# NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR
## Department of Electrical Engineering
## Revised Curriculum and Syllabi

## Program Name
## Master of Technology in Electrical Engineering (Instrumentation and Control)
## Effective from the Academic Year: 2022-2023

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| Recommended by DPAC | : |
| Recommended in PGAC | : 01.03.2022 |
| Approved by the Senate | : 11.04.2022 |

# CURRICULUM

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|---|---|---|---|---|---|---|---|---|
| | | **Semester – I** | | | | | | |
| **Sl. No.** | **Code** | **Subject** | | **L** | **T** | **S** | **C** | **H** |
| 1 | EE1021 | Background Course | Instrumentation and Measurement Techniques | 3 | 0 | 0 | 3 | 3 |
| 2 | EE1022 | Specialization Core – I | Advanced Control System I | 3 | 1 | 0 | 4 | 4 |
| 3 | EE1023 | Specialization Core – II | Biomedical Instrumentation | 3 | 1 | 0 | 4 | 4 |
| 4 | EE9020, EE9011, EE9016, EE9033, EE9034, EE9035, EE9036 | Specialization Elective – I | Electric Vehicle, Soft Computing Techniques, Machine Learning and Expert System, Advanced Sensors, Condition Monitoring and Intelligent Systems, Intelligent Control, Robotics & Automation | 3 | 0 | 0 | 3 | 3 |
| 5 | | Specialization Elective – II | | 3 | 0 | 0 | 3 | 3 |
| 6 | EE1071 | Laboratory 1 | Instrumentation Laboratory | 0 | 0 | 4 | 2 | 4 |
| 7 | EE1072 | Laboratory 2 | Biomedical Instrumentation Laboratory | 0 | 0 | 4 | 2 | 4 |
| | | **Total** | | **15** | **2** | **8** | **21** | **25** |
| | | **Semester – II** | | | | | | |
| **Sl. No.** | **Code** | **Subject** | | **L** | **T** | **S** | **C** | **H** |
| 1 | EE2021 | Specialization Core – III | Advanced Control System II | 3 | 1 | 0 | 4 | 4 |
| 2 | EE9021, EE9037, EE9038, EE9039, EE9040 | Specialization Elective – III | Digital Signal Processing, Distributed Energy Systems, Industrial Instrumentation, Micro-electromechanical Systems (MEMS), Non-Destructive Testing | 3 | 1 | 0 | 4 | 4 |
| 3 | EE9018, EE9019, EE9022, EE9023, EE9028, EE9023, EE9041, EE9042, EE9013 | Specialization Elective – IV | Embedded System, FACTS Devices, Estimation of Signals and Systems, Power System Control and Instrumentation, Process Instrumentation and Control, Robust & Optimal Control, Medical Imaging, Image Understanding | 3 | 0 | 0 | 3 | 3 |
| 4 | | Specialization Elective – V | | 3 | 0 | 0 | 3 | 3 |

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| 5 | EE2071 | Laboratory 3 | Advanced Control Laboratory | 0 | 0 | 4 | 2 | 4 |
| 6 | EE2072 | Laboratory 4 | Intelligent System Laboratory | 0 | 0 | 4 | 2 | 4 |
| 7 | EE2073 | Mini Project with Seminar | | 0 | 0 | 6 | 3 | 6 |
| | | **Total** | | **14** | **2** | **14** | **23** | **30** |
| | | **Semester – III** | | | | | | |
| 1 | EE907X | Audit Lectures/Workshops | | | | | | 2 |
| 2 | EE3071 | Dissertation – I | | 0 | 0 | 24 | 12 | 24 |
| 3 | EE3072 | Seminar – Non-Project / Evaluation of Summer Training | | 0 | 0 | 4 | 2 | 4 |
| | | **Total** | | **0** | **0** | **28** | **14** | **30** |
| | | **Semester – IV** | | | | | | |
| 1 | EE4071 | Dissertation – II / Industrial Project | | 0 | 0 | 24 | 12 | 24 |
| 2 | EE4072 | Project Seminar | | 0 | 0 | 4 | 2 | 4 |
| | | **Total** | | **0** | **0** | **28** | **14** | **28** |

# SYLLABUS

<table>
<tr><td colspan="9">Department of Electrical Engineering</td></tr>
<tr><td rowspan="2">Course Code<br>EE 1021</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>Background Course</td><td>Instrumentation and Measurement Techniques</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Basic understanding on measurement, measuring systems, analog and digital electronics</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7"><ul>
<li>CO1: Given details of different measurement systems, conclude to find the most suitable one, by estimating percentage error in each case.</li>
<li>CO2: A parameter to be measured for a given application of electrical engineering, explore different alternative measuring instruments (having different working principles, for example moving coil, moving iron, electrodynamic, etc.); appraise their suitability for the application, with the knowledge of limitations, static and dynamic characteristics, reliability and economy for each of the alternatives.</li>
<li>CO3: Given set of specifications for measurement of an electrical parameter, find suitable primary sensing element, design associated analog signal conditioning circuit and digital circuit (as per given output specification, if any), and evaluate the system (available detail component data sheet) to designate that the measuring system meet the given specification criteria.</li>
<li>CO4: Given electrical system and parameters to be measured, compare different measurement schemes having different measurement locations and different sensing and signal conditioning circuits, by judging possibility of errors, noises and drifts.</li>
<li>CO5: Synthesize a measurement system using suitable set of measuring units and data acquisition system along with the required building blocks for a given complex real life application related to the field of electrical engineering (for example motor protection system, electrical substation monitoring and control, etc.), involves monitoring of multiple parameters and also require to generate control action while meeting the real time specification criteria.</li>
<li>Give measurement application and measurement criteria, design a suitable Data Acquisition System and justify how it meet the specified conditions.</li>
</ul></td></tr>
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| Topics Covered | Introduction to measurement and Instrumentation. Static characteristics of measuring instruments. Dynamic characteristics of measuring instruments. Measurement Errors and Loading effect of measuring instrument. Statistical analysis of measurement error. Reliability, choice and economics of measurement systems.[10]<br><br>DC potentiometers and its application for measurement of resistance, voltage, current and power.AC potentiometers and its use for measurement of self-inductance, voltage current, and power. Measurement of medium and low resistance. Measurement of high, insulation and earth resistance. Locating fault location in cables. Measurement of Inductance using bridges Measurement of Capacitance using bridges PT and CT for measurement of voltage and current. [8]<br><br>Introduction to electromechanical instruments and D' Arsonval galvanometer Ballistic and Vibration galvanometer Moving coil instruments Moving iron type instruments Electrostatic instruments Electrodynamics instruments Induction type instruments Thermal and Rectifier type instruments Measurement of Power, Energy, frequency and phase; AC bridges [8]<br><br>Review of operational amplifier, instrumentation and programmable gain amplifiers Peak detector and zero crossing detectors Precision rectifier, Lag and lead compensator Signal generator A/D convertor and S/H circuit D/A converter, signal conditioning circuit. [7]<br>Measurement current using Hall Effect sensor and clamp on meter True rms voltmeters and solid state energy meter Electronic Voltmeters, Analog and Digital Multimeter Cathode Ray Oscilloscope (CRO) Digital Storage Oscilloscope Measurement of frequency, phase angle and time period [4]<br>Introduction to DAS, software and hardware co-design Analog input output sub system Digital input output subsystem and input output interfaces Software features in real time application Supervisory Control and Data Acquisition System for real life application of electrical engineering.<br>Measurement of process variables; temperature, pressure, strain, flow etc. [5] |
| Text Books, and/or reference material | Text Books<br>1. A. D. Helfrick and William David Cooper, Modern electronic instrumentation and measurement techniques, Prentice Hall<br>2. John-G. Webster (ed.), The Measurement, Instrumentation, and Sensors: Handbook, Springer<br>3. John P. Bentley's book may also be added.<br><br>Reference Books:<br><br>1. Curtis D. Johnson, Process control instrumentation technology, Prentice Hall |

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| | 2. Robert N. Thurston and Allan D. Pierce, Ultrasonic measurement methods, Academic Press<br>3. William Bolton, Programmable Logic Controllers, Newness<br>4. Stuart A. Boyer, Supervisory Control And Data Acquisition, International Society of Automation<br>5. T. V. Kenneth and B. T. Meggitt, Optical Fiber Sensor Technology, Springer. |

| Department of Electrical Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE1023 | BIOMEDICAL INSTRUMENTATION | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Knowledge on Electrical Measurement, Analog and Digital Electronics, Electrical Transducers | | | | | |
| | | CT+EA | | | | | |
| Course Outcomes | • CO1: Familiarisation with biomedical transducers<br>• CO2: Design of biomedical equipments and signal processing circuitry<br>• CO3: Familiarisation with various biopotentials linke ECG, EEG, EMG and EOG<br>• CO4: Acquiring knowledge about various electrodes used in bio instrumentation.<br>• CO5: Procedures for measurement of blood flow, blood pressure and heart sound<br>• CO6: Introduction to medical imaging | | | | | | |
| Topics Covered | Introduction to biomedical Instrumentation, biomedical electronics, Components of Analog and digital circuits, Analog & digital circuit design, Multistage amplifier gain, Gain Bandwidth product, frequency response. [8]<br><br>Various types of signal conditioners, signal conditioning processes, Signal Acquisition, graphical user interface, Transformer based and transformer less power supply. [4]<br><br>Medical instrumentation constraints, Various biomedical transducers. [4]<br><br>Generation of Nernst Potential, Establishment of diffusion potential, Goldmann Equation, Measurement of membrane potential, resting potential, action potential, Voltage Clamp, Hodgekin Huxley Model [4]<br><br>Use of electrodes for measurement of bio potentials, polarization in electrodes, principle of operation of Ag/AgCl electrode, Equivalent circuit of electrode, motion | | | | | | |

