(Autonomous Institute VEERMATA JIJABAI TECHNOLOGICAL INSTITUTE
(VJTI)
MATUNGA, MUMBAI 400 019

(Autonomous Institute Affiliated to University of Mumbai)

Curriculum
(Scheme of Instruction, Evaluation and Course Contents)

For
Two-Year Postgraduate Program

Leading to Master of Technology

(M. Tech.) Degree in

Electrical Engineering with specialization in Embedded Control Systems (ECS)

Implemented from the batch admitted in the Academic Year 2025-26

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems in Embedded Control Systems.

PO2: An ability to write and present a substantial technical report/document in the area of Embedded Control Systems

PO3: Students should be able to demonstrate a degree of mastery, higher than the requirements in the bachelor program in the area of Embedded Control Systems

CREDIT STRUCTURE

SEM I - IV			
Abbr.	**Description**	**No of Courses**	**Credits**
PSMC	Program Specific Math Course	1	1*3=3
PCC	Program Core Course	2*3+2*4	14
PSC	Program Specific Course	2*3+2*4	14
MLC	Mandatory Learning Course	2 (1 non-credit)	1*3=3
LC	Laboratory Course	6	6*1=6
IOC	Interdisciplinary Open Course	2	2*3=6
LLC	Liberal Learning Course	2	2*1=2
SLC	Self-Learning Course	2	2*1=2
SBC	Skill-Based Course	4	10+12=22
Total		**27**	**72**

No. of Credits (semester-wise)					
	SEM I	**SEM II**	**SEM III**	**SEM IV**	**Total**
PSMC	3	-	-	-	3
PCC	7	7	-	-	14
PSC	7	7	-	-	14
MLC	-	3	-	-	3
LC	3	3	-	-	6
IOC	3	3	-	-	6
LLC	1	1	-	-	2
SLC	-	-	2	-	2
SBC	-	-	10	12	22
Total	**24**	**24**	**12**	**12**	**72**

SEMESTER I

Scheme of Instruction				Scheme of Evaluation				
Sr. No	**Course Code**	**Course Title**	**L-T-P**	**Credits**	**TA**	**MST**	**ESE**	**ESE hours**
1 (PSMC-1)	EEECS5001S	Computational Methods	3-0-0	3	20	30	50	3
2 (PCC-1)	EEECS5011T	Linear Control theory: Analysis and Design	3-0-0	3	20	30	50	3
3 (PCC-2)	EEECS5012T	Embedded Systems	3-1-0	4	20	30	50	3
4 (PSC-1)	EEECS5021S/ EEECS5022S	Program Elective I	3-1-0	4	20	30	50	3
5 (PSC-2)	EEECS5031T/ EEECS5032T	Program Elective II	3-0-0	3	20	30	50	3
6 (IOC-1)		Open elective I	3-0-0	3	20	30	50	3
7 (LC-1)	EEECS5011P	Linear Control Theory: Analysis and Design Lab	0-0-2	1	60 CIE		40	-
8 (LC-2)	EEECS5012P	Embedded Systems Lab-1	0-0-2	1	60 CIE		40	-
9 (LC-3)	EEECS5031P/ EEECS5032P	System Identification & Estimation Lab/ Modeling of Machines Lab	0-0-2	1	60 CIE		40	-
10 (LLC-1)		Liberal Learning	0-0-2	1	100% CIE			-
Total			**28**	**24**				

Abbreviations:

L	**:**	Lecture
T	**:**	Tutorial
P	**:**	Practical
TA	**:**	Teacher Assessment / Term Work Assessment
MST	**:**	Mid Semester Test
ESE	**:**	End Semester Written Examination
CIE	**:**	Continuous In-semester Evaluation

SEMESTER II

Scheme of Instruction				Scheme of Evaluation				
Sr. No	**Course Code**	**Course Title**	**L-T-P**	**Credits**	**TA**	**MST**	**ESE**	**ESE hours**
1 (MLC-1)	EEECS5002S	Research Methodology & IPR	3-0-0	3	20	30	50	3
2 (PCC-3)	EEECS5013S	Optimal Control	3-0-0	3	20	30	50	3
3 (PCC-4)	EEECS5014T	Embedded Systems Design	3-1-0	4	20	30	50	3
4 (PSC-3)	EEECS5041S/ EEECS5042S	Program Elective III	3-1-0	4	20	30	50	3
5 (PSC-4)	EEECS5051T/ EEECS5052T	Program Elective IV	3-0-0	3	20	30	50	3
6 (IOC-2)		Open Elective II	3-0-0	3	20	30	50	3
7 (LC-4)	EEECS5014P	Embedded Systems Lab-II	0-0-2	1	60 CIE		40	-
8 (LC-5)	EEECS5051P/ EEECS5052P	Filtering Theory Lab/ High Performance Drives Lab	0-0-2	1	60 CIE		40	-
9 (LC-6)	EEECS5076L	Technical Writing and Seminar	0-0-2	1	60 CIE		40	-
10 (LLC-2)		Liberal Learning	0-0-2	1	100 CIE			-
			28	**24**				

Abbreviations:

L	:	Lecture
T	:	Tutorial
P	:	Practical,
TA	:	Teacher Assessment / Term work Assessment
MST	:	Mid Semester Test
ESE	:	End Semester Written Examination
CIE	:	Continuous In-semester Evaluation

List of Program Elective I

Sr. No.	Course Code	Course Title
T1.1	EEECS5021S	Nonlinear System Analysis and Control
T2.1	EEECS5022S	Cyber-Physical Systems

List of Program Elective II

Sr. No.	Course Code	Course Name
T3.1	EEECS5031T	System Identification and Estimation
T4.1	EEECS5032T	Modeling of Machines

List of Program Elective III

Sr. No.	Course Code	Course Title
T1.2	EEECS5041S	Adaptive Control
T2.2	EEECS5042S	Electric Vehicles: Dynamics and Architectures

List of Program Elective IV

Sr. No.	Course Code	Course Name
T3.2	EEECS5051T	Filtering Theory
T4.2	EEECS5052T	High Performance Electric Drives

List of Open Elective I

Sr. No.	Course Code	Course Title
1		
2.		

List of Open Elective II

Sr. No.	Course Code	Course Title
1		
2.		

List of Liberal Learning Course

Sr. No.	Course Code	Course Title
1		
2.		

SEMESTER III

Scheme of Instruction					Scheme of Evaluation
Sr. No	**Course Code**	**Course Title**	**L-T-P**	**Credits**	
1 (SBC-1)	EEECS5091D	Skill Based Course (Project Stage -I)	---	5	100% CIE
2 (SBC-2)	EEECS5092D	Skill Based Course (Project Stage -II)	---	5	100% CIE
3 (SLC-1)	EEECS5101S	Self-Learning Course - 1	1-0-0	1	100% ESE of 3 hours or credit transfer
4 (SBC-2)	EEECS5201S	Self-Learning Course - 2	1-0-0	1	100% ESE of 3 hours or credit transfer
5 (MLC-2)	EEECS5301S	Mandatory Non-Credit Course	2-0-0	0	100% ESE of 3 hours or credit transfer
				12	

SEMESTER IV

Scheme of Instruction					Scheme of Evaluation
Sr. No	**Course Code**	**Course Title**	**L-T-P**	**Credits**	
1 (SBC-3)	EEECS5093D	Skill Based Course (Project Stage -III)	---	5	100% CIE
2 (SBC-4)	EEECS5094D	Skill Based Course (Project Stage -IV)	---	7	100% CIE
				12	

