# COEP Technological University Pune

**(A Unitary Public University of Govt. of Maharashtra)**

## NEP 2020 Compliant

Proposed Curriculum Structure

## M. Tech.
## Electrical – Embedded Control Systems

**(Effective from: A.Y. 2025-26)**

**PG Program in Embedded Control Systems (ECS)**

PG Program in Embedded Control Systems (ECS) has following objectives:

The M. Tech. Embedded Control Systems program has following Program Outcomes (POs).

**Program Outcomes (POs):**

PO1. An ability to independently carry out research/investigation and development work to solve practical control problems.

PO2. Ability to write and present a substantial technical report/document.

PO3. Students should be able to demonstrate masterly knowledge of control systems and its implementation using software and embedded tools.

**Program Specific Objectives (PSOs):**

PSO4. Ability to analyze, design and implement linear and nonlinear control systems in various applications.

PSO5. Ability to design advanced robust controllers and estimators.

PSO6. Ability to implement control solutions in real time environment.

## PG Program [M. Tech. Electrical – Embedded Control Systems]
## Proposed Curriculum Structure
## W.e.f AY 2025-26

### List of Abbreviations

| Abbreviation | Title | No of courses | Credits | % of Credits |
|---|---|---|---|---|
| PSMC | Program Specific Mathematics Course | 1 | 4 | 5 % |
| PSBC | Program Specific Bridge Course | 1 | 3 | 3.75% |
| PCC | Program Core Course | 8 | 24 | 30 % |
| PEC | Program Specific Elective Course | 3 | 9 | 11.25% |
| RM | Research Methodology | 1 | 3 | 3.75 % |
| OE | Open Elective | 1 | 3 | 3.75 % |
| AEC | Ability Enhancement Course | 1 | 2 | 2.5 % |
| LLC | Liberal Learning Course | 1 | 1 | 1.25 % |
| SLC | Self-Learning Course | 2 | 6 | 7.5 % |
| OJT | Internship | 1 | 3 | 3.75 % |
| Project | Dissertation Phase – I and II | 2 | 22 | 27.5 % |
| | **Total** | **22** | **80** | **100%** |

## PG Program [M. Tech. Electrical – Embedded Control Systems]

## Proposed Curriculum Structure

### Semester I

| Sr. No. | Course Type | Course Code | Course Name | Teaching Scheme | | | | | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | S | Cr | Theory | | | Laboratory | |
| | | | | | | | | | MSE | TA | ESE | ISE | ESE |
| 1 | PSMC | ECS-25001 | Mathematical Modelling and Analysis of Dynamic Systems | 3 | 1 | -- | 1 | 4 | 30 | 20 | 50 | -- | -- |
| 2 | PSBC | ECS-25002 | Engineering Optimization | 2 | -- | 2 | 1 | 3 | 30 | 20 | 50 | 50 | 50 |
| 3 | PCC | ECS-25003 | Digital Control System : Analysis and Design | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 4 | PCC | ECS-25004 | Embedded Systems | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 5 | PCC | ECS-25005 | Linear System Theory: Analysis and Design | 3 | 1 | -- | 1 | 4 | 30 | 20 | 50 | -- | -- |
| 7 | PCC | ECS-25006 | Embedded Systems Lab I | -- | -- | 4 | -- | 2 | -- | -- | -- | 50 | 50 |
| 8 | PEC-1 | ECS (PE)-25001 | **Program Specific Elective -1**<br>a. Intelligent Control | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | ECS (PE)-25002 | b. Industrial Automation and Control | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | ECS (PE)-25003 | c. Probability and statistics | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | d. Any other course offered by faculty approved by school council | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| 9 | RM | SET-25001 | Research Methodology | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| **Total Credit** | | | | **20** | **2** | **6** | **7** | **25** | | | | | |

**Legends:**
**L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits**
**ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation, MSE-Mid-Semester-Evaluation, TA-Teachers'**

## PG Program [M. Tech. Electrical – Embedded Control Systems]
## Proposed Curriculum Structure

### Semester II

| Sr. No. | Course Type | Course Code | Course Name | Teaching Scheme Credits | | | | | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | S | Cr | Theory | | | Laboratory | |
| | | | | | | | | | MSE | ISE | ESE | ISE | ESE |
| **1** | OE | | Open Elective Engineering Optimization (For other dept.) | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| **2** | PCC | | Optimal Control | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| **3** | PCC | | Nonlinear Dynamical Systems | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| **4** | PCC | | Embedded System Design | 3 | -- | 2 | 1 | 4 | 30 | 20 | 50 | 50 | 50 |
| **6** | PCC | | HIL Lab | -- | -- | 4 | -- | 2 | -- | -- | -- | 50 | 50 |
| **7** | PEC-2 | | **Program Specific Elective -2** a. Artificial Intelligent and Machine Learning | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | b. Adaptive Control | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | c. Sliding Mode Control | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | d. Any other course offered by faculty approved by school council | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| **8** | PEC-3 | | **Program Specific Elective -3** a. Control Related Estimations | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | b. Fractional Order Control | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | c. Modelling and control of Power converters | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | d. Embedded Sensing, Actuation and Interfacing Systems | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |
| | | | e. Any other course offered by faculty approved by school council | 3 | -- | -- | 1 | 3 | 30 | 20 | 50 | -- | -- |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **9** | AEC | SET-25002 | Technical Communication skills | 1 | -- | 2 | 1 | 2 | 50 | 50 | -- | 100 | -- |
| **10** | LLC2 | | Liberal Learning Course | -- | -- | 2 | 2 | 1 | -- | -- | -- | 100 | -- |
| **Total Credit** | | | | **19** | **--** | **10** | **9** | **24** | | | | | |

**Legends:**
**L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits**
**ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation, MSE-Mid-Semester-Evaluation, TA-Teachers', CIE-Continuous-Internal-Evaluation**

- Exit option to qualify for **PG Diploma in Embedded Control Systems**:
    - Eight weeks domain specific industrial internship in the month of June-July after successfully completing first year of the program.

## PG Program [M. Tech. Electrical – Embedded Control Systems]

## Proposed Curriculum Structure

### Semester-III

| Sr. No. | Course Type | Course Code | Course Name | Teaching Scheme | | | | | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | L | T | P | S | Cr | MSE | ISE | ESE | ISE | ESE |
| 1. | SLC | | Massive Open Online Course –I | 3 | -- | -- | 1 | 3 | -- | -- | 100 | -- | -- |
| 2. | SLC | | Massive Open Online Course –II | 3 | -- | -- | 1 | 3 | -- | -- | 100 | -- | -- |
| 3. | OJT | | Internship | -- | -- | -- | -- | 3 | -- | -- | 100 | -- | -- |
| 4. | Project | | Dissertation Phase–I | -- | -- | 22 | 12 | 11 | -- | -- | -- | 70 | 30 |
| | | | **Total Credits** | **9** | **--** | **22** | **14** | **20** | | | | | |

**Legends:**
**L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits**
**ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation, MSE-Mid-Semester-Evaluation, TA-Teachers'**

### Semester-IV

| Sr. No. | Course Type | Course Code | Course Name | Teaching Scheme | | | | | Evaluation Scheme (Weightages in %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Theory | | | Laboratory | |
| | | | | L | T | P | S | Cr | MSE | ISE | ESE | ISE | ESE |
| 1. | Project | | Dissertation Phase–II | -- | -- | 22 | 12 | 11 | -- | -- | -- | 70 | 30 |
| | | | **Total Credits** | **--** | **--** | **22** | **12** | **11** | | | | | |

**Legends:**
**L-Lecture, T-Tutorial, P-Practical, S-Self Study, Cr-Credits**
**ISE-In-Semester-Evaluation, ESE-End-Semester-Evaluation, MSE-Mid-Semester-Evaluation, TA-Teachers'**

- **MOOC Courses Identified:**

  - Real Time Embedded Systems
  - Advanced IOT Applications
  - Digital Signal Processing and its Applications
  - Advanced Neural Science for Engineers
  - Applied Linear Algebra For Signal Processing, Data Analytics And Machine Learning
  - Design Of Photovoltaic Systems
  - Stochastic Control And Communication
  - Economic Operations And Control Of Power Systems
  - Digital Control in Switched Mode Power Converters and FPGA-based Prototyping
  - Design Of Photovoltaic Systems
  - Any other relevant course offered by swayam NPTEL during the respective semester.