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| | artifact, various types of electrodes for bio potential measurement. [8]<br><br>Measurement of ECG, Einthoven triangle method, unipolar and bipolar limb leads, Chest Limb Leads, ECG amplifiers, Problems encountered in ECG recording [6]<br><br>Analysis of ECG Signals, Pacemakers, Different types of pacing modes, Physiological effects of electric currents, Defibrillators. [6]<br><br>Measurement of blood pressure, measurement of blood pH, measurement of blood flow, measurement of heart sounds, use of Surface Plasmon Resonance for detection of toxins. [8]<br><br>Introduction to medical imaging, Radiography, Computerized tomography, X Ray,-CT, MRI, PET, SPET, Gamma Camera, Ultrasound Imaging, Color Doppler, Recent trends in medical imaging, EIT, DOT, PAT, AEI. [8] |
| Text Books, and/or reference material | Text Books:<br>1. John Enderle. Joseph Brinzino, *Introduction to Biomedical Engineering*, Elsevier, 2012.<br>2. John G Webster, *Medical Instrumentation, Application & Design*, John Wiley & Sons, 2009<br>Reference Books:<br>1. L. Cromwell, Fred J. Weibell, Erich A. Pfeiffer, , *Biomedical Instrumentation & Measurements*, PHI, 2014<br>2. Arthur C Guyton, John E Hall, *Textbook of Medical Physiology*, Elsevier, 2006 |

| Department of Electrical Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 1022 | Advanced Control System I | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| Control System Engineering in B Tech | | CT+EA | | | | | |
| Course Outcomes | • CO1: To learn the performance goals of closed loop control system design and the methods of analysis<br>• CO2: To illustrate different advanced control system topologies, their design methods and synthesis of the controller designed | | | | | | |

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| | • CO3: To develop the concept of state variable approach for linear time invariant system modelling and control<br>• CO4: To design feedback control in State space domain<br>• CO5: To design observed based state feedback control system<br>• CO6: To design Linear Quadratic Regulator, Kalman Bucy Filter for optimal design in state space |
| Topics Covered | <u>Performance Objectives/ Goals:</u><br>Response and Loop Goals, Stabilization, Pole-placement, Tracking, Robustness, Disturbance Rejection, Noise Attenuation [6]<br><u>Performance Analysis and Tests:</u><br>Time Domain Analysis, Internal Model Principle (IMP),Frequency Response analysis by bode diagram and Nyquist criterion, Loop Shaping Techniques, Sensitivity analysis, Utilities of Gain and Phase Margin determination [8]<br><u>Compensation:</u><br>Feedforward Control, Feedback Control, Classical Controller P, PI, PID, Lead and Lag, One degree-of-freedom (1 DOF) control, Two DOF configurations, Sylvester matrix Formulation, Internal Model Control (IMC), Internal Model Principle (IMP) [12]<br><u>State Space Representation of Continuous-time Systems:</u><br>State model state models for linear continuous time systems, conversion of state variables models to transfer functions in s-domain, solutions of state equations, state transition matrix, state transition flow graphs, eigenvalues, eigenvectors and stability similarity transformation, decompositions of transfer functions, canonical state variable models, controllability and observability, Linear State Variable Feedback (LSVF) control and pole placement, Full Order Observer and Reduced Order Observer, Design examples, MATLAB tools and practical case studies [20]<br><u>Optimal Control</u><br>Linear Quadratic Regulator (LQR), Linear Quadratic Guassian (LQG), LQR with state estimator, Kalman-Bucy filter/state estimator, Design Examples, Practical case studies [10] |
| Text Books, and/or reference material | Text Books:<br>1. Modern Control Engineering, K. Ogata,<br>2. Modern Control System Theory, M. Gopal,<br>3. Feedback Control Theory, John Doyle, Bruce Francis, Allen Tannenbaum,<br>4. Kalman Filtering Theory and Practice, Mahinder S. Grewal and Angus P Andrews<br>Reference Books:<br>1. Linear Control System Analysis And Design With MATLAB, John J. D’Azzo and Constantine H. Houpis and Stuart N. Sheldon<br>2. Linear Robust Control, Michael Green and David J.N. Limebeer |

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<tr><td colspan="10">Department of Electrical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2" colspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>EE 9020</td><td colspan="2">Electric Vehicle</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), Mid Sem (MS) and end assessment (EA))</td></tr>
<tr><td colspan="3">Electrical Technology<br>Electrical Machines I</td><td colspan="6">CT+MS+EA</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="7">• CO1:To acquire an idea about electric vehicles (EVs) and hybrid electric vehicles (HEVs)<br>• CO2: To learn the fundamentals of different types of EVs and HEVs systems and their components.<br>• CO3: To study about the Electric Propulsion Units required in EVs and HEVs.<br>• CO4: To learn about the different types of Energy Sources and Storage units used in EVs and HEVs systems.<br>• CO5:To study the Impacts of EVs and HEVs on power system and Environment.<br>• CO6: To Learn about the EV simulation software and EV simulation for designing and modelling.</td></tr>
<tr><td colspan="2">Topics Covered</td><td colspan="7">Introduction to Electric Vehicles: History of Electric Vehicles and hybrid electric vehicles, Recent EVs and HEVs, EV Advantages, social and environmental importance of hybrid and electric vehicles, impact of modern HEVs on energy supplies. [5]<br>Conventional Vehicles: Basics of vehicle performance, vehicle power source characterization, transmission characteristics, and mathematical models to describe vehicle performance. [5]<br>Structure and Components of EVs and HEVs: EV systems, HEV systems, Concept and architecture of hybrid electric drive trains, series and parallel of hybrid electric drive trains, torque and speed coupling of hybrid electric drive trains. [5]<br>Electric Propulsion Unit: Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency [7]</td></tr>
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| | **Energy Sources and Storage:** Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. [10]<br>**Impacts on power system and Environment:** Harmonic impact, Harmonic compensation, Current demand impact, Current demand minimization, Transportation pollution, Environment-sound EVs. [5]<br>**EV Simulation:** Simulation Softwares, System level simulation, case studies of EV simulation [5] |
| Text Books, and/or reference material | TEXTBOOK:<br>Iqbal Husain, "Electric and Hybrid Vehicles Design Fundamentals"<br>Published by: CRC Press, Boca Raton, Florida, USA, 2003.<br><br>REFERENCES:<br>Chan, "Modern Electric Vehicle Technology", Oxford 2002 |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9011 | SOFT COMPUTING TECHNIQUES | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | |
| Basic analytical and programming attribute | | | CT+EA | | | | |
| Course Outcomes | ● CO1: For the given linear and non-linear problems under practical limitations, compare classical analytical method and soft computing technique.<br>● CO2: For a given single objective problem (SOP), apply binary coded genetic algorithm (BCGA) and real coded genetic algorithm (RCGA) with different types of crossover, mutation and also understand the impact of different parent selection strategies.<br>● CO3: For a given non-linear or non-derivative problem, tune the control parameters of adaptive particle swarm optimization (APSO) for efficiently controlling the global exploration and local exploitation.<br>● CO4: For a given realistic problem, explain the significance of the Difference vector in Differential Evolutionary (DE) technique and also illustrate self-adaptive differential evolutionary (SADE) technique. | | | | | | |

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| | ● CO5: For a given problem, logically clarify the impact of hidden layers in artificial neural networks (ANN) and also stepwise explicate the back propagation algorithm of ANN.<br>● CO6: For a given problem, describe a fuzzy knowledge base controller (FKBC) showing information and computational flow with membership function, rule base and defuzzification. |
| Topics Covered | Introduction to soft-computing techniques and its necessity.[2]<br>Fundamentals of genetic algorithm, Genetic algorithm, Encoding, Fitness function, Reproduction, Genetic modelling, Cross Over, Inversion and Deletion, Mutation operator, Bit-wise operators, examples. [10]<br>Basic Steps in Particle Swarm Optimization algorithm, Bird flocking & fish schooling, velocity, inertia weight factor, pbest solution, gbest solution, local optima, global optima, examples, new modifications of PSO, Parameter Selection in PSO. [10]<br>Fundamentals of Differential Evolution algorithm, difference vector and its significance, Mutation and crossover, comparisons among DE, PSO and GA, Examples, new modifications of DE, Improved DE schemes for noisy optimization problems. [10]<br>Fuzzy set theory, Fuzzy systems, crisp sets and fuzzy sets, fuzzy set operations and approximate reasoning, Fuzzification, inferencing and defuzzification, Fuzzy knowledge and rule bases, examples;[10]<br>Biological neural networks, Model of an artificial neuron, neural network architecture, Characteristics of neural network, learning methods, Taxonomy of neural network architecture, Back propagation networks, architecture of a back propagation network, back propagation learning, Examples, RBF network, Associative memory, Adaptive resonance theory;[10]<br>Applications of Soft Computing to various fields of engineering. [4] |
| Text Books, and/or reference material | Text Books:<br>1. Devendra K. Chaturvedi, “Soft Computing- techniques and its application in electrical engineering”, Springer, 2008.<br>2. Carlos A. Coello,Garry B. Lamont, David A. van Veldhuizen, “Evolutionary Algorithms for solving Multi-objective Problems”, Second Edition, Springer, 2007.<br>Reference Books:<br>1. Jyh-Shing Roger Jang, Chuen-Tsai Sun &EijiMizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, Prentice Hall<br>2. S. Rajasekaran and G. A. VijayalakshmiPai, Neural Networks, Fuzzy Logic and genetic Algorithm Synthesis and Applications, PHI<br>3. Simon Haykin, Neural Networks: A Comprehensive Foundation, Prentice Hall<br>4. L. A. Zadeh, Fuzzy Sets and Applications, John Wiley & Sons |

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| | | | Total Number of contact hours | Credit |

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
|---|---|---|---|---|---|---|---|
| **EE 9016** | MACHINE LEARNING & EXPERT SYSTEM | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites: NA | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| | | CT+EA | | | | | |

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| Course Outcomes | • CO1: Understand complexity of machine learning algorithms and their limitations<br>• CO2: Be capable of confidently applying common Machine Learning algorithms in practice and implementing their own<br>• CO3: Understand modern notions in data analysis oriented computing<br>• CO4: Be capable of performing experiments in machine learning using real-world data.<br>• CO5: Be capable of designing machine learning based expert system using real-world data. |
| Topics Covered | Introduction: Definition of learning systems, Goals and applications of machine learning, Aspects of developing a learning system [4]<br><br>Concept Learning and the General-to-specific Ordering: Concept learning. General-to-specific ordering of hypotheses. Finding maximally specific hypotheses. Version spaces and the candidate elimination algorithm. [4]<br><br>Decision Tree Learning: Concepts as decision trees. Recursive induction of decision trees. Picking the best splitting attribute: entropy and information gain. Searching for simple trees and computational complexity, Occam's razor, Over fitting, noisy data, and pruning. [4]<br><br>Bayesian Learning: Probability theory and Bayes rule, Naive Bayes learning algorithm. Parameter smoothing. Generative vs. discriminative training. Logisitic regression. Bayes nets and Markov nets for representing dependencies. [4]<br><br>Instance-Based Learning: Constructing explicit generalizations versus comparing to past specific examples. k-Nearest-neighbour algorithm. Case-based learning, Translating decision trees into rules, Heuristic rule induction using separate and conquer and information gain, First-order Horn-clause induction. [5]<br><br>Clustering and Unsupervised Learning: Learning from unclassified data. Clustering. Hierarchical Aglomerative Clustering. k-means partitional clustering. Expectation |

