Department of Electrical Engineering

"Curriculum and Syllabi for M. Tech. in Control and Industrial Automation (CIA)"

With effect from 2019 entry batch

Mission and Vision of the Institution

The Vision of the National Institute of Technology Silchar is establishing unique identity by development of high quality human and knowledge resources in diverse areas of technologies to meet local, national, and global economic and social need and human society at large in self-sustained manner.

The mission of National Institute of Technology Silchar is to train and transform young men and women into responsible thinking engineers, technologists and scientists, to motivate them to attain professional excellence and to inspire them to proactively engage themselves for the betterment of the society.

Mission and Vision Statement
of
Electrical Engineering Department

The mission of the Electrical Engineering Department is to impart quality education to our students and provide a comprehensive understanding of electrical engineering, built on a foundation of physical science, mathematics, computing and technology and to educate a new generation of Electrical Engineers to meet the future challenges.

The Vision of Electrical Engineering Department is to be a model of excellence in technical education and research by producing world-class graduates who are prepared for life-long engagement in the rapidly changing fields of electrical and related fields.

Program Educational Objectives (PEOs)

PEO1: The postgraduates of CIA will do their research, developmental, technical and non-technical works to solve real-life problems for acceptable, implementable and sustainable solutions.

PEO2: The postgraduates of CIA will demonstrate their research ethics, professionalism, life-long learning ability, productive-psychomotor and affective domains skills, ability to work in a team through their day-to-day works.

PEO3: The postgraduates of CIA will exhibit their effective oral and written communication skills in their daily activities.

PO Statements (POs):

PO1: An ability to carry out research /investigation and development work independently and as a member of a team to solve practical problems.

PO2: An ability to write and present with effective communication skill, a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be reflected through their solution approaches by considering society, environment, economy and sustainability.

PO4: Students should be able to demonstrate their ethics, professionalism and ability for lifelong learning.

PO5: Students should be able to exhibit productive psychomotor and affective domains skills.

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Course Structure

Semester I

S. N.	Code	Subject	L	T	P	Credits
1	EE 5101	Linear control Theory	3	0	0	3
2	EE 5102	Industrial Automation	3	0	0	3
3	EE 5103	Digital Image Processing and Applications	3	0	0	3
4	EE 5104	Control Systems Laboratory I	0	0	3	2
5	EE 5110	Seminar -I	0	0	2	1
6	EE 51XX	Elective – I	3	0	0	3
7	EE 51XX	Elective - II	3	0	0	3
		Total contact hours/credits	15	0	5	18

Semester II

S. N.	Code	Subject	L	T	P	Credits
1.	EE 5111	Estimation and Adaptive Control	3	0	0	3
2.	EE 5112	Optimal and Robust Control	3	0	0	3
3	EE 5113	Embedded Systems and Applications	3	0	0	3
4.	EE 5114	Control Systems Design Laboratory	0	0	3	2
5.	EE 5115	Seminar - II	0	0	2	1
6.	EE 51XX	Elective III	3	0	0	3
7.	EE 51XX	Elective IV	3	0	0	3
8.	EAA	Extra Academic Activities (Yoga)	0	0	2	0
		Total contact hours/credits	15	0	6	18

Semester: III and IV

S. N.	Code	Subject	L	T	P	Credits	Semester
1	EE 6198	Project Phase -I	-	-	-	06	III
2	EE 6199	Project Phase -II	-	-	-	08	IV
		Total contact hours/Credits	-	-	-	14	---

Elective I

S. N.	Code	Subject	*Prerequisites, if any*
1	EE 5131	Modelling of Dynamical Systems	
2	EE 5132	Digital Control Systems	
3	EE 5133	Nonlinear Systems	

Elective II

S. N.	Code	Subject	*Prerequisites, if any*
1	EE 5141	Industrial Instrumentation	
2	EE 5142	Nonlinear Dynamics and Chaos	

Elective III

S. N.	Code	Subject	*Prerequisites, if any*
1	EE 5151	Intelligent Control Systems	
2	EE 5152	Multivariable Control Systems	

Elective IV

S. N.	Code	Subject	*Prerequisites, if any*
1	EE 5156	Sensors and Signal Conditioning	
2	EE 5157	Control Systems Components	
3	EE 5158	Fault Detection and Diagnosis	

EE 5101	Linear Control Theory M. Tech in Control and Industrial Automation Electrical Engineering Branch	L T P C 3 0 0 3

Pre-requisites: Control Systems

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Module-1: Linear spaces and linear operators: fields, vectors and vector spaces; linear independence, dimension of linear space; inner product of vectors, quadratic functions and definite matrices, vector and matrix norms, scalar product and norm of vector functions; range space, rank, null space and nullity of a matrix, homogeneous equation, nonhomogeneous equation; eigenvalues, eigenvectors, generalized eigenvectors, similarity transformation, Canonical form representation of linear operators, diagonal form representation of linear operator, Jordan form matrix representation of linear operator; Cayley-Hamilton theorem.

Module-2: Review of time domain and frequency domain responses, analysis of time and frequency domain common tools, time and frequency domain specifications, and their relationship; design of lag-lead compensator; PID controller tuning.

Module-3: Review of state space representations, controllable canonical form, observable canonical form, diagonal form; solution of vector-matrix differential equation, modal decomposition.

Module-4: Concept of controllability, observability, and their significance; state feedback controller; full order and reduced order observer design; observer-based state feedback controller.

Module-5: Introduction to non-linear system, common differences with linear system; concept of linearization; describing function of common nonlinearities.

Module-6: Lyapunov's concept of stability, asymptotically stable, uniformly asymptotically stable, uniformly asymptotically stable in the large, instability; Lyapunov function, Lyapunov's theorems, stability analysis of linear and non-linear systems using Lyapunov concept.