# SEMESTER – I

## [ECS-25001] Mathematical Modeling and Analysis of Dynamical Systems

**Teaching Scheme:**
Lectures: 3 hrs/week
Tutorial: 1 hr/week
Self Study: 1 hr/week

**Examination Scheme:**
Mid Sem Exam. -30 Marks
TA- 20 Marks
End-Sem Exam: 50 Marks

**Course Outcomes:**

After successful completion of this course the students will be able to

1. Develop mathematical models of various engineering and physical systems using classical and energy approach.
2. Demonstrate linearization techniques.
3. Analyze the models for various practical systems.
4. Validate the mathematical models of practical systems using software.

**Course contents:**

Modeling by first principle approach of simple Mechanical, Electrical, Thermal, Chemical systems. Modeling by energy Approach using Lagrangian and Hamiltonian. Linearization of nonlinear models, state space approach for analyzing the dynamic models.

Modeling and Analysis of some typical systems such medical disease and treatment, Rocket Launcher, Resource Management etc., Numerical models using impulse response, step response. Several case studies (Mechanical, Thermal, Electric, etc.). Validation of practical system models using software.

**References:**


1. K. Ogata, "System Dynamics", Pearson Prentice-Hall, 4th Edition, 2004.
2. M. Gopal, "Modern Control Systems Theory", 2nd Edition, John Wiley, 1993
3. E.O. Doeblin, "System Modeling and Response", John Wiley and Sons, 1980.
4. Desai and Lalwani, "Identification Techniques", Tata McGraw Hill, 1977.
5. Goldstain, "Classical Mechanics"

## [ECS-25002] Engineering Optimization

| Teaching Scheme: | Examination Scheme: |
| --- | --- |
| Lectures: 2 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| Practical: 2 hrs/week | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Explain and use the basic theoretical principles of optimization and various optimization techniques.
2. Develop and select appropriate models corresponding to problem descriptions in engineering and solve them correctly.
3. Solve and analyze complex optimization problems in power system/control system/machine drive.
4. Develop and implement various optimization software tools to solve engineering problems.

**Course contents:**

Introduction to optimization, Classical Optimization: Single variable optimization, Multivariable optimization with no constraints, Multivariable optimization with equality constraints, Multivariable optimization with inequality constraints. Linear Programming: Simplex Method, Duality, Transportation problems. Nonlinear Programming: One dimensional minimization methods, unconstrained and constrained optimization.

Dynamic Programming: Development of dynamic programming, Principle of optimality. Practical Aspects of Optimization: Reduced basic techniques, Sensitivity of optimum solution to problem parameters, evolutionary optimization techniques, applications of optimization techniques to power system/control systems/power electronics and machine drives

**References:**


1. R. Fletcher, "Practical Optimization", Second edition, John Wiley and Sons, New York, 1987.
2. S. S. Rao, "Engineering Optimization-Theory and practice", fourth edition, Wiley Easter Publications, January 2009.
3. K. V. Mital and C. Mohan, "Optimization Methods in Operations Research and System Analysis", New age International Publishers, Third edition, 1996.
4. Bazaraa M. S., Sherali H.D. and Shetty C. "Nonlinear Programming Theory and Algorithms", John Wiley and Sons, New York 1993.
5. Bertsekas D. P., "Constrained Optimization and Lagrange Multiplier Methods", Academic Press, New York, 1982.Durga Das Basu, "Introduction to the Constitution of India" Prentice Hall EEE, 19th/20th Edn., 2001. (Students Edn.)

**e Learning Resources:**

- Prof. A. Goswami, Dr. Debjani Chakraborty, IIT Kharagpur online lecture series on Optimization, https://nptel.ac.in/courses/111105039/

## [ECS-25002] Simulation Lab

**Teaching Scheme:**
Practical: 2 hrs/week

**Examination Scheme:**
Continuous Assessment- 50 Marks
Final Practical/Oral Exam – 50 Marks

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Demonstrate use of advanced software tools like MATLAB, PSIM for problem analyzing the system performance.
2. Simulate the dynamic system and its control
3. Analyze and interpret the result.
4. Validate the design of controller using MATLAB / Simulink.

**Course contents:**

Simulation experiments/assignments on the platform like MATLAB / Simulink. The problems will be related to the core subjects. Few are listed below

1. MATLAB for continuous time and discrete time control systems: representation with various models, responses , performance specifications.
2. Modeling and design of magnetic levitation system
3. Digital controller design in state space
4. Feedback linearzed controller for level control system

## [ECS-25003] Digital Control System: Analysis and Design

**Teaching Scheme:**
Lectures: 3 hrs/week
Self Study: 1 hr/week

**Examination Scheme:**
Mid Sem Exam. -30 Marks
TA- 20 Marks
End-Sem Exam: 50 Marks

### Course Outcomes:

After successful completion of this course the students will be able to,

1. Obtain discrete representation of linear systems
2. Analyze stability of open loop and closed loop discrete system
3. Design and analyze Discrete Controller
4. Design state feedback controller and estimators

### Course contents:

Discrete time systems, discretization, sampling, aliasing, choice of sampling frequency, ZOH equivalent, state space models of discrete systems. Z-Transform for analyzing discrete time systems, transfer function, Internal stability, design of discrete time control using conventional methods, Stability of discrete time systems, state space analysis, pole placement and observer

### References:


1. K. Ogata, "Discrete Time Control Systems", Prentice hall, 1995.
2. Kuo, Benjamin C, "Digital Control Systems", New York : Holt, Rinehart and Winston, 1980.
3. M. Gopal, "Digital Control and State Variable Methods", McGraw Hill, 2009.
4. G. F. Franklin, J. D. Powell, M.L. Workman, "Digital Control of Dynamic Systems", Saddison-Wesley, Reading, MA, 1998.


### e Learning Resources:

- Dr. Indrani Kar, Prof. S. Majhi, IIT Guwahati, online lecture series on Digital Control System, https://nptel.ac.in/courses/108103008 /

## [ECS-25004] Embedded Systems

| Teaching Scheme: | Examination Scheme: |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Deploy low end applications using low and high level languages on microcontroller platform.
2. Test and debug peripherals in embedded system.
3. Identify and design applications on embedded platform.
4. Implement and deploy applications using embedded platform.

**Course contents:**

Introduction to Embedded System and Embedded System Design Flow. Signal Conditioning & Various Signal Chain Elements, Critical Specifications, How to smartly choose elements from wide choice available in market. Use Case Analysis. Systems on Chip, Memory Subsystem , Bus Structure, Interfacing Protocol, Peripheral interfacing, Testing & Debugging, Power Management, Software for Embedded Systems, Design of Analog Signal Chain from Sensor to Processor with noise, power, signal bandwidth, Accuracy Considerations. Software Programming Optimization, Concurrent Programming. Real Time Scheduling, I/O Management, Embedded Operating Systems. RTOS, Developing Embedded Systems, Building Dependable Embedded Systems.