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| | maximization (EM) for soft clustering. Semi-supervised learning with EM using labeled and unlabled data. [3]<br><br>Artificial Neural Networks: Neurons and biological motivation, Linear threshold units. Perceptrons: representational limitation and gradient descent training, Multilayer networks and backpropagation. Hidden layers and constructing intermediate, distributed representations. Overfitting, learning network structure, recurrent networks. [3]<br><br>Support Vector Machines: Maximum margin linear separators. Quadractic programming solution to finding maximum margin separators. Kernels for learning non-linear [4]<br><br>Evaluation of Learning Algorithms: Measuring the accuracy of learned hypotheses. Comparing learning algorithms: cross-validation, learning curves, and statistical hypothesis testing. [3]<br><br>Introduction to Deep Learning: Convolutional neural networks (CNN) for image classification, CNN for object detection, Fully convolutional networks (FCN) for image segmentation. [4]<br><br>Expert System design: Face detection algorithm, Computer-aided diagnosis system [4] |
| Text Books, and/or reference material | Text Books:<br>1. Tom M. Mitchell, Machine Learning<br>2. Christopher Bishop, Pattern Recognition and Machine Learning. |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9033** | Advanced Sensors | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course assessment methods (continuous (CT) and end assessment (EA)) | | | | | |
| Basic understanding on measurement, measuring instruments, analog and digital electronics. | | CT+EA | | | | | |

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| Course Outcomes | • **CO1:** To understand the basics of sensors and actuators and their applications<br>• **CO2:** To learn about sensors for measuring motion, pressure, fluid flow and temperature.<br>• **CO3:** To learn about Biosensors, biopotential electrodes and Bio-Chemical Sensors<br>• **CO4:** To understand about the micro-sensors and their fabrication and applications.<br>• **CO5:** To learn about sensor instrumentation, signal acquisition and processing.<br>• **CO6:** Application of sensors in Power Plants |
| Topics Covered | **Introduction and Applications of Sensors:** Introduction sensors and transducers, various primary sensing elements, Active and Passive Transducers, Sensor parameters, Static Characteristics and Calibration, Dynamic Characteristics, Input-Output Configuration of Instruments and Measurement System, choice and economics of sensors, Sensors for different applications like mechanical, electrical, thermal, magnetic, optical, radiation, chemical and biological types. [6]<br>**Motion Measurement:** Introduction to motion sensors, Motion and dimensional measurement by Resistive Potentiometer, Strain gauge, LVDT, Piezoelectric transducers and Synchros, Measurement and translational and rotational velocity by tachometer and stroboscopic methods. [4]<br>**Measurement of pressure:** Introduction to pressure sensors, Measurement of pressure by using Diaphragm Gauges, McLeod Gauge and ionisation gauge, Measurement of Sound by Capacitive microphone [4]<br>**Flow sensors:** Introduction to flow measurement, Measurement of flow by electromagnetic flow meter, hot-wire anemometer, Doppler flow meter, water flow measurement, blood flow sensor, gas flow measurement. [4]<br>**Measurement of temperature:** Measurement of temperature by resistance thermometer, thermistor, Thermocouples and Pyrometers and junction semi-conductor sensors. [4]<br>**Bio-potential electrodes:** Introduction to physiological measurement, bio potentials electrodes, skin-electrode interface, equivalent circuit of electrode and electrode interface, electrode surface electrodes, needle electrodes, Electrocardiography (ECG) electrodes, Electroencephalography (EEG) electrodes, Electromyography (EMG) electrodes. [4]<br>**Biosensors and Bio-Chemical Sensors:** Introduction to biosensors, introduction to chemical sensors, pH-sensor, blood-glucose sensor, alcohol-sensor. [4]<br>**Micro-sensors:** Introduction to Microsystems, MEMS, Micro-fabrication, Micro pressure sensor, micro-accelerometer, micro-biosensors, nano-particle based sensing. [4]<br>**Sensor Instrumentation:** Manipulation, Transmission and acquisition of data: Bridge Circuits, OPAMP, Instrumentation amplifiers, Noise Problems and its remedy, Chopper stabilized amplifier, Charge Amplifier, Analog and digital filters, Amplitude, Phase and frequency modulation, spectrum analyzers, Cable |

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| | and fibre optic transmission of data, Data Acquisition system, virtual instruments Sensors and transducers applied in power plant. Optical sensors and ultrasonic sensors. [8] |
| Text Books, and/or reference material | Text Books<br>1. E.O. Doebelin, Measurement System: Application and Design, McGraw- Hill.<br>2. D. Patranabis, Sensors and Transducers, PHI.<br>3. Sensors and Actuators: Engineering System Instrumentation, Second Edition Hardcover – 10 August 2015, by Clarence W. de Silva (Author), CRC Press (10 August 2015)<br>Reference Books:<br>1. R.P. Areny and J.G. Webster, Sensors and Signal Conditioning, Wiley India<br>2. Ian Sinclair, Sensors and Transducers, Elsevier<br>3. Nadim Maluf, An Introduction to Micro Electro Mechanical System Design, Artech House, 2000.<br>4. Medical Instrumentation Application and Design, 4-Ed, by John G. Webster, Wiley (2015) |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9034** | Condition Monitoring and Intelligent Systems | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |
| Course Outcomes | • CO1: Fundamental knowledge of condition monitoring and its application.<br>• CO2: Able to know the basic parameters responsible for causing the failure of equipment in a system.<br>• CO3: Create the skills to find out the causes of failures and its prevention in rotating machines.<br>• CO4: Skilful knowledge to find out the causes of failures and its prevention of transformer and transformer oil. | | | | | | |

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| Topics Covered | **Introduction:** Overview of condition monitoring and the needs for reliable operation of equipment in a system, causes of failure, preventive maintenance concepts its economics and application [5]<br>**Physical parameters monitoring**<br>Electrical parameters of equipment's, Temperature measurement, Local and Hot-spot measurement with the concept of thermal image processing, Humidity and pressure measurement with advanced sensors. [6]<br>**Condition Monitoring of Rotating Electrical Machines:** Introduction to condition monitoring of rotating machines, Construction of electrical machines and their types operation, failure modes of electrical machines, Machine specification and failure modes. Overview of vibration monitoring, vibration transducers, transducers selection, machinery signature, analysis technique, measurement location, severity criteria, permanent monitoring, and rotating machinery signals. [15]<br>**Condition Monitoring of Transformer:**<br>Introduction of transformer monitoring and its aging, study of failure analysis for prediction of life of transformer.<br>Conventional tests: AC High voltage test, Impulse voltage test of transformers and transformer oil. Measurement of capacitance and tan delta of transformer oil and bushings, Dissolved gas analysis of transformer oil, Key Gas method, Gas Ratio Method and others, Partial Discharge measurements for transformer and transformer oil with different methods, PD Measuring circuits, calibration, signature analysis for prediction of failure of transformer. [14]<br>Failure prediction of transformers and rotating machines using Artificial Intelligence (AI) and Machine Learning (PM) techniques. Condition monitoring of bridge, large multi storey building [2] |
| Text Books, and/or reference material | **Text Books:**<br>1. Transformers by BHEL, Bhopal, Tata McGraw Hill<br>2. Introduction to Machinery Analysis and Monitoring/ John S. Mitchell/ Perm Well Books, Perm Well Publishing Company, Tulsa, Oklahoma,1993.<br>**Reference Books:**<br>1. R. A. Collacott, "Vibration monitoring and diagnosis", Wiley, 1979.<br>2. Rao J.S., "Vibratory Condition Monitoring of Machines", CRC Press, 2000.<br>3. Isermann R., Fault Diagnosis Applications, Springer-Verlag, Berlin, 2011. |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |
| EE 9036 | Robotics and Automation | PEL | 3 | 0 | 0 | 3 | 3 |

| Pre-requisites | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) |
|---|---|
| Control System Engineering in B Tech | CE+EA |
| Course Outcomes | • CO1: To understand the basic concepts of robotics<br>• CO2: To learn about the power sources, sensors, actuators etc. essential for robotics and automation technology<br>• CO3: To get the idea of programming languanges and techniques for path planning of robots<br>• CO4: To design and solve real life problems for control and automation related to robotics<br>• CO5: To get acquainted with industrial applications of robotic and automation systems<br>• CO6: To design optimal control algorithms for path planning and control of industrial robots |
| Topics Covered | BASIC CONCEPTS: Definition and origin of robotics – different types of robotics – various generations of, robots – degrees of freedom – Asimov's laws of robotics – dynamic stabilization of, robots. [4]<br>POWER SOURCES AND SENSORS: Hydraulic, pneumatic and electric drives – determination of HP of motor and gearing ratio – variable speed arrangements – path determination – micro machines in robotics –machine vision – ranging – laser – acoustic – magnetic, Fiber optic and tactile sensors. [6]<br>MANIPULATORS, ACTUATORS AND GRIPPERS: Construction of manipulators – manipulator dynamics and force control – electronic and pneumatic manipulator control circuits – end effectors – U various types of grippers –design considerations. [6]<br>KINEMATICS AND PATH PLANNING: Solution of inverse kinematics problem – multiple solution Jacobian work envelop – hill climbing techniques – robot programming languages [6]<br>CONTROL SYSTEMS: The manipulator Control problem, Linear control schemes, Linear model of a manipulator joint, Joint actuators, PID control scheme, Computed torque control, Force control strategies, Hybrid position/force control architecture, Impedance force/torque control, Adaptive Control. [6]<br>CASE STUDIES: Multiple robots – machine interface – robots in manufacturing and non- manufacturing applications – robot cell design – selection of robot. [6]<br>INDUSTRIAL APPLICATIONS OF VISION-CONTROLLED ROBOTIC SYSTEMS: Presence, Object location, Pick and place, Object identification, Visual inspection, Visual guidance [4]<br>ROBOT APPLICATIONS:<br>Industrial Applications, material handling, Processing applications, Assembly applications, Inspection application, Principles for Robot application and planning, Justification of Robots, Robot safety, Non-industrial applications [4] |
| Text Books, and/or reference material | Text Books:<br>1.L. Sciavicco and B. Siciliano, Modeling and Control of Robot Manipulators, Springer |