Module-7: Phase plane analysis, classification of singular points, limit cycle and closed trajectory; stability analysis using phase plane; stability analysis using describing function.

Reference Books:

1. Linear Systems, Thomas Kailath, Prentice Hall.

2. Control Systems – Principles and Design, Modan Gopal, C H Houpis, Tata McGraw Hill.
3. Linear Control System – Analysis and Design – Conventional and Modern, Johm J D'Azzo, C H Houpis, McGraw Hill International Edition.
4. Modern Control System Theory, M. Gopal, New Age Int.(P) Limited.
5. Nonlinear Systems, Hassan K. Khalil, Pearson New International Edition.
6. Nonlinear Systems Analysis, M. Vidyasagar, Society for Industrial and Applied Mathematics.

Course Outcomes: At the end of this course, students will be able to:

1. Explain the fundamental concepts of linear spaces and linear operators.
2. Analyze linear systems in time and frequency domain; compare the outcome of different common tools; relate different time and frequency domain specifications with a given description of a system; use the relations between time and frequency domain specifications.
3. Identify nonlinear systems; analyze a nonlinear system using describing function and phase plane analyses.
4. Deduce the conditions of stability and comment on the nature of stability of linear and nonlinear systems.
5. Design different types of controller and observer.

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	Industrial Automation	**L**	**T**	**P**	**C**
EE 5102	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Module-1: Introduction to industrial automation and control, architecture of industrial automation systems. Functionality of each layer with industrial relevance. Introduction to process flow of different industries. A brief introduction to sensors and measurement systems.

Module-2: Introduction to process control, PID control, controller tuning, implementation of PID controllers, special control structures: feed forward control, ratio control, predictive control, control of systems with inverse Response, cascade control, overriding control, selective control, split range control.

Module-3: Introduction to sequence control, PLC and relay ladder logic, sequence control: scan cycle, RLL syntax, structured design approach, IL, SFC, PLC hardware environment.

Module-4: Introduction to actuators: flow control valves, hydraulic actuator systems: principles, components and symbols, pumps and motors, proportional and servo valves, introduction to pneumatic control systems: system components, actuators, and controllers.

Module-5: Electric drives: Introduction, energy saving with adjustable speed drives, DC motor drives: induction motor drives, stepper motor drives.

Module-6: Introduction to industrial data communication: networking of sensors, actuators and controllers, fieldbus

Module-7: Measurement of temperature, pressure, force, displacement, speed, flow, level humidity, pH etc. signal conditioning and processing, estimation of errors and calibration, data acquisition.

Reference Books:

1. Principles of Measurement Systems, J P Bentley, Pearson Education.
2. Programmable Logic Controllers – Principles and Applications, J W. Webb, Ronald A Reis, PHI.
3. Process Control Instrumentation Technology, C D Johnson, PHI.
4. Hydraulic and Pneumatic Controls, R. Srinivasan, Vijoy Nicole Imprints Private Limited.
5. Process Control – Modelling, Design, and Simulation, B E Bequette, PHI.
6. Principles of Measurement Systems, J P Bentley, Pearson Education.

Course Outcomes: At the end of this course, students will be able to:

1. Identify the control and automation levels of an industry and tell the characteristics well known industrial devices used for sensors, actuators, controllers etc.
2. Justify the choice of appropriate control scheme for well-known industrial situations and design the controller to meet the requirement.
3. Design a suitable RLL program to meet a desired sequence control requirement.
4. Recognize the well-known controller, actuators in electronic, pneumatic and hydraulic form.
5. Explain the utility and operations of various power electronic devices used for industrial control applications.

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	Digital Image Processing and Applications	**L**	**T**	**P**	**C**
EE 5103	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Module-1: Introduction to Digital image – Digital Image Fundamentals – concept of visual perception, image sensing and acquisition, image sampling and quantization, basic relationships between pixels

Module-2: Image enhancement in the spatial domain – Gray level transformations, histogram processing, enhancement using arithmetic/logic operations, spatial filtering, smoothing and sharpening of spatial filters.

Module-3: Image enhancement in the frequency domain – Fourier transform, smoothing and sharpening of frequency domain filters, homomorphic filtering, implementation of these filters

Module-4: Image restoration - Colour Image Processing- colour models, pseudo colour image processing, basics of full colour image processing, colour transformations, smoothing, sharpening, segmentation, compression;

Module-5: Image compression – compression models, Error free compression, lossy compression, image compression standards.

Module-6: Wavelets and multiresolution processing – multiresolution expansions, wavelet transform in one dimension and two-dimension, fast wavelet transforms.

Module-7: Morphological Image processing – opening and closing, hit or miss transformation, basic morphological algorithms, extension to gray scale images.

Module-8: Image segmentation – detection of discontinuities, edge linking and boundary detection, thresholding, region-based segmentation, segmentation by morphological watersheds, use of motion in segmentation.

Module-9: Representation and description – representation, boundary descriptors, regional descriptors, use of principal component for description; Object recognition – patterns and pattern classes, recognition based on decision theoretic methods, structural methods.

Module-10: Applications – In intelligent traffic control, Machine Vision, Automation, etc.

Reference Books:

1. Digital Image Processing, R C Gonzalez & R E Woods, Prentice Hall of India.
2. Digital Image Processing, Pratt, Willey India.
3. Digital Image Processing, S Sharma, S.K.Kataria & Sons.
4. Digital Signal & Image Processing, T. Bose, Wiley Publications.

Course Outcomes: At the end of this course, students will be able to:

1. Describe an image, image processing and different components of image processing
2. Define image segmentation and should be able to develop techniques for image segmentation
3. Design and develop program for image enhancement
4. Perform different transforms such as DFT, DCT, DWT, fast wavelet and principal component analysis and apply them for image compression, image quality, object recognition or for computer vision purposes.