**References:**


1. Steve Heath, "Embedded Systems Design", Newnes (an imprint of Butterworth-Heinemann Ltd ); 2nd edition (30 October 2002).
2. Wyne Woff "Principles of Embedded computing system design", Morgan Koffman publication 2000
3. Rajkamal, "Embedded Systems- Architecture, Programming and Design", 2007- TMH.
4. Qing Li, "Real Time Concepts for Embedded Systems", Elsevier, 2011.
5. Shibu K.V, "Introduction to Embedded Systems", Mc Graw Hill.
6. Frank Vahid, Tony Givargis, "Embedded System Design", John Wiley.
7. Lyla "Embedded Systems", Pearson, 2013.

## [ECS-25005] Linear System Theory: Analysis and Design

**Teaching Scheme:**
Lectures: 3 hrs/week
Tutorial: 1 hr/week
Self Study: 1 hr/week

**Examination Scheme:**
Mid Sem Exam. -30 Marks
TA- 20 Marks
End-Sem Exam: 50 Marks

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Evaluate linear control system using vector spaces.
2. Design linear control system using state space and optimal control approach.
3. Analyze the stability of linear systems.
4. Design Linear quadratic regulator to achieve desired system performance

**Course contents:**

Review of Linear Algebra : Vector space, linear combination, linear independence, bases of a vector space, representation of any vector on different basis, matrix representation of a linear operator, change of basis, rank, nullity, range space and null space of a matrix, Eigen value and Eigen vector of a matrix, similarity transform, diagonalization. Linear System analysis in state space: Controllability, Observability and Stability, Lyapunov's stability analysis of SISO and MIMO linear systems. Minimal realizations and co-prime fractions. Control Design: State feedback controller by pole placement and design of observer for linear systems Optimal Control: Formulation of optimal control problem, linear quadratic regulator (LQR), Riccati equations for control design.

**References:**


1. Chi-Tsong Chen, "Linear System Theory and Design", Oxford University Press.
2. David C. Lay, Steven R. Lay, Judi J. McDonald, "Linear Algebra and its Apllication " 5th edition Pearson.
3. Thomas Kailath, "Linear System", Prentice Hall, 1990
4. K. Hoffman and R. Kunze, "Linear Algebra", Prentice-Hall (India), 1986.
5. Norman Nise, "Control System Engineering", John Wiley and sons, 4th Edition, 2004
6. K. Ogata, "Modern Control Theory", Prentice Hall India


**e Learning Resources:**

- PROF. RAMKRISHNA PASUMARTHY Department of Electrical Engineering IIT Madras, online lecture series on LINEAR SYSTEMS THEORY
  https://archive.nptel.ac.in/courses/108/106/108106150/

# [ ECS-25006 ] Embedded System Lab I

**Teaching Scheme:**
Lectures: 4 hrs/week

**Examination Scheme:**
Continuous Assessment- 50 Marks
Final Practical/Oral Exam – 50 Marks

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Perceive what is a microcontroller, microcomputer, embedded system.
2. Compile different components of a micro-controller and their interactions.
3. Become familiar with programming environment used to develop embedded systems
4. Experiment with key concepts of embedded systems like I/O, timers, interrupts, interaction with peripheral devices
5. Learn debugging techniques for an embedded system

**Course contents:**
Experiments based on above objectives such as PID control, LED Interface, timers, counters, ADC, DAC , PWM and Design of Energy meter etc.

**References:**


1. Steve Heath, "Embedded Systems Design", Publisher Butterworth-Heinemann.
2. Wyne Woff "Principles of Embedded computing system design", Morgan Koffman publication 2000
3. Rajkamal, "Embedded Systems- Architecture, Programming and Design", 2007- TMH.
4. Qing Li, "Real Time Concepts for Embedded Systems", Elsevier, 2011.
5. Shibu K.V, "Introduction to Embedded Systems", Mc Graw Hill.
6. Frank Vahid, Tony Givargis, "Embedded System Design", John Wiley.
7. Lyla "Embedded Systems", Pearson, 2013.
8. MSP 430 Guide

## Program Specific Elective –I

## [ECS (PE)-25001] Intelligent Control

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Justify the use of intelligent control systems.
2. Design Fuzzy Logic Control System for Engineering Application.
3. Design Neural Network based Control System for Engineering Application.
4. Apply Genetic Algorithms to Parametric Optimization.

**Course contents:**

Artificial Neural Networks, Learning Methods, Supervised and Unsupervised learning, Recurrent Neural Networks. Fuzzy logic, Fuzzy Arithmetic, Relations, Reasoning, Mamdani and Takagi-Sugeno knowledge representation and inference mechanism, genetic algorithm, Fuzzy Neural networks.
System Identification using Neural and Fuzzy Neural Networks, Stability analysis. Adaptive control using Neural and fuzzy Neural networks, Direct and Indirect adaptive control, and Self-tuning PID Controllers. Introduction to Genetic Algorithm and use of GA for Parametric Optimization. Intelligent control applications such as robot manipulator dynamic control, inverted pendulum.

**References:**


1. K. Passino, "Biomimicry for Optimization, Control and Automation", springer verlag,2005.
2. Kevin M. Passino and Stephen Yurkovich, "Fuzzy Control", Addison Wesley Longman, Menlo park, CA 1998.
3. Antsaklis P.J., PassinoK. M., "An Introduction to and Autonomous Control", Kluwer Publishers' Norwell MA 1993.
4. Timothi J. Ross, "Fuzzy logic with engineering applications", Wiley, 1995.
5. Rossiter, J.A., "Predictive Control: a practical approach "
6. Stanislaw H. Zak , "Systems & Control"


**e Learning Resources:**

- Prof. Laxmidhar Behera Department of Electrical Engineering IIT Kanpur online lecture series on Intelligent Systems and Control https://nptel.ac.in/courses/108104049/

## [ECS (PE)-25002] Industrial Automation and Control

| Teaching Scheme: | Examination Scheme: |
| --- | --- |
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Select suitable component for given applications, built suitable control strategy for application.
2. Deploy the use of signal measurements and conditioning methods.
3. Design various types of control structure for given application.
4. Develop ladder logic for given applications.
5. Use communication protocols of industrial systems

**Course contents:**

Introduction to Industrial Automation and Control, Architecture of Industrial Automation Systems, Introduction to sensors and measurement systems like Temperature , Pressure ,Force , Displacement and speed , Flow measurement techniques, level, humidity, pH etc. Signal Conditioning and Processing, Estimation of errors and Calibration

Introduction to Process Control, P-I-D Control, Controller Tuning, Implementation of PID Controllers, Special Control Structures : Feed forward and Ratio Control, Predictive Control, Control of Systems with Inverse Response , Cascade Control, Overriding Control, Selective Control, Split Range Control

Introduction to Sequence Control, PLCs and Relay Ladder Logic, Scan Cycle, RLL Syntax , Structured Design Approach, Advanced RLL Programming, The Hardware environment Introduction to Actuators : Flow Control Valves , Hydraulic Actuator Systems : Principles, Components and Symbols, Pumps and Motors, Proportional and Servo Valves

Pneumatic Control Systems: System Components, Controllers and Integrated Control Systems

Networking of Sensors, Actuators and Controllers: The Field bus, The Field bus Communication Protocol.

