M. TECH. – EMBEDDED CONTROL AND AUTOMATION

Department of Electrical and Electronics Engineering

Embedded Control and Automation is a diverse and rapidly expanding discipline which has become increasingly important in a wide range of industries. The use of multiple disciplines and the heterogeneity of applied technologies are the important factors in making the embedded control and automation special. This M. Tech. programme has wide range of applications starting from day to day life to space exploration. With increased use of digital technologies, new methods, algorithms and techniques are needed to solve problems associated with various aspects of embedded and digital control systems. This programme provides necessary theoretical and practical background with a good blend of applied mathematics along with in depth coverage of various aspects of embedded systems, control systems and automation entities. Study of state-of-the-art technologies with focus in industrial R/D requirements including locomotion, robotics, biomedical, aeronautics, biological systems and defense & space industries also comes under the program.

All the courses are lab oriented to provide insight into finding solutions for real time engineering problems. The core courses include automatic, economic, efficient and reliable control and automation techniques with a wide range of electives in Advanced control systems, Instrumentation, Robotics, Guidance and Control, Automotive Systems, Biological systems etc. This M. Tech. course in Embedded Control and Automation ensures students to get employed in all production related industries, Aerospace and Aeronautical industries, research institutes, oil and gas industries, Petrochemical industries, Automotive companies, Telecommunication sector, Power and Defense, Biomedical industries, Hospitals etc.

CURRICULUM

FIRST SEMESTER

Course Code	Type	Course	L – T – P	Credits
21MA608	FC	Computational Linear Algebra, Differential Equations and Probability Theory	2 – 0 – 2	3
21EM601	FC	Digital Signal Controllers	3 – 0 – 2	4
21EM602	FC	Dynamics of Linear & Nonlinear Systems	2 – 0 – 2	3
21EM604	SC	Modelling and Identification of Dynamic Systems	3 – 0 – 2	4
21EM603	SC	Embedded Control System	3 – 0 – 2	4
21EM605	SC	Process Control and Automation	3 – 0 – 2	4
21HU601	HU	Amrita Values Program*		P/F
21HU602	HU	Career Competency I *		P/F
			Credits	**22**

***** Non-credit course

SECOND SEMESTER

Course Code	Type	Course	L – T – P	Credits
21EM611	SC	Digital Control for Automation	3 – 0 – 2	4
21EM612	SC	Optimal and Adaptive Control	3 – 0 – 2	4
21EM613	SC	Smart Sensing and Signal Processing	3 – 0 – 2	4
	E	Elective –I	3 – 0 –0	3
	E	Elective –II	3 – 0 – 0	3
21EM681	FC	Application Development Lab	0 – 0 – 2	1
21HU603	HU	Career Competency II	0 – 0 – 2	1
21RM608	SC	Research Methodology	2 – 0 – 0	2
			Credits	**22**

THIRD SEMESTER

Course Code	Type	Course	L – T – P	Credits
21EM798	P	Dissertation I		10
			Credits	**10**

FOURTH SEMESTER

Course Code	Type	Course	L – T – P	Credits
21EM799	P	Dissertation II		16
			Credits	**16**

Total credits: 70

LIST OF COURSES

Foundation Core (FC)

Course Code	Course	L – T – P	Credits
21MA608	Computational Linear Algebra, Differential Equations and Probability Theory	2 – 0 – 2	3
21EM602	Dynamics of Linear and Nonlinear Systems	2 – 0 – 2	3
21EM601	Digital Signal Controllers	3 – 0 – 2	4
21EM681	Application Development Lab	0 – 0 – 2	1

Subject Core (SC)

Course Code	Course	L – T – P	Credits
21EM604	Modelling and Identification of Dynamic Systems	3 – 0 – 2	4
21EM603	Embedded Control System	3 – 0 – 2	4
21EM605	Process Control and Automation	3 – 0 – 2	4
21EM611	Digital Control for Automation	3 – 0 – 2	4
21EM612	Optimal and Adaptive Control	3 – 0 – 2	4
21EM613	Smart Sensing and Signal Processing	3 – 0 – 2	4

Electives

(Subjects from areas including Advanced Control Systems, Embedded Systems, Automation, Instrumentation, Robotics, Guidance and Control)

Course Code	Course	L – T – P	Credits
21EM631	Advanced Digital Signal Controllers and Applications	3 – 0 – 0	3
21EM632	Advanced Digital Signal Processing	3 – 0 – 0	3
21EM633	Artificial Intelligence in Automation	3 – 0 – 0	3
21EM634	Automotive Control System Design	3 – 0 – 0	3
21EM635	Biological Control Systems	3 – 0 – 0	3
21EM636	Biomedical Instrumentation	3 – 0 – 0	3
21EM637	Cloud Computing	3 – 0 – 0	3
21EM638	Cyber Physical Systems	3 – 0 – 0	3
21EM639	Electrical Drives and Control	3 – 0 – 0	3
21EM640	Estimation Theory and Stochastic Control	3 – 0 – 0	3
21EM641	Flight Dynamics and Control	3 – 0 – 0	3
21EM642	Guidance and Control of Autonomous Systems	3 – 0 – 0	3
21EM643	Intelligent Control Systems	3 – 0 – 0	3
21EM644	Logic and Distributed Control Systems	3 – 0 – 0	3
21EM645	Modern Optimization Techniques	3 – 0 – 0	3
21EM646	Multi Agent Systems	3 – 0 – 0	3
21EM647	Nonlinear System Analysis and Control	3 – 0 – 0	3
21EM648	Power Plant Instrumentation	3 – 0 – 0	3
21EM649	Robotics and Control	3 – 0 – 0	3
21EM650	Robotics for Industrial Automation	3 – 0 – 0	3
21EM651	Robust Control	3 – 0 – 0	3
21EM652	Smart Electrical Network & Intelligent Communication Systems	3 – 0 – 0	3
21EM653	Variable Structure and Sliding Mode Control	3 – 0 – 0	3
21EM654	Virtual Instrumentation	3 – 0 – 0	3

*****Any of the elective subjects offered in any semester in any department may also be permitted with the concurrence of the department.

Project Work

Course Code	Course	L – T – P	Credits
21EM798	Dissertation I		10
21EM799	Dissertation II		16

21MA608 COMPUTATIONAL LINEAR ALGEBRA, DIFFERENTIAL EQUATIONS ANDPROBABILITY THEORY 2-0-2-3

Course Outcome:

CO1	To understand about roots of equations.
CO2	To understand about Systems of linear
CO3	To study about probability and its functions
CO4	To study about Ordinary differential equations

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	2		
CO2	3	3	2		
CO3	3	3	3		
CO4	3	3	2		

Linear Algebra: Matrix, Geometry of linear equations, Vector spaces and subspaces, linear independence, basis and dimensions, linear transformations, applications of linear transformations, inner product space, Orthogonality, projections and least square applications, Eigen values and Eigen vectors. Overview of Ordinary Differential Equations and applications of integration. Probability: Random Variables, Mass and Density Functions, Conditional Probability, Conditional Expectation, Independence, Correlation, Special Distributions and their Generating Functions, Binomial, Poisson, Normal, Linear Combinations of Normal Variables, Limit Theorems, Types of Convergence, Continuity Theorem, Central Limit Theorem. Laboratory Practice: Case studies and simulation experiments in system modelling, path planning, estimation and detection and so on.

TEXT BOOKS/REFERENCES

1. *Erwin Kreyszig, "Advanced Engineering Mathematics", 10th Edition, Wiley,2013.*
2. *Howard Anton, "Elementary Linear Algebra with Applications",11th Edition,Wiley,2005.*
3. *Douglas C. Montgomery and George C. Runger, "Applied Statistics and Probability for Engineers", 6th Edition, John Wiley & Sons, 2014.*
4. *E. A. Coddington and N. Levinson, "Theory of ordinary Differential Equations",Tata-McGraw Hill, 1984.*
5. *E. L. Ince, "Ordinary Differential Equations", Dover, 1956.*

21EM601 DIGITAL SIGNAL CONTROLLERS 3-0-2-4

Course Outcome:

CO1	Understand architecture of Digital Signal Controllers
CO2	Selection of Microprocessors/Microcontrollers/Digital Signal Controllers based on application
CO3	Familiarization and use of programming environment of Digital Signal controllers
CO4	Study on various peripherals associated with digital signal controllers.
CO5	Application development using digital signal controller.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2			2	
CO2	1		1	3	
CO3			1	3	
CO4	1		1		
CO5	3	2	2	2	2

Digital Signal controllers: Introduction, file registers, memory organization, interrupts, electrical characteristics, peripherals: Ports, Timer, ADC, USART, PWM Channels. Signal generation: PWM, SPWM and servo signals. Filtering algorithms: FIR filters, IIR filters, Control Algorithms: P, PI, PID controllers, Fourier Transforms: DFT, FFT, DCT algorithms. Simulation/hardware experiments with latest digital signal controllers. Lab Practice: Interfacing power electronic switches, voltage and current measurement techniques, digital ammeter and voltmeter, PWM generation for Servo Motor control, harmonics analysis in DSC using FFT.

TEXT BOOKS/ REFERENCES:

1. *dsPIC30F Family Reference Manual, 2017 Microchip Technology Inc., DS70046E.*
2. *dsPIC30F Programmer's Reference manual, Microchip, 2008*
3. *PICmicroTM Mid-Range MCU Family Reference Manual, 2017 Microchip Technology Inc., December 1997 /DS33023A.*
4. *Atmel-8271J-AVR- ATmega-Datasheet_11/2018.*
5. *PICmicrocontroller, PIC16F87XA Data Sheet 28/40/44-Pin Enhanced Flash Microcontrollers, 2003 Microchip Technology Inc., DS39582B.*
6. *Richard C Dorf, "The Engineering Handbook," Second edition, CRC press, 2005.*
7. *Katsuhiko Ogata, "Discrete-time Control Systems," Pearson India, 2ndediton, 2015.*

21EM602 DYNAMICS OF LINEAR AND NONLINEAR SYSTEMS 2-0-2-3

Course Outcome:

CO1	To design a controller/compensator using time and frequency domain techniques
CO2	Acquire knowledge to design observers and controllers for linear systems using a methodology which is implementable for practical control systems.
CO3	Analyse the behaviour of nonlinear system and develop suitable controller
CO4	Familiarize various Linearization techniques
CO5	Acquire knowledge to develop and utilize modern software tools for analysis and design of linear and nonlinear system.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	2	1
CO2	3	3	3	2	1
CO3	3	3	2	2	1
CO4	3	2	1	1	1
CO5	3	3	3	2	1

Overview: Introduction to control system design. Time domain and frequency domain techniques: compensators, controllers, Concept of controllability and Observability: Kalman's and Gilbert's tests. Design of control system in state space: Pole placement controller, control law design for full state feedback, design of servo systems. Observer design: Reduced order observer, design of regulator systems with observers. Case study: Computer aided designs. Introduction to nonlinear and time-varying systems. Mathematical background: norms, Lipschitz continuity, Lp norms for signals and Lp spaces, induced norms for systems. Existence and uniqueness of solutions to nonlinear differential equations. Linearization through Taylors series, Hartman-Grobmann Theorem. Characteristics of nonlinear systems. Second order systems, Phase plane techniques, Describing Functions, Lyapunov based Design. Lab Practice: Simulation/hardware experiments in design of compensators, controllers, observers, linearization, nonlinear system analysis with the help of an example from industries.

