NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI

M.TECH. PROCESS CONTROL AND INSTRUMENTATION

Curriculum Effective from 2024-25

DEPARTMENT OF CHEMICAL ENGINEERING

VISION OF THE INSTITUTE

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

VISION OF THE DEPARTMENT

To be a global leader in Chemical Engineering

MISSION OF THE DEPARTMENT

- To produce competent graduates through effective Teaching-Learning, State of the art Research and Innovation
- To foster community by providing leadership in solving societal problems for sustainable eco system
- To serve organization and society as adaptable engineers, entrepreneurs or leaders

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1	A successful career in Process Control, Instrumentation, Automation and inter-disciplinary fields.
PEO2	Research and contribution to technological development in the fields of Process Control and Instrumentation
PEO3	Attaining professional competency and project management skills to resolve the technological needs of society and industrial problems.

PROGRAMME OUTCOMES (POs)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present 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 at a level higher than the requirements in the appropriate bachelor program

CURRICULAR COMPONENTS

Category	Credits offered
Core Courses	24
Elective Courses	20
Laboratory	4
Internship	2
Open electives (OE) / Online courses	6
Project Work	24
Total	**80**

CURRICULUM STRUCTURE

M.Tech. (Process Control and Instrumentation)

Components	No. of Courses	No. of Credits
Programme Core (PC)	3/ semester (6/year)	44
Programme Elective (PE)	3/ semester (6/year)	
Essential Laboratory Requirements (ELR)	2/year	4
Internship / Industrial Training / Academic Attachment (I/A)	1	2
Open Elective (OE) / Online Course (OC)*	2	6
Project Phase-I	1	12
Project Phase-II	1	12
Total Credits		**80**

* Open Elective (OE) / Online Course (OC) can be completed between I – IV semester

CURRICULUM

The total minimum credits required for completing the M.Tech. Programme in Process Control and Instrumentation Engineering is 80.

SEMESTER I

CODE	COURSE OF STUDY	L	T	P	C
CL651A/B	Measurement Systems / Chemical Process Systems	3	1	0	4
CL653	Modern Control Engineering	3	1	0	4
CL601	Advanced Process Control	3	1	0	4
	Elective – 1	3	1	0	4
	Elective – 2	3	0	0	3
	Elective – 3	3	0	0	3
CL655	Process Control & Instrumentation Laboratory	0	0	3	2
	TOTAL	18	4	3	24

SEMESTER II

CODE	COURSE OF STUDY	L	T	P	C
CL652	Computational Techniques in Control Engineering	3	1	0	4
CL654	Process Flow-Sheeting	3	1	0	4
CL656	Industrial Instrumentation	3	1	0	4
	Elective – 4	3	1	0	4
	Elective – 5	3	0	0	3
	Elective – 6	3	0	0	3
CL658	Process Simulation Laboratory	0	0	3	2
	TOTAL	18	4	3	24

SUMMER TERM (Evaluation in the III semester)

Code	Course of Study	Credit
CL659	Internship / industrial training / academic attachment (6 weeks to 8 weeks)	**2**

SEMESTER III

CODE	COURSE OF STUDY	L	T	P	C
CL697	Project work Phase – I	0	0	24	12

SEMESTER IV

CODE	COURSE OF STUDY	L	T	P	C
CL698	Project work Phase – II	0	0	24	12

OPEN ELECTIVES

(Open Elective (OE) / Online Course (OC) can be completed between I – IV semester)

Code	Course of Study	Credit
	Open elective I / Online Course	3
	Open elective II / Online Course	3
	Total	**6**

PROGRAMME ELECTIVES (PE)

Sl. No.	Code	Course of Study	Credit
1.	CL661	Signal conditioning and processing	3
2.	CL662	Computer Control of Processes	3
3.	CL663	Analytical Instrumentation	3
4.	CL664	Applied Soft Computing	4
5.	CL665	Multi Sensor Data Fusion	3
6.	CL666	System Identification and Adaptive control	4
7.	CL667	Logic & Distributed Control Systems	3
8.	CL668	Industrial Data Communication Systems	3
9.	CL669	Micro Electro Mechanical Systems	3
10.	CL670	Optimal Control	3
11.	CL671	Real-Time and Embedded Systems	3
12.	CL672	Cyber physical system	3
13.	CL673	Biomedical instrumentation	3
14.	CL674	Machine learning	3
15.	CL675	Optimization Techniques	3
16.	CL676	Controller Tuning	3
17.	CL677	Wireless sensor networks	3
18.	CL678	Mathematical Methods for Engineers	3
19.	HS611	Technical Communication	3

LIST OF OPEN ELECTIVES (OE)

1.	CL674	Machine learning	3
2.	CL675	Optimization Techniques	3

CL601 ADVANCED PROCESS CONTROL

L	T	P	C
3	1	0	4

Course Objective:
Expose students to the advanced control methods used in industries and research. This course prepares the student to take up such challenges in his profession.

Course Content:
Review of Systems: Review of first and higher order systems, closed and open loop response. Response to step, impulse and sinusoidal disturbances. Transient response. Block diagrams.

Stability Analysis: Frequency response, design of control system, controller tuning and process identification. Zigler-Nichols and Cohen-Coon tuning methods, Bode and Nyquist stability criterion. Process identification.

Special Control Techniques: Advanced control techniques, cascade, ratio, feed forward, adaptive control, Smith predictor, internal model control, model predictive control.

Multivariable Control Analysis: Introduction to state-space methods, Control degrees of freedom analysis, Interaction, Bristol arrays, Niederlinski index, design of controllers, Tuning of multivariable controllers.

Sample Data Controllers: Basic review of Z transforms, Response of discrete systems to various inputs. Open and closed loop response to step, impulse and sinusoidal inputs, closed loop response of discrete systems. Design of digital controllers. Introduction to PLC and DCS.

REFERENCES:

1. *D. E. Seborg, T. F. Edger, D. A. Millichamp and F.J. Doyle III, 'Process Dynamics and Control', Wiley, IV Edition, 2017.*
2. *D.R. Coughanowr and S.E.LeBlanc, 'Process Systems Analysis and Control', Mc.Graw Hill, III Edition, 2009.*
3. *B.A.Ogunnaike and W.H.Ray, "Process Dynamics, Modelling and Control", Oxford Press, 1994.*
4. *B.W. Bequette, 'Process Control: Modeling, Design and Simulation', PHI, 2006.*
5. *S. Bhanot, 'Process Control: Principles and Applications', Oxford University Press, 2008.*

COURSE OUTCOMES

Upon completing the course, the students will be able to

CO 1	analyze the transient response of a system and perform system identification
CO 2	apply the knowledge of stability and perform controller design and tuning
CO 3	design various advanced control algorithms and digital controllers
CO 4	analyze multivariable control systems and tuning of multivariable controllers.

Mapping of Course Outcomes with Programme Outcomes

	PO1	**PO2**	**PO3**
CO1	1	-	1
CO2	1	-	2
CO3	2	1	3
CO4	2	1	3

CL651-A **MEASUREMENT SYSTEM** **L T P C**
3 1 0 4

Course Objectives: This course is primarily to introduce various measurement techniques to students from non-circuit branches.

Course Content:

General concepts and terminology of measurement systems, static and dynamic characteristics, errors, standards and calibration.

Introduction, principle, construction and design of various active and passive transducers. Introduction to semiconductor sensors and its applications; Design of signal conditioning circuits for various Resistive, Capacitive and Inductive transducers and piezoelectric transducer.

Introduction to transmitters, two wire and four wire transmitters, Smart and intelligent Transmitters. Design of transmitters.

Introduction to EMC, interference coupling mechanism, basics of circuit layout and grounding, concept of interfaces, filtering and shielding.

Introduction to safety, electrical hazards, hazardous areas and classification, non-hazardous areas, enclosures – NEMA types, fuses and circuit breakers. Protection methods: Purging, explosion proofing and intrinsic safety.

REFERENCES:

1. John P. Bentley, *Principles of Measurement Systems*, Third edition, Addison Wesley Longman Ltd., UK, 2000.
2. Doebelin E.O, *Measurement Systems* - Application and Design, Fourth edition, McGraw- Hill International Edition, New York, 1992.
3. M. Sze, *Semiconductor sensors*, John Wiley & Sons Inc., Singapore, 1994.
4. Noltingk B.E., *Instrumentation Reference Book*, 2nd Edition, Butterworth Heinemann, 1995.
5. L.D.Goettsche, *Maintenance of Instruments and Systems – Practical guides for measurements and control*, ISA, 1995.