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| | 2. K. S. Fu, R. C. Gonzalez and C. S. G Lee, Robotics: Control, Sensing, Vision, and Intelligence, McGraw-Hill Inc.<br>3. Mikell P. Weiss G.M., Nagel R.N., Odraj N.G., Industrial Robotics, McGraw-Hill, Singapore, 1996.<br>Reference Books:<br>1.J. J. Craig, Introduction to Robotics, Mechanics and Control, Addison Wesley<br>2. R. J. Schilling, Fundamentals of Robotics Analysis and Control, Prentice Hall. |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |
| EE 9035 | Intelligent Control | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) | | | | | |
| Control System Engineering in B Tech | | CE+EA | | | | | |
| Course Outcomes | • CO1: Biological motivation to design intelligent systems and control<br>• CO2: To study of control-theoretic foundations such as stability and robustness in the frame work of intelligent control.<br>• CO3: To analyse learning systems in conjunction with feedback control systems<br>• CO4: To simulate intelligent control systems to evaluate the performance.<br>• CO5: To have an exposure to many real world control problems.<br>• CO6: To design and solve real life problems with intelligent control | | | | | | |
| Topics Covered | Introduction: A challenge to automatic control, Advance in intelligent control, What is intelligent control, Structural theories of intelligent control, Research and applications of intelligent control [2]<br>Biological foundations to intelligent systems I: Artificial neural networks, Back-propagation networks, Radial basis function networks, and recurrent networks. [8] | | | | | | |

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| | Biological foundations to intelligent systems II: Fuzzy logic, knowledge representation and inference mechanism, genetic algorithm, and fuzzy neural networks. [6]<br>Fuzzy and expert control (standard, Takagi-Sugeno, mathematical characterizations, design example), Parametric optimization of fuzzy logic controller using genetic algorithm. [6]<br>System identification using neural and fuzzy neural networks. [5]<br>Stability analysis: Lyapunov stability theory and Passivity Theory. [6]<br>Adaptive control using neural and fuzzy neural networks, Direct and Indirect adaptive control, and Self-tuning Pill Controllers. [4]<br>Applications to pH reactor control, flight control, robot manipulator dynamic control, underactuated systems such as inverted pendulum and inertia wheel pendulum control and visual motor coordination. [5] |
| Text Books, and/or reference material | Text Books:<br>(1) Large-Scale Systems: Modeling, Control and Fuzzy Logic, Author:Mo Jamshidi<br>(2) L. A. Zadeh, Fuzzy Sets and Applications, John Wiley & Sons<br>(3) Simon Haykin, Neural Networks: A Comprehensive Foundation, Prentice Hall<br>Reference Books:<br>(1) Jyh-Shing Roger Jang, Chuen-Tsai Sun & Eiji Mizutani, Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence, Prentice Hall<br>(2) S. Rajasekaran and G. A. Vijayalakshmi Pai, Neural Networks, Fuzzy Logic and genetic Algorithm Synthesis and Applications, PHI |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |
| **EE 1071** | Instrumentation Laboratory | PCR | 0 | 0 | 2 | 6 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) | | | | | |
| Signal and systems in B.Tech. | | CE+EA | | | | | |

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| Course Outcomes | • CO1: To understand uncertainty analysis of measurement results and to compare the results obtained from stroboscope and tachometer for measurement of angular speed<br>• CO2: To compare the results obtained from Strain gauge and LVDT for measurement of displacement<br>• CO3: To under the principle of operation of RTD, Thermistor and Thermocouples<br>• CO4:To understand the Arduino based voltage measurement and wireless data transmission technique.<br>• CO5: Design and implementation of liquid level and flow control system using Programmable Logic Controller (PLC) and SCADA<br>• CO6: Characterization of PV cell in series and parallel condition under different radiation level |
| Topics Covered | • **Exp-01:** Calibration of wattmeter by phantom loading and uncertainty analysis of results<br>• **Exp-02:** Measurement of reactive power by wattmeter and uncertainty analysis of results<br>• **Exp-03:** Measurement of displacement and speed by various electrical sensors<br>• **Exp-04:** Measurement of temperature by RTD, Thermistor and Thermocouples<br>• **Exp-05:** Realizing Analog Switching Circuits using CD4067BE CMOS MUX/DEMUX ICs<br>• **Exp-06:** Realizing Wireless Data Transmission Using 433MHz RF Transmitter-Receiver Module<br>• **Exp-07:** To make an Arduino Based Digital Voltmeter<br>• **Exp-08:** Design and implementation of liquid level control system using Programmable Logic Controller (PLC) and SCADA<br>• **Exp-09:** Design and implementation of flow control system using Programmable Logic Controller (PLC) and SCADA.<br>• **Exp-10:** Characterization of PV cell in series and parallel condition under different radiation level |
| Text Books, and/or reference material | **Text Books:**<br>1. Electrical Measurement by E.W. Golding- Wheeler Students' Edition<br>2. Electronic Instrumentation by H. S. Kalsi- McGraw Hill<br>3. Digital Electronics (Oxford Higher Education) Paperback – Illustrated, 11 March 2010, by G.K. Kharate (Author), Oxford (2010).<br>4. Arduino Projects for Engineers, Paperback, July 2016 by Neerparaj Rai (Author), BPB Publications (2016) |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |

| **EE 1072** | Biomedical Instrumentation Laboratory | PEL | 0 | 0 | 2 | 6 | 2 |
|---|---|---|---|---|---|---|---|
| Pre-requisites | | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) | | | | | |
| Signal and systems in B.Tech. | | CE+EA | | | | | |

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| Course Outcomes | • CO1: To understand the methods of ECG signal analysis<br>• CO2: To under the method of EOG signal analysis<br>• CO3: Feature extraction from ECG and EOG signals<br>• CO4: To understand the designing method of an ECG Amplifier Circuit<br>• CO5: To understand the designing method of an EEG Amplifier Circuit<br>• CO6: To understand the designing method of an A Data Acquisition System |
| Topics Covered | • **Exp-01:** Removal of periodic noise from ECG signal<br>• **Exp-02:** Detection of QRS complex from ECG signals<br>• **Exp-03:** Detection of premature ventricular contraction from ECG Signals<br>• **Exp-04:** Detection of eye fatigue from EOG Signals<br>• **Exp-05:** Designing and Development of an ECG Amplifier Circuit<br>• **Exp-06:** Realization of an EEG Amplifier Circuit<br>• **Exp-07:** Designing of A Data Acquisition System using NI Hardware |
| Text Books, and/or reference material | **Text Books:**<br>1. J. G. Proakis & D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall of India.<br>2. Medical Instrumentation Application and Design, 4-Ed, by John G. Webster, Wiley (2015)<br>3. LabVIEW for Everyone (National Instruments Virtual Instrumentation Series) Paperback – Import, 16 November 2001, Prentice Hall (2001) |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 2021 | Advanced Control System II | PCR | 3 | 1 | 0 | 4 | 4 |

| Pre-requisites | Course Assessment methods (Continuous (CT) and end assessment (EA)) |
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| ADVANCED CONTROL SYSTEM I EE1022 | CT+EA |

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| Course Outcomes | • CO1: To acquire the knowledge of sampled data system, the sampling and hold process, understand, investigate and analyze the stability of the discrete time systems<br>• CO2: To analyze the sample data system both in time and frequency domain<br>• CO3: To learn digital control for sample data systems<br>• CO4: To get the idea of state variable analysis for discrete-time systems<br>• CO5: To understand dynamic property and stability of nonlinear systems<br>• CO6: To design control system for nonlinear systems |
| Topics Covered | Introduction to Digital Control: Sample Data System, The sampling process, Discrete-time signals and their classifications, Representation of discrete-time signals as sequences, Sampling Process; Sampling Theorem; Aliasing Sampling of Continuous-time signals, Signal reconstruction, Discrete-time Systems and their classifications, Finite dimensional LTI systems [8]<br><br>Difference equations, z-transform theory, z-transfer functions (pulse transfer functions), inverse z-transform and response of linear discrete systems, z-transform analysis of sampled data control systems, z and s domain relationship [6]<br><br>Stability analysis in z-plane, Jury's stability criteria, Root Locus Analysis, Frequency Response of Sample data system, Bilinear Transformation, Bode diagram in w-plane [6]<br>Digital Controllers: Feedback Control, Classical Controller P, PI, PID, Lead and Lag [6]<br>State Space Representation of Discrete-time Systems: State model state models for linear discrete time systems, conversion of state variables models to transfer functions in z-domain, solutions of state equations, state transition matrix, state transition flow graphs, eigenvalues, eigenvectors and stability similarity transformation, decompositions of transfer functions, canonical state variable models, controllability and observability, state feedback and pole placement, Observer Design, MATLAB tools and case studies [10]<br>**Nonlinear Systems and Control:**<br>Fundamentals of Nonlinear systems, dynamics, concept of stability and equilibrium point, Jacobian matrix and stability, domain of convergence, Phase plane analysis<br>Steady state frequency response analysis, Describing function, Extended Nyquist criteria<br>Lypunov stability Criteria, Application of Lyapunov stability, Popov criteria, stabilization via state feedback, Feedback linearization [20] |
| Text Books, and/or reference material | Text Books:<br>1. Discrete Time Control Systems, K Ogata<br>2. Digital Control System, B. C. Kuo<br>3. Applied Nonlinear Control, Slotine and Li, Prentice-Hall 1991<br>Reference Books:e Variable Methods, M. Gopal |

