channels, Analysis of BPSK, QPSK, M-PSK, M-QAM over fading channels; Estimation of Spectral efficiency, Outage probability and Average probability of error. Diversity techniques: Space, Different types of diversity techniques: Time, Frequency, Polarization, Angular, Transmitter and Receiver. Introduction to Multi-input Multi-output (MIMO) Systems. Introduction to Multicarrier Modulation (MCM): OFDM, OFDMA, MCCDMA and their Performance Analysis
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. K. Feher, Wireless Digital Communication, Prentice Hall of India, New Delhi, 1995. 2. T.S. Rappaport, Wireless Communication; Principles and Practice, Prentice Hall, NJ, 1996. **Reference Books:** 1. Andrea Goldsmith, Wireless Communications, Cambridge University Press, 2005.

Course Number	EC3206
Course Credit	3-0-0-3
Course Title	RF Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 4
Course Description	The course deals with the design of microwave coupler and dividers, filters and their implementation, microwave amplifiers, active microwave devices, oscillators and mixers.
Course Outline	Microstrip Transmission line, propagation module, Scattering parameters; Wave Guides, Rectangular Wave Guide, Circular Wave Guide, propagation modules, guided propagation. Microwave components, Filters, Planar transmission lines, Filters lumped as well as distributed element realization, Implementation using simulators. Analysis and design of passive components, Phase shifters, Directional couplers, Junctions, Power dividers, Isolators and circulators, Resonant circuits, Transmission line resonators. Radiation: Antenna fundamentals, potentials, Hertzian dipole, short loop, different antenna types, antenna parameters, gain, arrays-active/passive, antenna measurement techniques. Antenna Synthesis, Antenna Analysis. RF systems, RF Front end, design and analysis. Basics of RADAR principle.
Learning Outcomes	Complies with PLO 1b, 2a and 4a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. David M. Pozar, Microwave Engineering, Wiley India Private Limited; Fourth edition (14 May 2013). 2. C. A. Balanis: Antenna Theory: Analysis and Design, John Wiley, 2005, 3/e. 3. R. E. Collin, Foundations for Microwave Engineering, Wiley-Blackwell; 2nd Edition **Reference Books:** 1. D. M. Sullivan: Electromagnetic Simulation using the FDTD Method, Wiley-IEEE, 2000, 1/e. 2. B. S. Guru & H. R. Hiziroglu: Electromagnetic Field Theory Fundamentals, Thomson, 1997, 1/e 3. Skolnik, Merrill I. "Introduction to radar." Radar handbook, 1962

Course Number	EC4101
Course Credit	3-0-0-3
Course Title	Introduction to Quantum Computing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the key components and architecture of quantum computing systems, including qubits, quantum gates, and quantum circuits. It also focuses on comprehending the principles of quantum information theory, including quantum entanglement, quantum entropy, and quantum teleportation. Implementation and analysis of quantum algorithms, such as Shor's algorithm for factoring and Grover's algorithm for search problems is also included.
Course Outline	Introduction: History, Motivation, Need of quantum bits, quantum states, quantum computations, quantum information, and quantum algorithms Overview of complex numbers and Linear Algebra, Introduction to quantum mechanics and its postulates, Bloch sphere

	Quantum gates: X, Z, Y, H, R, S, T, Square root of NOT Quantum Circuits: Single qubits and multiple qubits operations and quantum teleportation Quantum Algorithms: Deutsch's algorithm, Deutsch-Jozsa algorithm, Simon's algorithm Quantum Tools and Applications: Goal Challenges, Lights and Photon, Decoherence, Ion Trap, Quantum Simulation
Learning Outcomes	Complies with PLO 1b, 2a and 3a
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Nielsen, M. A., and Chuang, I. L., Quantum computation and quantum information, 10th Anniversary Edition, 2010, Cambridge university press. 2. Yanofsky, N. S., and Mannucci, M. A., Quantum computing for computer scientists, 1st Edition, 2008, Cambridge University Press. **Reference Books:** 1. Johnston, E. R., Harrigan, N., and Gimeno-Segovia, M., Programming quantum computers: essential algorihms and code samples, 1st Edition, 2019, O'Reilly Media.