Course Outcome:

Upon completing this course the student would learn thoroughly about

CO1	basic measurement techniques
CO2	sensing and transducting various physical quantities
CO3	electromagnetic interference and data transfer
CO4	safety in handling industrial instruments

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	-	1	-
CO2	3	2	3
CO3	3	2	3
CO4	-	1	3

CL651-B CHEMICAL PROCESS SYSTEMS

L	T	P	C
3	1	0	4

Course Objectives: This course is primarily to introduce various chemical processes and modeling to students from circuit branches.

Course Content:
Historical overview of Chemical Engineering: Concepts of unit operations and unit processes, and more recent developments, The Chemical Industry-scope, features & characteristics. Flow sheets, and symbols for various operations.

Material balances in simple systems involving physical changes and chemical reactions; systems involving recycle, purge, and bypass, combustion reactions, Forms of energy, optimum utilization of energy, Energy balance calculations in simple systems. Introduction to Computer aided calculations-steady state material and energy balances, combustion reactions.

Basic Fluid Concepts: Dimensions and Units, Velocity and Stress Fields, Viscosity and surface tension, Non-Newtonian viscosity, Dimensional Analysis (Buckingham PI theorem), Types of flows, Methods of Analysis, Fluid Statics. Pipe flow, Pumps, Agitation and Mixing, Compressors.

Review of conduction, resistance concept, extended surfaces, lumped capacitance; Introduction to Convection, natural and forced convection, correlations; Radiation; Heat exchangers- Fundamental principles and classification of heat exchangers, Evaporators

Fundamental principles and classification of Distillations, Adsorption, Absorption, Drying, Extraction, Membrane Process. Energy and Mass Conservation in process systems and industries. Introduction to chemical reactors.

REFERENCES:

1. G.T. Austin, R.N. Shreve, *Chemical Process Industries*, 5th ed., McGraw Hill, 1984.
2. W.L. McCabe, J.C. Smith and P. Harriott, *Unit Operations of Chemical Engineering*, Sixth Edition, McGraw Hill, 2001.
3. R. M. Felder and R.W. Rousseau, *Elementary Principles of Chemical Processes*, 3rd ed., John Wiley, New York,2004.
4. L.B. Anderson and L.A. Wenzel, *Introduction to Chemical Engineering*, McGraw Hill, 1961.
5. H.S. Fogler, *Elements of Chemical Reaction Engineering*, 4th Ed., Prentice-Hall, 2006.

Course Outcome:
Upon completing this course, the student would understand

CO1	basic chemical process engineering.
CO2	fundamentals of fluid mechanics.
CO3	the working of heat exchangers.
CO4	the working of large-scale industrial processes such as distillation columns and reactors

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	1	2
CO2	3	1	2
CO3	3	1	2
CO4	3	1	2

CL652 COMPUTATIONAL TECHNIQUES IN CONTROL ENGINEERING

L	T	P	C
3	1	0	4

Course Objectives:

This course is an adaptation of numerical methods pertaining to control engineering problems. The algorithms are set in a numerical algebraic framework and are designed and analyzed in a formal way.

Course Content:

Review of Linear Algebra - Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product

Numerical Linear Algebra - Floating point numbers and errors in computations, Conditioning, Efficiency, Stability, and Accuracy, LU Factorization, Numerical solution of the Linear System Ax = b, QR factorization, Orthogonal projections, Least Squares problem, Singular Value Decomposition, Canonical forms obtained via orthogonal transformations.

Control Systems Analysis - Linear State-space models and solutions of the state equations, Controllability, Observability, Stability, Inertia, and Robust Stability, Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Control Systems Design - Feedback stabilization, Eigenvalue assignment, Optimal Control, Quadratic optimization problems, Algebraic Riccati equations, Numerical methods and conditioning, State estimation and Kalman filter.

Large scale Matrix computations, Some Selected Software.

REFERENCES:

1. B.N. Datta, *Numerical Methods for Linear Control Systems*, Academic Press/Elsevier, 2005 (Low cost Indian edition available including CD ROM).
2. G.H. Golub & C.F. Van Loan, *Matrix Computations*, 4/e, John Hopkins University Press, 2007 (Low cost Indian edition available from Hindustan Book Agency)
3. A. Quarteroni, F. Saleri, *Scientific Computing with MATLAB*, Springer Verlag, 2003.
4. www . scilab.org / download /

Course Outcome:

Upon completing this course, the student would understand

CO1	Understand and apply key concepts in Linear Algebra
CO2	Implement and evaluate numerical algorithms
CO3	**Analyze the behavior and stability of control systems**
CO4	Design and optimize control systems

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	1	3
CO3	3	2	3
CO4	3	3	3

CL653 MODERN CONTROL ENGINEERING

L	T	P	C
3	1	0	4

Course Objectives:

1. To introduce and teach advanced methods and techniques of linear system analysis and design from modern and digital control theory, and emphasize their interrelation.
2. To introduce mathematical modeling, analysis, and design of a larger class of systems in a unified framework.

Course Content:

State-space Models – Review of vectors and matrices, Canonical Models from Differential Equations and Transfer Functions, Interconnection of subsystems.

Analysis of Linear State Equations – First order scalar differential equations, System modes and modal decomposition, State Transition Matrix, Time-varying matrix case.

Lyapunov's stability theory for Linear Systems – Equilibrium points and stability concepts, Stability definitions, Linear system stability, The Direct method of Lyapunov, Use of Lyapunov's method in feedback design.

Controllability & Observability – Definitions, Controllability/Observability Criteria, Design of state feedback control systems, Full-order and Reduced-order Observer Design, Kalman canonical forms, Stabilizability & Detectability.

Digital Control Systems, Closed-loop Feedback Sampled-Data Systems, Stability Analysis, Implementation of Digital Controllers.

REFERENCES:

1. Hespanha, J.P., *"Linear Systems Theory,"* Princeton Univ. Press, 2009.
2. Brogan, W.L., *"Modern Control Theory,"* 3/e, Prentice Hall, 1990.
3. Sontag, E.D., *Mathematical Control Theory*, 2/e, Springer Verlag, 2014.
4. Hinrichsen, D., & Pritchard, A.J., *"Mathematical System Theory – I,"* Springer, 2010.

Course Outcome:

Upon completing this course, the student would understand

CO1	The student is exposed to an appropriate modern paradigm for the study of larger scale multi-input-multi-output systems.
CO2	The student understands the importance of linear algebra and matrix theory in designing
CO3	The student is motivated to study more general systems and their stability using Lyapunov's theory.
CO4	The student learns to implement modern control systems using a digital computer in the loop.

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	1	3
CO2	3	2	3
CO3	3	2	3
CO4	3	2	3

CL654 **PROCESS FLOW SHEETING** **L T P C**
3 1 0 4

Pre-Requisites: The students should have already learnt the chemical engineering fundamentals.

Course Objectives:

1. To the major objective is to understand how to invent chemical process flowsheets, how to generate and develop process alternatives, and how to evaluate and screen them quickly.
2. To simulate the steady-state behavior of process flowsheets using a suitable simulation software.
3. To utilize the flowsheet to propose a preliminary P&I diagram

Course Content:

Flowsheeting

Introduction, Symbols, Flowsheet presentation with examples, Manual flowsheet calculation, Constrains and their applications in flowsheet calculations, Types of flow sheets, Synthesis of steady state flow sheet.
Flowsheet on the computer, simulation models, Physical property service facilities.
Degree of freedom, Independent stream variables, Degree of freedom analysis for a flowsheet with examples.

Fowsheeting by sequential modular approach, partitioning, tearing a flowsheet, convergence of tear streams with suitable example.
Equation solving methods to flowsheeting, selection, decision and tearing of variables in a flowsheet. Solution, convergence of tear streams.

Flowsheeting software viz., VISIO, DWSIM and ASPEN

Piping and Instrumentation Diagram

Instruments for process variables and Symbols, control strategies for unit operations, Safety Instrumented Systems, Abbreviations and Identification for Instruments: - Mechanical Equipment, Electrical Equipment, Instruments and Automation Systems, Logic diagrams, Instrument loop diagram, Line symbols and Line designations.

Applications of Flowsheet and P&I D

Applications of P & I D in design stage -Construction stage - Commissioning stage - Operating stage - Revamping stage - Applications of P & I D in HAZOPS and Risk analysis.