TEXTBOOKS/ REFERENCES:

1. *Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall of India Pvt. Ltd., New Delhi, 2010.*
2. *M. Gopal, "Modern Control System Theory", New Age International, 3rd edition 2014.*
3. *Norman S. Nise, "Control Systems Engineering", John Wiley & Sons PTE Ltd, 2013.*
4. *Richard C. Dorf and Robert H. Bishop, "Modern Control Systems", Pearson, 2011.*
5. *Graham C. Goodwin, Stefan F. Graebe and Mario E. Salgado, "Control System Design", PHI Learning, 2003.*
6. *Thomas Kailath, "Linear Systems", Princeton University Press, 2009.*
7. *Hassan K Khalil, "Nonlinear Systems", Prentice – Hall PTR, 2013.*
8. *Jean-Jacques Slotine, Weiping Li, "Applied Nonlinear Control", Prentice Hall, 2005*
9. *S. Sastry, "Nonlinear Systems: Analysis, Stability, and Control", Springer 2013*
10. *AIsidori, "Nonlinear Control Systems", Springer, 2013.*
11. *K. Ogata, "System Dynamics", Pearson, 2006.*

21EM604 MODELLING AND IDENTIFICATION OF DYNAMICSYSTEMS 3-0-2-4

Course Outcome

CO1	To analyse the modelling of various systems
CO2	Acquire knowledge about Fourier and Spectral analysis
CO3	Acquire knowledge about parameter estimation
CO4	Acquire knowledge to develop and utilize modern software tools for analysis and modelling of various systems.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2		
CO2	3	3			
CO3	3	3	2		
CO4	3	3	3	2	2

Modelling by first principle approach of simple mechanical, electrical, thermal, chemical systems. Modelling by energy approach using Lagrangian and Hamiltonian, bond graph modelling of dynamical systems. Classical methods of system identification: Identification of system transfer function, Fourier analysis and spectral analysis. Sampling, Discrete domain to continuous domain conversion techniques. Offline methods of parameter estimation: least squares method, Generalized Least squares method, Instrumental Variable method (IV), Maximum Likely hood estimation. Stochastic modelling: Regression methods, Linear regression model, Polynomial Models. Online Identification methods: Recursive Least squares (RLS). Identification of multivariable systems and closed loop systems, order reduction of higher order systems, aggregation method. Lab Practice: Hardware/simulation of system identification case study using classical methods, least square estimates, stochastic modelling and so on.

TEXT BOOKS/ REFERENCES:

1. *Sinha N K, Kuztsa, "Modeling and Identification of Dynamic Systems", Van Nostrand Reinhold Company, 1983.*
2. *K. Ogata, "System Dynamics", Pearson Prentice-Hall, 4th Edition, 2004.*
3. *E.O. Doeblin, "System Dynamics: Modeling, Analysis, Simulation, Design", Marcel Dekker, 1998.*
4. *Lennart Ljung, "System Identification Theory for the User", Prentice Hall Inc, 1999.*
5. *Harold W Sorensen, "Parameter Estimation: Principles and Problems", Marcel Dekker Inc, New York, 1980.*
6. *Thomas Kailath, Ali H. Sayed, Babak Hassibi, "Linear Estimation", Pearson, 2000*

21EM603 EMBEDDED CONTROL SYSTEM 3-0-2-4

Course Outcome

CO1	To study about control system design.
CO2	To study controller implementation using embedded systems
CO3	Acquire knowledge about model based control system design
CO4	Acquire knowledge to develop and utilize modern software tools for analysis of embedded systems.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	1	1
CO2	3	1	3	1	1
CO3	3	1	2	1	1
CO4	3	2	3	2	1

Review of control system design: closed loop control, analysis of control loops, time and frequency domain specifications, stability. Approaches for controller design. Practical realization of a control loop. Controller Implementation: architecture of embedded controllers and description of various components. Design and implementation of control loops, choice of embedded computing platforms- Real-time Operating Systems, Tiny Operating systems, I/O and communication, scheduling algorithms and their performance analysis, real-time issues in co-design implementation. Validation techniques for embedded control systems. Model Based Control System Design: discrete systems, notion of state, infinite State Machines, Extended State Machines, Model based design, code generation, verification and validation, HIL, MIL, SIL, PIL. Performance assessment of control algorithms on the target implementation architectures. Case studies from automotive, aerospace, process control and other application domains.

TEXT BOOKS/ REFERENCES:

1. *Edward Ashford Lee and Sanjit Arunkumarr Seshia, “Introduction to* Embedded Systems: *A Cyber-Physical Systems Approach”, 2011.*
2. *Karl Johan Astrom, Bjorn Wittenmark, “Computer Controlled Systems”, Dover Publications, 2011.*
3. *Dimitrios Hristu-Varsakelis, William S. Levine, “Handbook of Networked and Embedded Control Systems”, Birkhäuser Boston,2005.*
4. *J. W. Valavano, “Embedded Microcomputer Systems: Real-time Interfacing”, Thompson Asia, 2011.*
5. *Wayne Wolf, “Computers as components: Principles of Embedded Computing Systems Design”, Academic Press, 2005.*
6. *H. Hanselmann, “Implementation of Digital Controllers- A Survey”, Automatica (journal), Volume 23, Issue 1, Pages 7-32, January 1987.*

21EM605 PROCESS CONTROL AND AUTOMATION 3-0-2-4

Course Outcome

CO1	To develop process models using various modelling principles.
CO2	To learn advanced process control techniques.
CO3	To familiarize with PLC and its applications in process control.
CO4	To understand computer based plant monitoring and control.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	2	2	1	1
CO3	3	2	2	2	1
CO4	3	2	1	2	1

Process Modelling: hierarchies. Theoretical models: transfer function, state space models, and time series models. Development of empirical models from process data, chemical reactor modelling. Feedback & feed forward control, cascade control, selective control loops, ratio control, feed forward and ratio, split range, selective, override, auctioneering, adaptive and inferential controls. Multi-loop and multivariable control: process interactions, Singular value decomposition, Relative gain array, I/O pairing. Decoupling and design of non- interactive control loops. Statistical process control, supervisory control, direct digital control, distributed control, Introduction to Automatic Control: PC based automation. SCADA in process automation. Time Delay Systems and Inverse Response Systems, Special Control Structures, Introduction to Sequence Control, PLC, RLL, Sequence Control. Scan Cycle, Simple RLL Programs, Sequence Control. RLL Elements, RLL Syntax, Lab practice: Implementation of RLL, sequence control etc. using PLC Hardware Environment

TEXT BOOKS/ REFERENCES:

1. *Dale E. Seborg, Duncan A. Mellichamp, Thomas F. Edgar, Francis J. Doyle “Process Dynamics and Control”, John Wiley & Sons, 2010.*
2. *Karl Johan Astrom, Bjorn Wittenmark, “Computer Controlled Systems”, Dover Publications, 2011.*
3. *Johnson D Curtis, “Process Control Instrumentation Technology”, Prentice Hall India, 2013.*
4. *Bob Connel, “Process Instrumentation Applications Manual”, McGraw Hill, 1996.*
5. *Coughanowr, D. R. and L. B. Koppel, "Process systems Analysis and Control ", Mc-Graw-Hill, 2nd. edition., 1991.*
6. *Luyben, W. L., “Process Modelling Simulation and Control for Chemical Engineers", McGraw Hill, 1990.*
7. *H. Hanselmann, “Implementation of Digital Controllers – A Survey”, Automatica (journal), Volume 23, Issue 1, Pages 7-32, January 1987.*

21EM611 DIGITAL CONTROL FOR AUTOMATION 3-0-2-4

Course Outcome

CO1	Familiarize basic concepts for analysis of discrete time domain systems.
CO2	Use of Pulse transfer function in discrete time systems.
CO3	Stability analysis of digital control systems
CO4	Design of compensators and controllers for desired time/frequency response.
CO5	Design of estimators and observers
CO6	Acquire knowledge to develop and utilize modern software tools for analysis of digital control systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	1	1
CO2	3	1	3	1	1
CO3	3	1	2	1	1
CO4	3	2	3	2	1
CO5	3	2	3	2	2
CO6	3	2	3	2	1

Review of Z-transforms. Pulse transfer function. Digital control system: sampling, quantization, data reconstruction and filtering of sampled signals. Mathematicalmodellingof sampling process. Simulation examples- effect of sampling rate. Analysis of filters in discrete domain. Z-transform analysis of closed loop and open loop systems, multirate Z -transform. Stability analysis of closed loop systems in the z- plane: root loci, frequency domain analysis, Stability tests. Discrete equivalents. Digital controller design for SISO systems: design based on root locus method in the z-plane, design based on frequency response method, design of lag compensator, lead compensator, lag lead compensator, design of PID Controller based on frequency response method, direct design, method of Ragazzini. 2DOF discrete PID controller-software approach. State space representation in discrete system. Controllability, observability, control law design, decoupling by state variable feedback, effect of sampling period. Estimator/ Observer Design: full order observers, reduced order observers, regulator design. Discrete LQR design. Introduction to event triggered systems: examples using state flow technique. Real-Time Applications of Computer-Aided Design. Case Study: Simulation/hardware experiments in controller, observer/estimator, design for automation. Use of IOT based systems for process control and automation.