**References:**

1. Frank Lamb, " Industrial Automation: Hands On"
2. Jon Stenerson, " Industrial Automation and Process Control"
3. Kevin Collins, " PLC Programming for Industrial Automation"
4. A.K. Gupta, S.K. Arora, Jean Riescher Westcott, " Industrial Automation and Robotics: An Introduction"
5. S. Mukhopadhyay, "Industrial Instrumentation, Control and Automation" Jaico Publishing House, 2012

**e Learning Resources:**

- Prof. Siddhartha Mukhopadhyay | IIT Kharagpur, online lecture series on Industrial Automation and Control, https://onlinecourses.nptel.ac.in/noc21_me67/preview /

**[ECS (PE)-25003] Probability and Statistics**

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Appreciate the importance of probability and statistics in computing and research
2. Develop skills in presenting quantitative data using appropriate diagrams, tabulations and summaries Use appropriate statistical methods in the analysis of simple datasets
3. Interpret and clearly present output from statistical analyses in a clear concise and understandable manner.

**Course contents:**
Sets and classes, limit of a sequence of sets, rings, sigma-rings, fields, sigma-fields, monotone classes. Classical, relative frequency and axiomatic definitions of probability, addition rule and conditional probability, multiplication rule, total probability, Bayes' Theorem and independence, problems.
Discrete, continuous and mixed random variables, probability mass, probability density and cumulative distribution functions, mathematical expectation, moments, probability and moment generating function, median and quantiles, Markov inequality, Chebyshev's inequality, problems. Discrete uniform, binomial, geometric, negative binomial, hyper geometric, Poisson, continuous uniform, exponential, gamma, Weibull, Pareto, beta, normal, lognormal, inverse Gaussian, Cauchy, double exponential distributions, reliability and hazard rate, reliability of series and parallel systems, problems. Function of a random variable, problems.

Joint, marginal and conditional distributions, product moments, correlation and regression, independence of random variables, bivariate normal distribution, problems. functions of random vectors, distributions of order statistics, distributions of sums of random variables, problems. The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Chi-Square, t and F distributions, problems.
Graphical representation, measures of locations and variability.
Unbiasedness, consistency, the method of moments and the method of maximum likelihood estimation, confidence intervals for parameters in one sample and two sample problems of normal populations, confidence intervals for proportions, problems.
Null and alternative hypotheses, the critical and acceptance regions, two types of error, power of the test, the most powerful test and Neyman-Pearson Fundamental Lemma, tests for one sample and two sample problems for normal populations, tests for proportions, Chi-square goodness of fit test and its applications, problems.

**References:**


1. V.K. Rohatgi & A.K. Md. E. Saleh, "An Introduction to Probability and Statistics"
2. J.S. Milton & J.C. Arnold , "Introduction to Probability and Statistics"
3. H.J. Larson, " Introduction to Probability Theory and Statistical Inference"
4. S.M. Ross, "A First Course in Probability Introduction to Probability and Statistics for Engineers and Scientists"
5. W.W. Hines, D.C. Montgomery, D.M. Gpldsman & C.M. Borror, "Probability and Statistics in Engineering"
6. M. Kac, "Lectures in Probability" (for example on independent events)
7. C.K. Wong (1972), "A note on mutually independent events. Annals of Statistics, V. 26, 27.(for example on independent events)"
8. P. Halmos, "Measure Theory(for algebra of sets)"


## [SET-25001] Research Methodology

**Teaching Scheme:**
Lectures:3 hrs/week
Self study: 1 hr/week

**Examination Scheme:**
Mid-Sem Exam - 30 marks
T. A. - 20 marks
End-Sem Exam – 50 marks

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Demonstrate research problem formulation and approaches of investigation of solutions for research problems.
2. Learn ethical practices to be followed in research.
3. Apply research methodology in case studies and acquire skills required for presentation of research outcomes
4. Summarize that it is an incentive for further research work and investment in R & D, leading

to creation of new and better products and generation of economic and social benefits

**Course Content:**

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem.
Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, necessary instrumentations.

Effective literature studies approaches, analysis. Use Design of Experiments /Taguchi Method to plan a set of experiments or simulations or build prototype. Analyze your results and draw conclusions or Build Prototype, Test and Redesign.

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

**References:**

1. Aswani Kumar Bansal, "Law of Trademarks in India"
2. B. L. Wadehra, "Law Relating to Patents, Trademarks, Copyright, Designs and Geographical Indications".
3. G.V.G Krishnamurthy, " The Law of Trademarks, Copyright, Patents and Design".
4. S K Roy Chaudhary & H K Saharay, "The Law of Trademarks, Copyright, Patents"

## SEMESTER – II

## [OE-   ] Engineering Optimization

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA-    20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Explain and use the basic theoretical principles of optimization and various optimization techniques.
2. Develop and select appropriate models corresponding to problem descriptions in engineering and solve them correctly.

3. Solve and analyze complex optimization problems in various engineering applications.
4. Implement various optimization software tools to solve engineering problems.

**Course contents:**

Introduction to optimization, Classical Optimization: Single variable optimization, Multivariable optimization with no constraints, Multivariable optimization with equality constraints, Multivariable optimization with inequality constraints. Linear Programming: Simplex Method, Duality, Transportation problems. Nonlinear Programming: One dimensional minimization methods, unconstrained and constrained optimization.
Dynamic Programming: Development of dynamic programming, Principle of optimality. Practical Aspects of Optimization: Reduced basic techniques, Sensitivity of optimum solution to problem parameters, evolutionary optimization techniques, applications of optimization techniques to various engineering applications.

**References:**

1. R. Fletcher, "Practical Optimization", Second edition, John Wiley and Sons, New York, 1987.
2. S. S. Rao, "Engineering Optimization-Theory and practice", fourth edition, Wiley Easter Publications, January 2009.
3. K. V. Mital and C. Mohan, "Optimization Methods in Operations Research and System Analysis", New age International Publishers, Third edition, 1996.
4. Bazaraa M. S., Sherali H.D. and Shetty C. "Nonlinear Programming Theory and Algorithms", John Wiley and Sons, New York 1993.
5. Bertsekas D. P., "Constrained Optimization and Lagrange Multiplier Methods", Academic Press, New York, 1982.Durga Das Basu, "Introduction to the Constitution of India" Prentice Hall EEE, 19th/20th Edn., 2001. (Students Edn.)

**e Learning Resources:**

- Prof. A. Goswami, Dr. Debjani Chakraborty, IIT Kharagpur online lecture series on Optimization, https://nptel.ac.in/courses/111105039/

# [ ECS- ] Optimal Control

**Teaching Scheme:**
Lectures: 3 hrs/week
Self Study: 1 hr/week

**Examination Scheme:**
Mid Sem Exam. -30 Marks
TA- 20 Marks
End-Sem Exam: 50 Marks

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Analyze and synthesize optimal open loop control signals using the Maximum principle.
2. Analyze and synthesize optimal feedback laws using the Hamilton-Jacobi-Bellman equation.
3. Apply LQR techniques to analyze the robustness of continuous and discrete time system.
4. Use numerical software to solve optimal control problems.