REFERENCES:

1. Ernest E. Ludwig, Applied Process Design for Chemical and Petrochemical Plants, Vol.I Gulf Publishing Company, Houston, 1989.
2. Max. S. Peters and K.D.Timmerhaus, Plant Design and Economics for Chemical Engineers, McGraw Hill, Inc., New York, 1991.
3. Coulson and Richardson's Chemical Engineering Volume 6 - Chemical Engineering Design (4th Edition), Butterworth-Heinemann Ltd. UK.
4. Anil Kumar,Chemical Process Synthesis and Engineering Design, Tata McGraw Hill publishing Company Limited, New Delhi - 1981.
5. A.N. Westerberg, et al., Process Flowsheeting, Cambridge University Press, 1979.
6. Paul Benedek, Steady state flow sheeting of Chemical Plants, Elsevier Scientific Publishing company.
7. B.G.Liptak, "Instrumentation Engineers Handbook (Process Measurement & Analysis)", Fourth Edition, Chilton Book Co, CRC Press, 2005

Course Outcome:
At the conclusion of this course the successful student should be able to

CO1	Understand the input/output structure of a flowsheet for a given manufacturing unit and synthesis a preliminary flowsheet.
CO2	Identify design constraints for flowsheet calculation
CO3	Use a suitable software to create a preliminary process flowsheet
CO4	Develop preliminary P&I Diagram based chemical process flowsheet
CO5	Apply P&I D for safety analysis

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	1	2	3
CO2	2	2	3
CO3	1	2	2
CO4	3	3	3
CO5	2	2	2

CL655 PROCESS CONTROL & INSTRUMENTATION LAB

L	T	P	C
0	0	3	2

Course Objectives

1. To provide students with hands-on experience to apply their practical knowledge in designing, testing and simulation of any instrumentation and process control system.
2. To provide practical experience to the students in simulation softwares and real time interfacing cards and also to make them familiar with important process control applications.

List of Experiments

1. Level Control using P, PI, PID Controllers
2. Ladder logic Programming using PLC
3. Thermocouple cold junction compensation
4. Design of temperature transmitter using RTD and XTR101
5. ADC and LCD interfacing with Microcontroller 8051
6. Stepper motor interfacing with MC8051
7. Real time Vibration control of a cantilever beam
8. On line system identification of a given system
9. Tank level control simulation in LABVIEW.
10. Temperature control of a water bath using LABVIEW DAQ card
11. Simulation of step and impulse response models and process identification
12. MIMO open loop analysis and closed loop control
13. Model predictive control for Processes

Course Outcome:

On completion of this lab students will be familiar with

CO1	Design of signal conditioning circuit for given sensor
CO2	Design and tuning of PI, PID controllers for different processes
CO3	Modeling of a given system
CO4	Implementation of simple closed loop control system in real time
CO5	Use of Microcontroller for the design of standalone instrumentation
CO6	Use of simulation in process control

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	3	3	3
CO2	3	3	3
CO3	3	3	3
CO4	3	3	3
CO5	3	3	3
CO6	3	3	3

CL656 INDUSTRIAL INSTRUMENTATION

L	T	P	C
3	0	0	3

Course Objectives:
To enable the students to understand the fundamentals of various types of industrial measurements.

Course Content:

Review of Industrial Instrumentation
Measurement of Velocity, Acceleration, Pressure, Temperature, Flow, Level, Humidity & Moisture (Qualitative Treatment Only).

Measurement in thermal power plant
Selection, Installation and maintenance of Instruments used for the measurement of fuel flow, Air flow, Drum level, Steam pressure, Steam temperature and other parameters in thermal power plant – Analyzers - Dissolved Oxygen Analyzers- Flue gas Oxygen Analyzers-pH measurement- Coal/Oil Analyzer – Pollution Controlling Instruments

Measurement in Petrochemical Industry
Parameters to be measured in refinery and petrochemical Industry-Temperature, Flow and Pressure measurements in Pyrolysis, catalytic cracking, reforming processes-Selection and maintenance of measuring instruments – Intrinsic safety.

Instrumentation for energy conservation & management and safety
Principle of energy audit, management & conservation and measurement techniques – Instrumentation for renewable energy systems – Energy management device (Peak load shedding) – Electrical and intrinsic safety - Explosion suppression and deluge systems – Flame arrestors, conservation vents and emergency vents – Flame, fire and smoke Detectors- Metal detectors.

Special Purpose Instrumentation
Toxic gas monitoring - Detection of Nuclear radiation – Water quality monitoring- Monitor measurement by neutron-Thermo-luminescent detectors – Measurement of length, mass, thickness, flow, level using nuclear radiation.

REFERENCES:

1. D.Patranabis, Principles of Industrial Instrumentation, Tata McGraw Hill Publishing Company Ltd., New Delhi, 1999.
2. John G Webster, Measurement, Instrumentation and Sensors Handbook, CRC press IEEE press
3. Liptak B.G, Instrumentation Engineers Handbook (Measurement), Chilton Book Co., 1994.
4. Reay D.A, Industrial Energy Conservation, Pergamon Press, 1977.
5. Hodge B.K, Analysis and Design of energy systems, Prentice Hall, 1988.
6. Liptak B.G, Instrument Engineers Handbook, Clinton Book Company, 1982
7. Ness S.A. Air monitoring for Toxic explosions, Air integrated Approach, Von Nostrand,1991.
8. Ewing G., Analytical Instrumentation hand book, Dekker,1991.

Course Outcome:
At the conclusion of this course the successful student should be able to

CO1	Understand and apply principles of industrial instrumentation
CO2	Select, install, and maintain instrumentation systems
CO3	Analyze and manage instrumentation needs

CO4	Implement and evaluate instrumentation systems

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	2	3
CO3	3	2	3
CO4	3	3	3

CL658 PROCESS SIMULATION LABORATORY **L T P C**
0 0 3 2

PRE-REQUISITE
Knowledge in modelling of Processes.

COURSE LEARNING OBJECTIVES
1. To implement the numerical techniques to solve the problems of engineering interest.
2. To use computational tools and commercial packages to solve process simulation problems.

LIST OF EXPERIMENTS
Simulation will be carried out for the design and estimation of following using MATLAB software
1. Simulation of interacting/Non-interacting system
2. Simulation of damped spring mass system
3. Optimization of a process
4. Step/Impulse/Ramp responses in Simulink
5. Controller tuning-P,PI,PID controllers
6. MIMO system analysis
7. MIMO system controller tuning
8. Data based modeling/ANN modeling

REFERENCES:

1. Edgar, T.F. and Himmelblau, D.M., Optimization of Chemical Processes, McGraw-Hill Book Co., 2008.
2. B.W. Bequette, Process Control: Modeling, Design and Simulation, PHI, 2006

COURSE OUTCOME
At the end of the course, students will be able to

CO1	Implement the numerical techniques to solve the problems of engineering interest.
CO2	Use computational tools and commercial packages to solve process simulation and control problems
CO3	Develop data-driven models using techniques like Artificial Neural Networks (ANN) in MATLAB
CO4	Able to simulate and control different processes

Mapping of Course outcome with Programme Outcomes

	PO1	**PO2**	**PO3**
CO1	3	2	3
CO2	3	2	3
CO3	3	2	3
CO4	3	3	3

CL661 SIGNAL CONDITIONING and PROCESSING

L	T	P	C
3	0	0	3

Course Objectives:

1. To impart practical skills in measurement techniques to students from non-electrical background
2. To teach an array of concepts widely used in the academia and the industry.

Course Content:

Introduction to Op-amps, Circuits with Resistive Feedback, Design of offset and drift compensation circuits, Frequency compensation, Instrumentation amplifiers, Isolation Amplifiers - Necessity for isolation amplifiers, industrial and medical applications of isolation amplifiers, Grounding and Shielding. Active filter circuits, Nonlinear circuits – comparators, peak detectors, sample-and-hold amplifier

Analog-Digital sampling, Introduction to A/D and D/A conversion, ADCs for signal conditioning, Hardware design techniques.

Characterization and classification of signals, Typical signal processing applications, Time domain representations of signals and systems, Discrete-time signals, Discrete-time systems, Characterization of LTI systems.

Transform domain representation of signals and systems, The discrete time Fourier transform, Discrete Fourier series, Discrete Fourier transform, Computation of DFT.

Basic structures for IIR systems, Basic structures for FIR systems.

REFERENCES:

1. S. Franco, *Design with Operational Amplifiers & Analog Integrated Circuits*, 3/e, TMH, 2002
2. H S Kalsi, *Electronic Instrumentation*, 4/e, TMH, 2001.
3. Daniel H. Sheingold, *Analog-Digital Conversion Handbook*, 3/e Prentice-Hall, 1986.
4. D Patranabis, *Sensors and Transducers*, PHI, 2003.
5. J.G.Proakis, and D.G.Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications*, 4/e, Pearson Prentice Hall, 2007.