TEXT BOOKS/ REFERENCES:

1. *Gene F. Franklin, J. David Powell, Michael Workman, "Digital Control of Dynamic Systems", Pearson, 3rdEdition, 2006.*
2. *M.SamiFadali, AntonioVisioli, "Digital Control Engineering: Analysis and Design", Elsevier, 2013.*
3. *Ioan DoréLandau,Gianluca Zito, "Digital Control Systems: Design, Identification and Implementation", Springer, 2006.*
4. *Cheng Siong Chin, "Computer-Aided Control Systems Design" CRC Press, 2013.*
5. *HemchandraMadhusudanShertukde, "Digital Control Applications-Illustrated with MATLAB" CRC Press Inc., 2015.*
6. *C. L. Philips, Troy Nagle,AranyaChakrabortty, "Digital Control System Analysis and Design", Prentice-Hall, 2014.*
7. *K. Ogata, "Discrete-Time Control Systems", Pearson Education, 2011.*
8. *M. Gopal, "Digital Control and State Variable Methods", Tata McGraw-Hill, 2012.*

21EM612 OPTIMAL AND ADAPTIVE CONTROL 3-0-2-4

Course Outcome

CO1	Analyse the mathematical area of 'calculus of variation' so as to apply the same for solving optimal control problems.
CO2	Acquire knowledge of problem formulation, performance measure and mathematical treatment of optimal control problems so as to apply the same to engineering control problems with the possibility to do further research in this area.
CO3	Apply the knowledge on solving optimal control design problems by taking into consideration the physical constraints on practical control systems.
CO4	Acquire knowledge to develop and utilize modern software tools for design and analysis of optimal control problems.
CO5	Apply the knowledge in model reference adaptive control system design and to extend this knowledge to other areas of model following control with the idea of pursuing research in this area.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	3	3	2
CO2	3	2	3	3	1
CO3	3	1	3	3	2
CO4	3	1	3	3	1
CO5	3	2	3	3	1

Optimal control problem: fundamental concepts and theorems of calculus of variations. Euler - Lagrange equation and extremal of functional, the variational approach to solving optimal control problems, Hamiltonian and different boundary conditions for optimal control problem. Linear regulator problem: LQR/LQG controller design, applications to practical systems. Multi objective optimization techniques, genetic algorithm. Introduction to Model Predictive Control (MPC): State space MPC, prediction model, Objective function, constraints and optimization. Pontryagin's minimum principle, dynamic programming, principle of optimality and its application to optimal control problem, Hamilton-Jacobi-Bellman equation. Discrete time optimal Control Systems. Adaptive control: Closed loop and open loop adaptive control. Self-tuning controller, parameter estimation using least square and recursive least square techniques, gain scheduling, model reference adaptive systems (MRAS), self-tuning regulators. Variable Structure Control.

TEXT BOOKS/ REFERENCES:

1. *Donald E. Kirk, "Optimal Control Theory, An Introduction", Prentice Hall Inc., 2004.*
2. *S. Boyd, and L. Vandenberghe, "Convex Optimization", Cambridge, 2006.*
3. *J. A. Rossiter, "Model-Based Predictive Control: A Practical Approach", CRCPress,2003.*
4. *Gang Tao, "Adaptive Control Design and Analysis", John Wiley & Sons, 2003.*
5. *Hans Butler, "Model Reference Adaptive Control: From Theory to Practice", Prentice Hall, 1992.*
6. *A.P. Sage, "Optimum Systems Control", Prentice Hall, 1977.*
7. *M. Krstic, I. Kanellakopoulos, and P. V. Kokotovic, "Nonlinear and Adaptive Control Design", Wiley, 1995.*
8. *Karl J Astrom, Bjorn Wittenmark, "Adaptive Control", Addison –Wesley series,1995*
9. Diederik M Roijers,ShimonWhiteson, "Multi Objective Decision Making",Morgan and Claypool Publishers,2017.

21EM613 SMART SENSING AND SIGNAL PROCESSING 3-0-2-4

Course Outcome

CO1	To study the fundamentals of sensors.
CO2	To comprehend interfacing of sensors and signal conditioning
CO3	To learn techniques to analyse operation of active filters
CO4	Apply the knowledge about hardware components for signal conditioning
CO5	Acquire knowledge about software components for signal conditioning

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	2	2	1	1

CO3	3	2	2	2	1
CO4	3	2	1	2	1
CO5	3	2	1	2	1

Sensors Fundamentals: Sensor classification, Thermal sensors, Humidity sensors, Capacitive sensors, Electromagnetic sensors, Light sensing technology, Moisture sensing technology, Carbon dioxide (CO_2) sensing technology, Sensors parameters, Selection of sensors. Interfacing of Sensors and Signal Conditioning: Change of bios and level of signals, Loading effects on Sensor's output, Potential divider, Low-Pass RC filter, High-Pass RC filter, practical issues of designing passive filters. Op-amp circuits in Instrumentation: Instrumentation amplifier, Isolation Amplifier, current to voltage and voltage to current converter. Active Filters: Transfer function, First order active filters, Standard second order responses, KRC filters, Multiple feedback filters, Sensitivity, Filter approximations, Cascade design, Direct design, Switched capacitor, Switched capacitor filter. Wireless sensors and sensors network: Introduction, Frequency of wireless communication, Development of wireless sensor network based project. Use of Arduino for Signal conditioning and signal processing: Study of ADC, Using math operations and filter operations in Arduino. Smart Transducers: Smart Sensors, Components of Smart Sensors, General Architecture of Smart Sensors, Evolution of Smart Sensors, Advantages, Application area of Smart Sensors. Introduction to Embedded Web servers, IOT cloud based data storage and processing. Lab experiments: Simulation/hardware experiments in filters, amplifiers, signal processing using Arduino, wireless sensor networks.

TEXT BOOK/REFERENCES:

1. *Smart Sensors, Measurement and Instrumentation by Subhas Chandra Mukhopadhyay, Springer Book Series.*
2. *Measurement and Instrumentation: Theory and ApplicationsBy Alan S Morris, Reza Langari, Academic Press, Elsevier, 2016*
3. *Franco S. , Operational Amplifiers and Analog Integrated Circuits , Fourth Edition, McGraw Hill International Edition, 2014.*
4. *Randy Frank , Understanding Smart Sensors , Second Edition, Artech House sensors library, 2000.*
5. *NikolayKirianaki, Sergey Yurish, Nestor Shpak, VadimDeynega, Data Acquisition and Signal Processing for Smart Sensors, John Wiley & Sons Ltd, 2002.*

21EM681 APPLICATION DEVELOPMENT LABORATORY 0-0-2-1

Course Outcome

CO1	Familiarize simulation tools like MATLAB IDE, SIMULINK, Control Systems Toolbox, LABVIEW
CO2	Lab training in ICs and kits
CO3	Acquire knowledge to write a technical paper
CO4	Acquire knowledge about software for embedded systems

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5

CO1	3	2	3	2	3
CO2	3	3	3	2	1
CO3	3	2	3	1	1
CO4	3	2	3	1	1

The student in consultation with the faculty advisor has to select a topic related to Control and Instrumentation area, write a paper and present it. Lab training sessions in commonly used ICs and kits (Microcontrollers, FPGA kits etc.) to prepare students for project phase.

21RM608 RESEARCH METHODOLOGY 2-0-0-2

Course Outcome

CO1	Introduction about research
CO2	Problem Formulation
CO3	Experimental research
CO4	Preparation for research and dissertation
CO5	Intellectual property rights
Mode	P1,P2, ES, Tests/ Assignments/ Project

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	2	1	1	1
CO2	2	3	3	2	2
CO3	2	2	3	2	1
CO4	2	2	1	1	1
CO5	2	2	2	1	1

Unit I:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research, Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach, Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

Problem Formulation, Understanding Modeling& Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work, Ethics in science

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., “Research Design and Methods – A Process Approach”, 8th Edition, McGraw-Hill, 2011

2. C. R. Kothari, “Research Methodology – Methods and Techniques”, 2nd Edition, New Age International Publishers

3. Davis, M., Davis K., and Dunagan M., “Scientific Papers and Presentations”, 3rd Edition, Elsevier Inc.

4. Michael P. Marder,“ Research Methods for Science”, Cambridge University Press, 2011

5. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”. Aspen Law & Business; 6th Edition July 2012

21EM643 INTELLIGENT CONTROL SYSTEMS 3-0-0-3

Course Outcome

CO1	Design and implementation of ANN as controller/part of a control system for real world problems.
CO2	Design and implementation of knowledge based experts system-fuzzy logic controller and its stability studies for real world problem solving.
CO3	Design and implementation of evolutionary computation techniques-GA and fitness formulation for real world problem solving
CO4	To understand the concept of PSO and ACO.
CO5	To apply combination of knowledge representation, evolutionary computation, and machine learning techniques to real-world problems.
Mode	P1,P2, ES, Tests/Simulation Assignments

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	2	1
CO2	3	3	3	2	1
CO3	3	2	3	1	1
CO4	3	2	3	1	1
CO5	3	2	3	1	1

Introduction to Neural Networks, Artificial Neural Network (ANN) based control: ANN Architectures, Classification Taxonomy of ANN-Connectivity, Learning Strategy: Supervised, Unsupervised, Reinforcement, Learning Rules. Feed Forward Neural Networks, Perceptron Models: Discrete, Continuous and Multi-Category, Training Algorithms: Backpropagation (BP) algorithm, Competitive Learning, Vector Quantization, Self Organized Learning Networks, Kohonen Networks, Radial Basis function (RBF). Artificial Neural Network application: inverse model approach, direct model reference control, model predictive control, indirect adaptive controller design using neural network. Fuzzy logic based control: fuzzy controllers, preliminaries, Mamdani and Sugeno inference methods, fuzzy sets in commercial products, defuzzification, basic construction of fuzzy controller, fuzzy PI, PD and PID control, T-S fuzzy model, Neural and fuzzy-neural networks. Genetic algorithm: basics of Genetic Algorithms, design issues in Genetic Algorithm, genetic modelling, hybrid approach, GA based fuzzy model identification, Particle Swarm Optimization: concept, algorithm, PSO variations and applications. Ant colony optimization. Mathematical modelling of intelligent robotic systems.