**Course contents:**
Introduction – Performance Index- Constraints – Formal statement of optimal control system – Calculus of variations – Function, Functional, Increment, Differential and variation and optimum of function and functional – The basic variational problem Extrema of functions and functional with conditions – variational approach to optimal control system
Linear Quadratic Optimal Control System- Problem formulation – Finite time Linear Quadratic regulator – Infinite time LQR system: Time Varying case- Time-invariant case – Stability issues of Time invariant regulator – Linear Quadratic Tracking system: Fine time case and Infinite time case Variational calculus for Discrete time systems – Discrete time optimal control systems:- Fixed final state and open-loop optimal control and Free-final state and open-loop optimal control – Discrete time linear state regulator system – Steady state regulator system
Pontryagin Minimum Principle – Dynamic Programming:- Principle of optimality, optimal control using Dynamic Programming – Optimal Control of Continuous time and Discrete-time systems – Hamilton Jacobi-Bellman Equation – LQR system using H-J-B equation
Constrained Optimal Control Systems
Time optimal control systems – Fuel Optimal Control Systems- Energy Optimal Control Systems – Optimal Control Systems with State Constraints

**References:**


1. Donald E. Kirk, "Optimal Control Theory – An Introduction", Dover Publications, Inc. Mineola, New York, 2004.
2. Frank L. Lewis, DragunaVrabie, Vassilis L. Syrmos, "Optimal Control, 3rd Edition", Wiley Publication, 2012.
3. D. Subbaram Naidu, "Optimal Control Systems", CRC Press, New York, 2003.
4. M Gopal "Modern Control System Theory", New Age International, 1993
5. Andrew P. Sage, "Optimum Systems Control", Prentice Hall, INC
6. B.D.O. Anderson and J.B. Moore, "Optimal Control – Linear Quadratic Methods," PHI, 1991.
7. Optimum system Control

8. R.T.Stefani, B.Shahian, C.J.Savant, J.G.H.Hosletter, "Design of Feedback Control Systems", Oxford University Press, 2009.

**e Learning Resources:**

- Prof. Barjeev Tyagi , IIT Roorkee online lecture series on Optimal control https://onlinecourses.nptel.ac.in/noc21_ee48/

## [ECS- ] Nonlinear Dynamical Systems

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Explore tools for stability analysis and response evaluation of control systems with significant nonlinearities.
2. Compute the performance and stability of the system.
3. Identify the design problem and distinguish between the controls strategies.
4. Correlate between design parameters and the system performance.

**Course contents:**

Introduction to Nonlinear Systems, Linearization and equilibrium points, Stability of nonlinear systems, types of equilibrium points. Phase Plane and Describing Function Methods for Analysis of Nonlinear Systems, Lyapunov's stability: Autonomous Systems , La Salle's Invariance Principle, Systems Analysis based on Lyapunov's Direct Method (Krasovaskii's method, Variable Gradient Method), Lyapunov like Analysis using Barbalet's Lemma ,Passivity Theorem, Popov Stability criterion, Poincare- Bendixon theorem, Nonlinear control systems design by Feedback Linearization. Some design examples of nonlinear systems such as the ball and beam, flight control, magnetic levitation and robotic manipulator etc. Approximate solution of nonlinear system using the perturbation method and averaging method.

**References:**


1. H. K. Khalil, "Nonlinear Systems", Prentice Hall, 2001.
2. Jean-Jacques E. Slotine, Weiping Li, "Applied nonlinear Control", Prentice Hall, 1991.
3. M Vidyasagar, "Nonlinear systems Analysis", 2nd Edition, Prentice Hall, 1993.
4. Alberto Isidori, "Nonlinear Control System", Vol I and II, Springer, 1999.
5. M. Gopal, "Modern Control System" New Age International Private Limited; Forth edition (1 October 2021


**e Learning Resources:**

- PROF. ARUNKUMAR D. MAHINDRAKAR and PROF. RAMKRISHNA PASUMARTHY, Department of Electrical and Electronics Engineering, IIT Madras, online lecture series on NONLINEAR SYSTEM ANALYSIS https://archive.nptel.ac.in/courses/108/106/108106162/

- Prof. Harish K. Pillai and Prof. Madhu N.Belur, Department of Electrical Engineering IIT Bombay, online lecture series on Nonlinear Dynamical Systems https://archive.nptel.ac.in/courses/108/101/108101002/

## [ECS- ] Embedded System Design

| Teaching Scheme: | Examination Scheme: |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| Practical: 2 hrs/week | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Illustrates memory organization
2. Test and debug peripherals in embedded system
3. Elaborate RTOS
4. Design small RTOS based embedded system

**Course contents:**

Systems on chip, Memory Subsystem, Peripheral Interfacing, Testing & Debugging, Power Management, Software for embedded Systems, Software Programming Optimization, Concurrent Programming. Real time scheduling, I/O Management, Embedded Operating Systems, Networked embedded systems. Designing Embedded Systems, Special Networking Protocols (CAN Bluetooth) Applications. Introduction to RTOS, Comparison of Embedded RTOS, Consideration of RTOS for programming, System architecture of RTOS, Thread creation, thread management, synchronization mechanism for RTOS, Semaphores, message Queues, Pipes, Interrupts for RTOS. Application development using OS. Process stack management, run-time buffer size, swapping, overlays, block/page management, replacement, algorithms, real-time garbage collection

**References:**


1. Steve Heath, "Embedded Systems Design", Publisher Butterworth-Heinemann.

2. Wyne Woff "Principles of Embedded computing system design", Morgan Koffman publication 2000
3. J. J Labrosse, "MicroC/OS-II: The Real –Time Kernel", Newnes, 2002.
4. Qing Li, "Real Time Concepts for Embedded Systems", Elsevier, 2011.
5. Shibu K.V, "Introduction to Embedded Systems", Mc Graw Hill.
6. Jane W. S. Liu, "Real-time systems", Prentice Hall, 2000.
7. Philips A. Laplante, "Real-Time System Design and Analysis", 3rd Edition, John Wley& Sons, 2004

## [ECS- ] Embedded System Design Lab

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 2 hrs/week | Continuous Assessment- 50 Final Practical/Oral Exam – 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Demonstrate use of instructions and Interrupt Processing in embedded processor
2. Write, Test and Debug programs in embedded board.
3. Port RTOS on embedded board.
4. Write, Test and Debug RTOS based programs in embedded board

**Course contents:**

After understanding of MSP 430 architecture inclusive of Memory, I/O, Pipeline, Lab assignments will be based on use of instruction set, ISS, Communication/Display/User Interface Peripherals/Serial/PWM to solve specific embedded problems, power, Foot Print, Interrupt Latency, Real Time Response, introduction to Real Time Operating System Concepts.
Blocking semaphores, priority scheduling, performance measures

**References:**

1. Atmega 32 datasheet
2. MSP 430 datasheet
3. MSP 430 Technical Reference Manual
4. AVR Microcontroller and Embedded Systems by Muhammad Ali Mazidi, Pearson Publication.

## [ECS- ] HIL LAB

**Teaching Scheme:**
Laboratory : 4 hrs/week

**Examination Scheme:**
Continuous Evaluation: 50 Marks
End-Sem Exam – 50 marks

**Course Outcomes:**
After successful completion of this course, students will be able to:
1. Mathematically formalize requirements based on design objectives.
2. Trace the design project requirements through modeling and control design.
3. Perform, analysis and design in the discrete domain using ADC and DAC.
4. The students will gain knowledge and hands on experience with sensor and actuator calibration, signal amplification, sampling, DAC and ADC, uncertainties and noise, continuous and discrete filters, safety measures for HIL implementations.
5. Independently setup HIL experiments using SIMULINK and dSpace virtual HIL software packages.
6. Creates a virtual real-time environment which contains a model of control system, and an external physical system.

**Course contents:**
Three lab sessions to work with MATLAB/SIMULINK. Develop the model and controller, and validate and verify their SIMULINK files according to the predefined requirements.
The learning objectives of the first two lab sessions were— 1) Develop and debug the model/controller in MATLAB/SIMULINK, 2) Design MIL tests in order verify and validate the model/controller according to predefined requirements, 3) Generate and debug production code, and performing SIL tests, 4) get hands on experience of V&V tools in MATLAB/SIMULINK

Three labs on dSPACE software package and verifying/validating their developed code with VHIL. The learning objectives of these three lab sessions were — 1) Independently setting up VHIL, and recording data using data acquisition tools in dSPACE, 2) Learning to work with dSPACE software packages, 3) Designing and implementing DOE tests on the VHIL platform.

Two labs to perform HIL simulation using dSpace and implementation of controller on real time system like power converters, electric motors.