Abbreviations:

L : Lecture

T : Tutorial

P : Practical

CIE : Continuous In-semester Evaluation

SEMESTER I

<table>
<tr><td rowspan="1"></td><td colspan="4">M. TECH. IN
ELECTRICAL ENGINEERING
with specialization in
EMBEDDED CONTROL SYSTEMS (ECS)</td><td colspan="2">FIRST YEAR
SEM - I</td></tr>
<tr><td rowspan="3">COURSE CODE</td><td rowspan="3">[EEIPS5001S]
(PSMC-1)</td><td colspan="5">CREDITS ASSIGNED</td></tr>
<tr><td>THEORY</td><td>TUTORIAL</td><td>LAB</td><td>TOTAL HRS</td><td>TOTAL CREDITS</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">COMPUTATIONAL METHODS (CM)</td><td colspan="5">EVALUATION SCHEME</td></tr>
<tr><td>TA</td><td>MST</td><td>ESE</td><td colspan="2">TOTAL MARKS</td></tr>
<tr><td>20</td><td>30</td><td>50</td><td colspan="2">100</td></tr>
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Prerequisite: Undergraduate Engineering Mathematics, Basic integrals and ODEs, Matrix operations, Maxima and minima of a function, Solution to algebraic linear and nonlinear equations and ODEs

Course Outcomes:

CO1:	Analyze linear algebra concepts and apply them to engineering problem-solving.
CO2:	Analyze and implement unconstrained and constrained optimization methods, for both linear and nonlinear objectives
CO3:	Apply fundamental principles of probability theory to model and analyze uncertain events
CO4:	Develop and analyze time series models and apply them for effective forecasting of temporal data in practical applications.

Course Contents

Module 1: Linear Algebra

Scalars, Vectors, Vector spaces, Subspaces, Span, Linear Independence, Basis and Dimension, Matrices and Linear transformations, Rank and Determinant, Eigenvalues and Eigenvectors, Singular Value Decomposition, Inner product spaces and Orthogonality, Gram- Schmidth Orthonormalization

Module 2: Optimization

Unconstrained optimization: gradient descent, steepest descent, line search methods, conjugate gradient methods

Constrained optimization: Linear programming- equality constraints, Lagrange multiplier, inequality constraints, KKT conditions. Primal-dual dynamics, Solving using simplex method, interior-point method

Module 3: Probability Theory

Probability: Introduction, Probability axioms, Random variables, Jointly Distributed Random variables, Conditional probabilities & Expectations, Bayes theorem, Stirling's approximation

Discrete Distributions: Binomial, Poisson

Continuous Distributions: Normal, t-distribution, Central Limit theorem
Module 4: Time Series Analysis Introduction and Basics, Autoregressive processes, Moving average processes, Mixed processes, Forecasting
Books Recommended: (1) Gilbert Strang, *Introduction to Linear Algebra*, Wellesley Cambridge press, 6^{th} ed., 2023. (2) Jorge Nocedal, Stephen J. Wright, *Numerical Optimization*, 2^{nd} Ed., Springer Science 2006. (3) Michael J Panik, *Statistical Inference,* Wiley Publications, 2012. (4) K Hoffman & R Kunze, *Linear Algebra*, PHI, 1971 (5) A. Papoulis, *Probability, Random Variables & Stochastic Processes,* 3^{rd} edition, McGraw Hill, 1991. (6) Gebhard Kirchgässner & Jürgen Wolters, *Introduction to Modern Time Series Analysis,* Springer, 2008 (7) S C Gupta, V K Kapoor, *Fundamentals of Mathematical Statistics*. S. Chand & Sons, January 2014

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SEM - I</td></tr>
<tr><td rowspan="3">COURSE CODE</td><td rowspan="3">[EEECS5011T]
(PCC-1)</td><td colspan="5">CREDITS ASSIGNED</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">LINEAR CONTROL THEORY: ANALYSIS AND DESIGN (LCTAD)</td><td colspan="5">EVALUATION SCHEME</td></tr>
<tr><td>TA</td><td>MST</td><td>ESE</td><td colspan="2">TOTAL MARKS</td></tr>
<tr><td>20</td><td>30</td><td>50</td><td colspan="2">100</td></tr>
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Pre-requisites: Feedback systems, Transfer function modelling, Block diagram algebra, Stability concepts (Routh-Hurwitz, root-locus, frequency response), Laplace transforms, Review of basic stability, Steady-state and transient response of second order system to various inputs, steady state error, Root-locus method, Bode method, State Space Modelling

Course Outcomes:

CO1:	Design controllers using PID, Lead/Lag, state feedback, and observers.
CO2:	Evaluate the observability of linear time-invariant systems.
CO3:	Analyze the controllability and stabilizability of linear time-invariant systems.
CO4:	Apply robust and optimal control techniques like H-infinity and LQR.

Course Contents

Module 1: Compensator Design

Need for compensator, Lead/Lag compensator design using Root locus technique, Full state feedback control design, PID controller design, Observer design, Internal Model Control.

Module 2: Controllability and State Feedback

Controllable and reachable subspaces, Controllable systems, Controllable decompositions, stabilizability

Module 3: Observability and Output Feedback

Observability, Output feedback, minimal realizations, Linearization principles for observability, Observers and Detectability

Module 4: Advanced Topics in Control

Robust Control: System uncertainties, robust stability, small gain theorem, Sensitivity and Complementary sensitivity function, H-infinity control, Loop shaping.

Optimal Control: Formulation of optimal control problem, Linear Quadratic Regulator (LQR), Riccati equations for control design

Books Recommended:

(1) Norman S. Nise, *Control System Engineering*, 8th Edition, John Wiley & Sons Inc, 2019
(2) Morari and Zafiriou, *Robust Process Control*, Prentice Hall, Englewood Cliffs, New Jersey
(3) Kemin Zhou, *Essentials of Robust and Optimal Control*, Prentice Hall, 1998
(4) Jo˜ao P. Hespanha, *Linear Systems Theory,* PowerEn, 2010.
(5) Graham C. Goodwin, Stefan F. Graebe, and Mario E. Salgado, *Control System Design*, Prentice Hall, 2001
(6) Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, and Francis J. Doyle, *Process Dynamics and Control*, 4^{th} edition, Wiley, 2017

<table>
<tr><td rowspan="1">EED, VJTI</td><td colspan="3">M. TECH. IN
ELECTRICAL ENGINEERING
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SEM - I</td></tr>
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(PCC-2)</td><td colspan="6">CREDITS ASSIGNED</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">EMBEDDED SYSTEMS (ES)</td><td colspan="6">EVALUATION SCHEME</td></tr>
<tr><td>TA</td><td>MST</td><td>ESE</td><td colspan="3">TOTAL MARKS</td></tr>
<tr><td>20</td><td>30</td><td>50</td><td colspan="3">100</td></tr>
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Pre-requisites: Digital Electronics / Computer Organization, Signals and Systems, Control Systems (Introductory Level), Programming in C / Embedded C, Microprocessor and Microcontrollers

Course Outcomes:

CO1:	Understand embedded system fundamentals, including sampling, finite automata, hybrid systems, and real-time scheduling principles.
CO2:	Identify and apply essential hardware components such as microcontrollers, DSPs, data acquisition systems, and Systems on Programmable Chips (SoPCs).
CO3:	Develop and verify real-time embedded control systems using RTOS concepts, multitasking, functional analysis, and scheduling techniques.
CO4:	Implement embedded control applications using MATLAB/Simulink and xPC Target, and integrate hardware/software components in real-world control scenarios.