TEXT BOOKS/ REFERENCES:

1. *Klir G. J. and Folger T. A., “Fuzzy Sets, Uncertainty and Information”, Prentice Hall of India, 2006.*
2. *Bose N. K. and Liang P., “Neural Network Fundamentals with Graphs, Algorithmsand Applications”, Tata McGraw-Hill, 2006.*
3. *Robert Fuller, “Advances in Soft Computing, Introduction to Neuro Fuzzy Systems”,Springer, 2000.*
4. *Astrom K., “Adaptive Control”, Second Edition, Pearson Education Asia Pvt. Ltd,2002.*
5. *Gang Tao, “Adaptive Control, Design and Analysis”, John Wiley and Sons, 2003.*
6. *Zi-Xing Cai, "Intelligent control: Principle, Techniques and Applications", World Scientific Publishing Co. Ptc. Ltd, 1997*
7. *LaxmidharBehera, IndraniKar, “Intelligent Systems and Control”,OxfordUniversity press,2009.*

21EM649 ROBOTICS AND CONTROL 3-0-0-3

Course Outcome

CO1	Ability to describe robotic manipulators using mathematical tools like linear algebra.
CO2	Ability to analyze and think critically about fundamental problems in robotics, such as forward and inverse kinematics.
CO3	Understand different industrial robot configurations and their mathematical models
CO4	Ability to design control systems for robotic manipulators used in industries.
Mode	P1,P2, ES, Tests/Simulation Assignments

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	2	2
CO2	3	1	3	2	2
CO3	1	1	3	2	2
CO4	3	1	3	2	2

Mathematical representations of rigid bodies in 3D space, the concept of a 4 x 4 homogeneous transformations and elementary screw theory. Lab: Different kinds of actuators and their mathematical models: stepper, DC servo and AC motors, model of a DC servo motor, sensors: internal and external sensors, common sensors, encoders, tachometers, strain gauge based force-torque sensors, proximity and distance measuring sensors and vision. Symbolic representation of robots: representation of joints, link representation using D-H parameters, kinematics of serial robot. Direct Kinematics: forward solutions for Stanford and PUMA robots, Inverse Kinematics: inverse (back) solution by Geometric approach with co-ordinate transformation and manipulation of symbolic T and A matrices. Lab: Software simulation of manipulators. Wheeled mobile robots: Kinematic models of holonomic and non-holonomic mobile robots, modelling of slip. Introduction to ROS.

TEXT BOOKS/ REFERENCES:

1. *R. K. Mittal and I. J. Nagrath, "Robotics and Control", Tata McGraw-Hill, 2006.*
2. *John J. Craig, "Introduction to Robotics: Mechanics and Control", Pearson Education, 2008.*
3. *Kozlowski and Krzysztof, "Robot Motion and Control", Springer, 2012.*
4. *Peter Corke, "Robotics, Vision and Control: Fundamental Algorithms In MATLAB", Springer, 2nd edition, 2017*
5. *www.wiki.ros.org*

21EM641 FLIGHT DYNAMICS AND CONTROL 3-0-0-3

Course Outcome

CO1	Understand fundamentals of aircraft performance
CO2	Analyse different modes of flight motion and stability considerations
CO3	Development of autopilots for aircraft
CO4	Basics of dynamics and control of launch vehicles
CO5	Familiarization of sensors and navigational aids

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	3	2	1	2
CO3	3	3	2	3	3
CO4	3	2	2	1	2
CO5	3	1	1	1	2

Aerodynamic forces: lift, drag and moment coefficients-variation with angle of attack aerodynamic center, Aircraft Performance: drag polar of vehicles from low speed to hypersonic speed. Six DOF Equations of motion of aircraft. Aircraft Stability and Control: longitudinal and lateral dynamics stability, conditions for longitudinal static stability. Modes of motion: Short period, phugoid, spiral divergence, Dutch roll, stability derivatives, roll coupling. Aircraft transfer functions, control surface actuator, longitudinal autopilots, displacement autopilot, pitch autopilot, lateral, autopilots, yaw and roll autopilots, attitude control systems stability augmentation, numerical problems. Dynamics and control of Launch Vehicles (SLV). Inertial sensors: Gyros, accelerometers, MEMS devices for aerospace navigation, IMU. Navigational aids: Instrument landing system, radar, GPS.

TEXT BOOKS / REFERENCES:

1. *John D Anderson Jr, "Introduction to Flight", McGraw Hill International, 8th edition, 2015*
2. *John D. Anderson Jr, "Fundamentals of Aerodynamics", McGraw HillInternational, 5th edition, 2010.*
3. *Thomas R. Yechout, "Introduction to Aircraft Flight Mechanics", AIAA EducationSeries, 2003.*
4. *Robert C. Nelson, "Flight Stability and Automatic Control", WCB McGraw-Hill,2nd edition, 1998.*
5. *David Titteron and John Weston, "Strapdown Inertial Navigation Technology" Second Edition IEE Radar, Sonar, Navigation and Avionics Series, 2005.*

6. *Arthur l Greensite, "Control Theory Vol II, Launch vehicle control and analysis,1970*

21EM654 VIRTUAL INSTRUMENTATION 3-0-0-3

Course Outcome

CO1	Review of virtual instrumentation
CO2	Get adequate knowledge of VI tool sets and programming
CO3	Analyse and design programmes based on data acquisition
CO4	Applications of VI tools sets for control engineering

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2		3		
CO2	2		3	1	
CO3	2	1	2	2	
CO4	2	1	2	3	

Virtual Instrumentation: Historical perspective, advantages, block diagram and architecture of a virtual instrument, data flow techniques, graphical programming in data flow, comparison with conventional programming. Development of Virtual Instrument using GUI, Real–time systems, Embedded Controller, OPC, HMI / SCADA software, Active Xprogramming.VI programming techniques: VIS and sub - VIS, loops and charts, arrays, clusters and graphs, case and sequence structures, formula nodes, local and global variables, string and file I/O, Instrument Drivers, Publishing measurement data in the web. Data acquisition basics: Introduction to data acquisition on PC, Sampling fundamentals, Input/output techniques and buses. ADC, DAC, Digital I/O, counters and timers, DMA, Software and hardware installation, Calibration, Resolution, Data acquisition interface requirements.VI Chassis requirements. Common Instrument Interfaces: Current loop, RS232C/ RS485, GPIB. Bus Interfaces: USB, PCMCIA, VXI, SCSI, PCI, PXI, Fire wire. PXI system controllers, Ethernet control of PXI. Networking basics for office & Industrial applications, VISA and IVI. VI toolsets, distributed I/O modules. Application of Virtual Instrumentation: Instrument Control, Development of Process database management system, Simulation of systems using VI, Development of Control system, Industrial Communication, Image acquisition and processing, Motion Control.

TEXTBOOKS/ REFERENCES:

1. *Gary Johnson, "LabVIEW Graphical Programming", Fourth edition, McGraw Hill, Newyork, 2007*
2. *Lisa K. wells & Jeffrey Travis, "LabVIEW for everyone", Third Edition, Prentice Hall, New Jersey, 2007.*
3. *Kevin James, "PC interfacing and Data Acquisition: Techniques for measurement, Instrumentation and Control", First Edition, Newnes, 2004.*
4. *www.ni.com*

21EM644 LOGIC AND DISTRIBUTED CONTROL SYSTEMS 3-0-0-3

Course Outcome

CO1	To understand about data acquisition systems
CO2	To study about digital controller modes
CO3	To study about PLC programming
CO4	To learn about DCS architecture
CO5	Acquire knowledge about software for DAS and digital controllers

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	2	1	1
CO2	3	2	2	1	1
CO3	3	2	2	1	1
CO4	3	2	2	1	1
	3	3	2	1	1

Data loggers, Data Acquisition Systems (DAS), Direct Digital Control (DDC). Supervisory Control and Data Acquisition Systems (SCADA), sampling considerations. Functional block diagram of computer control systems, alarms, interrupts. Characteristics of digital data, controller software, linearization. Digital controller modes: Error, proportional, derivative and composite controller modes. PLC: Evolution, Components, advantages over relay logic, Architecture, Programming devices, Discrete and Analog I/O modules. Programming languages, Ladder diagrams, timers and counters. Instructions in PLC: Program control instructions, math instructions, sequencer instructions. Use of PC as PLC, Case studies using PLC. DCS Architectures, Comparison, Local control unit. Process interfacing issues. Communication facilities, configuration of DCS, displays, redundancy concept.

TEXT BOOKS/ REFERENCES:

1. *John. W. Webb, Ronald A Reis, "Programmable Logic Controllers - Principles andApplications", 5th Edition, Prentice Hall Inc., New Jersey, 2003.*
2. *M.P Lukcas, "Distributed Control Systems", Van Nostrand Reinhold Co., New York,1986.*
3. *Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw Hill,New York, 2016.*
4. *P.B.Deshpande and R.H Ash, "Elements of Process Control Applications", ISAPress, New York, 1995.*
5. *Curtis D. Johnson, "Process Control Instrumentation Technology, 8th Edition,Prentice Hall", New Delhi, 2006*
6. *Krishna Kant, "Computer-based Industrial Control", 2nd Edition, Prentice Hall,New Delhi, 2010.*

21EM651 ROBUST CONTROL 3-0-0-3

Course Outcome

CO1	Understand norms for signals and systems, uncertainty and robustness
CO2	Analyse stability
CO3	Discuss design constraints and performance
CO4	Control design

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	2	1	2	1	1
CO2	2	1	2	2	1
CO3	2	2	2	1	1
CO4	3	1	2	2	1

Norms for signals and systems, input output relationships, internal stability, asymptotic tracking, performance. Uncertainty and robustness: plant uncertainty, robust stability, robust performance. Stabilization: controller parameterization for stable plant, co- prime factorization, controller parameterization for general plant, asymptotic properties, strong and simultaneous stabilization. Design constraints: algebraic constraints, analytic constraints. Design for performance: unstable, design example, 2-norm minimization. Stability Margin Optimization: optimal robust stability, gain margin optimization, phase margin optimization. Loop Shaping, Sliding mode control and $H\infty$ control. Applications in control design.