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	Control Systems Laboratory-I	**L**	**T**	**P**	**C**
EE 5104	**M. Tech in Control and Industrial Automation**	**0**	**0**	**3**	**2**
	Electrical Engineering Branch				

Pre-requisites: Control Systems

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

List of possible experiments Control Systems Lab -I

1. Realization of a 2^{nd} order system using R, L, and C components and analysis of its response using ELVIS Kit and PC.
2. Realization of lead and lag compensators using Op-Amps, R and C components and analysis of its response using ELVIS Kit and PC.
3. Realization of PID controllers using Op-Amps, R and C components and analysis of its response using ELVIS Kit and PC.
4. Measurement of electrical and non-electrical quantity using Technology Tutor and evaluation of characteristics of different transducers and their behavior due to variation of some parameter.
5. Temperature control loop: Study and control of temperature.
6. Liquid level control loop: Study and control of liquid level.
7. Liquid flow control loop: Study and control of liquid flow.
8. Air flow control loop: Study and control of air flow.
9. Pressure control loop: Study and control of pressure.
10. Introduction to DCS and PLC and its operation.
11. Study and position control of a magnetic levitation system.
12. Study of ball and plate control system (both 1D and 2D).
13. Speed and position control of a DC modular servo system.
14. Speed and position control of an AC modular servo system.
15. Position control of an inverted pendulum

Course Outcomes: After completion of the course students will be able to:

1. Construct a 2^{nd} order system, lag-lead compensator, and PID controller physically using R, L, C, and Op-Amps and analyze its time and frequency domain behavior.
2. Measure of electrical and non-electrical quantities and evaluate of characteristics of different transducers using available transducer kit.
3. Explain the experiments for the level, flow, temperature, position, and speed control using available setups and the controllers provided by the manufacturer.
4. Explain the experiments for level, flow, temperature, and pressure control though PLC and DCS panel.

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		L	T	P	C
	Seminar - 1	**L**	**T**	**P**	**C**
EE 5110	**M. Tech in Control and Industrial Automation**	**0**	**0**	**2**	**1**
	Electrical Engineering Branch				

Course Outcome of Seminar:

At the end of seminar course, students will be able to:

(1) Prepare good slides and present a particular topic effectively.
(2) Develop team spirit and leadership qualities through group activities.
(3) Develop confidence for self-learning and overcome the fear of public presentations.
(4) Update knowledge on contemporary issues, prepare technical report and do presentations on these issues.
(5) Learn technical editing software Latex and write technical report using Latex.

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Syllabus of subject under the List of Elective – I

		L	T	P	C
	Modelling of Dynamical systems	**L**	**T**	**P**	**C**
EE 5131	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Prerequisites: BE/BTech in EE/ECE/Instrumentation/EEE

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Module 1: Introduction to system dynamics, introduction to mathematical modelling of dynamic systems, philosophy, role, significance, and limitations of modelling in control systems.

Module 2: Classification of modelling: deterministic models its characterization and analysis, continuous time modelling, discrete time modelling transfer-function approach, state-space approach, system identification, stochastic models and its characterization and analysis, Spatial modelling, two-patch models with dispersal.

Module 3: Modelling of physical systems and analysis: electrical systems, mechanical systems, electromechanical Systems, mechatronic systems, hydraulic systems, pneumatic systems, thermal systems, biological systems, modelling of time variant system.

Module 4: Model reduction: parameterized partial differential equation, projection-based model reduction, proper orthogonal decomposition, balanced truncation, moment matching, local parametric approaches, nonlinear model reduction.

Text and Reference Books:

1. System Dynamics (4th ed.), K. Ogata, Pearson: Prentice Hall.
2. Probabilistic Modelling, Isi Mitrani, Cambridge University Press.
3. System Identification: Theory for the User (2nd Edition), Lennart Ljung, Pearson: Prentice Hall.
4. Model Order Reduction: Theory, Research Aspects and Applications, Schilders, Wilhelmus H., van der Vorst, Henk A., Rommes, Joost, Springer.

Course Outcomes: At the end of this course, students will be able to:

1. Explain the philosophy, role, significance, and limitations of modelling of a system.
2. Classify different types of modelling approaches and their applicability.
3. Develop a model a system and analyse the model.
4. Deduce a reduced order model from a higher order model using suitable techniques.

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	Digital Control Systems	**L T P C**
EE 5132	**M. Tech in Control and Industrial Automation**	**3 0 0 3**
	Electrical Engineering Branch	

Pre-requisites: Signal and Systems, Control Systems

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Module-1: Introduction to Digital Control: Introduction, Discrete time system representation, Mathematical modelling of sampling process, Data reconstruction

Module-2: Modelling Discrete-Time Systems by Pulse Transfer Function: Revisiting Z-transform, Mapping of s-plane to z-plane, Pulse transfer function, Sampled signal flow graph

Module-3: Time Response of Discrete systems: Transient and steady-state responses

Module-4: Stability Analysis of Discrete Time Systems: Jury stability test, Stability analysis using bi-linear transformation

Module-5: Design of Sampled Data Control Systems: Root locus method, Nyquist stability criteria, Bode plot, Controller design using root locus, Lag-lead compensator design in frequency domain

Module-6: Discrete State Space Model: Introduction to state variable model, State transition matrix, Solution of discrete state equation

Module-7: Controllability, Observability and Stability of Discrete State Space Models: Controllability and Observability, Stability, Lyapunov stability theorem

Module-8: State Feedback Design for Discrete Systems: Pole placement by state feedback, Full order observer, Reduced order observer

Module-9: Introduction to Optimal Control for Discrete Systems: Basics of optimal control, Performance indices, Linear Quadratic Regulator (LQR) design

Reference Books:

1. Digital Control and State Variable Methods, M. Gopal, Tata McGraw-Hill Publishing Company Limited.
2. Digital Control Systems, B. C. Kuo, Oxford University Press.
3. Discrete Time Control Systems, K. Ogata, Prentice Hall International.
4. Digital Control of Dynamic Systems, G. F. Franklin, J. D. Powell and M. L. Workman, Addison-Wesley.

