Electrical Engineering

M. Tech Electrical Engineering						
Sr No	**Course Code**	**Course Name**	**L**	**T**	**P**	**C**
1	EE 634	**Linear Algebra and its applications**	3	0	0	6
2	EE 690	**Embedded Systems**	3	0	0	6
3	EE 629	**Probability Models and Applications (PMA)**	3	0	0	6
4	EE 622	**Multivariable Control Systems**	3	0	0	6
5	EE 688	**Physics of Transistors**	3	0	0	6
6	EE 610	**VLSI Design**	3	0	0	6
7	EE 601	**Analog IC design**	3	0	0	6
8	EE 648	**Nanoelectronics**	3	0	0	6
9	EE 621	**Speech Processing**	3	0	0	6
10	EE 613	**Speech Processing Laboratory**	0	0	3	3
11	EE 691	**Photovoltaic Systems Design**	3	0	0	6
12	EE 607	**Power System Dynamics and Control**	2	0	1	6
13	EE 633	**Mixed signal VLSI Design**	3	0	0	6
14	EE 626	**VLSI Technology**	3	0	0	6
15	EE 701	**Power Semiconductor Devices**	3	0	0	6
16	EE 632	**System Design of Electronic Products**	3	0	0	6
17	EE 656	**VLSI Test & Testability**	3	0	0	6
18	EE 609	**Pattern Recognition and Machine Learning (PRML) Laboratory**	3	0	0	6
19	EE 624	**Optimization Theory and Algorithms**	3	0	0	6
20	EE 612	**Pattern Recognition and Machine Learning (PRML) Laboratory**	0	0	3	3
21	EE 433	**Next Generation Wireless Systems / Wireless Networks**	3	0	0	6
22	EE 620	**Neural Networks and Deep Learning (NNDL) Laboratory**	3	0	0	6
23	EE 608	**Wireless Communication**	3	0	0	6

Electrical Engineering

24	EE 611	**Neural Networks and Deep Learning (NNDL) Laboratory**	0	0	3	3
25	EE 631	**Advanced Electric Drives**	2	0	2	6
26	EE 684	**Design of Power Converters**	1.5	0	3	3
27	EE 642	**Microgrid Dynamics and Control**	3	0	0	6
28	EE 632	**System Design of Electronic Products**	3	0	0	6
29	EE 654	**Smart Grid**	3	0	0	6
30	EE 628	**Modeling and Control of Renewable Energy Resources**	3	0	0	6
31	EE 653	**Electric Vehicles: Systems and Components**	2	0	2	6
32	EE 623	**Advanced Power Electronics and Drives**	3	0	0	6
33	EE 422	**Power System Protection**	3	0	0	6
34	EE 643	**Power System Operation and Control**	3	0	0	6
		Total Credits				

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Linear Algebra and its applications (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Basic calculus.
3	**Course content**	**The following topics will be covered:** Vector spaces, linear dependence, basis; Representation of linear transformations with respect to a basis.; Inner product spaces, Hilbert spaces, linear functions; Riesz representation theorem and adjoints.; Orthogonal projections, products of projections, orthogonal direct sums; Unitary and orthogonal transformations, complete orthonormal sets and Parseval's identity; Closed subspaces and the projection theorem for Hilbert spaces.; Polynomials: The algebra of polynomials, matrix polynomials, annihilating polynomials and invariant subspaces, forms, Solution of state equations in linear system theory; Relation between the rational and Jordan forms.; Numerical linear algebra: Direct and iterative methods of solutions of linear equations; Matrices, norms, complete metric spaces and complete normal linear spaces (Banach spaces); Least squares problems (constrained and unconstrained); Eigenvalue problem and SVD.
4	**Texts/References**	**1.** K. Hoffman and R. Kunze, Linear Algebra, Prentice-Hall, (1986). **2.** G.H. Golub and C.F. Van Loan, Matrix Computations, Academic, 1983.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Embedded Systems** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None for M. Tech EE students. Good grasp of undergraduate level microprocessors/microcontrollers course is essential.
3	**Course content**	Introduction to embedded systems, comparison with general-purpose computers, application- specific challenges and constraints; Architecture introduction (typically pure ARM Cortex, C2000 or PSoC-ARM). registers, memory, and peripherals. Introduction to embedded software toolchain: compiler, linker, and debugger. Code development discipline (version control, unit testing, etc.) Review of data structures and datatypes. Interrupts: designing interrupt-driven systems, interrupt prioritization and masking, and dependency tracking. Introduction to RTOS concepts: atomic operations, Mutex, message parsing, threads, memory mapping, scheduling
4	**Texts/References**	--