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| | 2. Digital Control Of Dynamic Systems, G.Franklin, J.Powell, M.L. Workman.<br>3. Nonlinear System, H. K. Khalil |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9038** | INDUSTRIAL INSTRUMENTATION | PEL | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |
| Course Outcomes | ● CO1: Given specifications of different measuring instruments for measurement of particular parameter of some known electrical system, compare and judge to find the most suitable one.<br>● CO2: Given application of electrical engineering for measurement of particular parameter along with specified range and accuracy, choose most suitable measuring instrument with the understanding of individual working principles, also judge to fit the given application.<br>● CO3: For some specific parameter to be measured, along with the given range, resolution, accuracy and output format, choose suitable sensor, design associated signal conditioning and analog/digital processing circuit to meet the desired specification.<br>● CO4: Give multi-parameter control application of electrical engineering design a suitable instrumentation loop using PLC<br>● CO5: Integration of different components of Data Acquisition System with sensors/transducer for some complex electrical system such.<br>● CO6: Design of optical fiber based current sensor | | | | | | |
| Topics Covered | Measurement of Process Variables: Pressure, Flow, Temperature, Liquid Level, Strain, Force, Torque, Linear and angular displacement/speed etc.; [10]<br><br>Programmable Logic Controller (PLC): Introduction, Application, Physical and functional components, Timers, Counters, Shift Registers, Memory, Ladder Diagram, PLC Programming, Interfacing with sensors and actuators. Advance PLCs, analog input output, HMI, SCADA, Communication protocols, PID control through PLC; Data Acquisition Systems: Objective of a DAS, single channel DAS, Multi-channel DAS, Components used in DAS– Converter Characteristics-Resolution-Non-linearity, settling time, Monotonicity; [10] | | | | | | |

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| | Optical Fiber Based Instrumentation: General principles of optical fiber, brag grating fiber, amplitude modulating FO sensors, measurement of high current and voltage, temperature etc.; Power System Instrumentation: Measurement of Voltage, Current Frequency Phase and Transmission line Transients; [5]<br><br>Ultrasonic Instrumentation: Ultrasonic transmitter and receiver properties, propagation through medium and interfaces, application in Non-destructive Testing (NDT), measurement of process variables such as flow, level, thickness etc.; Partial discharge (PD) measurement and detection using ultrasonic sensor. [5]<br>Digital Measurement Techniques and instrumentations: Different Digital Instrumentation, Digital Measurement of Power Factor, Frequency and Time Period, Counters; [5]<br>Recorders and Data Loggers: General Description, Measuring Parts and Recording Means; [6]<br>Microprocessor Based Instruments: Embedded systems, Microprocessor/Microcontrollers, classification, different field of application, design of microcontroller based measuring instrument. [8]<br>Industrial Process Control, ON-OFF Control, P, PI and PID control of interacting and non-interacting process. [7] |
| Text Books, and/or reference material | **Text Books**<br>1. A. D. Helfrick and William David Cooper, Modern electronic instrumentation and measurement techniques, Prentice Hall<br>2. John-G. Webster (ed.), The Measurement, Instrumentation, and Sensors: Handbook, Springer<br>**Reference Books:**<br>1. Curtis D. Johnson, Process control instrumentation technology, Prentice Hall<br>2. Robert N. Thurston and Allan D. Pierce, Ultrasonic measurement methods, Academic Press<br>3. William Bolton, Programmable Logic Controllers, Newness<br>4. Stuart A. Boyer, Supervisory Control And Data Acquisition, International Society of Automation<br>5. T. V. Kenneth and B. T. Meggitt, Optical Fiber Sensor Technology, Springer. |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9037 | Distributed Energy Systems | PEL | 3 | 1 | 0 | 4 | 4 |

| Pre-requisites | Course Assessment methods (Continuous (CT), Mid Sem (MS) and end assessment (EA)) |
|---|---|
| (EE1011) Advanced Power Electronics – I<br>(EE2012) Machine Drives - II | CT+MS+EA |
| Course Outcomes | • CO1: To learn to summarize the energy conversions from renewable energy resources such as solar, wind, small hydro, biomass, tidal, geothermal.<br>• CO2: To learn to apply the solar energy systems/ bio-gas for practical use.<br>• CO3: To learn to determine a suitable turbine and an induction generator for generation of power from small hydro power plant.<br>• CO4: To learn to compare different power electronics converter topology and their controls for different types of renewable energy generations.<br>• CO5: To learn to recognize different generating systems and the associated mode of operations.<br>• CO6: To learn control of distributed generation systems |
| Topics Covered | Renewable Energy Basics (6)<br>Solar Energy (7)<br>Wind Energy (7)<br>Small-scale Hydro Electric Power Plants (7)<br>Energy from Biomass (7)<br>Other Renewable Energy Sources (7)<br>Renewable Energy Sources using Modern Power Electronics Technologies (8)<br>Control of Distributed Generation in Island Mode and Grid Connected situations (6) |
| Text Books, and/or reference material | Text Books:<br>1. G.D. Rai, Non-conventional energy resources, Khanna Publishers, New Delhi, 2003.<br>2. N. G. Clavert, Wind Power Principle, their application on small scale, Calvert Technical Press.<br>Reference Books:<br>1. Fuel Cell Handbook, Parsons Inc.<br>2. I. Earnest and T. Wizelius, Wind Power Plants and Projects development, PHI. |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |
| **EE 9021** | DIGITAL SIGNAL PROCESSING | PEL | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) | | | | | |

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| Signal and systems in B.Tech. | CE+EA |
| Course Outcomes | • CO1: To understand the properties of signals and systems.<br>• CO2: To understand the concept of signal processing.<br>• CO3: To analyze discrete time signals and systems in time as well as frequency domain.<br>• CO4: To design digital filters.<br>• CO5: To get acquainted with digital processors recently used. |
| Topics Covered | Discrete time signals and systems, properties, convolution, analysis of discrete time systems in time-domain [4]<br>Frequency domain representation of discrete time systems and signals, Gibbs phenomenon, band limited signals, sampling theorem aliasing sampling of continuous time signals [6]<br>Z- transforms, region of convergence, Z- transform theorems and properties, methods of Inverse Z-transforms, analysis of discrete time signals and systems in Z-domain, pole-zero plots, stability [4]<br>Realization of FIR Systems and IIR systems [4]<br>Discrete time Fourier transform of discrete time signals and systems, Inverse discrete time Fourier transform, Eigenfunction [6]<br>Discrete Fourier transform (DFT), properties of DFT, Linear convolution using DFT, Computation of DFT by FFT algorithms like decimation in frequency and decimation in time [10]<br>Various Filter design techniques for FIR and IIR filters [8]<br>Sampling rate conversion, up and down rate sampling, interpolation and decimation [6]<br>Introduction to discrete Hilbert Transform, [4]<br>Practical applications of DSP, DSP processors. [4] |
| Text Books, and/or reference material | **Text Books:**<br>5. Discrete Signal Processing by A.V. Oppenheim and R.W. Schafer (Prentice-Hall).<br>6. J. G. Proakis & D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms and Applications*, Prentice Hall of India.<br>**Reference Books:**<br>1. Digital Signal processing by Sanjit K. Mitra (Tata McGraw-Hill).<br>2. Theory and Application of Digital Signal Processing by L. R. Rabiner and B. Gold, Pearson Education, 2004 |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |

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| **EE 9039** | Micro-Electro-Mechanical Systems (MEMS) | PEL | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course assessment methods (continuous (CT) and end assessment (EA)) | | | | | |
| Basic understanding on engineering physics, engineering mathematics, electrical technology, analog and digital electronics. | | CT+EA | | | | | |

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| Course Outcomes | • **CO1:** Understanding the fundamentals of MEMS technology and its applications<br>• **CO2:** To study and learn the different aspects of Microfabrication Procedures.<br>• **CO3:** To learn about the Microfabrication Procedures.<br>• **CO4:** To study about the Microsensors and Microactuators and their application.<br>• **CO5:** Learn about the RF-MEMS and Bio-MEMS techniques and applications.<br>• **CO6:** To learn the modelling and computer simulation techniques for MEMS designs. |
| Topics Covered | 1. **Introduction to MEMS:** Introduction to MEMS technology, Why MEMS, Advantages, Applications, examples of MEMS devices, MEMS in Electronic Industries, VLSI Technology for fabrication of integrated circuitschips. **(4L).**<br>2. **Fundamentals of Microfabrication Procedures:** Introduction to Thin Film Technology, Clean rooms, Surface Micromachining, MEMS fabrications process flow (Deposition, Lithography and Etching), MEMS fabrication instruments, MEMS fabrication bench, Micromachining, Surface Modelling. **(10L).**<br>3. **Thin Film Deposition Techniques:** Substrate Materials, Silicon Wafer, Metal Polymer, Plastic substrate, Thin Film Deposition Process, Physical Deposition process, Chemical Vapour Deposition, Sputtering, Electrodeposition, Electroplating, Oxidation. **(8L).**<br>4. **Fundamentals of Lithography:** Introduction to Thin Film Technology, Different Lithography Technique, Mask and Mask Material, Photoresists, Positive Photoresists, Negative Photoresists, Lift-off, LIGA. **(6L).**<br>5. **Etching Procedures:** Need for etching process, different etching techniques, wet etching, dry etching, etching materials, Chemical Etching, Plasma Etching, precautions. **(6L).**<br>6. **Microsensors and Microactuators:** Accelerometers, Gyroscopes, Angle-Sensors, Pressure Sensor, Microphones and MEMS sensors. **(4L).** |

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| | 7. **Introduction to BioMEMS:** MEMS technology in biomedical applications, Microelectrodes for Biomedical Engineering, Introduction to Microfluidics and its Applications. **(4L).**<br>8. **RF MEMS:** MEMS for telecommunications (RF MEMS), RF MEMS Components, RF-MEMS applications, Recent RF MEMS development, RF MEMS Limitations, RF MEMS Challenges. **(4L).**<br>9. **Computational Modeling of MEMS and MEMS Devices:** Overview of MEMS-CAD software; followed by tour of MEMS Design Centre, COMSOL, IntelliSuite. **(6L).**<br>10. **Recent Development in Microtechnology:** Introduction to Nanotechnology, Carbon Nanotube, Graphene, CNT Sensors Graphene Sensors. **(4L)** |
| Text Books, and/or Reference Material | **Text Books:**<br>An Introduction to Microelectromechanical Systems Engineering: Nadim Maluf, Artech House, 2000<br>Microsystem Technology: Wolfgang Menz, Jürgen Mohr, Oliver Paul, John Wiley & Sons, 2008.<br>**Reference Books:**<br>An Introduction to Microelectromechanical Systems Engineering: Nadim Maluf, Kirt Williams, Artech House, 2004.<br>Fundamentals of Microfabrication: The Science of Miniaturization, Marc J. Madou, CRC Press; 2nd Ed. 2002.<br>MEMS: A Practical Guide to Design, Analysis, and Applications: Jan Korvink Oliver Paul, William Andrew; 1 edition (November 14, 2005) |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9040** | Nondestructive Testing (NDT) | PEL | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course assessment methods (continuous (CT) and end assessment (EA)) | | | | | |
| Basic understanding on engineering physics, engineering mathematics, electrical technology, analog and digital electronics. | | CT+EA | | | | | |