Course Outcomes: At the end of this course, students will be able to:

1. Describe and analyse digital control technique
2. Apply digital control methods
3. Design a controller

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	Nonlinear Systems	**L T P C**
EE 5133	**MTech on Control and Automation**	**3 0 0 3**
	Electrical Engineering Branch	

Module-1: Introduction to nonlinear systems: Models and nonlinear phenomena, common nonlinearity. (4 hours)
Module-2: Concepts and characterization of 2nd order nonlinear systems: Qualitative behaviour of linear systems, multiple equilibria, qualitative behaviour near equilibrium points, limit cycles, the existence of periodic orbits, bifurcation (6 hours)
Module-3: Fundamental properties of nonlinear systems: Existence and uniqueness of the solution, sensitivity equation, comparison principle (3 hours).
Module-4: Lyapunov stability: Autonomous systems, invariance principle, linear systems and linearization, nonautonomous systems, converse theorems, boundedness (8 hours).
Module-5: Input-output stability: $\mathcal{L}$ stability, $\mathcal{L}$ stability of state models, $\mathcal{L}_2$ gain, small-gain theorem (5 hours).
Module-6: Passivity and its connection with Lyapunov and $\mathcal{L}_2$ stability: Memoryless functions, state models, $\mathcal{L}_2$ and Lyapunov stability, passivity theorems (5 hours).
Module-7: Frequency domain analysis of feedback systems: Absolute stability, circle criterion, Popov criterion, describing function method (4 hours).
Module-8: Advanced stability analysis: Centre manifold theorem, the region of attraction, invariance-like theorem, the stability of periodic solutions (5 hours).

Textbooks:

Nonlinear Systems, Hassan K Khalil, Prentice Hal.

NB:

1) MATLAB simulation will be used to validate the concepts. It will be a group activity.
2) Recent papers will be self-studied to find the application of the above concepts in a group.

Course Outcome: At the end of this course, students are expected to be able to:

1. Apply the concepts to find various nonlinear phenomena of a given system using its model and evaluate its significance in the actual working system and differences from a linear system.
2. Analyze the qualitative behavior of a 2nd order nonlinear system; evaluate the existence of periodic orbits and bifurcation; validate the evaluation using simulation.
3. Apply various concepts of Lyapunov and Input-output stability on a system; analyze and evaluate the outcomes to find the differences of these concepts in its practical sense.
4. Analyze a given system using different concepts of frequency-domain and compare the outcome with that of CO3.
5. Analyze a system using passivity and advanced-stability concepts; compare and evaluate the outcomes with that of other approaches.

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<u>**Syllabus of subject under the list of Elective – II**</u>

		L	T	P	C
	Industrial Instrumentation				
EE 5141	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Instrumentation

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:

Module-1: Basic terminologies (range, span, settling time dead zone, input impedance, etc.)

Module-2: 1st order and second order instruments with step, ramp and sinusoidal input/ output characteristics

Module-3: Basic measurement technique, Signal conditioning

Module-4: Strain gauge, derivation of gauge factor, strain gauge rosette, unbalanced Wheatstone bridge, Link type load cell, beam type load cell, ring type load cell and their sensitivities, Frequency response of link type load cell, Torque cell and its data transmission (slip ring and radio telemetry)

Module-5: LVDT, phase compensation, phase sensitive demodulation, thermistor and its linearization, RTD, its construction, three wire and four wire method Muller bridge

Module-6: Thermocouple, their relative comparison, cold junction compensation using AD590, grounded thermocouple

Module-7: Potentiometer as displacement sensor, Capacitance as displacement and level transducer, push pull arrangement

Module-8: Pressure transducer [Bourdon gauge, diaphragm gauge (metal and semiconductor), etc.], vacuum gauges

Module-9: Photo electric transducer and its application, Liquid in glass thermometer, pressure spring thermometer

Module-10: Venturi meter, Orifice meter, pilot tube, Rotameter, Weir, electromagnetic flow meter, turbine flow meter, Hot wire anemometer, its phase compensation and expression of volumetric flow rate or velocity in each case

Module-11: Variable reluctance displacement sensor, tachogenerator
Module-12: Measurement of viscosity, conductivity and pH of a liquid

Reference Books:

1. A Course in Electrical and Electronic Measurements and Instrumentation, D. V. S. Murty, Dhanpat Rai and Co.
2. Transducers and Instrumentation, D. Patranabis, PHI Learning Pvt. Ltd., New Delhi.
3. Principal of Industrial Instrumentation, A. K Sawhney, Mc Graw Hill India.