Course Contents

Module 1: Introduction to Embedded and Hybrid Control Systems

Overview of Embedded Systems and Control Applications, Life Cycle and Design Challenges, Basics of Sampling and Quantization, Discrete Event Systems, Introduction to Hybrid Systems, Finite Automata and Hierarchical State Machines, Design Space Exploration, Basics of Computer Architecture, Basics of Network Fundamentals

Module 2: Real-Time Systems and Operating Fundamentals

Real-Time Scheduling for Embedded Systems, Task Scheduling, Multitasking, and Determinism, Temporal Logic, RTOS Fundamentals and Kernel Abstractions, From Control Loops to Real-Time Programs, Functional Analysis of Embedded Systems, Verification Techniques for Correctness

Module 3: Embedded Hardware and Interfacing Techniques

Embedded Processors and Memory Architecture, Microcontrollers, Systems on Programmable Chips (SoPCs), Digital Signal Processors (DSPs), Basics of Data Acquisition Systems, Sensor and Actuator Integration, Input/Output Interfacing and Communication.

Module 4: Software Tools and System Integration

Real-Time Control with MATLAB, Simulink, and xPC Target, Embedded Real-Time

Controller Design via Model-Based Tools, Code Generation and Rapid Prototyping, System Testing and Debugging
Case Studies: Motor Control, PID Implementation, Networked Sensor Systems, Overview of Industrial Protocols: CAN, Modbus, Capstone Project Planning

Books Recommended:

(1) Dimitrios Hristu-Varsakelis & William Levine, *Handbook of Networked and Embedded Control Systems*, Birkhauser, 2005
(2) Edward Lee & Sanjit Seshia, *Introduction to Embedded Systems: A Cyber-Physical Systems Approach*, MIT Press, 2nd edition, 2017.
(3) K.V. Shibu, *Introduction to Embedded Systems*, McGraw Hill, 2009
(4) Steve Furber, *ARM System-on-Chip Architecture*, Pearson, 2nd edition, 2000
(5) Sloss, Symes, and Wright, *ARM System Developer's Guide*, Elsevier, 2004.
(6) Raj Kamal, *Embedded Systems – Architecture, Programming and Design*, McGraw Hill, 3rd edition, 2017

Program Elective-I

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - I
COURSE CODE	**[EEECS5021S] (PSC-1)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**1**	**0**	**4**	**4**
COURSE TITLE	**NONLINEAR SYSTEM ANALYSIS AND CONTROL (NSAC)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Control Systems (Linear), Ordinary Differential Equations (ODEs) and Dynamical Systems, Linear Algebra, Basic Nonlinear Functions and Analysis (from Applied Math or Systems courses)

Course Outcomes:

CO1:	Analyze nonlinear systems using phase space and phase plane methods.
CO2:	Assess stability using Lyapunov's methods for both autonomous and nonautonomous systems.
CO3:	Assess stability using Lyapunov's methods for non-autonomous systems
CO4:	Design nonlinear controllers using feedback linearization techniques.

Course Contents

Module 1: Introduction to Nonlinear Control and Phase Space Analysis

Nonlinear models and Nonlinear phenomena, Examples, Concept of Phase space analysis, Constructing Phase portraits, Phase plane analysis of Linear and Nonlinear systems, Existence and non-existence of limit cycles.

Module 2: Fundamentals of Lyapunov Theory

Nonlinear systems and equilibrium points, concepts of stability, LaSalle's Invariance principle, Linearization and local stability, Lyapunov's Direct method, System Analysis and Control design based on Lyapunov's Direct method, Lyapunov's Indirect method.

Module 3: Lyapunov Analysis Of Non-Autonomous (NA) Systems

Stability of NA systems, Lyapunov's Direct method for NA systems, Positive Linear systems, The Passivity formalism.

Module 4: Nonlinear Control Systems Design By Feedback Linearization

Feedback realization and the canonical form, Mathematical tools, Input-state linearization of SISO systems, Input-output linearization of SISO systems.

Books Recommended:

(1) Slotine J.J.E. and Li. W, *Applied Nonlinear Control*, Prentice Hall, 1991.
(2) Hassan K Khalil, *Nonlinear Systems*, 3rd edition, PHI, 2013.
(3) M. Vidyasagar, *Nonlinear Systems Analysis*, Prentice Hall, Englewood Cliffs, New Jersey, 2nd edition, 1993
(4) Alberto Isidori, *Nonlinear Control Systems*, Springer, 1995

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)				FIRST YEAR SEM - I	
COURSE CODE	**[EEECS5022S] (PSC-1)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**1**	**0**	**4**	**4**
COURSE TITLE	**CYBER-PHYSICAL SYSTEMS (CPS)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Probability and Statistics, Computer Networks and Communication Protocols, Machine Learning Fundamentals, Embedded Systems / Real-Time Systems (Introductory Level)

Course Outcomes:

CO1:	Understand the fundamentals of CPS, including system classification, decision-making, and communication networks.
CO2:	Explain the layered architecture of CPS and analyze the role of network protocols
CO3:	Apply Machine learning and Decentralized technologies and evaluate their potential in future communication paradigms.
CO4:	Apply CPS concepts to real-world systems like smart grids, healthcare, and traffic management.

Course Contents

Module 1: Introduction to Cyber-Physical Systems (CPS)

Classification of systems, uncertainty and Probability theory, Mathematical Information and Communication, CAN bus, Network types, Processes on networks and applications, From Big data to Mathematical abstractions, Forms of decision making, Game theory, Optimization, Rule-based decisions.

Module 2: Layers of CPS

Three layers of CPS, Dynamics of CPS Data Networks and Wireless Communications, Network Layers and Their Protocols, Network: Edge and Core, IoT, Machine-Type Communications, and 5G.

Module 3: ICT Technologies

Machine Learning: Data, Model, and Loss Function, Formalizing and Solving a ML Problem, ML Methods, Decentralized Computing and Distributed Ledger Technology, Federated Learning and Decentralized Machine Learning, Blockchain and Distributed Ledger Technology Future Technologies: A Look at the Unknown Future, Quantum Internet

Module 4: Applications

Power grid, public health surveillance system, Real-time Traffic Routing

Books Recommended:

(1) Pedro H. J. Nardelli, *Cyber-Physical Systems: Theory, Methodology and Applications*, Wiley, 2022.
(2) Walid M. Taha, et-al, *Cyber-Physical Systems: A Model-Based Approach*, Springer, 2021
(3) Rajkumar, de Niz & Klein, *Cyber-Physical Systems*, Pearson, 2017

Program Elective -II

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - I	
COURSE CODE	**[EEECS5031T] (PSC-2)**	**CREDITS ASSIGNED**					
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**	
		3	**0**	**0**	**3**	**3**	
COURSE TITLE	**SYSTEM IDENTIFICATION AND ESTIMATION (SIE)**	**EVALUATION SCHEME**					
		TA	**MST**	**ESE**	**TOTAL MARKS**		
		20	**30**	**50**	**100**		

Pre-requisites: Signals and Systems, Probability and Random Processes, Estimation Theory Basics, State-Space Models

Course Outcomes:

CO1:	Analyze linear time-invariant systems and random processes
CO2:	Apply data-based identification techniques to model static systems.
CO3:	Implement subspace model identification techniques for dynamic systems
CO4:	Evaluate and apply different parameter estimation methods in system modeling.