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Probability Models and Applications (PMA) (3-0-0-6)**
2	**Pre-requisite courses(s)**	Data analysis and Introduction to probability (6 credits course that all batches are currently doing as core)
3	**Course content**	**Introduction to** Probability theory. **Review of** sample space, events, axioms of probability, introduction to probability as a measure, Random variables, Notion of independence and mutually exclusive events Probability Space, limits and sequence of events, continuity of probability, measurable functions, notions of induced measures, connection with cdf, change of measure, conditional probability, and conditional expectation, simulating discrete and continuous random variables - accept-reject method, importance sampling. **Random vectors and Stochastic processes:** Introduction to random vectors, Gaussian vectors, notion of iid random variable's introduction to elementary stochastic processes like Bernoulli process and Poisson process. **Markov Process.** Discrete time and continuous time Markov chains**,** classification of states, notion of stationary distribution. Simulating stochastic processes like Gaussian process, Poisson process, Markov chains and Brownian motion. Introduction to Markov chain monte Carlo methods, Hidden Markov chain and Markov decision process, Introduction to Brownian motion and stationary process. **Statistics:** MLE, MAP and Bayesian Estimation, sufficient statistics, Cramer-Rao bound
4	**Texts/References**	**1.** Sheldon Ross "Introduction to probability models" 9th Ed., Elsevier AP **2.** Sheldon Ross, 'Stochastic process,' John Wiley, 2nd Ed., April 1996. **3.** David Stirzaker, 'Stochastic process and models,' Oxford press.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Multivariable Control Systems (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to control systems
3	**Course content**	**Review of basic mathematics:** Review of differential equations, Fourier and Laplace transform, basic linear algebra: matrices, rank,inverses, decompositions etc., **Review of frequency domain modelling:** revision of frequencydomain modelling, transfer functions **Introduction to State Variables:** Motivation for State Variables,Implementation of Differential Equations, Formal Definitions **Basic Realization Theory:** Similarity Transformation, Canonical Realizations: Jordan and real canonical forms, Minimal realization **Connections to Transfer Functions:** Characteristic/Minimal Polynomials, matrix. exponentials, Markov parameters and other invariants **Review of frequency domain analysis:** Recall root locus, stability analysis using Routh-Hurwitz criteria, bode plots, Nyquist plots etc.**Observability, Controllability:** Canonical Realizations, Decomposition of Uncontrollable and Unobservable realizations, State Feedback, Asymptotic Observers, Separation Principle and Pole Placement Theorem **Extensions to MIMO systems:** Transfer matrices, Controllability,Observability and Pole Placement, Controller/Observer forms, Minimality and relations to Controllability and observability, MIMO Realization theory
4	**Texts/References**	**1.** T. Kailath, Linear Systems, Prentice-Hall, New Jersey, 1st edition, (11th February 1980) **2.** Richard Dorf and Robert Bishop, Modern Control Systems,Pearson; 13th edition (5 January 2016) **3.** Karl Johan Aström, Richard M. Murray, Feedback Systems:An Introduction for Scientists and Engineers, Princeton University Press (21 April 2008) **4.** João P. Hespanha, Linear Systems Theory, Princeton University Press (2 October 2009) **5.** Karl Johan Aström, Richard M. Murray, Feedback Systems: AnIntroduction for Scientists and Engineers, Princeton University Press, 2nd edition (2 March 2021) **6.** João P. Hespanha, Linear Systems Theory, Princeton University Press (2 October 2009), 2nd edition, 13 February 2018

Electrical Engineering

List of electives

Autumn (Odd) Semester

Basket: VLSI and Microelectronics	• VLSI Design • Physics of Transistors • Analog IC design • Nanoelectronics
Basket: Communication, Signal Processing and Machine learning	• Speech Processing • Speech Processing Lab
Basket: Power electronics and powersystems	• Photovoltaic system design (newcourse) • Power Systems Dynamics andControl

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Physics of Transistors (3-0-0-6)**
2	**Pre-requisite courses(s)**	Not applicable
3	**Course content**	Semiconductor Physics Review. **The MOS transistor:** MOS Capacitor Fundamentals, Fixed Oxide and Interface Charge Effects, Carrier Transport in MOS capacitor, Basic MOSFET operation, Measurement of MOS transistor parameters, Small Signal Equivalent Circuit, Non-ideal effects, MOSFET scaling and short channel effects, Advanced MOSFET structures (High-k gate, SOI MOSFET and Fine FET), Radiation and Hot-electron effects in transistors, MOSFET reliability, CMOS technology, Charged Coupled Device (CCD). **Bipolar transistor:** Basic BJT operation, Minority carrier distribution, Ideal current-voltage characteristics, non-ideal effects, Base width modulation, High injection, Emitter bandgap narrowing, Current crowding, Nonuniform base doping, Breakdown voltage, Equivalent circuit models, switching characteristics, Insulated-gate bipolar transistor (IGBT). **Heterojunction Transistors:** Heterostructure fundamentals, High electron mobility transistor (HEMT), and Heterojunction bipolar transistor (HBT).
4	**Texts/References**	**References:** **1.** Tsividis Y. and Mcandrew C., **The MOS Transistor**, New York, Oxford University Press, 2012. **2.** Taur Y. and Ning T. H., **Fundamentals of Modern VLSI Devices**, 2nd edition, New Delhi, Cambridge University Press, 2009. **3.** Sze S. M. and Ng K. K., **Physics of Semiconductor Devices**, 3rd edition, New Jersey, John Wiley & Sons, 2007. **4.** Shur M., **Physics of Semiconductor Devices**, Noida, Pearson, 2019. **5.** Neamen D. A., **Semiconductor Physics and Technology: Basic Principles**, 4th edition, New York, McGraw Hill, 2012

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**VLSI Design (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to basic concepts in calculus and probability
3	**Course content**	Review of MOS transistor models, Technology scaling, CMOS logic families including static, dynamic, and dual rail logic. Integrated circuit layout; design rules, parasites. low power design, high performance design, logical effort, Interconnect aware design, clocking techniques. VLSI design: data and control path design, floor planning, Design Technology: introduction to hardware description languages (VHDL), logic, circuit, and layout verification.
4	**Texts/References**	**1.** N. Weste and D. M. Harris, "CMOS VLSI Design, A circuits and systems perspective" Pearson, 2010 **2.** S. Kang and Y. Leblebici, "CMOS Digital Integrated circuits," Tata McGraw Hill edition, 2003 **3.** Jan M. Rabaey, A. Chandrakasan and B. Nikolic, "Digital Integrated circuits" Pearson, 2016

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Analog IC design (3-0-0-6)**
2	**Pre-requisite courses(s)**	Electronic Devices, Analog Electronics
3	**Course content**	Active and passive CMOS devices, MOS transistors and small signal models, Noise sources, current mirrors, Single stage opamp, cascade amplifier, folded cascode amplifier, 2 stage opamp and compensation, Negative feedback, fully differential amplifiers, Common mode feedback, PLL's.
4	**Texts/References**	**1.** Jacob Baker, CMOS Circuit Design, Layout, andSimulation, Wiley; 1 edition (2009) **2.** Behzad Razavi, Design of Analog CMOS Integrated Circuits, McGraw Hill Education; Second edition **3.** Hurst, Lewis, Meyer Gray Analysis and Design ofAnalog Integrated Circuits, Wiley; 5 editions