Course Outcome:

Upon completing this course student from non-electrical background would learn

CO1	about practical signal conditioning circuits.
CO2	about analog-digital conversion and hardware design techniques.
CO3	the fundamentals of digital signal processing.
CO4	analysis and design of IIR and FIR filters for digital signal processing.

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	1	3
CO2	3	2	3
CO3	3	2	3
CO4	3	2	3

CL662 COMPUTER CONTROL OF PROCESSES

L	T	P	C
3	0	0	3

Course Objectives:

To impart knowledge on sampled-data control systems, various discrete control algorithms, parameter estimation methods, and adaptive control algorithms.

Course Content:

Computer control – Introduction – Review of Z Transform, Modified Z Transform and Delta Transform. Relation between Discrete and Continuous Transfer Function-Poles and Zeros of Sampled Data System (SDS) – Stability Analysis in Z domain

Introduction to Pulse Transfer function- Open loop and closed loop response of SDS- Design and implementation of different digital control algorithm: Dead beat, Dahlin, Smith predictor and Internal Model Control algorithm with examples.

Different Models of Discrete System: LTI System: - Family of Discrete Transfer Function Models- State Space models- Distributed Parameter Model. Models for Time varying and Non- Linear System: Linear Time varying models- Non-linear State space models- Non-linear Black Box Models- Fuzzy Models

Parameter Estimation Methods: General Principles- Minimizing Prediction errors- Linear Regression and the Least Square method- Statistical Frame work for Parameter Estimation and the Maximum Likely hood method- Instrument Variable method – Recursive and Weighted Least square method

Adaptive Control: Introduction -Deterministic Self Tuning Regulator: Indirect and Direct self-tuning regulator -Model Reference Adaptive system: Design of MRAS using Lyapnov and MIT Rule- Auto tuning and Gain scheduling adaptive control design with examples.

REFERENCES:

1. Lennart Ljung,*System Identification Theory for the user*, Prentice Hall Information and system sciences Series, NJ, 1999.
2. P. Deshponde and Ash, *Computer Controlled System*, ISA Press, USA
3. Richard H. Middleton and Graham C. Goodwin, *Digital Control and Estimation A Unified Approach*, Prentice Hall NJ, 1990
4. Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, *Process Dynamics and Control*, Willey India, 2006.
5. Astrom .K. J, Bjorn Wittenmark, *Adaptive Control*, Second Edition, Prentice Hall of India, New Delhi, 1994.

Course Outcome:

After completing this course, the student is exposed to

CO1	the fundamentals of various discrete-time systems.
CO2	employing a digital computer in the process loop.
CO3	curve fitting from the data and estimation techniques.
CO4	adaptive control paradigm.

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	3	3
CO2	3	2	3
CO3	3	2	3
CO4	3	2	3

CL663 ANALYTICAL INSTRUMENTATION

L	T	P	C
3	0	0	3

Course Objectives: To understand different instrumentation techniques for measurement of environmental parameters

Course Content:
Electromagnetic radiation, Characteristics - Interaction of e.m. radiation with matter - Spectral methods of analysis - absorption spectroscopy - Beer's law - radiation sources - monochromators and filters - diffraction grating - ultraviolet spectrometer - single beam and double beam instruments.

Particles emitted in radioactive decay - nuclear radiation detectors - injection chamber - Geiger - Muller counter - proportional counter - scintillation counter - Semiconductor detectors.

Measurement techniques for water quality parameters - conductivity - temperature - turbidity. Measurement techniques for chemical pollutants - chloride - sulphides - nitrates and nitrites - phosphates - fluoride - phenolic compounds.

Air pollution: its effect on environment, its classification, Measurement techniques for particulate matter in air. Measurement of oxides of sulphur, oxides of nitrogen unburnt hydrocarbons, carbon- monoxide, dust mist and fog.

Noise pollution: basics of sound pollution, its effect to environment, measurement of sound, tolerable levels of sound. Measurement of sound level. Measurement techniques for soil pollution.

REFERENCES:

1. H.H. Willard, Merrit and Dean, *Instrumental Methods of Analysis*, 5th Edn., 1974.
2. R.K. Jain, *Fundamentals of Mechanical and Industrial Instrumentation*",1999.
3. S.P. Mahajan, *Pollution Control in Process Industries*, Tata McGraw Hill, 2004.
4. G. N. Pandey and G.C. Carney, *Environmental Engineering*, Tata McGraw-Hill, 2004.

Course Outcome:
After completing this course, the student is exposed to

CO1	Understand the principles of electromagnetic radiation
CO2	Analyze and operate various nuclear radiation detectors
CO3	Apply measurement techniques to assess water quality
CO4	Evaluate and measure environmental pollutants

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	3	3
CO2	3	2	3
CO3	3	2	3
CO4	3	2	3

CL664	APPLIED SOFT- COMPUTING	L	T	P	C
		3	1	0	4

Course Objectives:

1. This course is designed to expose students to ANN, fuzzy methods of analyzing problems which involve incomplete or vague criteria rather than complete data sets. The course investigates requirements analysis, logical design, and technical design of components for fuzzy systems development.
2. The subject is primarily concerned with the definitions and concepts associated with a fuzzy set, Fuzzy reasoning, Fuzzy design and Fuzzy logic applications. The course also introduces Neuro-Fuzzy systems, Fuzzy Genetic Algorithms.

Course Content:

Overview of Artificial Neural Network (ANN) & Fuzzy Logic

Review of fundamentals - Biological neuron, Artificial neuron, Activation function, Single Layer Perceptron - Limitations - Multi Layer Perceptron - Back propagation algorithm (BPA); Fuzzy set theory - Fuzzy sets - Operation on Fuzzy sets - Scalar cardinality, fuzzy cardinality, union and intersection, complement, equilibrium points, aggregation, projection, composition, decomposition, cylindrical extension, fuzzy relation - Fuzzy membership functions.

Neural Networks for Modeling and Control

Modeling of nonlinear systems using ANN- NARX, NNSS, NARMAX - Generation of training data - optimal architecture - Model validation- Control of nonlinear system using ANN- Direct and Indirect neuro control schemes- Adaptive neuro controller - Familiarization of Neural Network Control Tool Box.

ANN Structures and Online Training Algorithms

Recurrent neural network (RNN) - Adaptive resonance theory (ART) based network- Radial basis function network- Online learning algorithms: BP through time - RTRL algorithms – Least Mean square algorithm - Reinforcement learning.

Fuzzy Logic for Modeling and Control

Modeling of nonlinear systems using fuzzy models - TSK model - Fuzzy Logic controller - Fuzzification - Knowledge base - Decision making logic - Defuzzification - Adaptive fuzzy systems - Familiarization of Fuzzy Logic Tool Box.

Hybrid Control Schemes

Fuzzification and rule base using ANN- Neuro fuzzy systems - ANFIS - Fuzzy Neuron - Introduction to GA - Optimization of membership function and rule base using Genetic Algorithm - Introduction to Support Vector Machine- Evolutionary Programming- Particle Swarm Optimization - Case study - Familiarization of ANFIS Tool Box.

REFERENCES:

1. Laurence Fausett, Fundamentals of Neural Networks, Prentice Hall, Englewood cliffs, N.J.,1992.
2. Timothy J.Ross, *Fuzzy Logic with Engineering Applications*, McGraw Hill Inc., 1997.
3. Goldberg, Genetic Algorithm in Search, Optimization and Machine Learning, Addison Wesley Publishing Company, Inc. 1989.
4. Millon W.T., Sutton R.S., and Webrose P.J., *Neural Networks for Control*, MIT Press, 1992.
5. Ethem Alpaydin, *Introduction to Machine Learning* (Adaptive Computation and Machine Learning Series), MIT Press, 2004.
6. Corinna Cortes and V. Vapnik, *Support - Vector Networks, Machine Learning*,12, 1995.
7. Zhang, Huaguang, Liu, Derong, *Fuzzy Modeling and Fuzzy Control Series: Control Engineering*,2006.

Course Outcome:
Upon the completion of the course, the students will be able to

CO1	Understand the overview of ANN and Fuzzy logic theory.
CO2	Solve and design various ANN models.
CO3	Apply and analyze the concept to existing systems.
CO4	Design of hybrid systems for engineering applications

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	3	2	3
CO2	3	1	3
CO3	3	1	3
CO4	3	2	3

CL665 **MULTI SENSOR DATA FUSION** **L T P C**
3 0 0 3

Course Objectives:
To learn the concepts and techniques used in sensor data fusion.

Course Content:

Multisensor data fusion: Introduction, sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data. Data fusion model. Architectural concepts and issues. Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta - heuristics.