**References:**

1. Martin Schlager, "Hardware-in-the-Loop Simulation" 2014, VDM
2. Adit Joshi, "Automotive Applications of Hardware-in-the-Loop (HIL) Simulation" SAE International
3. Manuals of respective devices and software.

**Program Specific Elective -II**

**[ECS (PE)- ] Artificial Intelligent and Machine Learning**

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course, the students will be able to,

1. Identify problems where artificial intelligence techniques are applicable.
2. Select appropriate technologies for a given problem and anticipate the design implication.
3. Understand the fundamental issues and challenges of machine learning algorithms.
4. Design and Apply the machine learning algorithms to real world problems.
5. Analyze the machine learning algorithms applied to real world problems.

**Course contents:**

Introduction to Artificial Intelligence: Artificial Intelligence problems, foundation of AI and history of AI intelligent agents: Agents and Environments, the concept of rationality, the nature of environments, structure of agents, problem solving agents, problem formulation.
Searching- Searching for solutions, uniformed search strategies – Breadth first search, depth first Search. Search with partial information (Heuristic search).
Introduction to Machine Learning: Basic definitions, types of learning, designing a learning system, perspectives and issues, hypothesis space and inductive bias, evaluation, cross-validation. Linear regression, Decision trees, Splitting Criteria, Issues in decision tree learning, over fitting and evaluation, nearest neighbor methods. Neural network: Perceptron, multilayer network, back propagation, introduction to deep neural network. Dimensionality Reduction: Feature reduction, Principal Component Analysis, Fischer's Discriminant Analysis. Probability and Bayes learning, Naive Bayes Model, Logistic Regression, Reinforcement learning. Support Vector Machine, Kernel function and Kernel SVM, Clustering: partitioning, k-means clustering, hierarchical clustering, and Case studies.

**References:**


1. S. Russel and P. Norvig, "Artificial Intelligence – A Modern Approach", Fourth Edition, Pearson Education
2. David Poole, Alan Mackworth, Randy Goebel," Computational Intelligence: a logical approach", Oxford University Press.
3. Ethem Alpaydin, Introduction to Machine Learning, Second Edition, The MIT Press, 2010.
4. Tom Mitchell, Machine Learning, McGraw-Hill, 1997.

5. Stephen Marsland, Machine Learning: An Algorithmic Perspective, CRC Press, 2009.
6. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006.

**e Learning Resources:**

- PROF. SUDESHNA SARKAR, Department of Computer Science and Engineering IIT Kharagpur, online lecture series on INTRODUCTION TO MACHINE LEARNING https://archive.nptel.ac.in/courses/106/105/106105152/

## [ECS (PE)- ] Adaptive Control

**Teaching Scheme:**
Lectures: 3 hrs/week
Self Study: 1 hr/week

**Examination Scheme:**
Mid Sem Exam. -30 Marks
TA- 20 Marks
End-Sem Exam: 50 Marks

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Analyze the stability of an adaptive linear system
2. Design a MRAC or L1 adaptive controller
3. Design and simulate indirect/direct adaptive controllers
4. Design adaptive parameter identifiers

**Course contents:**

**Introductory Concepts:** Representative process control problems -Liquid Surge Tank, Blending Process. Incentives for Chemical Process Control. Classification of variables and design elements of a control system.
**Modeling Considerations:** Rationale for process modeling. General modeling principles; balance equations - mass, energy, momentum; Thermodynamics and reaction kinetics; degrees of freedom analysis. State variables, State equations; input-output models. Lumped and distributed parameter systems. Steady state and dynamic behavior. Examples – liquid serge tank, isothermal chemical reactor.
**Dynamic behavior of Chemical Processes:** Solving algebraic equations and integration of ODEs. Concept of nonlinearity; linearization of nonlinear processes; deviation variables. Concept of Laplace Transform (LT); the LT of basic functions - step, impulse, pulse, ramp, exponential, integral, derivative, time delay; initial and final value theorems. Solution of differential equation using LT techniques - Partial fraction expansion, direct division. Transfer function of Single Input Single Output (SISO) process; Transfer function matrix of Multi Input Multi Output (MIMO) process. Properties of transfer function; Poles and Zeros of a transfer function; stability issues, unstable and non-minimum phase behavior. Dynamic response of a

first order process, first order plus dead time process, second order process, pure capacitive process, pure dead time, higher order process; inverse response; Padé approximation. Interacting and non-interacting processes. Development of Empirical model - Model development using linear and nonlinear regression, fitting first and second order models using step test results. Frequency response analysis - Bode and Nyquist plot.

**Feedback controller:** Introduction to feedback control. Elements of Control loop - controller, measuring device, final control element, transmission lines, transducers, transmitters, block diagram. Concept of servo and regulatory problems. Selection of measured, manipulated and controlled variables. Types of controller - P, PI, PID, on-off. Effects of proportional, integral and derivative actions. Notion of stability - characteristic equation, Routh-Hurwitz criteria, root-locus analysis. Design of feedback controller - performance criteria, controller tuning methods, Cohen- Coon method, 1/4th 12 decay ratio method, direct synthesis methods, gain and phase margins, Ziegler-Nichols method, Bode & Nyquist stability criteria, robustness analysis. Compensation for large dead time and inverse response, Smith Predictor.

**Other control strategies:** Feed forward controller - design with steady state model, design with dynamic model, combination of feed forward-feedback structure. Cascade control structure - analysis and design. Ratio control, split range control, selective control, overrides control, auctioneering control. Concepts of adaptive and inferential control.

**Multi loop multivariable control:** Process and control loop interaction. Singular Value Decomposition (SVD), Relative Gain Array (RGA), I/O pairing. Sensitivity to model uncertainty; failure sensitivity. Decoupling and design of non-interacting control loops. Example - Design of controller and control structure for a 4 input x 4 output Distillation Column.

**Instrumentation:** Final Control Elements - Valve characteristics, thyristors. Measuring Devices for flow, temperature, pressure and level. Instrumentation symbols. Introduction to Process Flow Diagram (PFD) and Piping & Instrumentation Diagram (P&ID).

**References:**

1. Stephanopoulos, G., " Chemical Process Control: An Introduction to Theory and Practice ", Prentice-Hall, New Jersey, 1984.
2. Coughanowr, D. R. and L. B. Koppel, "Process systems Analysis and Control ", Mc-Graw-Hill, 2nd. Ed., 1991.
3. Luyben, W. L.," Process Modelling Simulation and Control for Chemical Engineers ", McGraw Hill, 1990.

## [ECS (PE)-  ] Sliding Mode Control

**Teaching Scheme:**
Lectures: 3 hrs/week
Self Study: 1 hr/week

**Examination Scheme:**
Mid Sem Exam. -30 Marks
TA-    20 Marks
End-Sem Exam: 50 Marks

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Illustrate Notion of variable structure systems and sliding mode control
2. Design and analyze sliding mode controller for uncertain systems
3. Design estimators for state and uncertainty estimations.
4. Develop discrete sliding mode controller with various reaching laws.

**Course contents:**

Notion of variable structure systems and sliding mode control, sliding hyperplane design: pole placement and LQR method,  control, chattering issue, Alleviation of chattering. Integral Sliding Mode Control. Sliding Mode Observer for state estimation. Discrete sliding mode control analysis and design. Discrete disturbance estimator. Introduction to higher order sliding mode control, twisting and super twisting algorithms

**References:**

1. Spurgeaon and Edwards, "Sliding Mode Control Theory and Applications".
2. B. Bandyopadhyay and S. Janardhanan , "Discrete-time Sliding Mode Control : A Multirate-Output Feedback Approach", Ser. Lecture Notes in Control and Information Sciences, Vol. 323, Springer- Verlag, Oct. 2005.
3. Sliding Mode Control using Novel Sliding Surfaces, B. Bandyopadhyay, Deepak Fulwani and K. S. Kim, Vol.392 Lecture Notes in Control and Information Science, Springer-Verlag, ISBN 978-3-642-03447-3, Oct. 2009.
4. Sliding Mode Control in Electromechanical Systems, Vadim Ivanovich Utkin, Jürgen Gulder, Jingxin Shi, CRC PressINC, 2009-485 pages.