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Nanoelectronics (3-0-0-6)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Introduction:** Shrinking of dimensions from micrometers to nanometers, scaling and limitations of scaling of conventional devices. **Quantum Nanostructures:** Introduction to quantum wells, quantum wires and quantum dots. Fundamentals of carrier transport in quantum structures. **Advanced Electronic Devices:** Single electron transistors, HEMTs, FINFETs, resonant tunneling transistors, optoelectronic and spintronic devices. **Nanomanufacturing:** Top-down and Bottom-up approaches of synthesis of nanomaterials. Introduction to different characterization techniques of nanomaterials like FESEM, TEM, XRD, XPS, FTIR. **Carbon Nanostructures and Applications:** Carbon nanotubes, graphene, fullerenes, band structures and their applications in sensing, energy storage, nano generation and in biomedical domain.
4	**Texts/References**	**1.** Nanoelectronics and Nano systems: From Transistors to Molecular and Quantum Devices, Karl Goser, Peter Glössekötter, Jan Dienstuhl, Springer, 2004. **2.** Introduction to Nanotechnology, C.P. Poole Jr., F.J. Owens, Wiley (2003). **3.** Emerging nanotechnologies for manufacturing by Waqar Ahmed& M.J Jackson William Andrew Publishing, 2009. **4.** Research papers.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Speech Processing (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to probability concepts.
3	**Course content**	**Introduction:** Speech production and perception, nature of speech; short-term processing: need, approach, time, frequency, and time- frequency analysis. **Short-term Fourier transform (STFT):** overview of Fourier representation, non-stationary signals, development of STFT, transform and filter-bank views of STFT. **Cepstrum analysis:** Basis and development, delta, delta- delta and mel-cepstrum, homomorphic signal processing, real and complex cepstrum. **Linear Prediction (LP) analysis:** Basis and development, Levinson-Durbin's method, normalized error, LP spectrum, LP cepstrum, LP residual. **Sinusoidal analysis:** Basis and development, phase unwrapping, sinusoidal analysis, and synthesis of speech. **Applications:** Speech recognition, speaker recognition, speech synthesis, language and dialect identification and speech coding.
4	**Texts/References**	**1.** L.R. Rabiner and R.W. Schafer, Digital Processing of SpeechSignals Pearson Education, Delhi, India, 2004 **2.** J. R. Deller, Jr., J. H. L. Hansen, and J. G. Proakis, Discrete- Time Processing of Speech Signals, Wiley-IEEE Press, NY, USA, 1999. **3.** D. O'Shaughnessy, Speech Communications: Human and Machine, Second Edition, University Press, 2005. **4.** T. F. Quatieri, "Discrete time processing of speech signals," Pearson Education, 2005. **5.** L. R. Rabiner, B. H. Jhuang and B. Yegnanarayana, "Fundamentals of speech recognition," Pearson Education, 2009.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Speech Processing Laboratory (0-0-3-3)**
2	**Pre-requisite courses(s)**	Currently taking or already taken Speech Processing theory course
3	**Course content**	The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the speech processing theory course.
4	**Texts/References**	**1.** L.R. Rabiner and R.W. Schafer, Digital Processing of Speech Signals Pearson Education, Delhi, India, 2004 **2.** J. R. Deller, Jr., J. H. L. Hansen, and J. G. Proakis, Discrete-Time Processing of Speech Signals, Wiley-IEEE Press, NY, USA, 1999. **3.** D. O'Shaughnessy, Speech Communications: Human and Machine, Second Edition, University Press, 2005. **4.** T. F. Quatieri, "Discrete time processing of speech signals," Pearson Education, 2005. **5.** L. R. Rabiner, B. H. Jhuang and B. Yegnanarayana, "Fundamentals of speech recognition," Pearson Education, 2009.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Photovoltaic Systems Design (3-0-0-6)**
2	**Pre-requisite courses(s)**	EE222: Introduction to Power Electronics for UG but for PG students there are no prerequisites.
3	**Course content**	Introduction to PV cells – operation, I-v characteristics, equivalent circuit modeling, and performance; insolation. Interconnection of PV Cells – series and parallel connection of PV cells, discussion on partial shading of PV cells. Maximum power point tracking – review on MPPT algorithms, discussion on circuits for maximum power point tracking. MPPT Controller – review of various DC-DC converters, power electronic interface for MPPT. PV and Battery interfacing: PV sizing, Battery sizing, and interfacing PV and Battery. Interfacing PV: with dc load, ac loads, and water pumping applications Grid Connection: discussion of grid integration of single and three-phase ac systems, review on frame transformation, power converter topologies, and controller implementation.
4	**Texts/References**	**1.** SERI “Basic Photovoltaic Principles and Methods” February 1982 **2.** Chenming Hu, Richard M. White “SOLAR CELLS - From Basics to Advanced Systems” McGraw Hill Book Company, 1983, ISBN0-07-030745-8 **3.** Rauschenbach,” Solar Cell Array Design Handbook: The Principles and Technology of Photovoltaic Energy Conversion,” SPRINGER, 1980, ISBN: 9789401179171.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Power System Dynamics and Control (2-0-1-6)**
2	**Pre-requisite courses(s)**	Power System, Electrical Machines
3	**Course content**	Modelling of Synchronous Machines, Modelling of Exciters, Small Signal Stability Analysis, Modelling of Turbine and Governors, Simulation of Power System Dynamic Response, Improvement of Stability, Sub- synchronous Oscillations.
4	**Texts/References**	**1.** Power System Dynamics and Stability: With Synchro phasor Measurement and Power System Toolbox, 2nd Edition **2.** Power System Stability and Control: Prabha Kundur Mc Graw Hill **3.** Power System Dynamics and Stability, J Machowski; J Bialek, J Bumby, John Wiley & Sons