Taxonomy of algorithms for multisensor data fusion. Data association. Identity declaration. Estimation: Kalman filtering, practical aspects of Kalman filtering, extended Kalman filters.

Decision level identify fusion. Knowledge based approaches.

Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

High performance data structures: Tessellated, trees, graphs and function. Representing ranges and uncertainty in data structures. Designing optimal sensor systems with in dependability bounds. Implementing data fusion system.

REFERENCES:

1. David L. Hall, Mathematical *techniques in Multisensor data fusion*, Artech House, Boston, 1992.
2. R.R. Brooks and S.S.Iyengar, *Multisensor Fusion: Fundamentals and Applications with Software*, Prentice Hall Inc., New Jersey, 1998
3. Arthur Gelb, *Applied Optimal Estimation*, M.I.T. Press, 1982.
4. James V. Candy, *Signal Processing: The Model Based Approach*, McGraw –Hill Book Company, 1987.

Course Outcome:
Upon completion of this course the students will be able to

CO1	Understand and apply the principles of multisensor data
CO2	Classify and implement various algorithms
CO3	Explore decision-level identity fusion
CO4	Design and optimize high-performance data structures

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	2	3
CO3	3	2	3
CO4	3	1	3

CL666 SYSTEM IDENTIFICATION AND ADAPTIVE CONTROL

L	T	P	C
3	1	0	4

Course Objectives:

Expose students to the system identification and adaptive control methods used in industries and research.

Course Content:

Introduction to system identification: experimental design – input design for identification, notion for persistent excitation (pulse, step, pseudo random binary sequence (PRBS), white noise)- drifts and de-trending – outliers and missing data – pre-filtering - robustness – Model validation and Model structure determination. Signal stationarity, auto-correlation, cross-correlation, power spectra.

Nonparametric model estimation: Correlation and spectral analysis for non-parametric model identification, obtaining estimates of the plant impulse, step and frequency responses from process data. Parametric model structures: Time series models (AR, MA, ARMA), ARX, ARMAX, OE, BJ models – Order determination of time series models using correlation-prediction error models of parametric models.

Linear regression - Least square estimates, statistical properties of LS Estimates- bias & consistency, Weighted least squares, maximum likelihood estimation, Instrumental variable method- square Residual analysis for determining adequacy of the estimated models. Recursive Algorithms: Least squares, Instrumental Variables, extended least square, prediction error methods- Exercises using Matlab

Adaptive Control: Deterministic indirect & direct Self-tuning regulators (STR)– Stochastic 7 predictive STR- LQ STR- Auto tuning for PID controllers- Adaptive Smith predictor control: Auto-tuning and self-tuning Smith predictor.

Design of MRAS using Lyapnov and MIT Rule- Auto tuning and Gain scheduling - adaptive control design with examples.

REFERENCES:

1. O.Nelles, Nonlinear System Identification, Springer-Verlag, Berlin, 2001.
2. Y.Zhu, Multivariable System Identification for Process Control, Pergamon, 2001.
3. L.Ljung, System Identification: Theory for the User, 2nd Edition, Prentice-Hall, 1999.
4. B.A. Ogunnaike and W.H. Ray, Process Dynamics, Modeling, and Control, Oxford University Press.
5. Arun K. Tangirala, Principles of System Identification: Theory and Practice, First Edition, CRC Press, 2014
6. Karel J. Keesman, System Identification: An Introduction, Springer-Verlag London, 2011
7. Astrom .K. J, Bjorn Wittenmark, Adaptive Control, Second Edition, Prentice Hall of India, New Delhi, 1994.

Course Outcome:

Upon completing the course, the student should have understood

CO1	Identification Methods
CO2	Estimation of Nonparametric models
CO3	Prediction-Error Model Structures
CO4	Adaptive control schemes.

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	3	3
CO2	3	2	3
CO3	3	2	3
CO4	3	1	3

CL667 LOGIC AND DISTRIBUTED CONTROL SYSTEMS

L	T	P	C
3	0	0	3

Prerequisite: Fundamental knowledge of process control.

Course Objective: This course is designed to expose students to understand the process automation concepts like Programmable logic controller and Distributed control system.

Course Content:
Review of computers in process control: 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.

Programmable logic controller (PLC) basics: Definition, overview of PLC systems, input/output modules, power supplies, isolators. General PLC programming procedures, programming on-off inputs/ outputs. Auxiliary commands and functions: PLC Basic Functions: Register basics, timer functions, counter functions.

PLC intermediate functions: Arithmetic functions, number comparison functions, Skip and MCR functions, data move systems. PLC Advanced intermediate functions: Utilizing digital bits, sequencer functions, matrix functions. PLC Advanced functions: Alternate programming languages, analog PLC operation, networking of PLC, PLC-PID functions, PLC installation, troubleshooting and maintenance, design of interlocks and alarms using PLC. Creating ladder diagrams from process control descriptions.

Interface and backplane bus standards for instrumentation systems. Field bus: Introduction, concept. HART protocol: Method of operation, structure, operating conditions and applications. Smart transmitters, examples, smart valves and smart actuators.

Distributed control systems (DCS): Definition, Local Control (LCU) architecture, LCU languages, LCU - Process interfacing issues, communication facilities, configuration of DCS, displays, redundancy concept - case studies in DCS.

REFERENCES:

1. John.W.Webb, Ronald A Reis, *Programmable Logic Controllers - Principles and Applications*, 4th Edition, Prentice Hall Inc., New Jersey, 1998.
2. M.P Lukcas, *Distributed Control Systems*, Van Nostrand Reinhold Co., New York, 1986.
3. Frank D. Petruzella, *Programmable Logic Controllers*, 2nd Edition, McGraw Hill, New York, 1997.
4. P.B.Deshpande and R.H Ash, *Elements of Process Control Applications*, ISA Press, New York, 1995.
5. Curtis D. Johnson, *Process Control Instrumentation Technology*, 7th Edition, Prentice Hall, New Delhi, 2002

Course Outcome:
Upon completion of the course, the student will be able to

CO1	Understand the popular process automation technologies.
CO2	Design and development of different PLC programming for simple process applications.
CO3	Understand the different security design approaches, Engineering and operator interface issues for designing Distributed control system.
CO4	Know the latest communication technologies like HART and Field bus protocol.

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	3	2	3
CO2	3	2	3
CO3	3	1	3
CO4	3	3	3

CL668 INDUSTRIAL DATA COMMUNICATION SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives:

The objective of this course is to expose students to Communication systems emerged in the field. As the industry is progressing towards adopting these methods to build large scale Automation systems, this course prepares the student to take up such challenges in his Industrial Environment.

Course Content:

Interface: Introduction, Principles of interface, serial interface and its standards. Parallel interfaces and buses.

Fieldbus: Use of fieldbuses in industrial plants, functions, international standards, performance, use of Ethernet networks, fieldbus advantages and disadvantages. Fieldbus design, installation, economics and documentation.

Instrumentation network design and upgrade: Instrumentation design goals, cost optimal and accurate sensor networks. Global system architectures, advantages and limitations of open networks, HART network and Foundation fieldbus network.

PROFIBUS-PA: Basics, architecture, model, network design and system configuration.

Designing: PROFIBUS-PA and Foundation Fieldbus segments: general considerations, network design.

REFERENCES:

1. Noltingk B.E., *Instrumentation Reference Book*, 2nd Edition, Butterworth Heinemann, 1995.
2. B.G. Liptak, *Process software and digital networks*, 3rd Edition, CRC press, Florida.

Course Outcome:

Upon completion of the course, the student will be able to

CO1	Understand and apply the principles of interface
CO2	Evaluate the use of Fieldbus technologies
CO3	Design and optimize instrumentation networks
CO4	Develop and implement network designs

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	2	3
CO3	3	1	3
CO4	3	3	3

CL669 MICRO-ELECTRO-MECHANICAL SYSTEMS

L	T	P	C
3	0	0	3

Course Objectives:

This course is designed to provide an introduction to microsystem technology and fabrication technologies followed by basic sensing and actuation principles of microsensors and actuators.

Course Content:

Introduction, emergence, devices and application, scaling issues, materials for MEMS, Thin film deposition, lithography and etching.

Bulk micro machining*:* Introduction, etch-stop techniques, dry etching, buried oxide process, silicon fusion bonding, and anodic bonding.

Surface micro machining*:* Introduction, sacrificial layer technology, material systems in sacrificial layer technology, plasma etching, combined IC technology and anisotropic wet etching.