Course Number	EC4104
Course Credit	3-0-0-3
Course Title	Introduction to Information Theory
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the fundamental concepts of information theory, understanding of coding, quantification, storage, and communication of information and analysis of source coding and channel coding.
Course Outline	Overview of random variable, Function of a random variable and its distribution, Discrete distributions, Continuous distributions, Random vector and its joint distribution. The concept of Amount of Information, Average Information, Information rate. Entropy, Joint Entropy and Conditional Entropy, Relative Entropy and Mutual Information, Chain rule for entropy, relative entropy, and mutual information. Source Coding: Fixed and Variable Length Codes, Kraft Inequality, Shannon-Fano Algorithm, Huffman Algorithm. Maximum entropy distribution for continuous and discrete random variables. Channel Capacity, Capacity of different channels: Noiseless binary channel, Noisy channel with nonoverlapping outputs, Binary symmetric channels, Binary erasure channel, symmetric channels, AWGN channels; Shannon Theorem, Bandwidth-SNR Trade-off, Channel Capacity Theorem, Shannon Limit. Maximum entropy distributions for continuous and discrete cases.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. T.M. Cover and J. A. Thomas, Elements of Information Theory, 2nd edition, 2006, Wiley. 2. R. Bose, Information Theory and applications, 2nd Edition, 2008, TMH. **Reference Books:** 1. J. G. Proakis, Digital Communications, 1995, McGraw-Hill. 2. Ross, Sheldon. A First Course in Probability. 8th Edition, 2009, Pearson Prentice Hall.

Course Number	EC4102
Course Credit	3-0-0-3
Course Title	Deep Learning for Video Surveillance Systems
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with video surveillance tasks such as monitoring and processing of video footage, and understanding and analyzing of machine and deep learning models. The course also develop competence to take logical, scientific and correct decisions while predicting model outcomes. Aptitude and ability of performance measurement and management of video surveillance cameras is also covered.
Course Outline	Introduction to Video Surveillance Systems: Introduction to image processing methods, Edge detection and linking, Image transforms, Introduction to video processing techniques, Video compression standards. Motion detection using optical flow method, motion modeling, Background modeling, Basic building blocks of video surveillance systems. Introduction to Deep Learning: Introduction to neural networks with linear algebra, Matrix mathematics and probability, Introduction to multilayer perceptron networks, forward and back propagation, Hyper-parameter tuning, Regularization and optimization in neural networks, Introduction to tensor-flow. Convolutional Neural Nets: Introduction to convolutional neural networks, Key concepts like convolution and pooling. Stacking convolutional layers for object detection. Recurrent Neural Nets: Introduction to recurrent neural networks (RNN, LSTM, GRU) for sequence level tasks (time series, video). Bidirectional and deep recurrent nets. Use them for activity recognition. Object Detection and Classification using Deep Learning: Haar like feature based object detection, Viola Jones object detection framework, Deep learning based object classification. Object Tracking using Deep Learning: Video monitoring for detection and tracking of single as well as multiple interacting objects, Region-based tracking, Contourbased tracking, Feature-based tracking, Model-based tracking, KLT tracker, Meanshift based tracking. Deep Learning based Human Activity Recognition: Template based activity recognition, CNN based activity recognition, RNN based activity recognition, abnormal behavior detection in crowded environments using deep learning Camera Networks for Surveillance: Types of CCTV (closed circuit television) camera- PTZ (pan-tilt zoom) camera, IR (Infrared) camera, IP (Internet protocol) camera, wireless security camera, multiple view geometry, camera network calibration, PTZ camera calibration, camera placement, smart imagers and smart cameras, Introducing graph signal processing, consensus networks. Emerging Techniques of Deep Learning in Visual Surveillance System: Augmented surveillance system, Operator attention based visual surveillance system, EEG and eye tracking based visual surveillance system, ONVIF standard for the interface of IP-based physical security products.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams

Suggested Reading	**Textbooks:** 1. M H Kolekar, "Intelligent Video Surveillance Systems: An Algorithmic Approach", CRC press Taylor and Francis Group, 2018 2. Q. Huihuan, X. Wu, Y. Xu, "Intelligent Surveillance Systems", Springer Publication, 2011. 3. Ian Goodfellow, Yoshua Bengio and Aaron Courville, "Deep Learning", The MIT Press, 2017. **Reference Books:** 1. Murat A. Tekalp, "Digital Video Processing", Prentice Hall, 1995. 2. Pradeep K Atrey, Mohan Kankanhalli, A Cavallaro, "Intelligent Multimedia Surveillance: Current Trends and Research" Springer Publication, 2013. 3. Y. Ma and G. Qian (Ed.), "Intelligent Video Surveillance: Systems and Technology", CRC Press, 2009. 4. H. Aghajan and A. Cavallaro (Ed.), Multi-Camera Network: Principles and Applications", Elsevier, 2009.