Spring (Even) Semester

Electrical Engineering

Basket: VLSI and Microelectronics	• Mixed signal VLSI Design • VLSI Technology • Power semiconductor devices • System Design of Electronic Products • VLSI Testing and testability
Basket: Communication, Signal Processing and Machine learning	• Pattern Recognition and Machine learning (PRML) • PRML Lab • Detection and estimation theory • Optimization theory and algorithms • Next-generation wireless networks • Wireless communications • Neural networks and deep learning (NNDL) • NNDL Lab
Basket: Power electronics and power systems	• Advanced Electric Drives • Design of power converters • Microgrid dynamics and control • System Design of Electronic Products • Power system protection • Smart grid • Power systems operation and control • Modeling and control of renewable energy sources • Electric Vehicles: Systems and components • Advanced power electronics and drives • Power System Protection (3-0-0-6) • Power System Simulation Lab (0-0-3-3)(new course)

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Mixed signal VLSI Design (3-0-0-6)**
2	**Pre-requisite courses(s)**	CMOS Analog VLSI Design
3	**Course content**	**1.** CML logic for high-speed mixed signal circuits **2.** Switch design and switch capacitor circuits. **3.** Sampling theory and discrete-time signals **4.** Comparators **5.** Basics of data converters **6.** Nyquist rate ADC's: Parallel (single-step converters), algorithmic (multi-step converters) and pipelined ADC' Architectures and design of Nyquist rate ADC's **7.** High resolution data converters (Δ Σ data converters) **8.** Digital to analog converters **9.** Selected topics in mixed-signal VLSI circuits
4	**Texts/References**	**1.** R. Jacob Baker, H. W. Li, and D.E. Boyce CMOS Circuit Design, Layout and Simulation, Prentice-Hall of ,1998. **2.** R. Jacob Baker, CMOS: Mixed-Signal Circuit Design, Wiley (1 January 2008) **3.** Pavan, Shanthi, Richard Schreier, and Gabor C. Temes. Understanding delta-sigma data converters. John Wiley & Sons, 2017.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**VLSI Technology (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Electronic Devices
3	**Course content**	Introduction on VLSI Design, Bipolar Junction Transistor Fabrication, MOSFET Fabrication for IC, Crystal Structure of Si, Defects in Crystal Crystal growth techniques – Bridgeman, Czochralski method, Floating- zone method Epitaxy – Vapour phase Epitaxy, Doping during Epitaxy, Molecular beam Epitaxy. Oxidation – Kinetics of Oxidation, Oxidation rate constants, Dopant Redistribution, Oxide Charges, Oxide Layer Characterization Doping – Theory of Diffusion, Infinite Source, Actual Doping Profiles, Diffusion Systems, Ion-Implantation Process, Annealing of Damages, Masking during Implantation Lithography Etching – Wet Chemical Etching, Dry Etching, Plasma Etching Systems, Etching of Si, Sio2, SiN and other materials, Plasma Deposition Process Metallization – Problems in Aluminum Metal contacts, IC BJT – From junction isolation to LOCOS, Problems in LOCOS, Trench isolation, Transistors in ECL Circuits, MOSFET Metal gate vs. Self- aligned Poly-gate, MOSFET II Tailoring of Device Parameters, CMOS Technology, Latch – up in CMOS, BICMOS Technology.
4	**Texts/References**	**1.** VLSI Technology by S. M. Sze **2.** Silicon VLSI Technology by J.D. Plummer, M. Deal and P.D. Griffin **3.** VLSI Fabrication Principles by S. K. Gandhi