Course Outcomes: At the end of this course, students will be able to:

1. Describe different types of sensors and transducers
2. Classify different sensing elements
3. Demonstrate measurement of physical parameter

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	Nonlinear Dynamics and Chaos		**L**	**T**	**P**	**C**
EE 5142	**M. Tech in Control and Industrial Automation**		**3**	**0**	**0**	**3**
	Electrical Engineering Branch					

Pre-requisites: Basic courses in Engineering Mathematics, Control Systems
Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics Covered:
Module-1: Introduction to dynamical system: Representations of dynamical Systems, discrete time dynamical systems, Vector Fields of nonlinear systems, limit cycles, nonlinear systems and their classification, Existence and uniqueness of solutions, fixed points and linearization, stability of equilibrium, dissipative, conservative and reversible systems, bifurcations in 1-D (Saddle-node, transcritical, pitchfork bifurcations). **[8 hrs.]**

Module-2: Tools for Detecting Chaos: Analysis of chaotic time series, phase plane, stable and unstable manifolds, Center manifold theory and Poincare maps, saddle-node, transcritical, pitchfork bifurcations, hopf bifurcation, global bifurcations, Lyapunov Exponents, power spectrum, frequency spectra of orbits, Dynamics on a torus. **[17 hrs.]**

Module-3: Analysis of some chaotic/hyperchaotic systems: Lorenz equation, strange attractors, Rossler equation, Forced Pendulum and Duffing oscillator, Chua's circuit, Logistics map. **[5 hrs.]**

Module-4: Control of chaos: Need for control of chaos, the OGY method, PC method, PID control, optimal control, Adaptive control, Non-feedback control, and state feedback control. **[5 hrs.]**

Module-5: Application of Chaos: Electrical and Electronic Systems (Electrical drive/power system), Communication systems, types and method of synchronization, synchronization in complex systems, synchronization technique using (PID, Adaptive, Active, Sliding Mode, Optimal) control, chaos-synchronization-based secure communications. **[5 hrs.]**

Reference Books:

1. Nonlinear Systems, 2nd edition, Khalil, H. K., Prentice Hall, NJ.
2. Nonlinear Dynamics and Chaos. Reading, Strogatz, S., MA: Addison-Wesley.
3. Chaos in Dynamical systems, Edward. Ott, Cambridge, UK.
4. From Chaos to Order, Parker, T. S., and L. O, World Scientific, Singapore.
5. Practical Numerical Algorithms for Chaotic Systems, Jordan, D. W., and P. Smith, New York, NY: Springer-Verlag.
6. Nonlinear Ordinary Differential Equations, Guckenheimer, J., and P. Holmes, Springer.

7. Nonlinear Oscillations, Dynamical Systems and Bifurcations of Vector Fields, K.T. Alligood, et al, New York, NY: Springer-Verlag.
8. Chaos: An Introduction to Dynamical Systems, Khalil, H. K., New York, NY: Oxford University Press.
9. Nonlinear Systems, 2nd edition, Strogatz, S., Prentice Hall, NJ.

Course Outcomes: At the end of this course, students will be able to:

1. Introduce the fundamental concept of the dynamical system and chaos.
2. Introduce students regarding the methods for detecting the chaos.
3. Analyze the chaotic and hyperchaotic system using the various numerical and analytical tools.
4. Formulate the control objective for the dynamical system.
5. Know how to apply the concept of the dynamical system and chaos to other problem.

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	Estimation and Adaptive Control	**L**	**T**	**P**	**C**
EE 5111	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Control Systems

Topics Covered:

Module-1: Probability and Random Variables & Systems:

Meaning of Probability, Axioms of Probability, conditional probability, Bayes theorem, Bernoulli's Trial, concept of random variables, distribution and density functions, Statistical Properties of Random Variables – mean, variance and moments, Concept of Multi-variant Random variables.

Module-2: Linear Discrete-time parameter & state estimation Theories (stochastic environment):

Linear measurement model, AR, ARMA, MA models, Least square estimation with batch processing, Least square estimation using SVD, Least square estimation with recursive processing, Bes linear unbiased estimation (BLUE), likely-hood concept, Maximum-likelihood estimation, Kalman-Bucy filter – complete derivation and implementation in MATLAB with applications, computational issues, Concept of Square root filter for nonlinear system, Concept and derivation of Extended Kalman filter (EKF).

Module-3: Adaptive Control & System Identification:

Concept of Adaptive Control – effect of process variation, need of adaptation, meaning of direct and indirect adaptive control, different adaptation control schemes. Self-tuning regulator, Model Reference adaptive control – concept, block diagram representation, MIT rules and its disadvantages, Lyapunov theory and design of MRAC, applications, difference between STR and MRAC. Gain Scheduling control – principle, design of gain scheduling control, discussion on application of gain scheduling control. Data based Identification method – system response and frequency response method (only principles and fundamental theories). Time-Invariant System Identification – static and dynamic system identification method (only principles and fundamental theories), Model validation – meaning and principle.

Reference Books:

1. Probability, Random Variables and Stochastic Process, A. Papoulis, Mac Graw Hill, 3rd Edition.
2. Lessons in Estimation theory for Signal processing, communication and Control, Jerry M Mendel, Prentice Hall. 1995.
3. Adaptive Control, K.J Astrom, Second Edition.
4. Identification of Continuous Systems, H Umbehauen and G P Rao.
5. System Identification, T Soderstrom and P Stoica, Prentice Hall, New York.
6. System Identification: An introduction, K.J. Keesman, Springer Verlag, 2011.
7. Adaptive Filtering Prediction and Control, G C Goodwin and K S Sin, Prentice Hall, New Jersey.

8. Adaptive Control – Stability, Convergence and Robustness, S Sastry and M. Bodson, PHI, New Delhi.

Course Outcomes: At the end of this course, students will be able to,

1. Illustrate several probability, random variable and stochastic process theories.
2. Formulate parameter and state estimation techniques in discrete-time domain.
3. Design of various types of estimators by interpreting the given scenario of uncertainty and noise.
4. Illustrate and design various adaptive control methods.
5. Comprehend different system identification techniques.

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	Optimal and Robust Control	**L T P C**
EE 5112	**M. Tech in Control and Industrial Automation**	**3 0 0 3**
	Electrical Engineering Branch	

Pre-requisites: Basic engineering mathematics,Linear matrix algebra, Linear control theory

Topics Covered:

Module 1: Introduction to optimization, concept of static optimization problem, some examples of optimum design problems.