**e Learning Resources:**

- Prof. S. Janardhana, IIT Delhi online lecture on Sliding Mode Control – An Introduction https://web.iitd.ac.in/~janas/smc_intro.htm/
- An open source lectures by Dr. Shyam Kamal, Department of Electrical Engineering, IIT (BHU) Varanasi.

## Program Specific Elective –III

## [ECS (PE)- ] Control Related Estimations

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Demonstrate the statistical properties of random variables.
2. Build Kalman filters for state estimation
3. Design the model based estimator
4. Predict the diagnosis using estimation

**Course contents:**

Introduction to random variables mean variance, normal distribution, stochastic estimation, Introduction to Kalman Filter, Kalman filter elementary approach, linearized and extended Kalman filter. Unscented kalman filter, particle filter, Model based estimation of states and disturbance. Robust estimation. Use of estimation approach for detection and diagnosis.

**References:**
1. Charles K. Chui, Guanrong Chen," Kalman Filtering: With Real-Time Applications‟, Springer Notes
2. Harold Wayne Sorenson," Kalman Filtering: Theory and Application", IEEE Press, 1960.

## [ECS (PE)- ] Fractional Order Modeling & Control

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Illustrate concept of fractional calculus
2. Develop fractional order models.
3. Design and analyze fractional control
4. Analyze fractional systems

**Course contents:**

Review of basic definitions of integer-order (IO) derivatives and integrals and their geometric and physical interpretations, Computation of these FDs for some basic functions. Laplace and Fourier transforms of FDs. Study of basic functions like Gamma function, Mittag-Leffler function, Dawson's function, Hyper geometric function Analysis of linear fractional-order differential equations (FDEs): formulation, Solution with different FDs, Initial conditions, Problem of initialization and the remedies. Analysis of fractional-order (FO) modeling, Models of basic circuits and mechanical systems using FO elements, Concept of anomalous diffusion, non-Gaussian probability density function and the development of corresponding FO model, FO models of heat transfer, A brief overview of FO models of biological systems. Fractional-order transfer function (FOTF) representation, stability, impulse, step and ramp response, Frequency response, non-minimum phase systems, Root locus, FO pseudo state-space (PSS) representation and the associated concepts like solution of PSS model, controllability, observability, FO lead/lag compensators, FO PID control, design of FO state-feedback, Realization and implementation issues for FO controllers Analysis of system of non-linear FDEs.

**References:**


1. Kilbas, H. M. Srivastava, and J. J. Trujillo. Theory and Applications of Fractional Differential Equations. Elsevier, Netherlands, 2006.
2. Podlubny Fractional Differential Equations. Academic Press, USA, 1999.
3. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, and V. Feliu. Fractional-order Systems and Control: Fundamentals and Applications. Springer-Verlag London Limited, UK, 2010.
4. R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. Fractional Order Systems: Modeling and Control Applications. World Scientific, Singapore, 2010.
5. K. S. Miller and B. Ross. An Introduction to the Fractional Calculus and Fractional Differential Equations. John Wiley & Sons, USA, 1993.


## [ECS (PE)- ] Modeling & Control of Power Electronics Converters

| **Teaching Scheme:** | **Examination Scheme:** |
| --- | --- |
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Evaluate the performance of power electronic converters.
2. Design and analyze model of converters.

3. Design the controller for the desired performance.
4. Demonstrate the performance of controllers in simulation.

**Course contents:**
Operating principles of various power electronics converters; Modeling of power converters: Switched model, circuit average model, state space model, small/large signal models; steady state model. Analysis of models in time and frequency domain using suitable software platform. Linear control approach normally associated with power converters; resonant controllers Nonlinear control methods including feedback linearization, stabilizing, passivity-based, and variable-structure control.

**References:**

1. Seddik Bacha, Iulian Munteanu, Antoneta Iuliana Bratcu "Power Electronics Converters Modeling & Control" Springer.
2. Keng C. Wu, "Switched Mode Power Converters: design and analysis", Elseware academic press
3. k. Kit Sum, "Switch Mode Power Conversion: Basic Theory and Design"


## [ECS (PE)- ] Embedded Sensing, Actuation and Interfacing Systems

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 3 hrs/week | Mid Sem Exam. -30 Marks |
| Self Study: 1 hr/week | TA- 20 Marks |
| | End-Sem Exam: 50 Marks |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Investigate various sensing, actuation units and other required accessories with embedded controller.
2. Build a complete modern embedded control system for intended applications.
3. Develop and select suitable smart sensors, actuators, with associated knowledge of interface electronics and signal conditioning for cutting-edge applications.
4. Implement smart integrated MEMS devices and renewable energy harvesting based self-powered embedded system.

**Course contents:**
**Introduction:**
Overview of embedded system; Importance of sensors, actuators and interfacing circuits in embedded control system; Characteristics; Applications.
**Embedded Sensors and Actuators:**
Various types of important sensors, actuators and their working principles: e.g, thermal,

mechanical, electrical, magnetic, optical, chemical, smart material and meta material based.

**Interfacing Aspects of Sensors and Actuators to Embedded Controller and their Communication Protocols:**

Signal conditioning circuits; Various Op-Amp based interfacing circuit implementation: Amplifier, Filter, ADC, DAC etc.; Various Serial Communication protocols for interfacing.

**Advancement in Interfacing Schemes of Resistive Sensors for Linearity Improvement and Error Reduction:**

Resistive sensor examples; Non-idealities in basic interfacing circuits; Linearization techniques; Error reduction schemes due to environmental effects and remote communication.

**Advanced Techniques for Direct Interfacing of Resistive Sensors with Embedded controller:**

Embedded controller based excitation system; Direct interfacing schemes of various resistive sensors topologies (e.g., single, differential and bridge type) to microcontrollers; Interfacing scheme for sensor array.

**Advanced Techniques for Direct Interfacing of Capacitive Sensors with Embedded Controller:**

Capacitive sensor examples; Interfacing scheme for different capacitive sensor configurations; Direct interfacing schemes.

**Advancement in Design of Interfacing Circuits for Lossy Capacitive Sensors:**

Lossy Capacitive sensor characteristics; Various advanced interfacing schemes for lossy capacitive sensor.

**Miniaturization Technology for Smart Sensors and Actuators:**

Background of miniaturization; Miniaturized device fabrication process technology for Smart sensors and actuators.

**Miniaturized Sensors, Actuators and their Interfacing Electronics:**

Various types of important MEMS sensors and actuators: Design and operation; Interfacing Electronics for MEMS Devices; System-on-Chip integration; Applications.

**Renewable Energy Harvesters to Develop Self-Powered Embedded System:**

Various renewable energy harvesting techniques; Interfacing power management circuits; Applications towards development of self-powered smart system.