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Power Semiconductor Devices (3-0-0-6)**
2	**Pre-requisite courses(s)**	Electronic Devices (EE229), Introduction to Power Electronics (EE209)
3	**Course content**	**Introduction:** Ideal and Typical Power Device Characteristics, Fundamental Material and Carrier Transport Properties, Recombination Lifetime, and Breakdown Voltage, Power Electronics Challenges. **Diode Rectifiers:** Schottky Rectifiers – Forward Conduction, Reverse Blocking, Device Capacitance, Barrier Height Adjustment, Edge Termination. PiN Rectifiers – Bipolar Current Transport, Switching Performance, Junction-Barrier Schottky (JBS) and Merged pin-Schottky (MPS) Diodes. **Power MOSFETs:** Power MOSFET structures such as V-MOSFET, VD-MOSFET and U-MOSFET and their working operation, Blocking Voltage, Specific On-Resistance, and Silicon Power MOSFETs. **Bipolar Power Switching Devices:** Power Bipolar Junction Transistor (BJT), Thyristors and Insulated Gate Bipolar Transistors (IGBTs): Current-Voltage Relationship, Blocking, On-state and Switching characteristics. **Wide Bandgap Power Devices:** Introduction to Silicon Carbide (SiC) Power Diodes and MOSFETs, Fundamentals of High-electron Mobility Transistors (HEMTs), Introduction to Gallium Nitride (GaN) - based Power HEMTs, Potential Applications and Challenges.
4	**Texts/References**	**1.** B. J. Baliga, Fundamentals of Power Semiconductor Devices, 2nd edition, Switzerland, Springer International Publishing AG, 2008. **2.** S. M. Sze, K. K. Ng, Physics of Semiconductor Devices, 3rd edition, New Jersey, John Wiley & Sons Inc., 2007. **3.** Y.C Liang, G. S Samudra, C.-F. Huang, Power Microelectronics: Device and Process Technologies, 2nd edition, Singapore, World Scientific Publishing, 2017. **4.** T. Kimoto, J. A. Cooper, Fundamentals of Silicon Carbide Technology, Singapore, John Wiley & Sons Inc., 2014. **5.** F. Iannuzzo, Modern Power Electronic Devices: Physics, applications, and reliability, UK, The Institution of Engineering and Technology, 2020. **6.** H. Yu, T. Duan, Gallium Nitride Power Devices, Singapore, Pan Stanford Publishing Ptv. Ltd, 2017.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**System Design of Electronic Products (3-0-0-6)**
2	**Pre-requisite courses(s)**	Strong performance in foundational core courses of a typical EE program as determined by the instructor and/or faculty advisor: Analog and digital design, control systems, communications, and embedded systems / programming. This is an upper undergraduate / graduate level course. B. Tech students would take up this course in 6th or 7th Semester of a typical 8-semester program in preparation for a hardware design project in the final semester.
3	**Course content**	**Introduction to Systems Design:** Electronic system design workflow, elements of product design; industrial design, design partitioning **Analog, Digital and Mixed Signal Design:** Passive components: design, specification and selection, modelling and non-idealities, error budgeting, parasitic, temperature, aging and vibration effects, reliability; D2A and A2D fundamentals, ground planes, and signal integrity, power integrity and power distribution networks, cabling, connectors, and bus bars. **Noise in Electronic Systems:** Sources, effects and mitigation, fundamentals of EMI/EMC, compliance standards, test processes **Electronic Systems Packaging, Prototyping and Production** Semiconductor packaging, PCB design, manufacture, and assembly, enclosures and interfaces, reliability and MTBF, materials, rapid prototyping, manufacturability, testability, etc. **Application Specific Aspects**: Automotive, Industrial, Space and Defense grade and cybersecurity **Case Studies, mini-projects, and design exercises**
4	**Texts/References**	**References:** **1.** H. W. Ott, Noise Reduction Techniques in Electronic Systems, Singapore: J. Wiley, 1989. **2.** R. Tummala, Fundamentals of Device and Systems Packaging: Technologies and Applications, Second Edition. United States, McGraw-Hill Education, 2019. **3.** L. Umanand, Power Electronics: Essentials & Applications, India. Wiley India Pvt. Limited, 2009. **4.** L. Marks, J. Caterina, Printed Circuit Assembly Design, Ukraine: McGraw-Hill Education, 2000.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**VLSI Test & Testability (3-0-0-6)**
2	**Pre-requisite courses(s)**	EE 224 Digital systems
3	**Course content**	The course describes the theoretical aspects of VLSI Testing and verification. Starting from the basic concepts of verification and testing to advance processor level verification and testing are going to be. discussed in this course. In addition to that, SoC testing strategy will also be discussed in this course. The objective of this course is to deal with the study of VLSI design flow, Functional verification, verification flow, simulator architecture and operation, assertions, need for electronic testing, fault modeling, test generation for combinational circuits, test generation for sequential circuits, fault simulation, Built-In Self-Test (BIST), Memory testing, Design for Testability (DFT), SoC test, fault diagnosis, and Analog/RF test.
4	**Texts/References**	**1.** William K. Lam, Hardware Design Verification: Simulation and Formal Method-Based Approaches, Prentice Hall (2008). **2.** Michael. L. Bushnell, and Vishwani. D. Agrawal, Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits, Kluwer Academic Publishers, Third Edition, 2004. **3.** William K. Lam, Hardware Design Verification: Simulation and Formal Method-Based Approaches-Pearson Prentice Hall,1st edition, 2005. **4.** Michael. L. Bushnell, and Vishwani. D. Agrawal, Essentials of Electronic Testing for Digital, Memory and Mixed-Signal VLSI Circuits, Springer, 2013

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Pattern Recognition and Machine Learning (PRML) (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to basic concepts in calculus and probability
3	**Course content**	**Overview of** Probability Theory, Linear Algebra, Convex Optimization. **Introduction:** History of pattern recognition & machine learning, distinction in focus of pattern recognition and machine learning. **Regression**: Linear Regression, Multivariate Regression, Logistic Regression. **Clustering:** Partitional Clustering, Hierarchical Clustering, Birch Algorithm CURE Algorithm, Density-based Clustering **PCA and LDA:** Principal Component Analysis, Linear Discriminant Analysis. **Kernel methods:** Support vector machine **Graphical Models**: Gaussian mixture models and hidden Markov models **Introduction to Bayesian Approach:** Bayesian classification, Bayesian Learning, Bayes Optimal Classifier, Naive Bayes Classifier and Bayesian Network.
4	**Texts/References**	**1.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006. **2.** S. Theodoridis and K. Koutroumbas, "Pattern Recognition" Second Edn, Elsivier, 2003 **3.** B. Yegnanarayana, "Artificial Neural Networks," PHI, 1999. **4.** Simon Hayking, "Neural Networks and Learning Machines,"Pearson, 1999.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Optimization Theory and Algorithms (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Calculus or equivalent
3	**Course content**	**The following topics will be covered:** Quick Review of Linear Algebra and basic calculus. Introduction to convex sets and functions, and their properties. Duality theory, Lagrangian dual and KKT conditions. Algorithms for unconstrained and constrained minimization. Subgradient methods for non-differentiable functions. Important standard classes such as linear and quadratic programming, semidefinite programming etc. Applications of convex programming in electrical engineering. Recognizing and formulating convex optimization problems in practice. Beyond convex optimization. Introduction to functional optimization theory.
4	**Texts/References**	**1.** Stephen Boyd and Lieven Vandenberghe, "Convex Optimization," Cambridge university press. **2.** David G. Luenberger, "Optimization by Vector Space Methods," Wiley publications.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Pattern Recognition and Machine Learning (PRML) Laboratory (0-0-3-3)**
2	**Pre-requisite courses(s)**	Currently taking or already taken PRML theory course
3	**Course content**	The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the PRML theory course.
4	**Texts/References**	**1.** C. Bishop, "Pattern Recognition and Machine Learning," Springer, 2006. **2.** S. Theodoridis and K. Koutroumbas, "Pattern Recognition" Second Edn, Elsivier, 2003 **3.** B. Yegnanarayana, "Artificial Neural Networks," PHI, 1999. **4.** Simon Hayking, "Neural Networks and Learning Machines," Pearson, 1999.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Next Generation Wireless Systems / Wireless Networks (3-0-0-6)**
2	**Pre-requisite courses(s)**	Principles/Fundamentals of Communications
3	**Course content**	Theory, design techniques, and analytical tools for characterizing next generation wireless systems. Performance analysis of digital communication systems over fading channels, rate and power adaptation, and multi-user diversity techniques; study of the fourth generation (4G) long term evolution (LTE) standard, its air interface, physical and logical channels, and physical layer procedures; introduction to fifth generation (5G) wireless communication and the 5G new radio (NR) standard, survey of non-orthogonal multiple access (NOMA) and the internet-of-things (IoT) related changes in 4G/5G..
4	**Texts/References**	**1.** Stefaniz Sesia, Issam Toufik, Matthew Baker, "LTE - The UMTS Long Term Evolution," John Wiley and Sons, 1st ed., 2009. **2.** 3GPP technical specifications available online at http://www.3gpp.org/ **3.** David Tse and Pramod Viswanath, “Fundamentals of Wireless Communication,” Cambridge University Press, 2005. **4.** 4. QUEUEING SYSTEMS, VOLUME 1: THEORY by Leonard Kleinrock John Wiley & Sons, Inc., New York, 1975