TEXT BOOKS/ REFERENCES:

1. *S.P. Bhattacharyya, H. Chapellat, L.H. Keel, "Robust Control: The ParametricApproach", Prentice Hall, 2007.*
2. *Chandrasekharan, P.C., "Robust Control of Linear Dynamical Systems", AcademicPress, 1996.*
3. *Kemin Zhou, John Comstock Doyle, "Essentials of Robust Control", Prentice HallInternational, 1998.*
4. *Sinha, "Linear Systems: Optimal and Robust Control", Taylor & FrancisGroup,2007.*
5. *U. Mackenroth, "Robust Control Systems Theory and Case studies", Springer, 2013.*

21EM631 ADVANCED DIGITAL SIGNAL CONTROLLERS AND APPLICATIONS 3-0-0-3

Course Outcome

CO1	Knowledge and understanding of DSP basic concepts
CO2	Knowledge and understanding of fundamental filtering algorithms
CO3	Knowledge and understanding of micro controllers as DSP computing platforms
CO4	Knowledge and understanding of software programming basics and principles
CO5	Intellectual ability to use different design methods to achieve better results
CO6	Practical ability to implement DSP algorithms and design methods on 8 bit micro controllers.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	2	1
CO2	3	1	2	2	1
CO3	3	1	2	2	1
CO4	3	1	2	2	1
CO5	3	1	2	2	1
CO6	3	1	2	2	1

Pre-requisite: General background of microprocessors and microcontrollers. Overview of Digital signal controllers: C2000 modules, Piccolo based controllers, Delfino based controllers, MAC units, hardware divide support, floating point signal processing support. dsPIC30F series DSC-CPU, data memory, program Memory, instruction set. Programming using XC16 compiler and C- Interrupt Structure. Peripherals of dsPIC30F: I/O Ports, timers, input capture, output compare, motor control PWM, 10 bit A/D converter, UART. Applications using dsPIC30F: Generating SPWM, generating PWM's for power converters, PID based control loops, signal processing based on FIR and IIR filter structures, developing single and multi-point communications with dsPIC and other IC's.

TEXT BOOKS/ REFERENCES:

1. *dsPIC30F Family Reference manual, Microchip, 2008*
2. *dsPIC30F Programmer's Reference manual, Microchip, 2008*
3. *Chris Nagy, "Embedded System Design using the TI MSP 430 series," First Edition. Newnes, 2003.*
4. *John G Proakis, G Manolakis, "Digital Signal Processing Principles, Algorithms, Applications," Fourth Edition, Prentice Hall India Private Limited, 2007.*
5. *Byron Francis, "Raspberry PI3: The Complete Beginner's Guide,"Create Space Independent Publishing Platform, 2016*

21EM640 ESTIMATION THEORY AND STOCHASTIC CONTROL 3-0-0-3

Course Outcome

CO1	Understand about estimation theory
CO2	Learn about different estimation techniques
CO3	To understand about different filters
CO4	To study about stochastic control
CO5	Acquire knowledge about softwares for simulation of estimators and non linear filters

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	1	1	1
CO2	3	1	2	1	1
CO3	3	2	2	1	2
CO4	3	1	1	1	1
CO5	3	1	1	1	2

Estimation Theory: Cramer Rao Lower Bound. Linear Modeling. Estimation Techniques: Least Squares Estimation, Recursive Least Squares Estimation, Best Linear Unbiased Estimation, Likelihood and Maximum Likelihood Estimation. Bayesian Philosophy: Maximum Aposteriori Estimation, Wiener Filter, Kalman Filter. Dynamic programming: basic problem, min-max control, set membership function. Stochastic Control: stochastic integrals, analysis of dynamical systems with stochastic inputs.

TEXT BOOKS/ REFERENCES:

1. *Steven M. Kay, "Statistical Signal Processing: Estimation Theory", Vol. 1, Prentice Hall Inc., 1998.*
2. *Steven M. Kay, "Statistical Signal Processing: Detection Theory", Vol. 2, Prentice Hall Inc., 1998.*
3. *Harry L. Van Trees, "Detection, Estimation and Modulation Theory", Part 1, John Wiley and Sons Inc. 2004.*
4. *Monson H. Hayes, "Statistical Digital Signal Processing and Modelling", John Wiley and Sons Inc., 2009.*
5. *H.Vincent Poor, "An Introduction to Signal Detection and Estimation", Second Edition, Springer, 2013.*
6. *Dimitri P BertsekSektas, "Dynamic Programming and Optimal Control", Athens Scientific, 2012.*

21EM646 **MULTI AGENT SYSTEMS** **3-0-0-3**

Course Outcome

CO1	To understand about different multi agent systems
CO2	Classification of Multi Agent Systems
CO3	To study about different applications of multi agent systems
CO4	Acquire knowledge about softwares for simulation of different multi agent systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	1	1	1
CO2	3	1	2	1	1
CO3	3	2	2	1	2
CO4	3	1	1	1	1

Introduction to Multi Agent Systems, Intelligent Agents: the design of intelligent agents, reasoning agents (eg: AgentO), agents as reactive systems (eg: subsumption architecture),hybrid agents (eg:PRS), layered agents (eg: Interrap) a contemporary (Java- based)framework for programming agents (eg:JADE Java Agent Development Environment).Multi-Agent Systems: Classifying multi-agent interactions ,cooperative versus non competitive,zero-sum and other interactions, cooperation, the Prisoner's dilemma and Axelrod's experiments. Interactions between self-interested agents: auctions & voting systems, negotiation. Interactions between benevolent agents: cooperative distributed problem solving (CDPS), partial global planning, coherence and coordination. Interaction languages and protocols: speech acts, KQML/KIF, the FIPA framework. Application to multi-UAV systems: Formation control with time-varying topology, Formation control with connectivity maintenance, Steady-state behaviours, Bearing-based formation control, formation of autonomous vehicles and consensus. Application to multi-UGV systems: Cooperative Mobile Manipulations, Cooperative exploration of unknown environments, Mutual localization with anonymous measurements, Target localization and encircling.

TEXT BOOKS / REFERENCES:

1. *Michael Woodbridge, "Introduction to Multi agent systems" Wiley, 2009.F. Bullo, J. Cort´es, and S. Mart´ınez.,"Distributed Control of Robotic Networks.*
2. *Applied Mathematics Series", Princeton University Press, 2010.*
3. *M. Mesbahi and M. Egerstedt, "Graph Theoretic Methods in Multiagent Networks.*
4. *W. Ren and R. W. Beard. , "Distributed Consensus in Multi-vehicle CooperativeControl. Communications and Control Engineering", Springer, 2008.*
5. *Rafael H. Bordini, Jomi Fred Hubner and Michael Wooldridge, "ProgrammingMulti-agent Systems in AgentSpeak Using Jason". Wiley 2007.*
6. *S. Russell and P. Norvig,"Artificial Intelligence – A Modern Approach", PrenticeHall, 2010.*

21EM648 POWER PLANT INSTRUMENTATION 3-0-0-3

Course Outcome

CO1	Estimate the energy flow using Sankey diagram in various parts of power plants
CO2	Illustrate the operation and layout of various power plant
CO3	Describe the different process and equipment associated with power plant.
CO4	Determine the behaviour of Boiler/Turbine instrumentation and its control
CO5	Development of automation for power plants.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	3	3	1	1
CO2	3	2	1	1	1
CO3	3	1		1	1
CO4	3	3		1	1
CO5	3	3	2	1	1

Introduction: Importance of Instrumentation and control in power generation, piping and instrumentation diagrams. Instrumentation and control in water circuit: boiler feed water circulation, measurements, controls, impurities in water and steam. Instrumentation and control in air-fuel circuit: measurements, controls, analytical measurements. Turbine monitoring and control: classification of turbines, instrumentation and control points of view, principal parts of turbines, turbine steam inlet system, turbine measurements, turbine control system, lubrication for turbo-alternator, turbo alternator cooling system. Basic principles of a nuclear plant. Nuclear power plant training simulator project. Design concepts of instrumentation and control of CWR, PWR and BWR reactors (different examples). Operator/Plant communication systems, main control systems, safety and safety related systems. Role of Instrumentation in hydroelectric power plant. Regulation and monitoring of voltage and frequency of output power. Pollution and effluent monitoring and control. Energy management. Electrical substation controls. Plant safety and redundancies of non-conventional power plants. Diesel generator controls.

TEXT BOOKS/ REFERENCES:

1. *K. Krishnaswamy, M. Ponni Bala, "Power Plant Instrumentation", PHI Learning Private limited, New Delhi, 2011.*
2. *David Lindsley, "Power Plant Control and Instrumentation, The Control of Boilers and HRSG systems", IEE Control Engineering Series 2000.*
3. *Philip Kiameh, "Power Plant Instrumentation and Controls", McGraw Hilldducation, 2014.*
4. *Singh S K, "Industrial Instrumentation and control" Tata- McGraw-Hill Publishing Company, 2009.*

5. *“Nuclear power plant instrumentation and control”, A guidebook, International atomic energy agency Vienna, 1984(online resource).*
6. *David Linsley, “Power plant control and instrumentation: The control of boilers and HRSG system”, Institution of Electrical Engineers,2000.*

21EM639 ELECTRIC DRIVES AND CONTROL 3-0-0-3

Course Outcome

CO1	Review of the basic characteristics of a controllable drive and select a suitable motor rating for a particular drive application
CO2	Formulate the mathematical model of DC and AC Machines for transient and steady state conditions and analyse the performance.
CO3	Apply reference frame theory to AC machines.
CO4	Illustrate suitable control techniques for DC & AC drives.
CO5	Investigate the vector control techniques for AC drives.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	3	1	1
CO2	3	2	2	3	0
CO3	3	1	2	1	0
CO4	3	3	3	2	0
CO5	3	2	3	3	0

Fundamentals of electric drives, dynamics of electric drives, multi quadrant operation, closed loop control of drives. Review of DC and AC Motor Drives: Primitive machine: unified approach to the analysis of electrical machine, basic two pole model of rotating machines, Kron’s primitive machine: voltage, power and torque equation, linear trans formation from 3 phase to 2 phase and from rotating axes to stationary axes, invariance of power. Principle of vector Control: vector controlled induction motor drive, basic principle, direct rotor flux oriented vector control, estimation of rotor flux and torque, implementation with current source and voltage source inverters. Stator flux oriented vector control, indirect rotor flux oriented vector control scheme, implementation, tuning (include lab practice). Vector control strategies for synchronous motor. Introduction to sensor-less control, basic principle of direct torque control, MRAS, PLC based control.