Course Contents

Module 1: Signals and Data Preprocessing for System Identification

Signal types: Continuous vs. Discrete-time signals, Sampling, and Nyquist-Shannon theorem.
Frequency-domain analysis: Fourier transforms, Frequency spectra.
Filter types: Low-pass, High-pass, Band-pass, Band-stop, and moving average filters.
Anti-aliasing filters and their role in ADC-based systems.
Finite impulse response (FIR) filters, Infinite impulse response (IIR) filters, Filter realization techniques.

Module 2: Data-Based Identification

System response methods- Impulse, step and sine-wave response
Frequency response methods- sine wave testing, empirical transfer function estimate
Correlation methods- correlation functions, frequency analysis using correlation techniques, spectral analysis
Static system identification- linear regression, least-squares estimation

Module 3: Subspace Model Identification

Subspace model identification for deterministic systems, Subspace identification with white measurement noise, Subspace identification with process and measurement noise, Using subspace identification with closed-loop data, N4SID

Module 4: Parameter Estimation Techniques

Introduction to Estimation, Types of Estimation Problems, Goodness of an Estimator, Estimation methods- method of moments, Least-squares method, Maximum-Likelihood estimation method, Bayes' estimation method, Estimator Accuracy considerations, Cramer-Rao lower bound.

Books Recommended:

(1) Tangirala, Arun K, *Principles of System Identification: Theory and Practice*. CRC Press, 2018.
(2) Ljung, Lennart. *System Identification: Theory for the User*, 2nd edition, Prentice-Hall, 1999.
(3) Karel J Keesman, *System Identification: An Introduction*, Springer 2011.
(4) Michel Verhaegen & Vincent Verdult, *Filtering theory and System Identification: A Least Squares Approach*, Cambridge University Press, 2007.
(5) S. M. Kay, *Fundamentals of Statistical Signal Processing: Estimation Theory*, PHI, 1993.

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - I
COURSE CODE	**[EEECS5032T] (PSC-2)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**0**	**0**	**3**	**3**
COURSE TITLE	**MODELING OF MACHINES (MoM)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Electrical Machines (DC, induction, synchronous), Electromechanical Energy Conversion and Dynamics, Modeling of Electromechanical Systems, State-Space Analysis and Control Basics, Torque–Speed Characteristics of Machines, Basics of Special Electric Machines (PM motors, SRM, BLDC, PMSM).

Course Outcomes:

CO1:	Develop mathematical models of electrical machines by analyzing electromagnetic and mechanical subsystems
CO2:	Model and analyze DC machines using equivalent circuits, state-space representations, and transfer function methods for predicting steady-state and dynamic performance.
CO3:	Develop and implement mathematical models of AC machines, applying space-phasor techniques to analyze and simulate their steady-state and transient behaviour.
CO4:	Evaluate and design modeling and control strategies for special electrical machines, with practical applications in high-performance electric drives and electric vehicles.

Course Contents

Module 1: Fundamentals of Modeling

Need for modeling, Problems of modeling, Neglected phenomena, Power of Electrical sources, Electromotive force, Voltage balance equation, Leakage flux, Energy of the coupling field, Power of electromechanical conversion, torque expression, mechanical subsystem, model of mechanical subsystem, Equations of Mathematical model.

Module 2: DC Machine Modeling

Theory of operation, induced EMF, equivalent circuit, electromagnetic torque production, electromechanical and state-space modeling, transfer function representation and block diagrams, field excitation effects, and modeling of Permanent Magnet Brushless DC (PMBLDC) motors.

Module 3: AC Machine Modeling

Induction machines: principle of operation, equivalent circuit, steady-state and dynamic modeling, space-phasor model, stator and rotor voltage and flux linkage equations, dq0 transformation, and control principles. Synchronous machines with permanent magnets (PMSM): dynamic modeling, voltage, and flux linkage equations, sub-transient and transient reactances, and torque expressions

Module 4: Special Machines Square wave and sine wave permanent magnet motors: modeling and control techniques. Switched reluctance motors (SRM): voltage and torque equations, inductance modeling, and control strategies. Applications in high-performance electric drives and electric vehicles.
Books Recommended: (1) S. Vukosavic, *Electrical Machines*, Springer, Reprinted 2018. (2) R. Krishnan, *Electric Motor Drives: Modeling, Analysis, and Control*, Pearson, 2017. (3) P. C. Krause, O. Wasynczuk, S. D. Sudhoff, A. K. Pekarek, *Analysis of Electric Machinery and Drive Systems*, 3rd edition, Wiley, 2022. (4) P. Kundur, *Power System Stability and Control*, Mc Graw Hill, 2006

Laboratory Courses

<table>
<tr><td rowspan="1"></td><td colspan="3">M. TECH. IN
ELECTRICAL ENGINEERING
with specialization in
EMBEDDED CONTROL SYSTEMS (ECS)</td><td colspan="3">FIRST YEAR
SEM - I</td></tr>
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<tr><td>THEORY</td><td>TUTORIAL</td><td>LAB</td><td>TOTAL HRS</td><td>TOTAL CREDITS</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">LINEAR CONTROL THEORY: ANALYSIS AND DESIGN LAB (LCTADL)</td><td colspan="5">EVALUATION SCHEME</td></tr>
<tr><td colspan="2">CIE</td><td>ESE</td><td colspan="2">TOTAL MARKS</td></tr>
<tr><td colspan="2">60</td><td>40</td><td colspan="2">100</td></tr>
</table>

Prerequisite: Fundamentals of Control Systems, Root Locus Method, Feedback Controller Design, State-Space Concepts, Basic MATLAB/Simulink Skills (if using simulation tools)

Lab Outcomes:

LO1:	Design and analyze classical and modern control systems by applying root locus, PID, and state-space techniques to meet desired time-domain and frequency-domain specifications.
LO2:	Develop and analyze state-space-based controllers and observers-including LQR, Luenberger observer, internal model control, and output feedback-to achieve robust control and state estimation.

List of Experiments

(1) Transform a system to controllable canonical form and analyze decompositions.
(2) Design an output feedback controller (e.g., observer-based feedback).
(3) Cascade lead compensator and cascade lag compensator design using Root locus.
(4) To obtain values of the proportional, integral and derivative gains of a PID controller so as to meet the desired specifications
(5) Design a full state feedback controller using pole placement so as to meet desired specifications
(6) Design a Luenberger observer for a given state-space model.
(7) Implement internal model-based controller for set-point tracking and disturbance rejection.
(8) Design a controller using loop-shaping principles and evaluate performance.
(9) Design a Linear Quadratic Regulator for a system and simulate its response.
(10) Hardware experiments based on the syllabus

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - I
COURSE CODE	[EEECS5012P] (LC-2)	CREDITS ASSIGNED				
		THEORY	TUTORIAL	LAB	TOTAL HRS	TOTAL CREDITS
		0	0	2	2	1
COURSE TITLE	EMBEDDED SYSTEMS LAB-I (ESL-I)	EVALUATION SCHEME				
		CIE		ESE	TOTAL MARKS	
		60		40	100	

Prerequisite: Basics of Microcontrollers / Microprocessors, Programming in Embedded C/ Assembly, Interrupts and Timers, Embedded System Hardware Basics

Lab Outcomes:

LO1:	Design and implement embedded system applications using core programming concepts such as timers, interrupts, analog/ digital interfaces, and serial communication protocols.
LO2:	Develop and simulate embedded control systems by applying principles of state machines, signal modulation, real-time scheduling, and hybrid dynamic system modeling