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Neural Networks and Deep Learning (NNDL) (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to basic concepts in calculus and probability
3	**Course content**	**Introduction to Artificial Neural Networks (ANN) and Deep Learning (DL):** Motivation, basics of ANN, overview of PRML, evolution deep learning and different architectures. Applications of ANN vs DL. **Feedforward Neural Networks (FFNN):** Working principle, basic architecture, analysis of FFNN for different PRML tasks. **Feedback Neural Networks (FBNN):** Working principle, basic architecture, Boltzmann machine, analysis of FFNN for different PRML tasks. **Competitive learning Neural Networks (CLNN):** Working principle, basic architecture, analysis of CLNN for different PRML tasks. **Deep Learning (DL) Architectures:** Deep FFNN, Convolutional neural networks (CNN), Recurrent neural network (RNN), Longterm shortterm memory (LSTM), Generative adversarial network (GAN), DL architectures with attention mechanism. Some recent DL architectures. **Applications of DL:** speech processing, image processing and other tasks.
4	**Texts/References**	**1.** B. Yegnanarayana, Artificial Neural Networks, PHI, 1999. **2.** Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, MIT Press, 2016.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Wireless Communication (3-0-0-6)**
2	**Pre-requisite courses(s)**	Signals and Systems, Probability (UG level), Principles/Fundamentals of Communications
3	**Course content**	Review of fundamentals in probability theory, random processes, spectral analysis of deterministic and random signals; review of digital modulation schemes, optimal receiver design under additive white Gaussian noise (AWGN) and error rate performance; orthogonal frequency division multiplexing (OFDM); channel modeling, capacity and diversity techniques in wireless communication; multi-input multi-output (MIMO) systems and space time block codes (STBC); cellular communication systems, multiple-access and interference management. . .
4	**Texts/References**	**1.** David Tse and Pramod Viswanath, "Fundamentals of Wireless Communication," Cambridge University Press, 2005. **2.** Andrea Goldsmith, "Wireless Communications," Cambridge University Press, 2005.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Neural Networks and Deep Learning (NNDL) Laboratory (0-0-3-3)**
2	**Pre-requisite courses(s)**	Currently taking or already taken NNDL theory course
3	**Course content**	The lab will closely follow the theory course. The idea is to have the students implement the basic algorithms on different topics studied in the NNDL theory course.
4	**Texts/References**	**1.** B. Yegnanarayana, Artificial Neural Networks, PHI, 1999. **2.** Ian Goodfellow, Yoshua Bengio, and Aaron Courville, Deep Learning, MIT Press, 2016.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Advanced Electric Drives (2-0-2-6)**
2	**Pre-requisite courses(s)**	Exposure to basic Power Electronics, Electric Machines, and foundational courses in EE; Instructor consent is required
3	**Course content**	**1.** Electric Drives Overview: Components, structure; performance, line-side, and machine-side specifications **2.** Rectifiers: Diode and Thyristor rectifiers, multi-pulse rectifiers: 6-pulse, 12- pulse, etc; THD and Power Factor effects **3.** Two-Level Inverters and PWM Techniques Power circuit analysis, Switching states, and Loss models. Sinusoidal PWM, Space- vector PWM, Harmonic Analysis, Over-modulation, Third-harmonic injection, Bus clamping, Selective-harmonic-elimination, current and flux error space-vectors. **4.** Multilevel Inverters: Topologies for multilevel converters: NPC, CHB and FC, MMCs; T-type and I-type; modulation scheme, voltage balancing, PWM techniques for multilevel inverter (level / phase shifted, NLM, sorting, etc) **5.** DC Drives: Structure, power circuit, and control schemes, decoupled control concepts **6.** Induction Motor Modelling: Transformations of abc-α-β-dq quantities, machine modeling in dq-domain, and linearization **7.** Induction Motor Drives: V/f control, vector control; controller design; field- oriented control; direct-torque-control, wound-rotor induction machines (DFIG)
4	**Texts/References**	**References:** **1.** S. Raju, N. Mohan, Analysis and Control of Electric Drives: Simulations and Laboratory Implementation, United States, Wiley, 2020. **2.** N. Mohan, Advanced Electric Drives: Analysis, Control, and Modeling Using MATLAB / Simulink, Germany, Wiley, 2009 **3.** M.G. Say, The Performance and Design of Alternating Current Machines: Transformers, Three-Phase Induction Motors and Synchronous Machines, India, CBS Publishers & Distributors, 2005 **4.** B. K. Bose, Modern Power Electronics and AC Drives, India, Prentice Hall PTR, 2002 **5.** B. Wu, High-Power Converters and AC Drives, United Kingdom, Wiley, 2007.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Design of Power Converters (1.5-0-3-3)**
2	**Pre-requisite courses(s)**	At least one course on Power Electronics at the undergraduate level. Not suitable for candidates with no prior exposure to power electronics.
3	**Course content**	Introduction to power converter topologies for EV applications, functional and operational constraints, design procedures, introduction to magnetics, thermal and mechanical aspects, packaging
4	**Texts/References**	None. Relevant material will be provided by the **external instructor** from datasheets, app notes and manuals.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Microgrid Dynamics and Control (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to electrical machines, power electronics, power system, renewable energy
3	**Course content**	Grid connected renewable energy resources, renewable power for control support, Microgrid concepts, structures, and operation modes, microgrid dynamics and modeling, Hierarchical Microgrid Control, DC Microgrid Control, Virtual Synchronous Generators: Dynamic Performance and Characteristics, virtual inertia-based stability, and regulation support, Robust microgrid control and emergency control
4	**Texts/References**	**1.** Gilbert M. Masters, "Renewable and Efficient Electric Power Systems," Wiley Interscience, 2^{nd} edition, 2004. **2.** Hassan bevrani, Bruno Francois, and Toshifumi Ise, "Microgrid Dynamics and Control," Wiley, Black Well, 1^{st} edition, 2017.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**System Design of Electronic Products (3-0-0-6)**
2	**Pre-requisite courses(s)**	Strong performance in foundational core courses of a typical EE program as determined by the instructor and/or faculty advisor: Analog and digital design, control systems, communications, and embedded systems / programming. This is an upper undergraduate / graduate level course. B. Tech students would take up this course in 6th or 7th Semester of a typical 8-semester program in preparation for a hardware design project in the final semester.
3	**Course content**	**Introduction to Systems Design:** Electronic system design workflow, elements of product design; industrial design, design partitioning **Analog, Digital and Mixed Signal Design:** Passive components: design, specification and selection, modelling and non-idealities, error budgeting, parasitics, temperature, aging and vibration effects, reliability; D2A and A2D fundamentals, ground planes, and signal integrity, power integrity and power distribution networks, cabling, connectors, and bus bars. **Noise in Electronic Systems:** Sources, effects and mitigation, fundamentals of EMI/EMC, compliance standards, test processes **Electronic Systems Packaging, Prototyping and Production** Semiconductor packaging, PCB design, manufacture, and assembly, enclosures and interfaces, reliability and MTBF, materials, rapid prototyping, manufacturability, testability, etc. **Application Specific Aspects**: Automotive, Industrial, Space and Defense grade and cybersecurity **Case Studies, mini-projects, and design exercises**
4	**Texts/References**	**References:** **1.** H. W. Ott, Noise Reduction Techniques in Electronic Systems, Singapore: J. Wiley, 1989. **2.** R. Tummala, Fundamentals of Device and Systems Packaging: Technologies and Applications, Second Edition. United States, McGraw-Hill Education, 2019. **3.** L. Umanand, Power Electronics: Essentials & Applications, India. Wiley India Pvt. Limited, 2009. **4.** L. Marks, J. Caterina, Printed Circuit Assembly Design, Ukraine: McGraw-Hill Education, 2000.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Smart Grid (3-0-0-6)**
2	**Pre-requisite courses(s)**	EE223: Introduction to Power Systems or equivalent as determined by the instructor or faculty advisor.
3	**Course content**	**1.** Synchrophasor & PMU, IEEE standards **2.** State estimation- WLS, Linear, Hybrid **3.** Cyber Security in Smart Grid **4.** Dynamic Security Assessment, Prediction and Control **5.** Wide Area Damping Control **6.** Mode Estimation- Ringdown & Ambient **7.** Dynamic State and Parameter Estimation **8.** Ancillary Services from Renewables, grid forming converter, Virtual Inert
4	**Texts/References**	**1.** Power System Grid Operation Using Synchrophasor Technology, Nuthalapati Sarma, Springer, 2019, ISBN 978-3-319-89378-5. **2.** Phasor Measurement Units and Wide Area Monitoring Systems, Antonello Monti, Carlo Muscas and Ferdinanda Ponci, ISBN: 9780128031407, Academic Press, 2016. **3.** Wide area smart grid architectural model and control: A survey, Renewable and Sustainable Energy Reviews, Vol. 64, pp. 311-328, 2016. **4.** Application of Time-Synchronized Measurements in Power System Transmission Networks, Mladen Kezunovic, Sakis Meliopoulos, Vaithianathan Venkatasubramanian, Vijay Vittal, Springer, 978-3-319-06217-4, Edition 1, 2014. **5.** F. Aminifar et. al. "Synchrophasor Measurement Technology in Power Systems: Panorama and State-of-the-Art," IEEE Access, Vol. 2., No. 1, pp. 1607-1628, 2014.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Modeling and Control of Renewable Energy Resources (3-0-0-6)**
2	**Pre-requisite courses(s)**	Modeling and Control of Renewable Energy Resources
3	**Course content**	Microgrids and distributed generation; Introduction to renewable energy technologies; electrical systems and generators used in wind energy conversion systems, diesel generators, combined heat. cycle plants, inverter-based generation, solar PV based systems, fuel cell and aqua- electrolyzer, battery and flywheel-based storage system; Voltage and frequency control in a microgrid; Grid connection interface issues.
4	**Texts/References**	**1.** Anaya-Lara, Jenkins, Ekanayake, Cartwright and Hughes, WIND ENERGY GENERATION Modelling and Control” Wiley, 1st Edison, 2009. **2.** Bevrani, Francois and Ise, Microgrid Dynamics and Control, Wiley; First edition, 2017. **3.** Gilbert M. Masters, Renewable and Efficient Electric Power Systems, Wile Interscience, 1st Edison, 2004.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Electric Vehicles: Systems and Components (2-0-2-6)**
2	**Pre-requisite courses(s)**	None for M. Tech SSM. For others, instructor consent is required
3	**Course content**	Each topic is accompanied by hands-on exercises. **Introduction to Electric Vehicles** – Discussion on the importance of EV; classification of EVs: e-bikes, 2 wheelers, 3-wheelers, 4-wheelers; light/medium/heavy duty, etc. **Electric Vehicle Components** – Components of EV, Electric Vehicle Supply Equipment (EVSE), Charging ports, connector configurations, Chargers, Battery, Drivetrain, BMS, AUX power converters, Electric motors, etc. **Electric Vehicle Supply Equipment** – Introduction to EVSE, basic requirements, different types, functional diagram, safety features, and requirements. **Electric Vehicle Battery Chargers** – Overview of EV Battery Chargers (onboard and stationery), different types, levels of charging, internal power electronic converters – Rectifiers, PFC, DC/DC converters, Communications, and control aspects. **Overview on EV Batteries and Battery Management Systems:** Introduction to various electric vehicle batteries, typical energy requirements in EV, battery management systems. **Discussion of EV Drivetrains:** Overview of electric motors for EV applications, limitations of existing motors, control of electric motors, and design aspects. **Electric Vehicle Control Unit:** discussion on requirements of VCU, inverter topologies and their control strategy, VCU design methodology. **AUX Power Converter Unit:** requirements, power converter topologies, discussion on design difficulties for high current low voltage converters. Implementation of Electric Vehicle Supply System - understanding fault trip mechanisms, hand shaking between vehicle and grid, controlling the charging profiles, etc. Electric Vehicle battery chargers - understanding various chargers - types, levels, and connectors configurations, different operating modes: CV and CC. Basic level implementation of EV chargers - input PFC stage, DC/DC stage, and EMI stage. Understanding design constraints of AUX power supply - DC/DC isolated and non- isolated stages, different power levels Power estimation at different stages - AUX, EV chargers, Battery rating, etc. Drivetrain testing and speed control - Vector control and V/f methods. Understanding automotive components testing techniques as per IEC61000 and CISPR25 &35 Complete vehicle integration and system level testing.