Course Number	EC4105
Course Credit	3-0-0-3
Course Title	Digital Image Processing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the fundamental concepts of digital image processing, including filtering, transforms, morphology, colour and image analysis. It also covers the basic image processing algorithms in C or Matlab or Python and make ready the students for advanced version of the course.
Course Outline	Introduction to Digital Image Processing & Applications, Sampling, Quantization, Basic Relationship between Pixels, ImagingGeometry, Image Transforms, Image Enhancement, Image Restoration, Image Segmentation, Morphological Image Processing, Shape Representation and Description, Object Recognition and Image Understanding, Texture Image Analysis, Motion Picture Analysis, Image Data Compression.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson 2. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall **Reference Books:** 1. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer

Course Number	EC4103
Course Credit	3-0-0-3
Course Title	FPGA based System Design
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with design of complex digital systems & use the design flow for using FPGA. This also gives exposure to Softcore Processor IP, Memory and other IO IPs and digital IPs, understanding of IP integration for large scale FPGA based digital System. Also, it covers performance analysis and issues of large scale digital system on FPGA and completion of a significant project on the FPGA platform.
Course Outline	Introduction to reconfigurable and FPGA based system Design; Basic and Advanced FPGA Fabrics; Combinational, Sequential logic and FSM realization on FPGA; FPGA Architecting: Speed, Area and Power; Issues on FPGA based system Design: Area, Timing and Power; Design Methodologies: Behavioral /high level Design and Implementation methodologies: RTL, IP Core, System Generator; Processor and memory cores; Timing analysis; Clock distribution and management systems; IP Cores for FPGA: Block and Distributed memory, FIFO, CORDIC, Clock distribution and management systems; Large scale System Design: Platform FPGA, Multi-FPGA System; Busses and I/O communication system; System Design and Implementation using FPGA: DSP and Communication Blocks and Cryptography blocks Introduction to FPGA based Embedded system platform: Soft processor, AHB Bus and I/O interfacing – Case studies.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text/Reference Books:** 1. Wayne Wolf, "FPGA Based System Design", Prentice Hall Modern Semiconductor Design Series, 2004. 2. Steve Kilts, "Advanced FPGA design – Architecture, Implementation and Optimization", Wiley publications,2007. 3. Ron Sass and Andrew G. Schmidt, Morgan Kaufmann (MK), "Embedded System design with Platform FPGAs", Elsevier,2010.

Course Number	EE4106
Course Credit	3-0-0-3
Course Title	Graph Signal Processing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with explanation of basic graph theory concepts and their extension to graph signal processing, and implementation of filtering, sampling, and reconstruction techniques for graph signals. It also covers spectral analysis of graph signals using the graph Fourier transform, and design and evaluation of graph filters for practical applications in various domains.
Course Outline	Introduction: Why Graph Signal Processing: concepts, applications and challenges Introduction to graph concepts: Linear algebra review, graph shift, graph shift invariance, graph signals, graph filtering, graph Fourier transform, graph convolution and modulation, graph frequency and graph spectral analysis of graph signals,

	Spectral graph theory: Orthogonal transforms review, Frequency interpretation – Nodal Theorems, Graph filtering: Vertex and Spectral interpretations, Advanced Topic 1: Shift invariance, localization and uncertainty principles, Advanced Topic 2: Down sampling, Advanced Topic 3: Wavelets, Advanced Topic 4: Multiresolution and graph approximation, Advanced Topic 5: Directed Graphs, Geometric Learning to extend deep learning models to learning with data supported by graphs.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. F. R. Chung, Spectral graph theory, volume92, AMS Bookstore, 1997. 2. D. M. Cvetkovic, P. Rowlinson, and S. Simic, An introduction to the theory of graph spectra. Cambridge University Press Cambridge, 2010. 3. D. K. Hammond, P. Vandergheynst, and R. Gribonval. Wavelets on graphs via spectral graph theory. Applied and Computational Harmonic Analysis, 30(2):129--150, 2011. **Reference Books:** 1. P. Milanfar. A tour of modern image filtering: new insights and methods, both practical and theoretical. Signal Processing Magazine, IEEE , 30(1):106--128, 2013. 2. S. K. Narang and A. Ortega. Perfect reconstruction two-channel wavelet filter banks for graph structured data. Signal Processing, IEEE Transactions on , 60(6):2786--2799, 2012. 3. A. Sandryhaila and J. M. Moura. Discrete signal processing on graphs. IEEE transactions on signal processing, 61(5-8):1644--1656, 2013. 4. D. I. Shuman, S. K. Narang, P. Frossard, A. Ortega, and P. Vandergheynst. The emerging field of signal processing on graphs: Extending high-dimensional data analysis to networks and other irregular domains. Signal Processing Magazine, IEEE, 30(3):83--98, 2013. 5. D. Spielman, Spectral graph theory, Lecture Notes, Yale University, 2009.