List of Experiments

Embedded Systems Programming and Interfaces

1. Timer-Based Delay Implementation in Embedded Systems
2. Implementation of Interrupt Handling in Embedded Systems
3. Analog Signal Acquisition and Display via Serial Interface
4. Bidirectional Serial Communication Between Controller and Host

Control Systems and Applications

5. Finite State Machine Design for a Traffic Light Control System
6. Modulation-Based Output Control in Embedded Systems
7. Modeling and Simulation of a PID Controlled System
8. Simulation of Hybrid Dynamic Systems with Continuous and Discrete Behavior
9. Embedded Control System Simulation on a Programmable Platform

Real-Time Systems and Scheduling

10. Simulation of Real-Time Task Scheduling in Embedded Systems

<table>
<tr><td></td><td colspan="2">M. TECH. IN
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with specialization in
EMBEDDED CONTROL SYSTEMS (ECS)</td><td colspan="5">FIRST YEAR
SEM - I</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">SYSTEM IDENTIFICATION AND ESTIMATION LAB
(SIEL)</td><td colspan="6">EVALUATION SCHEME</td></tr>
<tr><td colspan="2">CIE</td><td>ESE</td><td colspan="3">TOTAL MARKS</td></tr>
<tr><td colspan="2">60</td><td>40</td><td colspan="3">100</td></tr>
</table>

Prerequisite: Signals and Systems, Probability and Random Processes, Estimation Theory Basics, State-Space Models and Kalman Filtering

Lab Outcomes:

LO1:	Apply correlation-based techniques and time/frequency domain tools to analyze stationary random signals and identify appropriate dynamic models
LO2:	Implement and compare system identification and parameter estimation techniques for modeling and inference from noisy data.

List of Experiments

(1) Sampling and frequency analysis of signals

(2) Design and implementation of Digital Filters (FIR & IIR)

(3) System response identification using time-domain methods

(4) Frequency response estimation using Empirical Transfer Function Estimate (ETFE)

(5) Apply cross correlation coefficient to analyze and extract insights of the system.

(6) Identify the best suited model for given dataset using ACF/PACF plots

(7) Obtain the order of a moving average model using ACF and evaluate the model coefficients

(8) Identify a state-space model from input-output data using N4SID.

(9) Estimate static system parameters using least-squares fitting

(10) Compare MLE and Bayesian estimation on a simulated noisy system.

EED, VJTI	**M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)**	**FIRST YEAR SEM - I**

COURSE CODE	**[EEECS5032P] (LC-3)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		0	**0**	**2**	**2**	**1**
COURSE TITLE	**MODELLING OF MACHINES LAB (MoML)**	**EVALUATION SCHEME**				
		CIE		**ESE**	**TOTAL MARKS**	
		60		**40**	**100**	

Prerequisite: Modeling of Electromechanical Systems, Electromechanical Energy Conversion and Dynamics, Working principles of DC, induction, and synchronous machines, Torque-speed characteristics

Lab Outcomes:

LO1:	Develop and analyze dynamic models of electrical machines using transformation techniques and data-driven approaches to evaluate machine behavior under varying operating conditions.
LO2:	Design, simulate, and validate advanced control strategies and fault detection mechanisms for electrical machines using real-time simulation tools and signal analysis techniques.

List of Experiments

(1) Dynamic Modeling of DC Machines

(2) d-q Axis Modeling of Synchronous Machines

(3) Induction Machine Modeling using Space Vector Theory

(4) Field-Oriented Control (FOC) of Induction Machines

(5) Use offline tests (no-load, blocked rotor) to estimate parameters of IM and synchronous machines.

(6) Use real-time simulators (like dSPACE/OPAL-RT) to test control strategies on modelled machines.

(7) Any other hardware/simulation experiment

SEMESTER II

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - II
COURSE CODE	**[EEECS5002S] (MLC-1)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**0**	**0**	**3**	**3**
COURSE TITLE	**RESEARCH METHODOLOGY & IPR (RM&I)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Basics of probability, Probability Axioms, Conditional Probability and Marginal Probability, Mean, median, mode, variance, standard deviation, Familiarity with technical report writing or seminar presentations

Course Outcomes:

CO1:	Apply descriptive and inferential statistical methods to summarize and draw valid conclusions from data
CO2:	Prepare, clean, and analyze datasets using correlation, regression, and multivariate techniques.
CO3:	Design and communicate a complete research study
CO4:	Understand Intellectual Property Rights and Patent processes.

Course Contents

Module 1: Core Statistical Methods: From Description to Inference

Descriptive Statistics - Mean, Median, Mode, Range, Variance, Standard Deviation, Skewness, Kurtosis

Data visualization: Histograms, Boxplots, Bar charts

Sampling- Sampling techniques (random, stratified, etc.), sampling error, sample size estimation

Inferential Statistics - Hypothesis Testing (z-test, t-test, ANOVA, chi-square), Confidence Intervals, Type I and Type II errors

Module 2: Data Preparation and Advanced Analysis

Data Processing and Cleaning- Handling missing data, outliers, Data transformation and standardization

Correlation and Regression- Pearson and Spearman correlation, Simple and Multiple Linear Regression

Multivariate Techniques- Overview of PCA, Factor Analysis, and Cluster Analysis

Module 3: Research Design and Reporting

Formulating a research problem, conceptualizing a research design, data collection, selecting a sample, writing a research proposal, processing and displaying data, writing a research report

Module 4: IPR and Patents

Intellectual Property – The concept of IPR, IPR development process, Trade secrets, utility models, Role of WIPO and WTO in IPR establishments, Right of Property, Common rules of IPR practices, Types and Features of IPR Agreement, Trademark, Functions of UNESCO in IPR maintenance.

Patents – objectives and benefits of patent, Concept, features of patent, Inventive step, Specification, Types of patent application, process E-filling, Examination of patent, Grant of patent, Revocation, Equitable Assignments, Licenses, Licensing of related patents, patent agents, Registration of patent agents.

Books Recommended:

(1) Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners,* Sage Publications, 2024.
(2) Michael J Panik, *Statistical Inference,* Wiley Publications, 2012
(3) Siva Vaidhyanathan, *Intellectual Property: A Very Short Introduction*, Oxford Publications, 2017
(4) Sheldon M. Ross, *Introductory Statistics*, 3rd edition, Academic Press, 2010
(5) A. Papoulis, *Probability, Random Variables & Stochastic Processes*, 3rd edition, McGraw Hill, 1991

<table>
<tr><td colspan="2"></td><td colspan="5">M. TECH. IN
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with specialization in
EMBEDDED CONTROL SYSTEMS (ECS)</td><td colspan="2">FIRST YEAR
SEM - II</td></tr>
<tr><td rowspan="3">COURSE CODE</td><td rowspan="3">[EEECS5013S]
(PCC-3)</td><td colspan="7">CREDITS ASSIGNED</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">OPTIMAL CONTROL (OC)</td><td colspan="7">EVALUATION SCHEME</td></tr>
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<tr><td>20</td><td>30</td><td>50</td><td colspan="4">100</td></tr>
</table>

Pre-requisites: Linear Control Systems and State-Space Theory, Calculus of Variations and Advanced Calculus, Differential Equations and Dynamical Systems, Mathematical Optimization and Dynamic Programming (Basic)

Course Outcomes:

CO1:	Formulate and solve optimal control problems using dynamic programming principles
CO2:	Understand and apply the calculus of variations to derive conditions for optimality in control systems
CO3:	Apply the Pontryagin Maximum Principle to characterize optimal control laws for systems with state and control constraints
CO4:	Analyze and solve classical optimal control problems

Course Contents

Module 1: Introduction and Dynamic Programming

Problem formulation, State variable representation of system, Optimal control law, Principle of optimality, Application of the optimality to decision making, Dynamic programming applied to a routing problem, An optimal control system, Interpolation, A recurrence relation of dynamic programming, Computational procedure for solving control problems, Characteristics of dynamic programming solutions, Analytical results- discrete linear regulator problem, The Hamilton-Jacobi-Bellman equation, Continuous linear regulator problems.