Module 2: Dynamic optimization problem and its solution: Concept of functional, variational problems and performance indices, Euler-Lagrange equation to find extremal of a functional, transversality condition, application of variational approach to control problems, LQR problem and its solution, algebraic Riccati equation and its solution techniques, frequency domain interpretation of LQR problem, gain margin and phase margin of LQR controlled problem, optimal control with constraints on input, concept of time-optimal control problem.

Module 3: Robust control: Concept of system and signal norms, small-gain theorem, physical interpretation of H_∞ norm, computation of H_∞ norm, internal stability, sensitivity and complementary sensitivity functions

Reference Books:

1. Optimal Control systems, D S Naidu, CRC Press, 2003.
2. Linear Systems–Optimal and Robust Control, Alok Sinha, CRC Press, 2007.
3. Optimal Control, Frank L. Lewis, John Wiley & Sons, 1986.

Course Outcomes: At the end of this course,students will be able to:

1. Analyze optimal open-loop control
2. Solve constrained dynamic optimization problem
3. Design optimal control system
4. Identify a suitable controller which takes care of system parameter variations

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EE 5113	Embedded Systems and Applications M. Tech in Control and Industrial Automation Electrical Engineering Branch	L	T	P	C
		3	0	0	3

Pre-requisites: Microprocessor and Micro Controller

Topics Covered:

Module-1: Introduction to embedded systems: hardware and software component type's examples, characteristics, challenges in embedded computing system design, embedded system design processes. Terminology Gates- Timing Diagram - Memory – Microprocessors Buses – Direct Memory Access – Interrupts – Built-in on the Microprocessor – Conventions used for Schematic – Schematic. Interrupts Microprocessor Architecture – Interrupt basics – Shared Data Problem – Interrupt Latency.

Module-2: Hardware- software Co-design and program modelling: Fundamental Issues in hardware-software co- design, Computational Models in Embedded design, introduction to Unified Modelling Language, Hardware Software Trade – offs.

Module-3: Operating System Basics: Types of OS, Tasks, Process and threads, Multiprocessing and Multitasking, Task Scheduling, Threads, Processes and scheduling: Putting them together, Task Communication, Task Synchronization, Device drivers, How to choose an RTOS.

Module-4: ARM Processor: Architecture, Instruction set of ARM 7, Programming of real-time systems design using ARM Processors.

Module-5: Applications: Embedded system in automobiles (ABS), Mobile Phones, Digital Camera, etc. A case study on video-compression/Intelligent traffic control.

Reference Books:

1. Embedded System Design: A Unified Hardware/ Software Introduction, Frank Vahid and Tony Givargis, Pentice Hall.
2. Introduction to reconfigurable computing, Architecture, Algorithm and application, Christofer Bobda, Springer.
3. Embedded System Design: Modelling, Synthesis and Verification, Daniel D. Gajski, Andreas Gerstlauer, GunarSchirner, Springer.
4. Embedded System Design, AchimRettberg, Rainer Dömer, Mauro Zanella, Prentice Hall.

Course Outcomes: At the end of this course, students will be able to:

1. Define an embedded system and its characteristic features
2. Describe clearly the embedded system design processes
3. Gather a good knowledge of embedded processor architectures and able to program such processors.
4. Interpret real-time operating systems and analyse the tasks, processes and scheduling problems
5. Design an embedded system for some specific applications

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	Control Systems Design Laboratory	**L**	**T**	**P**	**C**
EE 5114	**M. Tech in Control and Industrial Automation**	**0**	**0**	**3**	**2**
	Electrical Engineering Branch				

Pre-requisites: Control Systems

<u>List of possible experiments in Control Systems Design Lab</u>

1. Design and Simulation of P, PI, PID controller using ZN and CC method.
2. Using MATLAB & Simulink, lead, lag and lag-lead compensator design using root locus method.
3. Using MATLAB, study of time and frequency domain specifications and their correlations.
4. Using MATLAB lead, lag and lag-lead compensator design using frequency-domain method.
5. Design and simulation of a State feedback type controllers.
6. Design and simulation of an observer (full order & reduced-order) based state feedback type controllers.
7. Design and simulation of MRAC.
8. Phase plane analysis using MATLAB and Simulink.
9. Stability analysis of nonlinear systems using describing function method
10. Design and simulation of the LQR type controller.
11. Design and simulation of sliding mode control.
12. Design and simulation of backstepping Control.
13. Design and simulation of fuzzy logic-based Controller
14. Design and simulation of neural network-based Controller
15. Tuning of controller parameters using metaheuristic optimization techniques.

Course Outcomes: After completion of the course students will be able to:

1. Interpret a 2nd order feedback control system and analyze its time and frequency domain behavior along with the co-relation between these using MATLAB and Simulink.
2. Design PID controller in MATLAB and Simulink from the experimental offline response using ZN and CC method.
3. Design a lag-lead compensator in MATLAB and Simulink using root locus and frequency domain techniques, Construct and analyze the phase trajectories, determine stability by describing function and Lyapunov stability in MATLAB and Simulink.
4. Design in MATLAB and Simulink state feedback controller, observer-based state feedback controllers, LQR, sliding mode controller, backstepping controller, and MRAC in MATLAB and Simulink.
5. Design a controller based on intelligent techniques such as ANN, Fuzzy-logic, metaheuristic algorithms, etc.