Microstereolithography: Introduction, Scanning Method, Projection Method, Applications. LIGA Process: Introduction, Basic Process and Application

MEMS devices, electronic interfaces, design, simulation and layout of MEMS devices using CAD tools.

REFERENCES:

1. S. M. Sze, *Semiconductor Sensors*, John Wiley & Sons, INC., 1994.
2. M.Elwenspoek, R.Wiegerink, Mechanical Microsensors, Springer-Verlag BerlinHeidelberg, 2001.
3. Massood Tabib-Azar, Microactuators - *Electrical, Magnetic, Thermal*, Optical, Mechanical, Chemical and Smart structures, Kluwer Academic Publishers, NewYork, 1997.
4. Eric Udd , *Fiber Optic Smart Structures* , John Wiley & Sons, New York, 1995.

Course Outcome:

Upon completion of the course, the student will be able to

CO1	Understand the fundamentals of MEMS technology
CO2	Analyze bulk micro machining techniques,
CO3	Apply surface micro machining processes
CO4	Design, simulate, and layout MEMS devices

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	2	3
CO3	3	1	3
CO4	3	3	3

CL670 **OPTIMAL CONTROL**

L	T	P	C
3	0	0	3

Course Objectives:

To impart knowledge on

1. Dynamic Programming
2. Calculus of variation
3. Pontryagin's Minimum Principle
4. Optimization techniques

Course Content:

Problem formulation – Mathematical model - Physical constraints - Performance measure Optimal control problem. Form of optimal control. Performance measures for optimal control problem. Selection a performance measure.

Dynamic Programming – Optimal control law – Principle of optimality. An optimal control system. A recurrence relation of dynamic programming - computational procedure. Characteristics of dynamic programming solution. Hamilton – Jacobi – Bellman equation. Continuous linear regulator problems.

Calculus of variations – Fundamental concepts. Functionals. Piecewise – smooth extremals Constrained extrema.

Variational approach to optimal control problems – Necessary conditions for optimal control – Linear regulator problems. Linear tracking problems. Pontryagin's minimum principle and state inequality constraints.

Minimum time problems – Minimum control – effort problems. Singular intervals in optimal control problems. Numerical determination of optimal trajectories – Two-point boundary - valve problems. Methods of steepest decent, variation of extremals. Quasilinearization. Gradient projection algorithm.

Course Outcomes: Expose the students to the fundamentals of dynamic programming, calculus of variation and various optimization techniques.

REFERENCES:

1. Donald E. Kirk, Optimal Control Theory: An Introduction, Prentice-Hall networks series, 1970.
2. D. Subbram Naidu, Optimal Control Systems, CRC Press, 2002.
3. B. D. O. Anderson, J. B. Moore, Optimal control linear Quadratic methods, Prentice Hall of India, New Delhi, 1991.
4. A.P. Sage, C.C. White, Optimum Systems Control, Second Edition, Prentice Hall, 1977.

Course Outcome:

Upon completion of the course, the student will be able to

CO1	Formulate and analyze optimal control problems
CO2	Apply dynamic programming techniques
CO3	Utilize calculus of variations to explore and solve optimization
CO4	Solve complex optimal control problems involving minimum time, minimum control effort, and singular intervals using

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	2	3
CO3	3	1	3
CO4	3	3	3

CL671	REAL TIME AND EMBEDDED SYSTEMS	L	T	P	C
		3	0	0	3

Course Objectives:

1. To provide an understanding of hardware and software design and integration for embedded devices.
2. To provide knowledge of Real-time operating systems that can be used to enhance their skills in developing real-time embedded systems.

Course Content:

Review of basic concepts of Embedded Systems: Embedded system – Examples, Classifications, Characteristics, generalized organization, hardware components, software for embedded systems, Microprocessor based system, microcontrollers – different types, RISC and CISC processors, Von Neumann and Harvard architecture, embedded systems design principles, Embedded software development tools.

Industrial Embedded Systems: Embedded Systems for monitoring and Control, Data Loggers - evolution, sampling concepts, aliasing, principles of data acquisition, ADC - types, characteristics; DAQ systems – components, analog I/O, digital I/O, Timing I/O, functional blocks, specifications, multichannel data acquisition, interrupt driven data acquisition, programming, DAC, Timer/Counter.

Embedded Systems for Remote Data Acquisition: Serial communication standards, Asynchronous Serial communication – principles, RS-232, RS-422 and RS-485 standards, UART programming, interfacing embedded system to PC using UART communication, Synchronous serial communication, interfaces – principles and features of I2C, SPI, MicroWire, IEEE1394, USB interfaces.

Networks: GPIB for data acquisition – Over view, GPIB commands, GPIB programming, Expanding GPIB, IEEE488.2, SCPI, CAN bus, Embedded systems with wireless communication support – wireless communication standards, ZigBee, Bluetooth

Real Time Operating System for Embedded applications: Introduction to OS, types of OS, interrupts, tasks,process, threads, multitasking, semaphores, multiprocessing, multithreading, tasks scheduling, task communication, tasks synchronization, process states, process scheduling, resource sharing, features of RTOS, commercial RTOSs.
Embedded system development life cycle (EDLC)

REFERENCES:

1. Embedded System Design, Santanu Chattopadhyay, PHI (2013).
2. Embedded System Design, II Ed., Peter Marwedel, Springer, (2011).
3. ZigBee Wireless Networks and Transceivers, Shahin Farahani, Newnes publications, (2008).
4. An Embedded Software Primer, David E. Simon, Pearson Education, (2000).

Course Outcome:

Upon completion of the course, the student will be able to

CO1	Understand and apply the foundational concepts of embedded systems
CO2	Design and implement industrial embedded systems for monitoring and control
CO3	Develop embedded systems for remote data acquisition
CO4	Analyze and integrate real-time operating systems (RTOS) in embedded applications

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	2	3
CO3	3	1	3
CO4	3	3	3

CL672	CYBER PHYSICAL SYSTEM	L	T	P	C
		3	0	0	3

Course Objective:

The objective of the course is

- to learn the principles of design and implementation of cyber-physical systems
- to develop an exposition of the challenges in implementing a cyber-physical system from a computational perspective.
- to expose the student to real world problems in this domain and provide a walk through the design and validation problems for such systems.

Course Content:

Introduction to Cyber-Physical Systems (CPS) in the real world, Basic principles of design and validation of CPS, Industry 4.0 standard, IIOT implications, CPS HW platforms - Processors, Sensors, Actuators, CPS Network – Wireless HART, CAN, Automotive Ethernet, RTOS, Scheduling Real Time control tasks Dynamical Systems and Stability, Controller Design Techniques, Stability Analysis: CLFs, MLFs, stability under slow switching, Performance under Packet drop and Noise.

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,

Tutorial: Control, Bus and Network Scheduling using Truetime Advanced Automata based modeling and analysis, Timed and Hybrid Automata, Formal Analysis: Flowpipe construction, reachability analysis, Attack models, Secure Task mapping and Partitioning, State estimation for attack detection CPS simulation softwares introduction and implementation. CPS case studies and application for automotive, healthcare and building automation.

REFERENCES:

1. "Principles of Cyber-Physical Systems" - Rajeev Alur, Cambridge, Massachusetts: The MIT Press, 2015
2. F. Bullo, J. Cortes, and S. Martinez, Princeton, Distributed Control of Robotic Networks, University Press, 2009.
3. Introduction to Embedded Systems – A Cyber–Physical Systems Approach" - E. A. Lee, Sanjit Seshia, Second Edition — MIT Press — 2017
4. Computational Foundations of Cyber Physical Systems (CS61063) course material from IIT Kharaghpur (http://cse.iitkgp.ac.in/~soumya/cps/cps.html)
5. Weblinks:(a) https://ptolemy.berkeley.edu/projects/cps/
6. https://ptolemy.berkeley.edu/projects/chess/

Course Outcome:

Upon completion of the course, the student will be able to

CO1	On completion of the course, the student can able to
CO2	Understand the design and validation of CPS
CO3	Able to analyze the CPS performance in the presence of network constraints
CO4	Apply the CPS concept for different real-world applications.

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	1	3
CO3	3	1	3
CO4	3	1	3

CL673	BIOMEDICAL INSTRUMENTATION	L	T	P	C
		3	0	0	3

Course Objectives

a. To introduce the principles and design issues of biomedical instrumentation
b. To understand the nature and complexities of biomedical measurements

Course Content:

Physiological systems and measurable variables- Nature and complexities of biomedical measurements- Medical equipment standards- organization, classification and regulation- Biocompatibility - Human and Equipment safety – Physiological effects of electricity, Micro and macro shocks, thermal effects.