Module 2: The Calculus Of Variations

Fundamental concepts, functions of a single function, fundamental theorem of calculus of variations, functions involving several independent functions, the simplest variational problem, piecewise smooth extremals, constrained extrema

Module 3: Pontryagin Maximum Principle

Heuristic Proof of Pontryagin Maximum principle, Lagrange-Mayer, Principle of Optimality, Temporal Variations of u, spatial variations of u, the variational equation, Terminal cone, separating hyper plane, Adjoint equation, Final proof.

Module 4: Optimal Control Problems

Time Optimal control problems, the bang-bang principle, Existence of optimal controls, Finite Horizon LQR problem, Riccati Differential equation.

Books Recommended

(1) M. Athans and P. L. Flab, Optimal control: An Introduction to the Theory and its Applications, McGraw-Hill, New York, 1966.
(2) A.E. Bryson and Y.-C. Ho, Applied Optimal Control, Hemisphere, 1975.
(3) Donald E. Kirk, Optimal Control theory: An Introduction, Dover Publications, 2004.
(4) D. Liberzon, Calculus of Variations and Optimal Control Theory: A Concise Introduction, Princeton University Press, 2012
(5) Luigi Fortuna, Mattia Frasca, Arturo Buscarino, Optimal and Robust Control. Advanced Topics with MATLAB, CRC Press, 2021.

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)				FIRST YEAR SEM - II
COURSE CODE	**[EEECS5014T] (PCC-4)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**1**	**0**	**4**	**4**
COURSE TITLE	**EMBEDDED SYSTEMS DESIGN (ESD)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Embedded Systems Fundamentals, Control Systems and Networked Control, Computer Networks and Communication Protocols, Hybrid Systems and Automata Theory (Introductory)

Course Outcomes:

CO1:	Model hybrid and networked control systems by integrating continuous and discrete dynamics.
CO2:	Analyze the architecture, protocols, and communication challenges of networked embedded systems.
CO3:	Design and implement real-time embedded control applications using protocols like CAN and Bluetooth.
CO4:	Apply advanced techniques for co-design of communication and control, fault tolerance, and security, using model-checking tools and real-world CPS case studies.

Course Contents

Module 1: Modelling of Hybrid and Networked Control Systems

Introduction to Cyber-Physical Systems, Modelling Hybrid Systems, Hybrid Automata: formalism, transitions, invariants, Time-triggered vs Event-triggered Systems, Overview of Hybrid Control, Modelling Networked Control Systems (NCS), Delays, packet drops, jitter, Model-based design of NCS, Introduction to verification and simulation tools

Module 2: Communication in Networked Embedded Systems

Architecture of Networked Control Systems (NCS), Communication Protocols, Ethernet: Real-time Ethernet, TCP/IP stack analysis, Bluetooth in Embedded Control, Zigbee / Wi-Fi – industrial usage and limitations, Feedback Control over Networks, Latency, packet loss handling, compensation strategies, Synchronization and Scheduling over Network

Module 3: Real-time Embedded Control Applications

CAN (Controller Area Network) for Vehicle Control, Frame structure, message arbitration, ECU-based control, Real-time task scheduling for embedded systems, Case study: Autonomous Mobile Robot control, Path planning, feedback control, sensor integration, Bluetooth-based Wireless Control Systems

Module 4: Advanced Topics & Case Studies in Networked Control

Co-design of Communication and Control, Fault Tolerance and Security in Embedded Control, Hybrid NCS design using model-checking tools, Case Studies: Smart Grid Control

Systems, Medical CPS
Books Recommended: (1) Dimitrios Hristu-Varsakelis, William S. Levine, *Handbook of Networked and Embedded Control Systems*, Birkhäuser, Boston, 2005 (2) Edward Ashford Lee and Sanjit Arunkumar Seshia, *Introduction to Embedded Systems: A Cyber-Physical Systems Approach*, 2nd edition, MIT Press, 2017 (3) Fei-Yue Wang and Derong Liu, *Networked Control Systems: Theory and Applications*, Springer, 2008 (4) Fei Hu and Xiaojun Cao, *Wireless Sensor and Actuator Networks: Enabling Technologies, Information Processing and Protocol Design*, CRC Press, 2013

Program Elective -III

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - II
COURSE CODE	**[EEECS5041S] (PSC-3)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**1**	**0**	**4**	**4**
COURSE TITLE	**ADAPTIVE CONTROL (AC)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Linear Control Systems, System Identification and Parameter Estimation, Nonlinear Systems and Stability Theory, Optimization and Learning Theory	
Course Outcomes:	
CO1:	Formulate and analyze adaptive control problems using model-based, model-free, and learning-based approaches with consideration for persistence of excitation.
CO2:	Design direct and indirect Model Reference Adaptive Control (MRAC) systems for unknown linear time-invariant (LTI) systems, ensuring parameter convergence and stability
CO3:	Apply extremum seeking techniques for indirect adaptive control of nonlinear systems with model uncertainties
CO4:	Design and analyze robust adaptive control schemes to ensure stability and performance
Course Contents	
Module 1: Introduction Adaptive Control problem formulation, Model-based adaptive control, Model-free adaptive control, Learning-based adaptive control, Classical Adaptive Control, Composite Adaptive Control, Persistence of Excitation.	
Module 2: Model Reference Adaptive Control Direct and Indirect MRAC Classical MRAC, Direct MRAC, Indirect MRAC, Combined MRAC for Unknown LTI Systems with Parameter Convergence Identification of system parameters, Tracking Error and Control Parameter convergence, Composite Adaptation with Parameter convergence	
Module 3: Extremum Seeking-Based Indirect Adaptive Control Nonlinear Models with Constant Model Uncertainties, Open-Loop Parametric Identification for Nonlinear Systems	
Module 4: Robust Adaptive Control Schemes Introduction, Plant uncertainties and robust control, modifications for robustness-simple examples, Robust adaptive laws, Robust MRAC	

Books Recommended:

(1) I. D. Landau, R. Lozano et al, *Adaptive Control*, *Algorithms, Analysis and Applications*, Springer-Verlag, 2011.
(2) Mouhacine Benosman, *Learning-Based Adaptive Control. An Extremum Seeking Approach - Theory and Applications*, Elsevier Science, 2016
(3) K. J. Astrom and B. Wittenmark, *Adaptive Control*, Addison-Wesley, 2nd edition, 1995
(4) S. Sastry and Bodson, *Adaptive Control: Stability, Convergence, and Robustness*, PHI, 1989.
(5) P. Ioannou and J. Sun, *Robust Adaptive Control*, PHI, 1996.

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - II
COURSE CODE	**[EEECS5042S] (PSC-3)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**1**	**0**	**4**	**4**
COURSE TITLE	**ELECTRIC VEHICLES: DYNAMICS AND ARCHITECTURES (EVDA)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Electrical Machines, Control Systems, Power Electronics, Basics of Communication Protocols

Course Outcomes:

CO1:	Explain the architecture, types, and evolution of electric vehicles.
CO2:	Model the dynamic behavior of electric vehicles and apply design considerations for auxiliary systems.
CO3:	Understand various motor controller strategies used in EVs.
CO4:	Design and evaluate Electric vehicle support systems.