TEXT BOOKS/REFERENCES:

1. *R. Krishnan, “Electric Drives: Modeling, Analysis and Control”, PHI, 2007.*
2. *Vedam Subramaniam, “Electric Drives: Concepts and Applications”, Tata McGraw Hill,2011.*
3. *Bose B. K, “Modern Power Electronics and AC Drives”, Pearson Education Asia,*

2002.
4. *N. K. De and P. K. Sen, "Electric Drives", PHI, New Delhi 2001.*
5. *M. D. Singh and K. B. Khanchandani, "Power Electronics", Tata McGraw Hill, 2008.*
6. *Joseph Vithayathil, " Power Electronics, Principles and Applications", McGraw HillSeries, 6 th. Reprint, 2013.*

21EM645 MODERN OPTIMIZATION TECHNIQUES 3-0-0-3

Course Outcome

CO1	To understand about different optimization techniques
CO2	Classification of different Optimization techniques
CO3	To study about different multi variable optimization techniques
CO4	Acquire knowledge about softwares for simulation of different optimization techniques

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	1	1	
CO2	3	1	2	1	
CO3	3	2	2	1	
CO4	3	1	1	1	

Historical Development, Engineering applications of Optimization. Art of Modelling: Objective function, Constraints and Constraint surface, Formulation of design problems as mathematical programming problems. Classification of optimization problems: Optimization techniques, classical and advanced techniques, Functions of single and two variables, Stationary points, Global Optimum, Convexity and concavity of functions of one and two variables, optimization of function of one variable and multiple variables, Gradient vectors, Examples. Optimization of function of multiple variables subject to equality constraints: Lagrangian Function, Hessian matrix formulation, Kuhn-Tucker Conditions, Examples. Advanced Topics in optimization: Piecewise linear approximation of a nonlinear function, Direct and indirect search methods. Evolutionary algorithms for optimization: Working Principles of Genetic Algorithm, genetic Operators, Selection, Crossover and Mutation, Issues in GA implementation. Particle Swarm Optimization: Fundamental principle, Velocity Updating, Advanced operators, Parameter selection. Simulated annealing algorithm, Tabu search algorithm, Ant colony optimization, Bacteria Foraging optimization. Multi objective optimization: Weighted and constrained methods, Multi level optimization, Concept of pareto optimality.

TEXT BOOKS/ REFERENCES:

1. *D. P. Kothari and J. S. Dhillon, "Power System Optimization", 2ndEdition, PHIlearning private limited, 2010.*
2. *Kalyanmoy Deb, "Multi objective optimization using Evolutionary Algorithms",*

JohnWiley and Sons, 2008.
3. *Kalyanmoy Deb, "Optimization for Engineering Design", Prentice hall of India firstedition, 1988.*
4. *Carlos A. CoelloCoello, Gary B. Lamont, David A. Van Veldhuizen, "EvolutionaryAlgorithms for solving Multi Objective Problems", 2nd Edition, Springer, 2007.*
5. *Kwang Y. Lee, Mohammed A. E L Sharkawi, "Modern heuristic optimizationtechniques", John Wiley and Sons, 2008.*

21EM642 GUIDANCE AND CONTROL OF AUTONOMOUS SYSTEMS 3-0-0-3

Course Outcome

CO1	To understand about different navigation techniques
CO2	To understand about different guidance techniques
CO3	To study about different controllers used for guidance and navigation
CO4	Acquire knowledge about softwares for simulation of different guidance, navigation and control techniques for autonomous systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	1	1	1
CO2	3	1	2	1	1
CO3	3	2	2	1	1
CO4	3	1	1	1	1

Introduction to the concepts of navigation, guidance and control. General principles of early conventional navigation systems, Geometric concepts of navigation, Reference frames. Inertial navigation: Gyros and Accelerometers, Inertial platforms: stabilized platforms, gimballed and strap down INS. Stabilization and Control of spacecrafts, Missile control systems and Autopilots, Launch vehicle flight control systems. Longitudinal and lateral autopilots for aircraft, Radar systems, Command and Homing guidance systems. Introduction to Manipulators and Mobile Robots: Direct Kinematics, Co-Ordinate Frames, Rotations, Homogeneous Coordinates, the Arm Equation. Kinematic Navigation and Guidance of Mobile Robots: Path Planning, Single Axis PID Control, PD Gravity Control, Computed Torque Control, Variable Structure Control, Impedance Control.

TEXT BOOKS/ REFERENCES:

1. *Marshall H Kaplan, "Modern Spacecrafts Dynamics and Control", John Wiley &Sons, 1976*
2. *Edward V B Stearns, "Navigation and Guidance in Space", Prentice-Hall Inc*
3. *John J. Craig, "Introduction to Robotics Mechanics and Control"',Pearson Education Asia. 2009*

4. *Ashitava Ghosal, “Robotics Fundamental Concepts and Analysis”, Oxford University Press. 2006*

21EM636 BIOMEDICAL INSTRUMENTATION 3-0-0-3

Course Outcome

CO1	Understand the principles of medical instruments used for biomedical applications
CO2	Analyse the qualitative functions of electrodes used for the biopotential measurements.
CO3	Measurement of noninvasive diagnostic parametres
CO4	Understand the position of biomedical instrumentation in modern hospital care.

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3: High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	3	1	1
CO2	3	2	2	1	1
CO3	3	2	2	2	1
CO4	3	3	2	3	1

Basics of biomedical instrumentation: Terminology, medical measurements, constraints, Classification of biomedical instruments. Introduction to biological system modelling: electrical and ionic properties of cellular membranes, sources and theories of bio-electric-potentials. Biomedical Transducers: types of transducers used in bio- instrumentation. Recording electrodes: electrodes theory, biopotential Electrodes, biochemical electrodes Biomedical signal measurement Basics: Bio amplifiers, Measurement of Ph, Oxygen and Therapeutic and prosthetic devices: cardiac pacemakers, defibrillators, hemodynamic & hae modialysis, ventilators, infant incubators, surgical instruments. Therapeutic Applications of Laser. Cardiovascular measurements: blood flow, pressure, cardiac output and impedance measurements, plethysmography. Measurement of heart sounds: introduction to Electrocardiography (ECG), elements of intensive care. Monitoring: heartrate Monitors, Arrhythmia Monitors. EEG & EMG: anatomy and functions of brain, bioelectric potentials from brain, resting rhythms, clinical EEG. Instrumentation techniques of Electroencephalography, Electromyography. Medical imaging systems: radiography, MRI, Computed Tomography, Ultrasonography. Non-invasive Instrumentation: t measurements, principles of Ultrasonic measurements, ultrasonic and its applications in medicine. Biotelemetry: introduction to biotelemetry, physiological parameters adaptable to biotelemetry, biotelemetry system components, implantable units and applications of telemetry in patient care.

TEXTBOOKS/ REFERENCES:

1. *L.A.Geddes and L.E. Baker,“Principles of Biomedical Instrumentation”,2nd edition,John Wiley & Sons Inc., 1989.*
2. *L.Cromwell, “Biomedical Instrumentation and Measurements”, 2nd edition, PrenticeHall, 1980.*

3. *John G.Webster (Ed.), "Medical Instrumentation – Application and Design", 4th Edition, John Wiley & Sons Inc., 2009.*
4. *R. S. Khandpur, "Handbook of Biomedical Instrumentation",3rdedition, TataMcGraw Hill, New Delhi, 2014.*

21EM652 SMART ELECTRICAL NETWORKS AND INTELLIGENT COMMUNICATIONSYSTEMS 3-0-0-3

Course Outcome

CO1	To understand about different data communication techniques in smart vehicles
CO2	To understand about various protocols for data communication
CO3	To study about different applications of communication systems
CO4	Acquire knowledge about softwares for simulation of communication in smart electrical vehicles

<u>Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High</u>

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	2	2	2	1	1
CO3	2	2	2	1	1
CO4	3	1	2	2	1

Data communication, Communication channels: Wireless and Wired communication. Layered architecture and protocols: ISO/OSI, TCP/IP models. Communication technologies: IEEE 802, Multi- protocol label switching, Power line communication. Protocols and standards for information exchange-Standards for smart metering, Modbus, DNP3, IEC61850, Ethernet, Power line carrier communication, CAN Bus, I2C, LIN Bus protocol, Modbus protocol structure: Profibus protocol stack, Profibus communication model, Bluetooth, ZigBee, IEEE 801.11-a,b,g,n, Z-Wave, Cellular networks, WiMAX .Sensing measurement control and automation technologies. Communications infrastructure and protocols for smart metering: Home area network, Neighbourhood area network, Data concentrator, Meter data management system. Demand side integration, Services provided by DSI, Hardware support to DSI implementations, system support. Distribution automation equipment: Substation automation, IED, Remote terminal units. Distribution management systems, SCADA, Modelling and analysis tools. Application: System monitoring, operation and management, Interactions in autonomy-stability, Inference and predictions, hierarchical control, decentralized control, swarm robotics. Networked control systems: Time driven, Event driven feedback schemes.

TEXT BOOKS / REFERENCES:

1. *J. Ekanayake, et al, "SMART GRID, Technology and Applications", Wiley, 2012.*
2. *Bernard Sklar., "Digital Communications", Second Edition, Pearson Education, 2001.*
3. *John G. Proakis., "Digital Communication", Fourth Edition, McGraw*

HillPublication,2001.