Course Number	EC4201
Course Credit	3-0-0-3
Course Title	Mobile Communications
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the basic concepts of mobile communication system, cellular architecture of mobile communication, design and analysis of the wireless communication systems, and design and development of the prototypes for next generation communication systems
Course Outline	History and evolution of mobile radio systems. Standards of mobile cellular networks (e.g. 2G, 3G, 4G, 5G and beyond). Global System for Mobile Communication (GSM) and the System Architecture of GSM. The Mobile Station and the Subscriber Identity Module, The Base Station Subsystem: Base Transceiver Station, Architecture and Functionality, Base Transceiver Station Configurations, Base Station Controller, Architecture and Tasks of the Base Station Controller. The Network Switching Subsystem, Home Location Register and Authentication Center, Visitor Location Register, The Mobile-Services Switching Center, Gateway MSC, The Relationship Between MSC and VLR. Overview of OSI Reference Model. Quality of Service, Tools for Protocol Measurements. Code Division Multiple Access (CDMA)-based mobile systems, Pseudo-random codes, modulation and demodulation techniques, synchronization. Wideband CDMA System. Cellular concept and frequency reuse, Multiple Access Schemes, Channel assignment and handoff, Interface and system capacity, Trunking and Erlang capacity calculations.

Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Gunnar Heine, GSM Networks: Protocols, Terminology and Implementation, Artech House Publishers (31 December 1998). 2. Vijay K. Garg and Joseph E. Wilkes, Principles and Applications of GSM, Prentice Hall, 1998. 3. T.S. Rappaport, Wireless Communication; Principles and Practice, Prentice Hall, NJ, 1996. **Reference Books:** 1. J. S. Lee and L. E. Miller, CDMA Systems Engineering Handbook, Artech House, 1998. 2. R. L. Peterson, R. E. Ziemer, and D. E. Borth, Introduction to Spread Spectrum Communications, Prentice Hall, 1995.

Course Number	EC4203
Course Credit	3-0-0-3
Course Title	Introduction to Optical Communication
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the needs and types of optical communication systems, basic elements of any optical transmission link, characteristics of optical fiber, which is a majorly used in optical channel and estimation/measurement of the performance of an optical communication link.
Course Outline	Overview of optical communication: Fiber Optic, Free Space, Underwater, Chip-to-chip. Optical Fiber: Structure, ray theory of light propagation, numerical aperture, modes. Types of optical fiber: Step index, graded index, single mode, multi-mode. Signal degradation in optical fiber: Loss, chromatic dispersion, polarization mode dispersion, nonlinearity. Bit rate distance product: Intermodal, chromatic dispersion. Optical Sources and Detectors: Light emitting diode, Laser Diode, PIN photodetector, avalanche photodiode. Wavelength division multiplexing. Optical system performance metrics: Eye-opening penalty, Q, BER, OSNR. Channel model: Free space optical communication, Underwater optical wireless communication. Link Analysis: Single channel point-to-point, WDM point-to-point.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. G Keiser, Optical fiber communications, 5th edition, McGraw Hill 2. J M Senior, Optical fiber communications principles and practice, 3rd edition, Pearson 3. J C Palais, Fiber optic communications, 5th edition, Pearson 4. Pallab Bhattacharya, Semiconductor optoelectronic devices, 2nd Edition, Phi Le **Reference Books:** 1. R Ramaswami, K.N. Sivarajan, G. H. Sasaki, Optical Networks: A Practical Perspective, 2009 Elsevier. 2. G. P. Agrawal, Fiber-optic communication systems, 3rd Edition, 2007, Wiley India. 3. M Cvijetic, Optical transmission systems engineering, 2004, Artech House Publishers.