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SEMINAR II **L T P C**

EE 5115 M. Tech in Control and Industrial Automation 0 0 2 1

Electrical Engineering Branch

Course Outcome of Seminar:

At the end of seminar course, students will be able to:

1. Prepare good slides and present a particular topiceffectively.
2. Develop team spirit and leadership qualities through groupactivities.
3. Develop confidence for self-learning and overcome the fear of publicpresentations.
4. Updateknowledgeoncontemporaryissues,preparetechnicalreportand dopresentationson theseissues.
5. Learn technical editing software Latex and write technical report usingLatex.

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List of Elective – III:

		L	T	P	C
EE 5151	**Intelligent Control Systems** **M. Tech in Control and Industrial Automation** **Electrical Engineering Branch**	**3**	**0**	**0**	**3**

Pre-requisites: Feedback control theory and design, optimization theory

Topics Covered:

Module-1: Introduction to intelligent control, comparison study between conventional and intelligent control, intelligent supervisory control, intelligent adaptive control.

Module-2: Introduction to Neural Network, theory of neural network for classification and function approximation, supervised and unsupervised learning rules, RBF neural network, Support vector machines, intelligent control using Neural Network, Approximation capabilities by feed-forward and recurrent neural network, Neuro-control based on backpropagation algorithm, system identification with neural network.

Module-2: Introduction to fuzzy set theory and logic, application of fuzzy logic in control system, fuzzy quantization of knowledge, fuzzy controller design, Fuzzy T-S modelling for dynamic system and stability using Lyapunov theory.

Module-3: Basic theory and operations of Genetic algorithm, GA based control system, optimization problem using GA related to control and other engineering problems.

Module-4: Bio-inspired evolutionary algorithms – like Particle swam optimization (PSO), simulated annealing, Fire-fly optimization, bacterial foraging etc. – only the concepts and case studies related control problems.

Reference Books:

1. Intelligent Control System, S. Haykin, IEEE Press.
2. Gentic Algorithm, Goldberg, Pearson Education.
3. Fuzzy logic (intelligence control and information), J. Yen and R. Langari, Pearson Education.
4. Foundation to Neural Network, M.M. Gupta and N.K Sinha, PHI.

Course Outcomes: At the end of this course, students will be able to:

1. Deliver and explain properly the theoretical concepts of NN, Fuzzy logic and GA.
2. Solve engineering and control problems using the concept of NN, fuzzy and GA.
3. Formulate a controller design problem for a complex dynamic system using NN, fuzzy logic.
4. Formulate control problems using hybrid intelligent methods after studying the concepts individually.

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	L	T	P	C
Multivariable Control				

EE 5152 **M. Tech in Control and Industrial Automation** **3 0 0 3**

Electrical Engineering Branch

Prerequisites: At least one basic course on Control Systems, Linear Algebra and Complex analysis

Topics:

Module-1: Introduction to multivariable Systems: Basic definitions, concept of pole and zero of multivariable systems, Smith-McMillan form, matrix fraction description (MFD) of transfer function matrix, state-space realization, controllability and observability.

Module-2: Multivariable gain and phase: Concept of gain, phase, and directionality in a multivariable system, singular value decomposition, representation of gain and phase in singular subspace, relation between open loop and closed loop properties.

Module-3: Stability of multivariable systems: Stability in state space, generalized Nyquist stability criterion for multivariable systems, Nyquist arrays and Gershgorin bands, Multivariable root loci, multivariable stability margins.

Module-4: Interaction in a multivariable system: Measure of interaction, relative gain array, pairing of input and output, dynamic decoupling, steady-state decoupling by SVD, decentralized control of MIMO systems, case studies: steam boiler, heat exchanger, mixing process, sugar mill etc.

Module-5: Multivariable controller design: Challenges and fundamental limitations of MIMO control design, pole placement, eigen structure assignment, characteristic loci method, Nyquist array-based methods.

Reference Books:

1. Multivariable feedback design, J. M. Maciejowski, Addison Wesley.
2. Multivariable control systems: An engineering approach, P. Albertos and A. Sala, Springer.
3. State space and multivariable theory, H. H. Rosenbrock, Thomas Nelson & sons Ltd.
4. Frequency domain properties of scalar and multivariable control systems, J. S. Freudenberg and D. P. Loose, Springer-Verlag.

Course Outcomes: At the end of this course, students will be able to:

1. Explain the significance of poles and zeros of a multivariable system and related properties and determine poles and zeros by decomposing a transfer function matrix into smith-McMillan form.
2. Explain the concept gain and phase of multivariable system and related
3. Determine the stability of a multivariable system form using various tools.
4. Measure the interaction in multivariable system and apply suitable decoupling techniques.
5. Apply the multivariable control theory in the design of controller for MIMO systems.

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List of Elective – IV:

		L	T	P	C
EE 5156	**Sensors and Signal Conditioning** **M. Tech in Control and Industrial Automation** **Electrical Engineering Branch**	3	0	0	3

Pre-requisites: Instrumentation/ Transducers

Topics Covered:

Module-1: Measurement system components: introduction to instrumentation; classification of transducers; performance characteristics of instruments – static and dynamic; errors in measurement; calibration and standards.

Module-2: Role of Laplace and Fourier Transform in signal analysis: Introduction to analog and digital modulation, Measurement of current, voltage, and resistance; Measurement of phase, frequency and time interval.

Module-3: Resistive transducer: RTD, hot – wire resistive transducers; resistive displacement, strain, pressure, and moisture transducers.

Module-4: Inductive transducers: Inductive thickness, displacement transducers; movable core type inductive transducers; eddy current type inductive transducers.

Module-5: Capacitive transducers: Capacitive thickness, displacement, and moisture transducers. Piezoelectric transducers: Piezoelectric force, pressure, strain, and torque transducers.

Module-6: Magnetostrictive transducers:Magnetostrictive phenomenon; magnetostrictive force transducers.

Module-7: Hall effect transducers: Hall effect phenomenon, application of hall effect in transducers.