Course Contents

Module 1: Introduction and Types of Electric Vehicles- EV architecture

Importance of EVs, History, EVs and the environment, IC Engine/ Electric Hybrid Vehicle, Fueled EVs, EVs using Supply Lines, EVs which use Flywheels or Supercapacitors, Solar-Powered Vehicles, Vehicles using Linear Motors, EVs for the Future

Module 2: Electric Vehicle Modeling and Design considerations

Tractive Effort, Modelling vehicle Acceleration, Modelling Vehicle range, Aerodynamic and rolling resistance considerations, Design of ancillary systems

Module 3: Electric Machines and Controllers

Brushed DC motor, DC regulation and Voltage conversion, Brushless motors, Motor cooling, efficiency, size and mass, Electric Machines for Hybrid vehicles

Module 4: EV Infrastructure, Auxiliaries and Battery Management Systems (BMS)

Battery Swapping and Charging, CAN Bus – protocol, and requirements, ABS, Power Steering, Regenerative braking systems.
BMS-Introduction, Battery modeling, functions of BMS, monitoring and safety, Cell-balancing.

Books Recommended:

(1) Mehrdad Ehsani, *Modern Electric, Hybrid Electric & Fuel Cell Vehicles*, CRC Press, 2018.
(2) C.C Chan and K. T. Chau, *Modern Electric Vehicle Technology*, Oxford Press, 2001.
(3) Larminie and Lowry, *Electric Vehicle Technology Explained*, Wiley, 2012.

Program Elective -IV

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - II
COURSE CODE	**[EEECS5051T] (PSC-4)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		3	**0**	**0**	**3**	**3**
COURSE TITLE	**FILTERING THEORY (FT)**	**EVALUATION SCHEME**				
		TA	**MST**	**ESE**	**TOTAL MARKS**	
		20	**30**	**50**	**100**	

Pre-requisites: Signals and Systems, Digital Signal Processing (DSP) – Basics, Probability and Random Processes, Basic Control Systems / Embedded Systems

Course Outcomes:

CO1:	Explain the fundamental concepts of stochastic processes and filtering theory
CO2:	Apply linear filtering techniques such as Kalman filtering and smoothing for estimation in linear time-invariant systems
CO3:	Analyze and implement nonlinear filtering algorithms for parameter estimation in dynamic systems
CO4:	Design adaptive filtering solutions and implement filter-based SLAM techniques in localization and mapping applications.

Course Contents

Module 1: Introduction to Stochastic Processes and Filtering Theory

Introduction: Probabilistic approach, Statistical methods
Probability law of a Stochastic processes, Convergence of random sequences, Gaussian Processes, Markov Processes, Brownian motion, White noise, Stochastic Differential equations.

Module 2: Linear Filtering Theory and Kalman Filters

Linear filtering theory: continuous-discrete filter, discrete filter, continuous filter
Kalman filtering: Kalman filter and Least squares, fixed interval smoothing, Kalman filter for LTI systems

Module 3: Nonlinear Filtering Theory

Nonlinear filtering theory: continuous-discrete filter, discrete filter, continuous filter
Extended Kalman Filter (EKF), higher order approaches, parameter estimations

Module 4: Adaptive Filtering and SLAM

Concepts of Adaptive filtering, LMS adaptive algorithm, applications
Simultaneous Localization and Mapping (SLAM)- Concepts-Filter based SLAM- Unscented Kalman Filters, Particle filters, Applications

Books Recommended:

(1) Dan Simon, *Optimal State Estimation: Kalman,* H_∞ *and Nonlinear Approaches*, Wiley Inter Science, 2006

(2) Michel Verhaegen and Vincent Verdult, *Filtering and System Identification: A Least square approach*, Cambridge University Press, 2007.

(3) Sebastian Thrun, Wolfram Burgard, Dieter Fox, *Probabilistic Robotics*, MIT Press, 2005.

(4) Mohinder Grewal, Angus Andrews, *Kalman Filtering, Theory and Practice using MATLAB,* Wiley, 2008.

(5) Peter E Caines, *Linear Stochastic Systems*, SIAM, 2018.

(6) Andrew H. Jazwinski, *Stochastic Processes and Filtering Theory*, Academic Press, 1970.

(7) Andrew P. Sage, James L. Melsa, *Estimation Theory with Applications to Communications and Control*, Mc Graw Hill, 1971.

<table>
<tr><td></td><td colspan="4">M. TECH. IN
ELECTRICAL ENGINEERING
with specialization in
EMBEDDED CONTROL SYSTEMS (ECS)</td><td colspan="3">FIRST YEAR
SEM - II</td></tr>
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<tr><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">HIGH PERFORMANCE ELECTRIC DRIVES (HPED)</td><td colspan="5">EVALUATION SCHEME</td></tr>
<tr><td>TA</td><td>MST</td><td>ESE</td><td colspan="2">TOTAL MARKS</td></tr>
<tr><td>20</td><td>30</td><td>50</td><td colspan="2">100</td></tr>
</table>

Pre-requisites: Fundamentals of Electrical Machines covering DC, induction, and synchronous machines; Power Electronics including converters, inverters, and switching devices; Control Systems focusing on feedback control and PID controllers; and essential concepts of Signal Processing and Circuit Analysis relevant to drive system modeling and analysis.

Course Outcomes:

CO1:	Design and analyze DC motor drives using phase-controlled converters and chopper-based control strategies for steady-state and dynamic performance
CO2:	Evaluate and compare induction motor drives employing voltage control, slip energy recovery, and frequency control methods, focusing on efficiency and torque-speed characteristics
CO3:	Describe principles of Vector Control
CO4:	Apply and implement vector control techniques for motors to achieve high-performance operation in Industrial and Electric Vehicle applications

Course Contents

Module 1: DC Motor Drives

Speed control of DC motors using phase-controlled converters; steady-state analysis of three-phase converter-fed DC motor drives; design of controllers for performance improvement; operation and analysis of four-quadrant chopper-controlled DC motor drives; torque-speed characteristics and efficiency evaluation.

Module 2: AC Motor Drives

Phase-controlled induction motor drives: stator voltage control and slip energy recovery schemes; steady-state and dynamic performance analysis. Frequency-controlled induction motor drives: static frequency changers, voltage source inverter (VSI) fed drives, and current source inverter (CSI) fed drives; derivation of voltage and torque equations; efficiency and power factor considerations.

Module 3: Direct Control principles

Vector control of induction motor drives: principles, direct vector control, and indirect vector control methods; speed controller design and dynamic performance analysis.

Module 4: Vector control strategies

Vector control strategies for permanent magnet synchronous motors (PMSM) and brushless DC (BLDC) motors; flux weakening operation, speed controller design, and sensor less control techniques. Applications in high-performance industrial drives and electric vehicles.

Books Recommended:

(1) G.K. Dubey, *Fundamentals of Electrical Drives*, 2nd Edition, Narosa (CRC Press), 2002

(2) G.K. Dubey, *Power Semiconductor Controlled Drives*, 2nd Reprint, New Age International Publishers, 2017

(3) R. Krishnan, *Electric Motor Drives: Modeling, Analysis and Control*, International Edition, Prentice Hall, 2001.

(4) Bimal K. Bose, *Modern Power Electronics and AC Drives*, Prentice Hall, 2001

(5) Mukhtar Ahmad, *High-Performance AC Drives: Modelling, Analysis and Control*, Springer, 2012.