Course Number	EC4205
Course Credit	3-0-0-3
Course Title	Biomedical Signal Processing
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with.various Biomedical Signal Processing and Monitoring Tasks, analyzing machine and deep learning biomedical models. The course also develop competence to take logical, scientific and correct decisions while predicting model outcomes
Course Outline	**Introduction of Biomedical signals**: Nervous system, Neuron anatomy, Basic Electrophysiology, Biomedical signal's origin and dynamic characteristics, biomedical signal acquisition and processing, Different transforms techniques. **The Electrical Activity of Heart**: Heart Rhythms, Components of ECG signal, Heart beat Morphologies, Noise and Artifacts, Muscle Noise Filtering, QRS Detection Algorithm, ECG compression techniques (Direct Time Domain (TP, AZTECH, CORTES, SAPA, Entropy Coding), Frequency Domain (DFT, DCT, DWT, KLT, Walsh Transform), Parameter Extraction: Heart rate variability, acquisition and RR Interval conditioning, Spectral analysis of heart rate variability. **The Electrical Activity of Brain**: Electroencephalogram, Types of artifacts and characteristics, Filtration techniques using FIR and IIR filters, Independent component analysis, Nonparametric and Model-based spectral analysis, Joint Time-Frequency Analysis, Event Related Potential, Noise reduction by Ensemble Averaging and Linear Filtering, Single-Trail Analysis and adaptive analysis using basis functions. **The Electrical Activity of Neuromuscular System**: Human muscular system, Electrical signals of motor unit and gross muscle, Electromyogram signal recording, analysis, EMG applications. **Frequency-Time Analysis of Bioelectric Signal and Wavelet Transform**: Frequency domain representations for biomedical Signals, Higher-order spectral analysis, correlation analysis, wavelet analysis: continuous wavelet transform, discrete wavelet transform, reconstruction, recursive multi resolution decomposition, causality analysis, nonlinear dynamics and chaos: fractal dimension, correlation dimension, Lyapunov exponent.
Learning Outcomes	Complies with PLO 1b, 2a and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Willis J. Tompkins, Biomedical Digital Signal Processing: C Language Examples and Laboratory Experiments for the IBM PC, Prentice Hall India 2. Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, John Wiley & Sons, 2006. 3. Rangaraj M. Rangayyan, Biomedical Signal Analysis: A Case-Study Approach, John Wiley & Sons, 2002 4. Steven J. Luck, An Introduction to the Event-Related Potential Technique, Second Edition, THE MIT PRESS 5. Leif Sornmo and Pablo Laguna, Bioelectrical Signal Processing in Cardiac and Neurological Applications, Academic Press, 2005 **Reference Books:** 1. Hojjat Adeli & Samanway Ghosh-Dastidar, Automated EEG based Diagnosis of Neurological Disorders, CRC Press. 2. Thomas P. Trappenberg, Fundamentals of Computational Neuroscience, Oxford University Press. 2002. 3. Mike X Cohen, Analyzing Neural Time Series Data Theory and Practice, THE MIT PRESS 4. Nait-Ali, Amine, Advanced Biosignal Processing, Spingers(Ed.). 2009 5. C. Koch, Biophysics of Computation. Information Processing in Single Neurons, Oxford University Press: New York, Oxford 6. Peter Dayan and LF Abbott, Theoretical Neuroscience Computational and Mathematical Modeling of Neural Systems, MIT 2001. 7. F. Rieke and D. Warland and R. de Ruyter van Steveninck and W. Bialek, Spikes: Exploring the Neuronal Code, A Bradford Book. MIT Press.