Module-8: Electromechanical transducers: Tachometer, Ultrasonic transducers, Photoelectric transducers.

Module-9: Electronic amplifier, signal generator, oscillators, and comparator – operational amplifier, instrumentation amplifier, charge amplifier.

Module-10: Wien – Bridge Oscillator, Crystal Oscillator, LC – tuned oscillator; square wave generator, pulse generator, etc.; Window comparator, Schmitt trigger.

Module-11: Filters: first, second and higher-order active filters, Introduction to analog and digital modulation, Introduction to analog multiplexer and demultiplexer.

Module-12: Display and recording systems: analog indicators, digital readout systems – alphanumeric devices and CRT readout; analog recorders, magnetic tape recorders.

Reference Books:

1. Sensors and Signal Conditioning, Ramon Pallaá S-Areny and John G. Webster, John Wiley & Sons, Inc.
2. Electronic Instrumentation, D. V. S. Murty, Tata McGraw-Hill Education.
3. Transducers and Instrumentation, Kalsi H S, PHI Learning Pvt. Ltd.
4. A Course in Electrical and Electronic Measurements and Instrumentation, A. K Sawhney,Dhanpat Rai and Co.
5. Handbook of Modern Sensors, Jacob Fraden, Springer.

Course Outcomes: At the end of this course, students will be able to

1. Analyze different instruments for the measurement of electrical and non-electrical quantities
2. Design different signal conditioning elements such as filters and amplifiers
3. Apply different sensors and signal conditioning elements for instrumentation circuits

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	Control Systems components	**L**	**T**	**P**	**C**
EE 5157	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Measurements and Measuring Instruments (EE-1204), Control Systems-I (EE-1302), and Control System-II (EE-1305)

Course Assessment methods (both continuous and semester end assessment): It may be class tests, assignments, attendance, quiz, poster/seminar presentation on different topics including contemporary issues, mid Semester examination, surprise tests, coding and simulation, self-learning, grand viva, group discussion, mini projects, end semester examination, etc.

Topics to be covered:

Module I: Control System Parameters: Introduction, accuracy and mode of control, closed-loop control system, components of control system. Sensors: Position sensors, angular velocity sensors, proximity sensors, load sensors, pressure sensor, temperature sensors, flow sensors, level sensors.

Module II: Potentiometers, ac and dc servomotors, stepper motors, tachogenerators, synchros, ac and dc bridges, self-balancing bridges, self-balancing potentiometer, switches and relays. Amplifiers, servo amplifiers, regulated power supply, attenuators, filters, converter/inverters, modulators, demodulators, phase sensitive detectors, electronic controllers.

Module III: Pneumatic, hydraulic, mechanical & electrical systems, hydraulic and pneumatic actuator/valves, PID controller, microprocessor-based control, PC based control, dedicated customized controllers, PLC, DCS, SCADA.

Reference Books:

1. Modern Control Technology: Components and Systems, Christopher T. Kilian, Delmar Thomson Learning.
2. Control System Components, M. D. Desai, PHI.

Course Outcomes: At the end of the course the students will be able to:

1. Analyse and describe basic principles of control system components & systems, control valves, pressure and flow sensors.
2. To explain the different types of motors, switches, actuators and configure the transmitters, and converters
3. Demonstrate the design of different types of controllers.

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		L	T	P	C
	Fault Detection and Diagnosis	**L**	**T**	**P**	**C**
EE 5158	**M. Tech in Control and Industrial Automation**	**3**	**0**	**0**	**3**
	Electrical Engineering Branch				

Pre-requisites: Control systems, Matrix algebra

Topics Covered:

Design methods for fault detection and diagnosis for dynamic systems using input/output information, System descriptors and mathematical models, Parity check methods in fault detection and diagnosis, Observer-based fault detection and diagnosis, Use of parameter identification techniques, General issues in fault-tolerant control.

Reference Books:

1. Fault Diagnosis in Dynamic Systems Theory and Applications, Ron Patton, Paul Frank and Robert Clark, Prentice Hall, 1989.
2. Fault Detection and Diagnosis in Engineering Systems, Janos J. Gertler.
3. System Identification, T. Söderström and PetreStoica, Prentice-Hall, 1989.
4. Model-based Fault Diagnosis Techniques: Design Schemes, Algorithms and Tools, S. X. Ding, Springer, 2008.

Course Outcomes: At the end of this course, students will be able to:

1. Classify/identify various faults in dynamical systems.
2. Distinguish between a hardware redundancy-based and software-based fault detection and diagnosis.
3. Design parity-space approach of FDD
4. Design observer-based approach of FDD
5. Design parameter-estimation based approach of FDD
6. Know the Preliminary concept of a fault-tolerant control system.

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	Project Phase -I	**L**	**T**	**P**	**C**
EE 6198	**M. Tech in Control and Industrial Automation**	**-**	**-**	**-**	**06**
	Electrical Engineering Branch				

Course Outcomes: At the end of this project phase I, students will be able to:

1. Identify the complex engineering problem and find possible solutions.
2. Apply the technical, software, and hardware knowledge to carry out their project work.
3. Create technical report of the project work.
4. Communicate the findings technically in written and oral forms with engineering community at large.

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	Project Phase -II	**L**	**T**	**P**	**C**
EE 6199	**M. Tech in Control and Industrial Automation**	**-**	**-**	**-**	**08**
	Electrical Engineering Branch				

Course Outcomes: At the end of this project phase I, students will be able to:

1. Identify the complex engineering problem and find possible solutions.
2. Apply the technical, software, and hardware knowledge to carry out their project work.
3. Create technical report of the project work.
4. Communicate the findings technically in written and oral forms with engineering community at large.

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END