Application Case Studies of Embedded Sensing, Actuation and Interfacing System in Automotives Domain

Application Case Studies of Embedded Sensing, Actuation andInterfacing System in Healthcare Domain

**References:**


1. Nathan Ida, 'Sensors, Actuators, and their Interfaces', 1st ed., SciTech Publishing, 2014.
2. Stuart R. Ball, 'Analog Interfacing to Embedded Microprocessor Systems', Elsevier, 2004.
3. B. George, J. Roy, V. Jagadeesh Kumar, S. C. Mukhopadhyay, 'Advanced Interfacing Techniques for Sensors', 1st ed., Springer, 2017
4. John G. Webster and Ramón Pallás-Areny, 'Sensors and Signal Conditioning', John Wiley & Sons, 2nd ed., 2000.
5. Marc Madou, 'Fundamentals of Microfabrication and Nanotechnology', CRC press, 3rd ed., 2018.
6. S. Nihtianov, A. Luque, 'Smart Sensors and MEMS', 1st ed., Elsevier, 2014
7. Bela G Liptak, 'Instrument Engineers Handbook' CRC press, 4th ed., 2003.
8. William B. Ribbens, 'Understanding Automotive Electronics: An Engineering Perspective', Elsevier, 8th ed., 2017.


**e Learning Resources:**

- Prof. Banibrata Mukherjee, IIT Kharagpur online lecture series on Embedded Sensing, Actuation and Interfacing Systems https://onlinecourses.nptel.ac.in/noc24_ee68/preview/

## [SET-25002] Technical Communication skills

| **Teaching Scheme:** | **Examination Scheme:** |
|---|---|
| Lectures: 1 hr/week | Mid Sem Exam. -50 Marks |
| Practical: 2 hrs/week | TA- 50 Marks |
| Self Study: 1 hr/week | |

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. produce effective dialogue for business related situations.
2. use listening, speaking, reading and writing skills for communication purposes and attempt tasks by using functional grammar and vocabulary effectively.
3. analyze critically different concepts / principles of communication skills.
4. demonstrate productive skills and have a knack for structured conversations.
5. appreciate, analyze, evaluate business reports and research papers.

**Course contents:**

Fundamentals of Communication: 7 Cs of communication, common errors in English, enriching vocabulary, styles, and registers Aural-Oral Communication: The art of listening, stress and intonation, group discussion, oral presentation skills. Reading and Writing: Types of reading, effective writing, business correspondence, interpretation of technical reports and research papers

**References:**

1. Raman Sharma, "Technical Communication", Oxford University Press.
2. Raymond Murphy "Essential English Grammar" (Elementary & Intermediate) Cambridge University Press.
3. Mark Hancock "English Pronunciation in Use" Cambridge University Press.
4. Shirley Taylor, "Model Business Letters, Emails and Other Business Documents" (seventh edition), Prentise Hall
5. Thomas Huckin, Leslie Olsen "Technical writing and Professional Communications for Non-native speakers of English", McGraw Hill.

## [LLC] Liberal Learning Course

**Teaching Scheme:**
Practical: 2 hrs/week
Self Study: 2 hrs/week

**Examination Scheme:**
ISE- 100 Marks

**Course Outcomes:**
After successful completion of this course the students will be able to,

1. Survey new topics from various disciplines and Select various sources and avenues to harvest/gather information.
2. Explain qualitative attributes of a good learner.
3. Demonstrate quantitative measurements of learning approaches and learning styles.
4. Appreciate openness to diversity.

**Course contents:**

Topic selected by the student from areas displayed by the institute. The sample list is below. Agriculture (Landscaping, Farming, etc.), Business (Management, Entrepreneurship, etc.), Defense (Study about functioning of Armed Forces), Education (Education system, Policies, Importance, etc.), FineArts (Painting, Sculpting, Sketching, etc.), Linguistics, Medicine and health (Diseases, Remedies, Nutrition, Dietetics, etc.), Performing Arts (Music, Dance, Instruments, Drama,etc.), Philosophy, Social Sciences (history, PoliticalSc., Archeology, Geography, Civics, Economics, etc.)

**References:**

1. Expert(s), Books, Texts, Newspaper, Magazines, Research Papers, Journal, Discussion with peers or faculty.

## SEMESTER – III

### [SLC- ] Massive Open Online Course-I

**Teaching Scheme:**
Lectures: 3 hrs/week
Self Study: 1 hr/week

**Examination Scheme:**
End-Sem Exam: 100 Marks

### [SLC- ] Massive Open Online Course-II

**Teaching Scheme:**
Lectures: 3 hrs/week
Self Study: 1 hr/week

**Examination Scheme:**
End-Sem Exam: 100 Marks

### [ ] Internship

**Teaching Scheme:**

**Examination Scheme:**
End-Sem Exam: 100 Marks

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. apply classroom concepts, theories, and methodologies to real-world industrial or organizational environments.
2. develop hands-on skills related to tools, technologies, or processes used in the specific field
3. enhance the ability to identify, analyze, and solve practical problems using innovative and logical approaches.
4. familiarize with workplace norms, standard operating procedures (SOPs), organizational structure, and professional ethics.
5. improve written, verbal, and interpersonal communication skills through interactions with mentors, team members, and clients.
6. develop skills in planning, organizing, and completing assigned tasks within deadlines.
7. build a sense of responsibility, accountability, and adherence to professional and ethical standards.
8. enable students to document work, prepare internship reports, and present outcomes effectively.
9. work effectively in teams, contribute to group tasks, and coordinate in a multicultural or multidisciplinary environment.
10. get insights into potential career paths, job roles, and industry expectations for better future planning.

## [ECS- ] Dissertation Phase-I

**Teaching Scheme:**
Practical:22 hrs/week
Self study: 12 hrs/week

**Examination Scheme:**
ISE – 70%
ESE– 30%

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Identify key research and development topics in the field of chosen dissertation area (Power Systems, Power electronics, Electrical machines, Energy systems and any interdisciplinary area).
2. Identify, summarize and critically evaluate relevant literature and write a literature review on the relevant topic.
3. Manage time effectively whilst working on independent research and prepare action plan.
4. Show evidence of clarity of argument, understanding of the chosen topic area, and presentation of technical information.
5. Use and develop written and oral presentation skills.

**Course contents:**

The M. Tech. project is aimed at training the students to analyze independently any problem in the field of Electrical Engineering or interdisciplinary. The project may be analytical, computational, experimental or a combination of three. The project report is expected to show clarity of thoughts and expression, critical appreciation of the existing literature and analytical, experimental, computational aptitude.

The student progress of the dissertation work will be evaluated in stage I by the departmental evaluation committee

**References:**

1. Various books, research papers, patents and IPRs on the topic selected for the dissertation.

**SEMESTER - IV**

**[ECS-] Dissertation Phase-II**

**Teaching Scheme:**
Practical:22 hrs/week
Self study: 12 hrs/week

**Examination Scheme:**
ISE – 70%
ESE– 30%

**Course Outcomes:**

After successful completion of this course the students will be able to,

1. Manage time and other resources effectively whilst working on independent research.
2. Identify, analyse and interpret suitable data to enable the research question to be answered.
3. Model, Simulate/ develop innovative hardware/ develop new algorithms/ emulate/ HIL/ develop prototype for the selected topic.
4. Describe the process of carrying out independent research in written format and report your results and conclusions with reference to existing literature and Analyze and synthesize research findings.
5. Use and develop written and oral presentation skills and Prepare good technical project reports for publication in journals and conferences.
6. Take up challenging issues in industry and provide solutions.

**Course contents:**

The M. Tech. project is aimed at training the students to analyze independently any problem in the field of Electrical Engineering or interdisciplinary. The project may be analytical, computational, experimental or a combination of three. The project report is expected to show clarity of thoughts and expression, critical appreciation of the existing literature and analytical, experimental, computational aptitude.
The student progress of the dissertation work will be evaluated in stage II by the departmental evaluation committee and final viva voce will be conducted by the external examiner.

**References:**

1. Various books, research papers, patents and IPRs on the topic selected for the dissertation