Course Number	EC4202
Course Credit	3-0-0-3
Course Title	Opto Electronic Devices
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the basic working mechanism of the devices, and governing equations to be able to perform calculations to characterize the performance of the devices. The practical knowledge and an understanding of the trade-offs when using these devices in their respective applications is also included.
Course Outline	**Elements Of Light And Solid-State Physics:** Wave and particle nature of light, Polarization, Interference, Diffraction, Light Source, review of Quantum Mechanical concept, Review of Solid-State Physics, Lithography Process, Characterization tools. **Display Devices And Lasers:** Introduction, Photo Luminescence, Cathode Luminescence, Electro Luminescence, Injection Luminescence, Injection Luminescence, LED, Plasma Display, Population Inversion, Optical Feedback, Threshold condition, Laser Modes, Classes of Lasers, Mode Locking, laser applications. **Optical Detection Devices:** Photo detector, Thermal detector, Photovoltaics, Photo Conductors, Sensors, Detector Performance. **Optoelectronic Integrated Circuits:** Introduction, hybrid and Monolithic Integration, Application of Opto Electronic Integrated Circuits, Integrated transmitters and Receivers, Guided wave devices.
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Pallab Bhattacharya "Semiconductor Opto Electronic Devices", Prentice Hall of India Pvt., Ltd., New Delhi, 2006. 2. Jasprit Singh, "Opto Electronics – As Introduction to materials and devices", McGraw-Hill International Edition, 1998 **Reference Books:** 1. S C Gupta, Opto Electronic Devices and Systems, Prentice Hal of India,2005. 2. J. Wilson and J.Haukes, "Opto Electronics – An Introduction", Prentice Hall, 1995.

Course Number	EC4204
Course Credit	3-0-0-3
Course Title	Low Power Circuits
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2 and 3
Course Description	The course deals with the different sources of power dissipation in circuits and systems, design of low power device architectures, and design of low power subsystems such as adder and multipliers
Course Outline	Introduction: Need for Low Power Circuits, Low Power Techniques at different Hierarchical levels MOS Transistors, Working principle, ON Current, subthreshold current, Short Channel Effects, Level 1, Level 2, Level 3 and BISIM Models Low Power Devices: DG MOSFETs., FinFETs, GAA MOSFETs, Tunnel FETs Low Power circuits: Inverters, CMOS inverters, Delay Estimation, driving large load MOS Logic Styles: Static CMOS, Dynamic CMOS and Pass transistor circuits, BiCMOS circuits Subsystem Design: 1 Bit Full adders, Full adders architectures, Multipliers architectures

	Low Power Memory Circuits: SRAM, DRAM, Static Power dissipation and minimization Techniques, MT CMOS, VT CMOS, DT CMOS and other techniques Dynamic Power dissipation and Minimization Techniques: Device, Circuits, and system level techniques, Minimizing switching capacitance at circuits and system level , short circuit power dissipation and minimization techniques Memory Design: SRAM, DRAM, 1T DRAM Adiabatic Circuits for Low Power Electronics
Learning Outcomes	Complies with PLO 1b, 2b and 3b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Ajit Pal, "Low-Power VLSI Circuits and Systems", Springer, 2015 2. J. B. Kuo and J-H. Lou, "Low-Voltage CMOS VLSI Circuits", Wiley, 1999. **Reference Books:** 1. K. Roy and S. C. Prasad, "Low-Power CMOS VLSI Circuit Design", Wiley, 2000.

Course Number	EC4206
Course Credit	3-0-0-3
Course Title	High-Power Semiconductor Devices
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2, 3 and 4
Course Description	The course deals with the fundamental principles and physics of high-power semiconductor devices, analysing the performance characteristics and limitations of various high-power semiconductor devices, designing and simulating high-power semiconductor devices using advanced computational tools, assessing the impact of material properties and device architecture on the performance and reliability of high-power semiconductor devices, applying knowledge of high-power devices in the development of power electronic systems and evaluating the latest research and technological advancements in high-power semiconductor devices.
Course Outline	Introduction to High-Power Semiconductor Devices: Overview of high-power devices, Applications in power electronics Semiconductor Physics for High-Power Devices: Charge carrier dynamics, Breakdown mechanisms Power Diodes: Structure, operation, and types (e.g., Schottky, PiN), Performance characteristics and applications Power Bipolar Junction Transistors (BJTs): Structure and operation principles, High-power performance characteristics Insulated Gate Bipolar Transistors (IGBTs): Design and operation principles, Power MOSFETs: Structure, operation, and characteristics, Comparison with other high-power devices Thyristors and Related Devices: Structure and types (e.g., SCR, GTO), Switching characteristics and applications Thermal Management in High-Power Devices: Heat generation and dissipation, Thermal modeling and packaging techniques Reliability and Failure Mechanisms: Degradation and failure modes, Reliability testing and improvement strategies Advanced Materials for High-Power Devices: Wide bandgap materials (e.g., SiC, GaN), Advantages and challenges Integration and Application of High-Power Devices: Power modules and converters, Applications in renewable energy and electric vehicles Recent Advances and Research Trends: Innovations in high-power device technology,
Learning Outcomes	Complies with PLO 1a, 2a, 2b, 3a, and 4a
Assessment Method	Quiz, Assignments and Exams