Modeling and simulation in Biomedical instrumentation – Difference in modeling engineering systems and physiological systems – Model based analysis of Action Potentials - cardiac output – respiratory mechanism - Blood glucose regulation and neuromuscular function.

Types and Classification of biological signals – Signal transactions – Noise and artifacts and their management - Biopotential electrodes- types and characteristics - Origin, recording

schemes and analysis of biomedical signals Electrocardiography(ECG), with typical examples of and Electroencephalography(EEG), Electromyography (EMG)– Processing and transformation of signals- applications of wavelet transforms in signal compression and denoising.

Advanced medical imaging techniques and modalities -Instrumentation and applications in monitoring and diagnosis- Computed tomography, Magnetic Resonance Imaging and ultrasound- Algorithms and applications of artificial intelligence in medical image analysis and diagnosis-Telemedicine and its applications in tele monitoring.

Implantable medical devices: artificial valves, vascular grafts and artificial joints- cochlear implants - cardiac pacemakers – Microfabriation technologies for biomedical Microsystems- microsensors for clinical applications – biomedical microfluid systems

REFERENCES:

1. John G.Webster, “Bioinstrumentation”, John Wiley & Sons, 2008.
2. Shayne C.Gad, “Safety Evaluation of Medical Devices”, CRC Press, Second Edition, 2002.
3. Michael C.K.Khoo, “Physiological Control Systems: Analysis, Simulation and Estimation, IEEE Press, 2000.
4. John G.Webster, “Medical Instrumentation Application and Design”, John Wiley & Sons, Third Edition, 2009.
5. L.Cromwell, Fred J.Weibell and Erich A.Pfeiffer, “Biomedical Instrumentation and Measurements”, Prentice Hall of India, Digitized 2010.
6. P.Strong, “Biophysical Measurements”, Tektronix, Digitized 2007.
7. K.Najarian and R. Splinter, “Biomedical Signal and Image Processing”, CRC Press, 2012.
8. John L.Semmlow, “Biosignal and Biomedical Image Processing”, CRC Press, First Edition, 2004.
9. Joseph J.Carr and John M.Brown, “Introduction to Biomedical Equipment Technology”, Prentice Hall, Fourth Edition, 2004.

Course Outcome:

Upon completion of the course, the student will be able to

CO1	Understand the principles of biomedical measurements
CO2	Ability to apply fundamental principles for designing and modelling biomedical systems.
CO3	Analyze and process biomedical signals like ECG, EEG, and EMG by understanding signal transduction, managing noise and artifacts, and utilizing wavelet transforms
CO4	Ability to use mathematical/computational tools for biomedical image and signal analysis

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	3	2	3
CO2	3	1	3
CO3	3	1	3
CO4	3	1	3

CL674 **MACHINE LEARNING** **L T P C**
3 0 0 3

Course Objectives

With the increased availability of data from varied sources there has been increasing attention paid to the various data driven disciplines such as analytics and machine learning. This course aims to provide students with the knowledge of key concepts of machine learning from a mathematically well motivated perspective. The course aims to familiarize the students with the two broad categories of machine learning algorithms - supervised and unsupervised.

Syllabus:

Introduction: Machine learning basics, Supervised Learning: Artificial Neural Network, classifying with k- Nearest Neighbour classifier, Support vector machine classifier, Decision Tree classifier, Naive Bayes classifier, Bagging, Boosting, Improving classification with the AdaBoost meta algorithm.

Forecasting and Learning Theory: Predicting numeric values: regression, Linear Regression, Logistic regression, Tree-based regression. Bias/variance tradeoff, Union and Chernoff/ Hoeffding bounds, Vapnik–Chervonenkis (VC) dimension, Worst case (online) learning.

Unsupervised Learning: Grouping unlabeled items using k-means clustering, Association analysis with the Apriori algorithm, efficiently finding frequent itemsets with FP-growth.

Reinforcement learning: Markov decision process (MDP), Bellman equations, Value iteration and policy iteration, Linear quadratic regulation, Linear Quadratic Gaussian, Q-learning Value function approximation, Policy search, Reinforce, POMDPs.

Dimensionality reduction: Feature extraction - Principal component analysis, Singular value decomposition. Feature selection – feature ranking and subset selection, filter, wrapper and embedded methods. Machine Learning for Big data: Big Data and MapReduce.

REFERENCES:

1. Introduction to Machine Learning” by E. Alpaydin, MIT Press Edition 2nd Edition, 2009
2. Machine Learning” by T. M. Mitchell, McGraw-Hill Edition, 1997
3. Machine learning in action” by P. Harrington, Manning Publications Co Edition, 2012
4. Pattern recognition and Machine Learning” by C. M. Bishop, Springer 130 Edition, 2007
5. Machine Learning for Big Data” by Author J. Bell Publisher Wiley Edition 2014

Course Outcome:

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

CO1	identify potential applications of machine learning in practice
CO2	describe the differences in approaches and applicability of regression, classification, and clustering
CO3	select the suitable machine learning task for a given application
CO4	implement feature extraction and selection to represent data as features to serve as input to machine learning models build an application that is based on machine learning

Mapping of Course Outcome with Programme Outcomes:

	PO1	PO2	PO3
CO1	3	2	3
CO2	3	1	3
CO3	3	2	3
CO4	3	2	3

CL675 **OPTIMIZATION TECHNIQUES**

L	T	P	C
2	1	0	3

PRE-REQUISITE
Knowledge in applied mathematics.

COURSE LEARNING OBJECTIVES
1. To understand the concepts and origin of the different optimization methods.
2. To get a broad picture of the various applications of optimization methods used in engineering

COURSE CONTENT

Functions of single variable and multi-variable, Classical optimization methods, Linear Programming, Transportation problems,

Non - linear programming, constrained and unconstrained optimization methods, Multi-objective optimization.

Quadratic and Geometric Programming: Quadratic and geometric programming problems, calculus of variations.

Stochastic Programming, Artificial Intelligence in Optimization: ANN based optimization, Fuzzy optimization, Genetic algorithm

REFERENCES:

1. S.S.Rao, *Engineering Optimization Theory and Practice*, Third edition, New Age International Publishers, India.
2. K. Deo, *Optimization Techniques*, Wiley Eastern, 1995.
3. R.Panneerselvam, *Operation Research*, Second edition, PHI,New Delhi, India.
4. Prem Kumar Gupta and D.S.Hira, *Problems in Operations Research (Principles and Solutions)*, S.Chand and company Ltd. New Delhi, India.

COURSE OUTCOME
Upon completing the course, the student will be able to

CO1	Understand and apply classical optimization techniques for single-variable and multi-variable functions
CO2	Analyze and solve non-linear programming problems using constrained and unconstrained optimization methods,
CO3	Apply quadratic and geometric programming methods to optimization problems
CO4	Explore stochastic programming and AI-based optimization techniques, such as artificial neural networks, fuzzy optimization, and genetic algorithms, for solving complex and uncertain optimization problems.

Mapping of Course Outcome with Programme Outcomes

	PO1	PO2	PO3
CO1	3	1	3
CO2	3	2	3
CO3	3	2	3
CO4	3	3	3

CL676 **CONTROLLER TUNING** **L T P C**
3 0 0 3

Course objectives:

This course is designed to learn the different tuning techniques for the controllers.

Course content:

Introduction to tuning of controllers. Classification of controllers. Open loop and closed loop tuning methods for SISO and MIMO systems

Fundamentals of fractional order control, Fractional-order PI, PID controller tuning, Tuning of fractional order lead lag compensator, Auto-tuning of Fractional order controllers

Relay based tuning of PID controllers. Feedback - Experimental Design, Approximate Transfer Functions: Frequency-domain Modeling - Simple Approach, Improved Algorithm, Parameter Estimation. Approximate Transfer Functions: Time-domain Modeling. Shape of Relay, Improved Relay Feedback. Auto tuning for Plant wide Control Systems - Recycle Plant, Control Structure Design, Unbalanced Schemes, Balanced Scheme, Controllability, Operability, Controller Tuning for Entire Plant. Guidelines for Auto Tune Procedure. Applications to case studies.

Introduction to nonlinear PID controller design.