4. *Theodore S. Rappaport., “Wireless Communications”, Second edition, Pearson Education, 2002.*
5. *Stephen G. Wilson, “Digital Modulation and Coding”, First Indian Reprint PearsonEducation,2003.*
6. *Clint Smith. P.E., and Daniel Collins, “3G Wireless Networks”, Second Edition, Tata McGraw Hill, 2007.*
7. *Vijay. K. Garg, “Wireless Communication and Networking”, Morgan Kaufmann Publishers, http://books.elsevier.com/9780123735805:,2007.*
8. *Kaveth Pahlavan. K. and Prashanth Krishnamurthy, "Principles of Wireless Networks", Prentice Hall of India, 2006.*
9. *Lubomir Bakule, “Decentralized control: An overview” Annual Reviews in Control,vol.32, pp. 87-98, 2008.*
10. *Sokratis Kartakis, Anqi Fu, Manuel Mazo, Julie A. McCann, “Communication Schemes for Centralized and Decentralized Event-Triggered Control Systems” IEEE*
11. *Transactions on Control Systems Technology, pp. 1-14, 2017.*

21EM653 VARIABLE STRUCTURE AND SLIDING MODE CONTROL 3-0-0-3

Course Outcome

CO1	To understand about variable structure systems
CO2	To understand about sliding mode control
CO3	To study about higher order SMC for variable structure systems
CO4	Acquire knowledge about softwares for simulation of variable structure systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	2	2	2	1	1
CO3	2	2	2	1	1
CO4	3	1	2	2	1

Notion of variable structure systems and sliding mode control, Existence conditions of sliding mode, sliding surface, Design of continuous sliding mode control, chattering reduction methods, Discrete sliding mode control, sliding mode observer, uncertainty estimation using sliding mode, Discrete output feedback SMC using multirate sampling, Introduction to higher order sliding mode control, twisting and super twisting algorithms.

TEXTBOOKS/ REFERENCES:

1. *Spurgeaon and Edwards, “Sliding Mode Control Theory and Applications”Taylor&Francis, 1998.*
2. *B. Bandyopadhyay and S. Janardhanan,“Discrete-time Sliding Mode Control :*

AMultirateOutput Feedback Approach", Ser. Lecture Notes in Control andInformation Sciences, Vol. 323, Springer-Verlag, Oct. 2005.
3. *Yuri Shtessel, Christopher Edwards, Leonid Fridman,Arie Levant "Sliding ModeControl and Observation", Birkhauser, 2013.*
4. *S. Kurode, B. Bandyopadhyay and P.S. Gandhi, "Output feedback Control for Sloshfree Motion using Sliding modes", Lambert Publications 2012.*

21EM637 CLOUD COMPUTING 3-0-0-3

Course Outcome

CO1	Introduction about clouds
CO2	To understand about different types of clouds
CO3	To study about different applications of clouds
CO4	Acquire knowledge about softwares for simulation of cloud computing

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO/PEO CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	2	2	2	1	1
CO3	2	2	2	1	1
CO4	3	1	2	2	1

The Cloud -Hype cycle-metaphorical interpretation-cloud architecture standards and interoperability- Cloud types; IaaS, PaaS, SaaS. Benefits and challenges of cloud computing, public, private clouds community cloud, role of virtualization in enabling the cloud. Requirement analysis: strategic alignment and architecture development cycle-strategic impact-Risk impact-financial impact-Business criteria technical criteria-cloud opportunities – evaluation criteria and weight-End to end design-content delivery networks-capacity planning-security architecture and design, Development environments for service development; Amazon, Azure, Google App-cloud platform in industry. Web Application Design- Machine Image Design-privacy design –Database management. Workload distribution architecture-Dynamic scalability-Cloud burstinghypervisor clustering-service quality metrics & SLA.

TEXTBOOKS/ REFERENCES:

1. *Reese, G. "Cloud Application Architectures: Building Applications and Infrastructure in the Cloud." O'Reilly Media, Inc. (2009).*
2. *John Rhoton,Cloud Computing Explained: Handbook for Enterprise Implementation 2013 edition, 2013, recursive press*
3. *RajkumarBuyya, Christian Vecchiola, S.ThamaraiSelvi, "Mastering Cloud Computing: Foundations and Applications",Elsevier publication, 2013*
4. *Thomas Erl, ZaighamMahmood, and Ricardo Puttini "Cloud Computing Concepts, Technology & Architecture," Prentice Hall, 2013*

21EM638 CYBER PHYSICAL SYSTEMS 3-0-0-3

Course Outcome

CO1	To understand about cyber physical systems
CO2	To understand about controller design for the systems
CO3	To study about advanced techniques for analysis of cyber physical systems
CO4	Acquire knowledge about softwares for simulation of cyber physical systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	2	2	2	1	1
CO3	2	2	2	1	1
CO4	3	1	2	2	1

Cyber-Physical Systems (CPS) in the real world , Basic principles of design and validation of CPS, CPS HW platforms : Processors, Sensors, Actuators , CPS Network, CPS S/w stack RTOS, Scheduling Real Time control tasks, Principles of Automated Control Design: Dynamical Systems and Stability , Controller Design Techniques, Stability Analysis: CLFs, MLFs, stability under slow switching , Performance under Packet drop and Noise, CPS: From features to software components, Mapping software components to ECUs, CPS Performance Analysis: effect of scheduling, bus latency, sense and actuation faults on control performance, network congestion, Formal Methods for Safety Assurance of Cyber- Physical Systems: Advanced Automata based modelling and analysis: Basic introduction and examples ,Timed and Hybrid Automata, Definition of trajectories, zenoness, Formal Analysis: Flow pipe construction, reachability analysis, Analysis of CPS Software, Weakest Pre- conditions, Bounded Model checking, Hybrid Automata Modeling : Flow pipe construction using Flowstar, SpaceX and Phaver tools, CPS SW Verification: Frama-C,CBMC, Secure Deployment of CPS : Attack models, Secure Task mapping and Partitioning, State estimation for attack detection, Automotive Case study : Vehicle ABS hacking, Power Distribution Case study : Attacks on Smartgrid.

TEXTBOOKS/ REFERENCES:

1. *E. A. Lee and S. A. Seshia, "Introduction to Embedded Systems: A Cyber-PhysicalSystems Approach", 2011.*
2. *R. Alur, "Principles of Cyber-Physical Systems," MIT Press, 2015.*
3. *T. D. Lewis "Network Science: Theory and Applications", Wiley, 2009.*
4. *P. Tabuada, "Verification and control of hybrid systems: a symbolic approach",Springer-Verlag 2009.*
5. *C. Cassandras, S. Lafortune, "Introduction to Discrete Event Systems", Springer 2007.*
6. *Constance Heitmeyer and Dino Mandrioli, "Formal methods for real-time computing",Wiley publisher, 1996.*

21EM634 AUTOMOTIVE CONTROL SYSTEM DESIGN 3-0-0-3

Course Outcome

CO1	To understand about automotive systems
CO2	To understand about control systems for automotive systems
CO3	To study about automotive protocols
CO4	Acquire knowledge about simulation of automotive systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	3	1	2	1	1
CO3	3	2	3	1	1
CO4	3	2	2	2	1

Automotive Systems Overview: Automotive Vehicle Technology, Overview of Vehicle Categories, Various Vehicle Sub Systems. Future Trends in Automotive Embedded Systems: Hybrid Vehicles, Electric Vehicles. Automotive Sensory System: Automotive Sensors and Transducers: Proximity Distance Sensors, Engine Speed sensor, Throttle Position Sensor, Pressure Sensors, Knock Sensor & Mass Flow Sensor. Automotive Control System Design : Digital Engine Control, Features, Control Modes for Fuel Control, Discrete Time Idle Speed Control, EGR Control, Variable Valve Timing Control, Electronic Ignition Control, Integrated Engine Control System, Summary of Control Modes, Cruise Control System, adaptive cruise control, Cruise Control Electronics, Anti-locking Braking System, Electronic Suspension System, Electronic Steering Control, Four-Wheel Steering, drive by wire system, ESP, Traction Control System, Active Suspension System, HVAC, vehicle immobilization and deactivation system, parking system, body electronics and central locking system. Automotive Protocols: LIN, CAN, FlexRay, Test, Calibration and Diagnostics tools for networking of electronic systems like ECU Software and Testing Tools, ECU Calibration Tools, AUTOSAR Architecture. Trends in Automotive Electronics: Intelligent Transportation System, V2V, V2I communication, Vehicle Network Simulation, autonomous vehicles architecture, control methods in autonomous vehicle navigation, vehicle platoon.

TEXT BOOKS/ REFERENCES:

1. *William B. Ribbens, "Understanding Automotive Electronics-An Engineering Perspective", Seventh edition, Butterworth-Heinemann Publications.*
2. *Ronald K. Jurgen, "Automotive Electronics Handbook", Mc -Graw Hill.*
3. *Kiencke, Uwe, Nielsen&Lars, "Automotive Control Systems for Engine, Drivelineand Vehicle", Second edition, Springer Publication.*
4. *Tao Zhang, Luca Delgrossi, "Vehicle Safety Communications: Protocols, Securityand Privacy", Wiley Publication.*

5. *Robert Bosch," Automotive Hand Book", Fifth edition, SAE Publications.*

21EM635 BIOLOGICAL CONTROL SYSTEMS 3-0-0-3

Course Outcome

CO1	To study about biological systems analysis
CO2	To understand about time domain analysis of biological systems
CO3	To understand about frequency response analysis of biological systems
CO4	To understand about stability analysis of biological systems
CO5	Acquire knowledge about simulation of biological systems

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	3	1	2	1	1
CO3	3	2	3	1	1
CO4	3	2	3	1	1
	3	2	2	2	1

Biological Control Systems Analysis. Comparison of Engineering and Biological Control System. Mathematical modelling of Biological (Physiological) Systems: Transfer function and State-Space Analysis, Computer Analysis and Simulation. Static Analysis of Biological Systems: Regulation of Cardiac Output, Regulation of Glucose, Chemical Regulation of Ventilation. Time-Domain Analysis: Linearized Respiratory Mechanics, Dynamics of Neuromuscular Reflex Motion. Frequency-Domain Analysis of Biological systems: Frequency Response of a Model of Circulatory Control, Frequency Response of Glucose-Insulin Regulation. Stability Analysis: Stability Analysis of the Pupillary Light Reflex Model of Cheyne-Stokes Breathing. Identification of Biological Control Systems: Identification of Closed-Loop Systems, Case studies. Optimization in Biological Control: Adaptive Control of Biological Variables. Nonlinear Analysis of Biological Control Systems: Models of Neuronal Dynamics

TEXT BOOKS/ REFERENCES:

1. *Michael C.K. Khoo, "Physiological Control Systems: Analysis, Simulation andEstimation". John Wiley & Sons, Inc., 2012.*
2. *Schlick, T., " Molecular Modeling and Simulation: An Interdisciplinary Guide". NewYork, NY: Springer, 2002.*
3. *Katsuhiko Ogata, "Modern Control Engineering", Prentice Hall of India Pvt. Ltd.,New Delhi, 2010.*
4. *Barry R. Dworkin, "Learning and Physiological Regulation*

(Hardcover)",Universityof Chicago Press, March 1993.
5. E. Carson, E. Salzsieder, "Modelling and Control in Biomedical Systems ", 2000(including Biological Systems) (IFAC Proceedings Volumes) (Paperback),Pergamon Publishing.