4	**Texts/References**	**1.** S. Raju, N. Mohan, Analysis and Control of Electric Drives: Simulations and Laboratory Implementation, United States, Wiley, 2020. **2.** Ali Emadi, Mehrdad Ehsani, and John M. Miller, "Vehicular Electric Power Systems: Land, Sea, Air, and Space Vehicles (Power Engineering," **3.** CRC Press, 1ed, 2003 **4.** Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals," CRC Press, 2ed, 2010. **5.** Who killed the Electric Car, a documentary, 2006. **6.** Michael Shnayerson, "The Car that Could: The Inside Story of GM's Revolutionary Electric Vehicle," 1996. **7.** Application Notes from Texas Instruments, Infineon; Curtis Instruments.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Advanced Power Electronics and Drives (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to Circuits, semiconductor devices and Electric Machines &power electronics
3	**Course content**	Basics of semiconductor devices, gate drives for BJT, MOSFET and IGBT, heat sink selection, snubber circuits, non- isolated converters like buck, boost and buck-boost converters, isolated converters like forward, push pull, half bridge, full bridge and fly back, design of magnetics for inductors and transformers, inverters, PWM generation - SPWM, space vector PWM, dq axis theory for 2 and 3 phase applications. Introduction to electric drives, and speed control of electric machines. Design examples like, EV Battery chargers, and grid connected PV inverter.
4	**Texts/References**	**1.** L. Umanand, Power electronics and applications, Wiley India Pvt. Limited, 2009. **2.** Chryssis, G.C., High frequency switching power supplies, Second Edn, McGraw Hill, 1989. **3.** R. W. Erickson, Dragan Maksimovic, Fundamentals of Power Electronics, Springer, 2001. **4.** N. Mohan, Power Electronics: Converter, Applications & Design, John Wiley & Sons, 1989