Suggested Reading	**Textbooks:** 1. B. Jayant Baliga, Power Semiconductor Devices, 1st Edition,Publisher: PWS Publishing Company, Year: 1995 2. B. Jayant Baliga, Fundamentals of Power Semiconductor Devices, 2nd Edition, Publisher: Springer, Year: 2010 **Reference Books:** 1. Josef Lutz, Heinrich Schlangenotto, Uwe Scheuermann, Rik De Doncker, Semiconductor Power Devices: Physics, Characteristics, Reliability, 2nd Edition, Publisher: Springer 2. Ned Mohan, Tore M. Undeland, William P. Robbins, Power Electronics: Converters, Applications, and Design, 3rd Edition, Publisher: Wiley, Year: 2002 3. B. Jayant Baliga, Wide Bandgap Semiconductor Power Devices: Materials, Physics, Design, and Applications, Publisher: Woodhead Publishing, Year: 2018

Course Number	EE4203
Course Credit	3-0-0-3
Course Title	Introduction to Energy Storage Techniques
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2, 3 and 4
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving a brief of energy storage techniques. Various storage techniques such as Battery, Fuel Cell etc will be discussed.
Course Outline	Energy storage systems overview - Scope of energy storage, needs and opportunities in energy storage, Technology overview and key disciplines, comparison of time scale of storages and applications, Energy storage in the power and transportation sectors. Thermal storage system-heat pumps, hot water storage tank, solar thermal collector, application of phase change materials for heat storage-organic and inorganic materials, efficiencies, and economic evaluation of thermal energy storage systems. Chemical storage system- hydrogen, methane etc., concept of chemical storage of solar energy, application of chemical energy storage system, advantages and limitations of chemical energy storage, challenges, and future prospects of chemical storage systems. Electromagnetic storage systems - double layer capacitors with electrostatically charge storage, superconducting magnetic energy storage (SMES), concepts, advantages and limitations of electromagnetic energy storage systems, and future prospects of electromagnetic storage systems. Electrochemical storage system (a) Batteries-Working principle of battery, primary and secondary (flow) batteries, battery performance evaluation methods, major battery chemistries and their voltages- Li-ion battery& Metal hydride battery vs lead-acid battery. (b) Supercapacitors- Working principle of supercapacitor, types of supercapacitors, cycling and performance characteristics, difference between battery and supercapacitors, Introduction to Hybrid electrochemical supercapacitors. (c) Fuel cell: Operational principle of a fuel cell, types of fuel cells, hybrid fuel cell-battery systems, hybrid fuel cell-supercapacitor systems.
Learning Outcomes	Complies with PLO 1b, 2a, 2b, 4a, 4b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Text books:** 1. F. S. Barnes and J. G. Levine: Large Energy Storage Systems Handbook (Mechanical and Aerospace Engineering Series), 2011, CRC press. 2. R. Zito: Energy storage: A new approach, 2010, Wiley. **References:** 1. G. Pistoia, and L. Boryann, Behaviour of Lithium-Ion Batteries in Electric Vehicles: Battery Health, Performance, Safety, and Cost, 2018, Springer International Publishing AG. 2. R. A. Huggins: Energy storage, 2010, Springer Science & Business Media. 3. P. Denholm, E. Ela, Brendan Kirby and Michael Milligan: The Role of Energy Storage with Renewable Electricity Generation, National Renewable Energy Laboratory (NREL) -a National Laboratory of the U.S. Department of Energy.