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| Course Outcomes | • **CO1:** To understanding the fundamentals of NDT and its applications.<br>• **CO2:** To study the X-Ray based NDT.<br>• **CO3:** To learn about the NDT based on Ultrasound.<br>• **CO4:** To understand the Eddy Current based NDT.<br>• **CO5:** To study the NDT procedures with Infrared thermography (IRT).<br>• **CO6:** To learn about the Ground Penetrating Radar (GPR) based NDT.<br>• **CO7:** To study the other NDT techniques such as Vibration Analysis, Magnetic Particle Testing, Liquid Penetrant Testing, Leak and pressure testing.<br>• **CO8:** To understanding the NDT for Electrical Engineering Materials. |
| Topics Covered | **Introduction to material characterization:** Introduction to materials, material structure and properties, material characterization, material testing, destructive testing, nondestructive testing, structural health monitoring, offline monitoring, online monitoring. **(4L).**<br>**Introduction to Nondestructive Testing (NDT):** Introduction to NDT, destructive testing, Comparison between destructive testing and nondestructive testing, structural health monitoring (SHM), NDT for material characterization, online monitoring, off-line monitoring, advantages of NDT, Applications of NDT. **(6L).**<br>**NDT with X-Rays:** Introduction to X-Rays, X-Ray tube, X-Ray generation, X-ray films and screens, X-Ray dosage, X-Ray attenuations, X-Ray planner radiography, Radiography instrumentation, X-ray safety, advantages and limitations, introduction to X-ray computed tomography, CT instrumentation, image reconstruction and image quality, CT procedure and precautions, industrial applications, advantages and limitations. **(8L).**<br>**Ultrasound and Acoustic Emission Testing (AE):** Principles of sound, principle of ultrasound, ultrasound for NDT, Piezoelectric Material, ultrasound transducers, types of transducers/probe, ultrasound equipment ultrasound beam and beam forming, ultrasound focusing, ultrasound penetration depth, A, B and C scan procedures with ultrasounds, applications, advantage, limitations **(6L).**<br>**Electromagnetic and Eddy Current Techniques:** introduction to electromagnetics, magnetic fields, magnetic materials, Eddy current, Eddy currents generation, Eddy current based NDT, Eddy currents instruments, Eddy currents techniques in industry, sensitivity, applications, advantages and limitations of Eddy current based NDTs. **(6L).**<br>**Infrared thermography (IRT):** Infrared radiation (IR), applications of Infrared, thermography, IR thermography, IR thermography as NDT, applications, limitations, IDNDT for industrial applications. **(6L).**<br>**Ground Penetrating Radar (GPR):** Introduction to GPR, GPR instrumentation, application of GPR, GPR testing procedures, advantages and limitations, GPR data interpretation. **(4L).**<br>**Other NDT Techniques:** |

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| | ***Vibration Analysis (VA):*** vibration, vibration of materials, source of vibrations, vibration testing instruments, vibration sensors, applications of vibration testing, advantages, limitations. **(3L).**<br>***Magnetic Particle Testing (MPT):*** Basic principles of MPT, steps of MPT, MPT equipment and instrumentation, MPT procedure, Magnetic Particle Testing: Important terminologies related to magnetic properties of material, principle, magnetizing technique, procedure, equipment, fluorescent MPT method, sensitivity, application and limitations. **(3L)**<br>***Liquid Penetrant Methods (LPM):*** introduction to dye penetrant testing/ liquid penetrant testing, Basic procedure of LPM, Mechanics of LPM, Types of penetrants, characteristics of penetrant, penetrant testing materials, removers and developers, fluorescent penetrant testing method– sensitivity, application and limitations. **(3L)**<br>***Leak and pressure testing (LPT):*** Definition of leak and types, Principle, Various methods of pressure and leak testing, Advantages of pressure and leak testing, Application and limitation. **(3L)**<br>**NDT for Electrical Engineering Materials:** Introduction to electrical engineering materials, NDT for engineering materials, testing of transformer oil, testing of electrical insulators, testing of electrical conductors. **(4L)** |
| Text Books, and/or Reference Material | **Text Books:**<br>1. Non-Destructive Test and Evaluation of Materials Hardcover – 1 July 2017, by J Prasad (Author), C. G. Krishnadas Nair (Author), McGraw Hill Education (1 July 2017).<br>2. Introduction to Nondestructive Testing: A Training Guide, 2nd Edition by Paul E. Mix, Wiley-Interscience (3 June 2005).<br><br>**Reference Books:**<br>1. Practical Non-Destructive Testing, Paperback – 1 January 2009, by Baldev Raj (Author), Narosa (1 January 2009)<br>2. Nondestructive Testing Handbook: Acoustic Emission Testing: 5 Hardcover – Import, 1987, by Ronnie K. Miller (Editor), Paul McIntire (Editor) |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9018** | EMBEDDED SYSTEMS | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |

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| Course Outcomes | • CO1: Comparing different microprocessor architectures and justifying their field of application.<br>• CO2: Given peripheral devices such as memory, ADC, DIOs, etc., design of interfacing circuit, and writing algorithms to fulfil a given specific application.<br>• CO3: Programming processor specific and processor independent software for different complex embedded system applications.<br>• CO4: Developing hardware and software for a given applications.<br>• CO5: Knowledge of advanced microcontrollers and RTOS features and their field of applications.<br>• CO6: Given single task application design a microprocessor based system. |
| Topics Covered | Introduction to Embedded systems:<br>Introduction – Features – Microprocessors – ALU - Von Neumann and Harvard Architecture, Classification, SPP, ASIC, ASIP [3]<br>CISC and RISC - Instruction pipelining. Fixed point and Floating point processor [2]<br>General characteristics of embedded system, introduction to different components etc[5]<br>Microcontroller 89CX51/52 Series: Characteristics and Features, Overview of architectures, and Peripherals, Timers, Counters, Serial communication, Digital I/O Ports[5]<br>Microcontroller PIC Series: Characteristics and Features, Overview of architectures, and Peripherals, Interrupts, Timers, watch-dog timer, I/O port Expansion, analog-to-digital converter, UART, I2C and SPI Bus for Peripheral Chips, Accessories and special features. [5]<br>ARM Architecture: Evolution, Characteristics and Features, Overview of architectures, Modes, Registers etc [5]<br>Digital Signal Processor [5]<br>Software architecture and RTOS:<br>Software Architecture: Round Robin- Round Robin with interrupts -Function Queue. Scheduling<br>Architecture RTOS: Architecture -Tasks and Task States -Tasks and Data - Semaphores and Shared Data Message Queues -Mail Boxes and pipes -Timer Functions -Events -Memory Management, Interrupt Routines. [6]<br><br>Basic design using a real time operating system:<br>Overview. General principles. Design of an embedded system.<br>Development Tool: Cross-Compiler, Cross-Assemblers, Linker/locator. PROM Programmers, ROM, Emulator, In-Circuit Emulators. Debugging Techniques. Instruction set simulators. The assert macro. [6] |
| Text Books, and/or reference material | **Text Books:**<br>1. Douglas V. Hall, *Microprocessors & Interfacing*, Tata McGraw-Hill<br>2. M. Predko, *Programming & Customising 8051 Microcontroller*, TMH |

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| | **Reference Books:**<br>1. John Uffenbeck, *Microcomputers and Microprocessors*, Pearson Education<br>2. Michel Slater, *Microprocessor Based Design*, PHI |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9019 | FACTS DEVICES | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| EEC401(POWERSYSTEMS-I)EEC501(POWER SYSTEMS– II) EEC503(POWER ELECTRONICS) | | CT+EA | | | | | |

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| Course Outcomes | • CO1: Understand the concept of FACTS devices as a whole.<br>• CO2: Acquire knowledge about different applications of FACTS devices in power system<br>• CO3:Acquire an idea about modelling of various FACTS devices and their interaction in power system.<br>• CO4: Understand how FACTS devices improve various power system performances like power flow control, stability etc. |
| Topics Covered | FACTS concept and General System of Considerations.[2]<br>Checklist of possible benefits from FACTS technology.[1]<br>Lumped/Distributed model analysis for Series and Shunt compensation.[5]<br>Methods of Controllable Var Generation:Variable Impedance Type Static Var Generators, lumped/distributed model analysis, TCR, TSR, TSC, FC-TCR.[8]<br>Switching Converter Type Var Generators, STATCOM, basicconcepts,lumped/distributed model analysis, basic converter configurations.[8]<br>Static Series Compensators:Basic principles of operation of TSSC, TCSC, SSSC, lumped/distributed model analysis Applications. [8] Static Voltage and Phase angle regulators: TCVR and TCPAR, lumped/distributed modelanalysis, Applications.[7]<br>Combined Compensators: Unified Power Flow Controller (UPFC), basic operating principles, conventional transmission control capabilities. Functional control of shunt converter and series converter, basic control systems for P and Q control, lumped/distributed model analysis.[11] |

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| | Introduction to steady state analysis and control, oscillation stability analysis and control by UPFC. Transient stability control by CSC, SSSC, SVC, STATCOM and UPFC. [8] |
| Text Books, and/or reference material | Text Books:<br>1. Y.H. Song and A.T. Johns," Flexible AC Transmission Systems (FACTS), IET Power and Energy Series, Shankar's Book Agency Publisher (Indian Edition).<br>2. K.R. Padyyar," FACTS Controller in Power Transmission and Distribution",<br>Reference Books:<br>1. Mey Ling Sen, Kalyan K. Sen," Introduction To FACTS Controllers – Theory, Modeling And Applications, Wiley (IEEE) Publisher.<br>2. N.G. Hingorani& L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems". |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9022 | ESTIMATION OF SIGNALS AND SYSTEMS | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) | | | | | |
| Advanced Control SYSTEM I | | CE+EA | | | | | |
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| Course Outcomes | CO1: | To develop insight on well known techniques for parameter estimation and identification of unknown parameters using these estimation methods for linear as well as nonlinear systems | | | | | |
| | CO2: | Familiarization with Random variables , Stochastic Processes and Probabilistic state space models, categorization of noise, Investigation of controllability and observability of linear as well as nonlinear systems | | | | | |
| | CO3: | To develop concept on Bayesian filtering, derivation of Kalman filter as a special case of Bayesian filter, familiarization with the properties of Kalman filters and its variants, ability to design and tuning Kalman filter | | | | | |
| | CO4: | To augment the concept of Kalman filtering for nonlinear dynamic systems, to appreciate Linearized Kalman filter and Extended Kalman filter as the nonlinear version of Kalman filter | | | | | |