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Power System Protection (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to power system, circuit theory.
3	**Course content**	Introduction to modern power system protection- philosophy and approach- Digital protection technology overview Phasor measurement techniques, Phasor measurement techniques, Overcurrent protection, Directional Relaying, Distance Relaying, Distance Relaying, CT and CVT response, Transformer protection, Differential protection of Line, Network Protection with Renewable sources, Travelling wave approach, Synchrophasor technology application.
4	**Texts/References**	**1.** Power system relaying by Stanley H. Horowitz, Arun G. Phadke, James K. Niemira, fifth Ed., 2022, John Wiley and Sons. **2.** Fundamentals of Power System Protection, by Paithankar, Bhide, second edition, 2013, PHI. **3.** Electrical Transients in Power Systems by Allan Greenwood, Wiley-Inter science; 2nd edition, 1991.

Electrical Engineering

1	**Title of the course (L-T-P-C)**	**Power System Operation and Control (3-0-0-6)**
2	**Pre-requisite courses(s)**	Exposure to electrical machines, power system.
3	**Course content**	Introduction to modern power systems, equipment and stability constraints, reactive power and voltage controls, economic load dispatch and unit commitment, active power and frequency control, line power flow controls, load dispatch center functions, Emergency Controls- Special Protection Schemes.
4	**Texts/References**	**1.** B F Wollenberg, "Power Generation, operation and control," 2nd edition, Wiley, 2006. **2.** Grainger and Stevenson, "Power System Analysis," 1st edition, McGraw Hill Education, 2017. **3.** Prabha Kundur, "Power System Stability and Control," McGraw Hill Education, 1s t edition, 2006.