(6) Austin Hughes & Bill Drury, *Electric Motors and Drives: Fundamentals, Types and Applications*, 5th Edition, Newnes, 2019.

Laboratory Courses

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - II
COURSE CODE	**[EEECS5014P] (LC-4)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		0	**0**	**2**	**2**	**1**
COURSE TITLE	**EMBEDDED SYSTEMS LAB-II (ESL-II)**	**EVALUATION SCHEME**				
		CIE		**ESE**	**TOTAL MARKS**	
		60		**40**	**100**	

Pre-requisites: Programming in C Language, Microcontroller Architecture and Peripherals, Embedded Systems Concepts, Device Drivers and Chip Support Libraries

Course Outcomes:

LO1:	Model and simulate hybrid and networked control systems incorporating switching logic, communication delays, and control feedback under real-time and non-ideal conditions.
LO2:	Design and implement embedded control applications involving actuator control, sensor integration, serial communication, and wireless protocols for real-time automation tasks.

List of Experiments

(1) Modelling a Hybrid Automaton in MATLAB/ State flow

(2) Design and Simulation of Control Systems with Switching Logic

(3) Simulation of Networked Control Systems with Communication Constraints

(4) Implementation of Controller Area Network (CAN) Based Communication Protocols

(5) Closed-loop Motor Control Using Pulse Width Modulation (PWM)

(6) Serial Communication Between Controller and Peripheral Devices

(7) Development of an Autonomous Obstacle Avoidance System

(8) Design of a Wireless Sensor-Based Control System

(9) Simulation and Control of Power Electronic Converters in Closed Loop

(10) Plant-Controller Co-Simulation and Hardware-in-the-Loop Testing

	M. TECH. IN ELECTRICAL ENGINEERING with specialization in EMBEDDED CONTROL SYSTEMS (ECS)					FIRST YEAR SEM - II
COURSE CODE	**[EEECS5051P] (LC-5)**	**CREDITS ASSIGNED**				
		THEORY	**TUTORIAL**	**LAB**	**TOTAL HRS**	**TOTAL CREDITS**
		0	**0**	**2**	**2**	**1**
COURSE TITLE	**FILTERING THEORY LAB (FTL)**	**EVALUATION SCHEME**				
		CIE		**ESE**	**TOTAL MARKS**	
		60		**40**	**100**	

Pre-requisites: Signals and Systems Fundamentals, Analog and Digital Filter Design, Adaptive Filtering Basics, Kalman Filtering, Wavelet Transform Basics (for wavelet-based denoising), Programming and Simulation Skills

Lab Outcomes:

LO1:	Design and evaluate digital filters (FIR and IIR) and analyze signal frequency characteristics using MATLAB for real-time signal processing applications.
LO2:	Implement and compare state estimation and adaptive filtering techniques.

List of Experiments

(1) Simulation of Gaussian and Markov Processes

(2) Numerical Simulation of Brownian Motion and SDEs

(3) Design of a Linear Discrete-Time Filter

(4) Kalman Filter Implementation for a 1D Motion Tracking Problem

(5) Fixed-Interval Smoothing Using Kalman Filter

(6) Apply EKF to a nonlinear system like a pendulum.

(7) Implement LMS algorithm to remove noise from a signal

(8) Filter-Based SLAM Using Unscented Kalman Filter or Particle Filter

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with specialization in
EMBEDDED CONTROL SYSTEMS (ECS)</td><td colspan="3" rowspan="3">FIRST YEAR
SEM - II</td></tr>
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<tr><td rowspan="3">COURSE CODE</td><td rowspan="3">[EEECS5052P]
(LC-5)</td><td colspan="5">CREDITS ASSIGNED</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">HIGH PERFORMANCE DRIVES LAB
(HPEDL)</td><td colspan="5">EVALUATION SCHEME</td></tr>
<tr><td colspan="2">CIE</td><td>ESE</td><td colspan="2">TOTAL MARKS</td></tr>
<tr><td colspan="2">60</td><td>40</td><td colspan="2">100</td></tr>
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Pre-requisites: Fundamentals of Electrical Machines, Power, Control Systems, Basic Signal Processing and Circuit Analysis- simulation tools using MATLAB

Lab Outcomes:

LO1:	Demonstrate various braking techniques (rheostatic, plugging, regenerative) for both DC and AC motors through hands-on experiments and interpret their impact on motor performance
LO2:	Simulate and analyze speed control and inverter-fed operations of different electric machines (DC, stepper, BLDC, and induction motors) using MATLAB/Simulink or equivalent tools.

List of Experiments

(1) To perform rheostatic braking on three phase Induction Motor.

(2) To perform rheostatic braking on D.C. Motor.

(3) To perform plugging on three phase Induction Motor.

(4) To perform plugging on D.C. Motor

(5) To perform regenerative braking on three phase Induction Motor.

(6) To simulate the performance & control of a Stepper motor.

(7) To simulate speed control of separately excited DC motor.

(8) To simulate Closed loop speed control of BLDC motor.

(9) To simulate two-level and three-level inverter with sinusoidal PWM.

(10) To simulate VSI fed Induction motor (square wave and PWM inverters).

(11) To simulate induction motor with open loop constant V/F control.

(12) To simulate induction motor with Indirect vector control.

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SEM - II</td></tr>
<tr><td rowspan="3">COURSE CODE</td><td rowspan="3">[EEECS5076L]
(LC-6)</td><td colspan="5">CREDITS ASSIGNED</td></tr>
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<tr><td rowspan="3">COURSE TITLE</td><td rowspan="3">TECHNICAL WRITING AND SEMINAR
(TWS)</td><td colspan="5">EVALUATION SCHEME</td></tr>
<tr><td colspan="2">CIE</td><td>ESE</td><td colspan="2">TOTAL MARKS</td></tr>
<tr><td colspan="2">60</td><td>40</td><td colspan="2">100</td></tr>
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Pre-requisites: Basic Academic Writing Skills, Literature Review and Research Skills, Presentation and Communication Skills

Lab Outcomes:

LO1:	Demonstrate the ability to write clear, concise, and well-structured technical documents and effectively use standard components and citation styles while adhering to ethical practices in writing and avoiding plagiarism
LO2:	Plan, prepare, and deliver effective technical presentations and seminars using appropriate visual aids and communication techniques to engage and inform an audience

Course Contents

Module 1: Introduction to Technical Writing

Definition and purpose of technical writing, Characteristics of good technical writing, Common types of technical documents (research article, project reports, conference papers). Grammar, punctuation, and sentence structure, Active vs. passive voice, Clarity, conciseness, coherence

Module 2: Report Structuring and Ethics in Writing

Abstract, Introduction, Methodology, Results, Discussion, Conclusion, References, IEEE/APA citation styles, Plagiarism, and how to avoid it

Module 3: Presentation and Seminar Skills

Planning and organizing presentations, Use of visual aids (PowerPoint, charts, videos), Voice modulation, body language, and audience engagement
Literature review and selection of seminar topic, Preparation of seminar report (8–10 pages), Delivery of seminar presentation, Q&A session, and feedback

Recommended Texts and References:

(1) Kumar, Sanjay & Pushp Lata, *Communication Skills*, Oxford University Press,2011
(2) Quirk & Randolph, *A University Grammar of English*, Pearson,2006
(3) Rutherford, Andrea J., *Basic Communication Skills for Technology*, Pearson, 2007
(4) Rizvi, M Ashraf, *Effective Technical Communication*, McGraw-Hill, 2009
(5) IEEE/ACM digital libraries for accessing sample papers