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| | CO5: | Understanding the general framework of Gaussian filter as a special case of Bayesian filter and deriving the variants of sigma point filters and Quadrature filter from the framework |
| | CO6: | To develop knowledge on Maximum likelihood estimation and its application for state and parameter estimation for dynamic system, Derivation of Cramer-Rao lower bound to investigate the accuracy aspects of the estimators. |
| Lecture# | Topics | Details |
| 6 | Parameter Estimation | Least Squares Estimation, The Recursive Least-Squares Algorithm, Initial Conditions and Properties of RLS, Estimation of Time-varying Parameters, Multi-Output, Weighted Least Squares Estimation, Generalized least squares, A probabilistic version of the LS, Nonlinear least squares, Equation error method, Application of these methods |
| 6 | Introduction to Linear Systems and Probability theory | Matrix algebra and matrix calculus, Stability, Controllability and observability for linear and nonlinear systems, Disceretization, The Gauss -Markov Discrete-time Model, Random variables, Transformations of random variables, Multiple random variables, Stochastic Processes and Probabilistic state space models, White noise and colored noise |
| 4 | Bayesian Filtering and introduction to Kalman filter | Origins of Bayesian filtering, Optimal filtering as Bayesian inference, Algorithms for Bayesian filtering and smoothing, Bayesian filtering equations and exact solutions, Framework of the Kalman Filter, The Discrete Kalman Filter as a Linear Optimal Filter |
| 3 | Properties of Kalman filters | Minimum Variance and Linear Minimum, Variance Estimation; Orthogonality and Projection, The Innovations Sequence, True Filtered Estimates and the Signal-to –Noise Ratio Improvement Property, Inverse Problems: |
| 8 | Variants of Kalman Filter | Information filtering, Square root filtering, Correlated process and measurement noise, Colored process and measurement noise, Steady-state filtering, Adaptive Kalman filters, Gaussian Sum filters |
| 3 | Introduction to Nonlinear Kalman filtering | The linearized Kalman filter, The extended Kalman filter, Higher-order approaches |
| 6 | General Gaussian filtering | Unscented transformations, Unscented Kalman filtering, Quadrature rules for Gaussian Integral Approximations, Gauss Hermite filters, Cubature filters, Cubature Quadrature filters, |
| 6 | Output error method of Estimation | Principle of maximum likelihood, Cramer-Rao lower bound, Maximum likelihood estimation for dynamic system, Accuracy aspects, Output error method |
| Text Book | Modelling and Parameter Estimation of Dynamic Systems by J.R. Raol, G. Girija and J. Singh, Institution of Engineering and Technology, London, United Kingdom<br>Optimal State Estimation: Kalman, H∞ and Nonlinear Approaches by Dan Simon, | |

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| Reference Books | Introduction to Random Signals and Applied Kalman Filtering by Robert Grover Brown & Patrick Y. C. Hwang, John Wiley & Sons<br>Bayesian Filtering and Smoothing by Simo Sarkka, Cambridge University Press |

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|---|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9028 | POWER SYSTEM CONTROL AND INSTRUMENTATION | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| EE1002 (Power System Operation) | | CT+EA | | | | | |
| Course Outcomes | CO1: For a given power system, apply load frequency control with tuning of Controller parameters for the better stability<br>CO2: For a given network, control both active and reactive power flow with UPFC for smart grid application.<br>CO3: For a given power test system, optimally place PMUs optimally for full observability with contingency.<br>CO4: Given application and data, evaluate to find suitable measurement system using statistical analysis tool.<br>CO5: Given condition of some power system utility, design a suitable PLC based system for control and operation including the programming of PLC.<br>CO6: Application of knowledge; in contemporary issues of advanced Instrumentation applied for monitoring and control of power system. | | | | | | |
| Topics Covered | Overview of Power System, Optimal Power Flow, Power System Stability, Conventional Control Scheme for Power System; [4]<br>Automatic Generation Control: Automatic Voltage Regulator (AVR), Load Frequency Control (LFC) with tuning of Controller parameters; [7]<br>Phasor Measurement Unit (PMU): Overview of Synchrophasor, PMU architecture,PMU Applications; [6]<br>Smart Grid (SG): SG concept, Impact of SG for power system control & Measurement, Systems & Functions of SG [6]<br>Measurement, Errors, Statistical Analysis of Errors [4]<br>Sensors and Transducers, Signal Conditioning Circuit, Converters, Optical Insulator, Instrument transformers. [8]<br>Supervisory control and data acquisition system: Functional blocks, Software and Hardware features, operation, PLCs and DCS; [7] | | | | | | |

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| Text Books, and/or reference material | Text Books:<br>1. S. Sivanagaraju & G. Sreenivasan, "Power System operation and Control", Pearson 2010.<br>2. Ernest O. Doebelin, Measurement system, Tata McGraw-Hill Education<br>3. Stuart A., Supervisory Control and Data Acquisition, Boyer International Society of Automation<br><br>Reference Books:<br>1. Surya Santoso, Mark F. McGranaghan, Roger C. Dugan, H. Wayne Beaty, Electrical Power Systems Quality, Access Engineering.<br>2. Andres Carvallo, John Cooper, "The Advanced Smart Grid: Edge Power Driving Sustainability", Artech House, Boston London, 2011. |

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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9023 | PROCESS INSTRUMENTATION AND CONTROL | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |
| Course Outcomes | • CO1: Given an application for measurement of liquid flow, choose suitable sensor and also justify the selection.<br>• CO2: Given an application for measurement of temperature, choose suitable sensor and also justify the selection..<br>• CO3: Given single-parameter control application of an industrial process design suitable instrumentation loop using PLC<br>• CO4: Integration of different given elements of a process for control application.<br>• CO5: Compare different actuators for a given process control application.<br>• CO6: Given application design of a PID control system. | | | | | | |

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| Topics Covered | Review of measurement principles, statistical analysis of measurement errors and error analysis. [4]<br>Measurement of Flow; Orifice, venturi, pitot tube, rotameter, ultrasonic flow meter, electromagnetic flow meter, mass flow meter, etc. [4]<br>Measurement of temperature, RTD, Thermistor, Thermocouple, Semiconductor type temperature sensor, IR sensor etc. [3]<br>Measurement of liquid level; float, capacitive, ultrasonic, radar gauge etc. [4]<br>Pressure measurement, Differential pressure, starin, force, displacement. [5]<br>Measurement of Torque, Linear and angular displacement/speed etc.; [4]<br>Actuators and Finalcontrol elements, Valves, Electrical, pneumatic, and hydraulic [4]<br>Programmable Logic Controller (PLC), Distributed Control System [4]<br>Process signal transmission, [3]<br>Process Control; ON-OFF Control, PID Control, of interactive and non-interactive systems. [7] |
| Text Books, and/or reference material | Text Books<br>1. A. D. Helfrick and William David Cooper, Modern electronic instrumentation and measurement techniques, Prentice Hall<br>2. John-G. Webster (ed.), The Measurement, Instrumentation, and Sensors: Handbook, Springer<br>Reference Books:<br>1. Curtis D. Johnson, Process control instrumentation technology, Prentice Hall<br>2. Robert N. Thurston and Allan D. Pierce, Ultrasonic measurement methods, Academic Press<br>3. William Bolton, Programmable Logic Controllers, Newness<br>4. Stuart A. Boyer, Supervisory Control And Data Acquisition, International Society of Automation<br>5. T. V. Kenneth and B. T. Meggitt, Optical Fiber Sensor Technology, Springer. |

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|---|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| EE 9041 | ROBUST & OPTIMAL CONTROL | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous evaluation (CE) and end assessment (EA)) | | | | | |
| Advanced Control Theory I | | CE+EA | | | | | |

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| Course Outcomes | CO1: | To develop concepts of model uncertainty, structured and unstructured uncertainty, analyze the stability, computation of gain margins and phase margins |
| | CO2: | To acquire knowledge on Linear Fractional Transformation, structured robust stability assessment based on LFT, to have an exposure to μ synthesis |
| | CO3: | Familiarization with H2 control problem, stability assessment of H2 controllers |
| | CO4: | Problem formulation and control law design based on H∞ Control |
| | CO5: | To learn standard optimization approaches for obtaining optimal solution of control problems |
| | CO6: | To develop concept on Dynamic programming and the computation procedures |

| Lecture# | Topics | Details |
|---|---|---|
| 8 | Model uncertainty and Robustness | Model uncertainty, Small Gain theorem, Stability under stable unstructured uncertainties, unstructured robust performance, gain margins and phase margins |
| 8 | Linear Fractional Transformation | Linear Fractional Transformation, Structured singular value, structured robust stability and performance, Overview on μ synthesis |
| 8 | $H_2$ Optimal Control | Extended LQR problem, Standard $H_2$ problem, Separation theory, Stability margin of $H_2$ controllers |
| 6 | $H_\infty$ Control | Problem formulation, Output feedback $H_\infty$ Control, Full information control, Full control disturbance feedforward, Output estimation, Separation theory, Controller interpretation, Optimal controller |
| 8 | Optimization | Linear programming and simplex method, Weierstrass' theorem, Karush Kuhn Tucker optimality conditions, algorithms, convergence, unconstrained optimization, Line search methods, method of multidimensional search, steepest descent methods, Newton's method, modifications to Newton's method |