21EM647 NONLINEAR SYSTEM ANALYSIS AND CONTROL 3-0-0-3

Course Outcome

CO1	Understand the characteristics of nonlinear systems
CO2	Methods to analyse the nonlinear systems(phase plane, describing function)
CO3	Stability analysis of nonlinear systems
CO4	Introduction to different Nonlinear system controllers
CO5	Familiarize various Linearization techniques

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	1	2	1	1
CO2	3	1	2	1	1
CO3	3	2	2	1	1
CO4	3	3	3	3	2
CO5	3	2	2	1	1

Introduction to nonlinear and time-varying systems. Mathematical background: norms, Lipschitz continuity, Lp norms for signals and Lp spaces, induced norms for systems. Existence and uniqueness of solutions to nonlinear differential equations. Linearization through Taylors series, Hartman-Grobmann Theorem. Characteristics of nonlinear systems. Second order systems, Phase plane techniques, Poincare-Bendixson Theorem, periodic orbits, stability of periodic solutions, slow and fast manifolds. Input-output analysis and stability- Small gain theorem, passivity, describing functions. Stability of nonlinear systems: Lyapunov stability, local linearization and stability in the small, direct method of Lyapunov, La Salles's invariance principle and singular perturbation. Lyapunov function for linear and nonlinear systems, variable gradient method, centre manifold theorem, input-output stability, stability of state models, L2 stability. Lyapunov based design, back stepping, sliding mode control, Analysis of feedback systems, circle criterion, Popov criterion, simultaneous Lyapunov functions. Feedback linearization, input state linearization, input output linearization, full state linearization, harmonic linearization, filter hypothesis, stabilization, regulation via integral control, tracking. Gain scheduling. Zero dynamics, MIMO systems, non-minimum phase systems, singularities. Introduction to variable structure control.

TEXT BOOKS/ REFERENCES:

1. *Hassan K Khalil, "Nonlinear Systems", Prentice – Hall PTR, 2013.*
2. *Jean-Jacques Slotine, Weiping Li, "Applied Nonlinear Control", Prentice Hall, 2005*
3. *S. Sastry, "Nonlinear Systems: Analysis, Stability, and Control", Springer 2013*

A. *Isidori, "Nonlinear Control Systems", Springer, 2013.*

4. *K. Ogata, "System Dynamics", Pearson, 2006.*
5. *Stephen Wiggins, "Introduction to Applied Nonlinear Dynamical Systems and Chaos", Springer, 2013.*
6. *H. Nijmeijer, A. J. Van der Schaft, "Nonlinear Dynamic Control Systems", Springer 2013.*
7. *M.Vidyasagar, "Nonlinear System Analysis", Prentice – Hall PTR, second edition 2002.*

21EM632 ADVANCED DIGITAL SIGNAL PROCESSING 3-0-0-3

Course Outcome

CO1	To study about discrete and random signal processing
CO2	To understand about spectrum estimation
CO3	To study about multi rate DSPs
CO4	Acquire knowledge about simulation of advanced DSP techniques

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	3	1	2	1	1
CO3	3	2	3	1	1
CO4	3	2	2	2	1

Discrete and random signal processing: Wide sense stationary process – Ergodic process – Mean – Variance - Auto-correlation and Autocorrelation matrix - Properties - Weiner Khitchine relation - Power spectral density – filtering random process, Spectral Factorization Theorem–Finite Data records, Simulation of uniformly distributed/Gaussian distributed white noise – Simulation of Sine wave mixed with Additive White Gaussian Noise. Spectrum Estimation: Bias and Consistency of estimators - Non-Parametric methods - Correlation method - Co-variance estimator - Performance analysis of estimators – Unbiased consistent estimators - Periodogram estimator - Barlett spectrum estimation - Welch estimation. Linear Estimation and Prediction Model based approach - AR, MA, ARMA Signal modeling - Parameter estimation using Yule-Walker method - Maximum likelihood criterion - Efficiency of estimator - Least mean squared error criterion – Wiener filter - Discrete Wiener Hoff equations – Mean square error. Adaptive filters: Recursive estimators - Kalman filter - Linear prediction – Forward prediction and Backward prediction, Prediction error - Whitening filter, Inverse filter - Levinson recursion, Lattice realization, Levinson recursion algorithm for solving Toeplitz system of equations. Mutltirate DSP: FIR Adaptive filters - Newton's steepest descent method - Adaptive filters based on steepest descent method - Widrow Hoff LMS Adaptive algorithm - Adaptive channel equalization - Adaptive echo canceller - Adaptive noise cancellation - RLS Adaptive filters - Exponentially weighted RLS – Sliding window RLS - Simplified IIR LMS Adaptive filter.

TEXT BOOKS/ REFERENCES

1. *Proakis J G and Manolakis DG Digital Signal Processing Principles, Algorithms and Application, PHI.*
2. *Openheim AV & Schafer RW, Discrete Time Signal Processing PHI.*
3. *Samuel D Stearns, "Digital Signal Processing with examples in MATLAB," CRC Press.*
4. *ES Gopi. "Algorithm collections for Digital Signal Processing Applications using Matlab," Springer.*
5. *TaanS.Elali, "Discrete Systems and Digital Signal Processing with MATLAB" CRC Press,2005*

21EM650 ROBOTICS FOR INDUSTRIAL AUTOMATION 3-0-0-3

Course Outcome

CO1	To study about automation and robotics
CO2	To understand about kinematics of robotic manipulators
CO3	To understand about generalised robotic coordinates
CO4	Acquire knowledge about simulation of robotics for industrial applications

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	3	1	2	1	1
CO3	3	2	3	1	1
CO4	3	2	2	2	1

Prerequisite: Mathematics -Vector Algebra, Introduction: Automation and Robotics, Historical Development, Definitions, Basic Structure of Robots, Robot Anatomy, Classification of Robots, Fundamentals about Robot Technology, Factors related to use Robots, Robot Performance, Basic Robot Configuration. Kinematics of Robot Manipulator: Introduction, General Mathematical Preliminaries on Vectors & Matrices, Direct Kinematics problem, Geometry Based Direct kinematics problem, Robotic Manipulator Joint Co-ordinate System, Euler Angle & Euler Transformations, Roll Pitch-Yaw (RPY) Transformation. DH Representation & Displacement Matrices for Standard Configurations, Jacobian Transformation in Robotic Manipulation. Dynamics of Robotic Manipulators: Introduction, Preliminary Definitions, Generalized Robotic Coordinates, Jacobian for a Two link Manipulator, Euler Equations, Lagrangian Equations of motion. Application of Lagrange– Euler (LE) for Dynamic Modeling of Robotic Manipulators.

TEXT BOOKS/REFERENCES:

1. *Robotics, control vision and intelligence-Fu, Lee and Gonzalez. McGraw Hill International, 2nd edition, 2007.*
2. *Introduction to Robotics- John J. Craig, Addison Wesley Publishing, 3rd edition, 2010. Robotics for Engineers -YoramKoren, McGraw Hill International, 1st edition, 1985.*
3. *Industrial Robotics-Groover, Weiss, Nagel, McGraw Hill International, 2nd edition, 2012.*
4. *Robotic Engineering - An Integrated approach, Klafter, Chmielewski and Negin, PHI, 1st edition, 2009.*

21EM633 ARTIFICIAL INTELLIGENCE IN AUTOMATION 3-0-0-3

Course Outcome

CO1	To study about artificial intelligence
CO2	To understand about intelligent agents
CO3	To understand about different search algorithms
CO4	To understand about different probabilistic estimation techniques
CO5	Acquire knowledge about simulation of different artificial intelligence techniques for automation

Course Articulation Matrix: Correlation level [1: low, 2: medium, 3:High

PO / CO	PO1	PO2	PO3	PO4	PO5
CO1	3	2	1	1	1
CO2	3	1	2	1	1
CO3	3	2	3	1	1
CO4	3	2	1	2	1
CO5	3	2	2	2	1

Artificial Intelligence: Foundations of Artificial Intelligence, History of Artificial Intelligence, Intelligent Agents: Agents and Environments, Problem-solving: Problem- Solving Agents. Informed (Heuristic) Search Strategies, Greedy best-first search, A* search, Heuristic Functions, The effect of heuristic accuracy on performance; Classical Search: Local Search Algorithms and Optimization Problems, Hill climbing search, Simulated annealing, Local beam search, Genetic algorithms, Local Search in Continuous Spaces, Searching with Nondeterministic Actions, Searching with Partial Observations, Online Search Agents and Unknown Environments. Knowledge Representation: Ontological Engineering, Categories and Objects, Events, Mental Events and Mental Objects, Reasoning Systems for Categories, Semantic networks, Description logics, Reasoning with Default Information, Truth maintenance systems, Uncertain knowledge and reasoning: Basic Probability Notation, Inference Using Full Joint Distributions, Bayes' Rule and Its Use, Probabilistic Reasoning, Representing Knowledge in an Uncertain Domain, Probabilistic Reasoning over Time: Hidden Markov Models, Kalman Filters, Dynamic Bayesian Networks, Keeping Track of Many Objects, Combining Beliefs and Desires under Uncertainty, Basis of Utility Theory, Utility Functions, Multi attribute Utility Functions, Decision Networks, The Value of Information. Expert system architecture.

TEXT BOOKS/ REFERENCES:

1. *Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Nowig, PEARSON 3rd ed.*
2. *A Guide to Expert Systems - Donald A Waterman, Addison Wesley,2nd edition,1986.*
3. *Introduction to Artificial Intelligence and Expert Systems – DAN.W.Patterson, PHI, 2nd edition, 2009.*
4. *Artificial Intelligence- George.F.Luger, Pearson Education, Asia, 3rd Edition,2009.*
5. *Artificial Intelligence: An Engineering Approach- Robert J. Schalkeff, PHI, Second edition, 1990.*