Course Number	EE4206
Course Credit	3-0-0-3
Course Title	Fundamentals of Electric Vehicle Technology
Learning Mode	Lectures
Learning Objectives	Complies with Program goals 1, 2 and 3
Course Description	The course is designed to meet the requirements of B. Tech. The course aims at giving a brief overview of electric vehicle technology. Drive power train concept, inverter design, charger design and motor control will be discussed.
Course Outline	History of electric vehicle journey, Electric vehicle architecture and its type and challenges, Dynamics of electric vehicle, Benefits of using electric vehicle, Concept of drive cycle, Electric vehicle drivetrain components, Electric vehicle auxiliaries. 3-phase inverter design & analysis and its control, Multilevel inverter design & analysis and its control. Power factor correction AC-DC converter and its control, Phase -shifted full bridge converter and its control. Basics of Batteries, Lithium-ion vs Lead Acid Battery, Modelling of Battery, Supercapacitor, Fuel Cell. Introduction motor drive and its control, Permanent magnet motor drive and its control, Switched reluctance drive and its control.
Learning Outcomes	Complies with PLO 1a, 1b, 2a and 2b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. N. Mohan, T. M, Undelnad, W. P, Robbins: Power Electronics: Converters, Applications and Design, 3rd Edition, 2002, Wiley. 2. M. Eshani, Y. Gao, Sebastien E Gay, Ali Emadi: Modern electric, hybrid electric and fuel cell vehicles, Fundamentals, Theory, and Design. 2005, Boca Raton, FL, CRC. **References:** 1. R. Ericson Fundamentals of Power Electronics, 2004, Chapman & Hall. 2. F. A. Silva; M. P. Kazmierkowski: Energy Storage Systems for Electric Vehicles, 2021, MDPI.

Course Number	EC4207
Course Credit	3-0-0-3
Course Title	Biomedical Instrumentation
Learning Mode	Lectures
Learning Objectives	Complies with Program Goal 1, 2, 3 and 4
Course Description	The course deals with the basic principles and functions of biomedical instruments, design and developing biomedical instruments for diagnostic and therapeutic purposes, analysing and interpreting data from biomedical instruments, applying knowledge of electronics, signal processing, and instrumentation in biomedical applications and addressing challenges in the design and application of biomedical instruments considering ethical and regulatory standards.

Course Outline	**Introduction to Biomedical Instrumentation:** Overview of biomedical engineering and instrumentation, History and evolution of biomedical devices, Types of biomedical instruments, Ethical and regulatory aspects in biomedical instrumentation **Biosignal Acquisition and Processing**: Types of biosignals (ECG, EEG, EMG), Basic transducer principles, Signal conditioning and processing techniques, Filtering and noise reduction **Biomedical Sensors and Measurement:** Types of biomedical sensors (e.g., temperature, pressure, flow sensors), Sensor characteristics and selection criteria, Measurement techniques and signal conditioning, Design principles Materials used in biomedical devices, Prototyping and testing **Diagnostic Instruments, Therapeutic and Prosthetic Devices:** Electrocardiographs (ECG), Electroencephalographs (EEG), Electromyographs (EMG), Imaging: X-ray, MRI, CT, Ultrasound; Pacemakers and defibrillators, Infusion pumps, Dialysis machines, Prosthetics and orthotics, Laser applications in medicine **Clinical Laboratory Instruments:** Blood gas analyzers, Hematology analyzers, Spectrophotometers Chromatography and electrophoresis, Immunoassay systems **Recent Advances in Biomedical Instrumentation:** Wearable health technology, Telemedicine and remote monitoring, Nanotechnology in medical devices Biomedical microelectromechanical systems (BioMEMS) Artificial intelligence and machine learning in biomedical instrumentation **Project and Case Studies:** Design and implementation of a biomedical device Case studies of biomedical instrumentation applications
Learning Outcomes	Complies with PLO 1a, 2a, 2b, 3a, 3b, 4a and 4b
Assessment Method	Quiz, Assignments and Exams
Suggested Reading	**Textbooks:** 1. Webster, John G., ed. Medical instrumentation: Application and Design. John Wiley & Sons, 2009. 2. Carr, Joseph J., and John Michael Brown. Introduction to Biomedical Equipment technology. John Wiley & Sons, 1981. 3. Reddy, Narender P. "Book review: biomedical signal analysis: a case-study approach, by Rangaraja M. Rangayyan." Annals of Biomedical Engineering 30 (2002): 983-983. 4. Bronzino, Joseph D. Biomedical Engineering Handbook. Springer Science & Business Media, 2000. 5. Chatterjee, Shakti, and Aubert Miller. Biomedical Instrumentation Systems. Cengage Learning, 2012. 6. Khandpur, Raghbir Singh. Compendium of Biomedical Instrumentation, John Wiley & Sons, 2020. **Reference Books:** 1. Geddes, L.A., and Baker, L.E. "Principles of Applied Biomedical Instrumentation", Wiley-Interscience. 2. Carr, J.J., and Brown, J.M. "Introduction to Biomedical Equipment Technology", Pearson. 3. Pallás-Areny, R., and Webster, J.G. "Sensors and Signal Conditioning", John Wiley & Sons.