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| 4 | Dynamic Programming | The optimal control law, The principle of optimality, Dynamic programming concept, Recurrence relation, computational procedure, The Hamilton-Jacobi Bellman equations. |
| Text Book | John C. Doyle, Bruce A. Francis, Allen R. Tannenbaum, Feedback Control Theory, Macmillan Publishing Co., 1990<br>D.E.Kirk, Optimal Control Theory- An Introduction, Dover Publications, New York, 2004<br>Green M., Limebeer D.J.N., Linear Robust Control, Pearson Education | |
| Referenc e Books | K. Zhou, J. C. Doyle, K. Glover, Robust and Optimal Control, Prentice Hall Inc., Upper Saddle River, NJ, 1995<br>B. D. O. Anderson and J. B. Moore, Optimal Control: Linear Quadratic Methods, Prentice Hall, 1995 | |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9042** | Medical Imaging Systems | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course assessment methods (continuous (CT) and end assessment (EA)) | | | | | |
| Basic understanding on engineering physics, engineering mathematics, electrical technology, analog and digital electronics. | | CT+EA | | | | | |
| Course Outcomes | • **CO1:** Understanding the fundamentals of medical imaging techniques<br>• **CO2:** To study and learn the X-Ray radiography and X-Ray tomography.<br>• **CO3:** To study about the Magnetic Resonance Imaging (MRI) procedures.<br>• **CO4:** Learn about the ultrasound imaging methods.<br>• **CO5:** To learn the nuclear medicine procedures and instrumentations.<br>• **CO6:** To learn about the modern trends on medical imaging procedures. | | | | | | |
| Topics Covered | 1. **Introduction to Medical Imaging:** Introduction to Human Anatomy and Physiology, Human Body parts and Organs and Their functions, Human Health and Disease, Medical Diagnostic Tools and Technologies, Introduction to medical Imaging Techniques, Different Medical Imaging Modalities. **(8L).**<br>2. **Fundamentals of X-Ray radiography:** Introduction to X-Rays, X-Ray tube, X-Ray generation procedure, X-Ray Radiography instrumentation, | | | | | | |

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| | X-Ray dosage, X-Ray attenuations, introduction to X-Ray planner radiography, advantages and limitations. **(5L).**<br>3. **X-Ray Computed Tomography:** Introduction to computed tomography, radiography versus tomography, introduction to X-Ray tomography, CT instrumentation, CT instrumentation, CT Clinic, CT Image Reconstruction, Fourier Slice Theorem, Radon Transform, CT Reconstruction Algorithm, CT procedure and precautions, advantages and limitations **(8L).**<br>4. **Magnetic Resonance Imaging (MRI):** Introduction to MRI, Physics or magnetic resonance, MRI instrumentation, MRI Clinic, MRI procedure and precautions, MRI versus CT, advantages and limitations, risk factors in MRI, introduction to functional MRI (fMRI), Magnetic resonance spectroscopy (MRS). **(6L).**<br>5. **Ultrasound imaging methods:** Introduction to ultrasonography (USG), Physics of ultrasound, piezoelectric materials, ultrasound generation, ultrasonography instrumentation, USG procedure and precautions, Doppler effect, Doppler imaging, colour Doppler advantages and limitations. **(6L).**<br>6. **Nuclear medicine procedures:** Introduction to nuclear medicine, radioisotopes, gamma camera, scintillation camera, Emission Computed Tomography (ECT), positron emission tomography (PET), Single Photon Emission Computed Tomography (SPECT), SPECT Classifications, Proton Annihilation, advantages and limitations . **(6L).**<br>7. **Recent Development in Medical Imaging:** Thermal Imaging, Electrical Tomography, Optical Tomography, multimodal imaging. **(3L)** |
| Text Books, and/or Reference Material | **Text Books**<br>1. Handbook of Biomedical Instrumentation - R.S. Khandpur, TMG<br>2. Medical Imaging Signals and Systems, 1e, by Prince and Links, 2008, Pearson Education (2008)<br>**Reference Books:**<br>1. Medical Instrumentation Application and Design, 4-Ed, by John G. Webster, Wiley (2015)<br>2. The Essential Physics of Medical Imaging Hardcover, by Jerrold T. Bushberg (Author), J.Anthony Seibert (Author), Edwin M. Leidholdt (Author), John M. Boone (Author), 2011, Lippincott Williams and Wilkins (2011)<br>3. Handbook of Medical Imaging, Volume 1. Physics and Psychophysics (Press Monographs) Paperback, 2000 by Richard L. Van Metter (Author), Jacob Beutel (Author), SPIE Press (2000)<br>4. Principles of Medical Imaging Kindle Edition, by K. Kirk Shung (Author), Michael Smith (Author), Benjamin M. W. Tsui (Author), Academic Press (2 December 2012) |

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|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 9013** | IMAGE UNDERSTANDING | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites: NA | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| | | CT+EA | | | | | |
| Course Outcomes | • CO1: Good understanding of several image enhancement techniques and their application to solve real life problem<br>• CO2: Sufficient expertise in both theory and application of several image processing tasks such as image restoration, image compression, and image segmentation.<br>• CO3: Expertise of several techniques for analysis of images<br>• CO4: Understanding the methods of feature extraction and pattern classification.<br>• CO5: Develop basic problem solving skills as they apply to different situations as an engineer | | | | | | |
| Topics Covered | **Introduction:** Image digitization, Pixel relationship, Distance transformation, Image transformation viz. 2-D DFT, 2-D discrete cosine transform (DCT) [5]<br>**Image Enhancement:** Point and algebraic operations, edge detection and sharpening, Filtering in the spatial domain, Histogram equalization, Histogram specification, Sharpening filters and gradient operators, Introduction to frequency domain filtering using Fourier Transform; Basics of 2D Fourier Transform, Butterworth and Gaussian filters. [7]<br>**Image Restoration**: Degradation models, Mean Filters, Order Statistics, Adaptive filters, Band reject Filters, Band pass Filters, Notch Filters, Optimum Notch Filtering, Inverse Filtering, Wiener filtering. [5]<br>**Color Image Processing:** Color image fundamentals - RGB, HSI and CMY models [5]<br>**Image Segmentation:** Contour and shape dependent feature extraction, textural features, region-based and feature-based segmentation and level set method [6]<br>**Features for Recognition:** Binary Image Analysis, Pattern Recognition Concepts, Shape based feature extraction, Texture based feature extraction, Content-Based Image Retrieval, features for image recognition [12] | | | | | | |

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| Text Books, and/or reference material | Text Books:<br>1. Digital Image Processing by Rafael C Gonzalez & Richard E Woods<br>2. Fundamentals of Digital Image Processing by Anil K Jain<br>3. Digital Image Processing by William K Pratt |

<table>
<tr><td colspan="9">Department of Electrical Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>EE 2071</td><td>Advanced Control System Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous evaluation (CE) and end assessment (EA))</td></tr>
<tr><td colspan="3">ADAVANCED CONTROL SYSTEM I XXEE10YY</td><td colspan="5">CE+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To understand the dynamic behaviour of real-time nonlinear systems.<br>• CO2: To simulate physical systems in real-time environment.<br>• CO3: To design feedback controllers to improve the performance characteristics of real-time systems.<br>• CO4: To determine the parameters and transfer function of physical systems from real-time experimentation.<br>• CO5: To get acquainted with MATLAB programming, MATLAB-SIMULINK in order to simulate, analyze and design of control system design for different plants under consideration<br>• CO6: To apply and verify modern and advanced control algorithms for real-time systems</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Hardware experiments: 8 working days<br>Design and Real-time implementation of PID, LSVF & LQR controllers for<br>1. Digital Cart-inverted pendulum system<br>2. Digital Twin rotor MIMO system<br>3. Digital Magnetic levitation (MAGLAV) system<br>4. Digital Servo system<br>Software Experiments: 7 working days<br>1. Design of a suitable controller for a given time delayed unity negative feedback closed loop system using root locus technique.</td></tr>
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| | 2. Design of lead, lag, lead-lag controller for a given unity negative feedback closed loop system using frequency domain design methods.<br>3. Design of linear quadratic optimal controller for a given continuous-time LTI plant.<br>4. Design of optimal state feedback controller for LTI plant where some of the states are not measurable.<br>5. Design of Kalman estimator when the sensors give noisy measurement for problem 3.<br>6. Design of H∝ full information controller for a given LTI plant.<br>7. Design of digital controller using frequency domain design technique for a unity negative feedback closed loop system with a given continuous-time plant |
| Text Books, and/or reference material | Text Books:<br>1. Modern Control Engineering, K. Ogata,<br>2. Modern Control System Theory, M. Gopal,<br>4. Discrete Time Control Systems, K Ogata<br>5. Digital Control System, B. C. Kuo<br>6. Kalman Filtering Theory and Practice, Mahinder S. Grewal and Angus P Andrews<br>Reference Books:<br>1. Linear Control System Analysis And Design With MATLAB,John J. D'Azzo and Constantine H. Houpis and Stuart N. Sheldon<br>2. Linear Robust Control, Michael Green and David J.N. Limebeer |

| Department of Electrical Engineering | | | | | | | |
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| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **EE 2072** | Intelligent System Laboratory | PCR | 0 | 0 | 2 | 6 | 2 |
| Pre-requisites: NA | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| | | CT+EA | | | | | |
| Course Outcomes | • CO1: Able to implement several image processing algorithms.<br>• CO2: To understand the designing method of bandpass filter using OpAmps.<br>• CO3: To understand the arbitrary signal simulation and processing.<br>• CO4: To understand the based data acquisition with NI Hardware.<br>• CO5: To understand advanced statistical analysis of physiological signals<br>• CO6: Implementation of distributed process monitoring and control | | | | | | |

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| Topics Covered | **Exp-01:** Implementation of face detection algorithm using public database<br>**Exp-02:** Computer aided diagnosis of breast cancer using public dataset<br>**Exp-03:** Understanding An Multifrequency Signal Generator Circuit Using High Frequency OpAmps<br>**Exp-04:** Design of A Variable Gain Variable Bandwidth Bandpass Filter using High Frequency OpAmps<br>**Exp-05:** Realization of Arbitrary Signal Simulation and Processing in NI LabVIEW<br>**Exp-06:** Design and Development of an Arduino Based Proximity Sensing Instrumentation for Home Security<br>**Exp-07**: Feature extraction of ECG signal by using higher order statistic<br>**Exp-08:** Implementation of Sensor Network and control of process parameters. |
| Text Books, and/or reference material | Text Books:<br>3. Christopher Bishop, Pattern Recognition and Machine Learning.<br>4. LabVIEW for Everyone (National Instruments Virtual Instrumentation Series) Paperback – Import, 16 November 2001, Prentice Hall (2001)<br>5. Arduino Projects for Engineers, Paperback, July 2016 by Neerparaj Rai (Author), BPB Publications (2016) |