REFERENCES:

1. Cheng-Ching Yu, Autotuning of PID controllers: Relay feedback approach, 2nd edition, Springer, 2006
2. Alfaro, Victor M., Vilanova, Ramon, Model-Reference Robust Tuning of PID Controllers, Springer, 2016.
3. A. Monje, YangQuan Chen, Blas M. Vinagre, Dingyu Xue, Vicente Feliu-Batlle, Fractional order systems and control: Fundamentals and applications, Springer,2010
4. Michael A. Johnson, Mohammad H. Moradi, PID Control: New Identification and Design Methods, Springer, 2005.
5. Ramon Vilanova, A. Visioli, PID Controller Design in The Third Millennium: Lessons Learned and New Approaches, Springer, 2013.
6. Seborg, D. E., Edgar, T. F., Millechamp, D. A., Doyle III, F. J., Process Dynamics and Control, 3rd Edition, Wiley, 2014

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

CO1	Design PID controllers using various design methods
CO2	Use right tuning method for tuning the PID controller
CO3	Design PID controllers for fractional order systems
CO4	Automate the control at plant level
CO5	Design PID controllers by incorporating process nonlinearity

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	3	1	2
CO2	3	1	2
CO3	3	1	3
CO4	3	1	3
CO5	3	1	3

CL677 **WIRELESS SENSOR NETWORKS** **L T P C**
3 0 0 3

Course Objectives

1. To introduce the technologies and applications for the emerging domain of wireless sensor networks
2. To impart knowledge on the design and development of the various layers in the WSN protocol stack
3. To elaborate the various issues related to WSN implementations
4. To familiarize the students with the hardware and software platforms used in the design of WSN

Challenges for wireless sensor networks, Comparison of sensor network with ad hoc network, Single node architecture – Hardware components, energy consumption of sensor nodes, Network architecture – Sensor network scenarios, types of sources and sinks, single hop versus multi-hop networks, multiple sinks and sources, design principles, Development of wireless sensor networks.

Wireless channel and communication fundamentals – frequency allocation, modulation and demodulation, wave propagation effects and noise, channels models, spread spectrum communication, packet transmission and synchronization, quality of wireless channels and measures for improvement, physical layer and transceiver design consideration in wireless sensor networks, energy usage profile, choice of modulation, power management.

MAC protocols –fundamentals of wireless MAC protocols, low duty cycle protocols and wakeup concepts, contention-based protocols, Schedule-based protocols, Link Layer protocols – fundamentals task and requirements, error control, framing, link management

Gossiping and agent-based uni-cast forwarding, Energy-efficient unicast, Broadcast and multicast, geographic routing, mobile nodes, Data –centric and content-based networking – Data –centric routing, Data aggregation, Data-centric storage, Higher layer design issue

Target detection and tracking, Habitat monitoring, Environmental disaster monitoring, Practical implementation issues, IEEE 802.15.4 low rate WPAN, Sensor Network Platforms and tools-Sensor node hardware, Node-level software platforms, node –level simulators.

Course Outcome

1. Ability to analyze WSN with respect to various performance parameters in the protocol stack
2. Ability to understand MAC algorithms and Network protocols used for specific WSN applications
3. Design and develop a WSN for a given application

REFERENCES:

1. Feng Zhao and Leonidas J. Guibas, "Wireless Sensor Networks: An Information Processing Approach", Elsevier, 2004.
2. Holger Karl and Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks", John Wiley, 2007.
3. Ivan Stojmenovic, "Handbook of Sensor Networks: Algorithms and Architectures", Wiley, 2005.
4. Kazem Sohraby, Daniel Minoli and Taieb Znati, "Wireless Sensor Networks: Technology, Protocols and Applications", John Wiley, 2007.
5. Bhaskar Krishnamachari, "Networking Wireless Sensors", Cambridge University Press, 2011.

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

CO1	Understand the challenges and design principles of wireless sensor networks (WSNs) by comparing them with ad hoc networks
CO2	Analyze wireless communication fundamentals such as frequency allocation, modulation, noise, and channel models
CO3	Evaluate and implement MAC and link layer protocols for WSNs
CO4	Design and optimize routing protocols and data-centric networking techniques in WSNs, including energy-efficient unicast, broadcast, and multicast methods, geographic routing, and applications in target detection, environmental monitoring, and disaster management

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	3	1	2
CO2	3	2	2
CO3	3	3	3
CO4	3	2	3

CL678 MATHEMATICAL METHODS FOR ENGINEERS **L T P C**
3 1 0 4

PRE-REQUISITE
Knowledge in basic mathematics.

Course Learning Objectives

1. Analysis of experiments
2. Describe chemical engineering processes in mathematical form by employing the appropriate conservation principles
3. Identify if an analytical solution to the model equations

Course Content
Design and experiments, Experiments with single factor, analysis of variance, factorial design, regression by least square.
Models, need of models and their classification, models derived by first principles,
Analytical solution of simultaneous linear and non-linear equations, Numerical techniques for linear and non-linear equations, linearization of non-linear equations
Numerical techniques for ordinary differential equations, initial value problems, Stiff ODEs, Explicit and implicit techniques
Numerical techniques for ordinary differential equations, boundary value problems, shooting method and finite difference method
Numerical solution to Partial differential equations. solution of PDEs by Finite difference techniques, Introduction to data based modelling.

REFERENCES:

1. Douglas. C Montgomery, "Design and Analysis of Experiments" John Wiley, 8th Edition, 2012
2. Richard G. Rice & Duong D. D, "Applied Mathematics and Modelling for Chemical Engineers" John Wiley & Sons, 1995.
3. Mark E. Davis, "Numerical Methods and Modelling for Chemical Engineers", John Wiley & Sons, 1984.
4. S. K. Gupta, "Numerical Techniques for Engineers", Wiley Eastern Ltd., New York, 1995

COURSE OUTCOMES
On completion of the course, the student can

CO1	Able to analyze the data with minimum number of experiments
CO2	Develop a mathematical model for processes
CO3	apply mathematics to solve the engineering problems.
CO4	apply numerical techniques to solve the model

Mapping of Course Outcome with Programme Outcomes

	PO1	**PO2**	**PO3**
CO1	3	3	3
CO2	3	3	3
CO3	3	3	3
CO4	3	3	3

HS611 TECHNICAL COMMUNICATIONS

L	T	P	C
3	0	0	3

Objectives:

The objective of the course is

To develop the professional and communicational skills of learners in a technical environment.

To enable students acquire functional and technical writing skills.

To enable students acquire presentation skills to technical and non-technical audience.

Course Description:

This course intends to focus on the discourse of technical communication to make students familiar with the major components and practices within the field. This course concentrates on advanced writing and other communication skills, Principles and procedure of technical writing; to analyzing audience and purpose, organizing information, designing graphic aids, and writing such specialized forms as abstracts, technical reports, proposals.

Learning Outcome:

Learners will be able to:

- Communicate to multiple professional audiences clearly and effectively through both written and verbal modes
- Identify weaknesses in their own writing and apply appropriate revision processes to strengthen communication
- Analyze rhetorical aspects of audience, purpose, and context to communicate technical information effectively in written, oral, and visual media.
- Recognize structures or genres typically used in science and engineering, understand the processes that produce them, and the organizational and stylistic conventions characteristic of them, and apply this knowledge to their own writing tasks.

Course Content

Communication:

Concepts, goals and levels of communication - Barriers to effective communication - Psychology of communication - Significance of technical communication - Demonstration and evaluation of Scientific Reports, Note Taking Techniques - Writing and Talking about workplace relationships, Gender Issues, Stereotypes, Biases, Labeling

Oral Communication:

Tools and skills of communication - Presentation skills and Use of PowerPoint Slides, Public Speaking - Extempore / Prepared Speech - Body language and Nonverbal Cues - Interview techniques -
Discussion and Debates after Listening, Podcasts and Webcasts -

Written Communication:

Effective Writing - Coherence and Cohesion - Report Writing - Drafting Proposals, Research papers - preparation of technical / software manuals - Reader Perspective - Two pass approach to reading papers and Summarizing a text - Nonverbal cues in Writing - literature survey and organization - Ethics and Plagiarism

Developing Listening Skills:

Kinds of Listening- Developing effective listening skills; Barriers to effective listening skills - Listening Comprehension - Retention of facts, data & figures - Role of speaker in listening, Difference between note taking and note making.

Technology and Communication:

Telephone etiquette - Effective email messages - Editing skills - Visual Aids, Presentation Software - Document Processing Software - Elements of style in technical writing - Role of media in technology and communication - Library and Reference skills.

References:

1. Andrea J. Rutherford. (2007). *Basic Communication Skills for Technology*. New Delhi: Pearson Education in South Asia.
2. R.C. Sharma and Krishnamohan.(2011).*Business Correspondence and Report Writing*.New Delhi: Tata McGraw Hill.
3. Whitesides, George M. (2004) Whitesides Group: Writing a Paper 302224, Advanced Materials 16 137530222677 (2004)
4. David Lindsay. (1995). *A Guide to Scientific Writing*. Macmillan.
5. Alley, Michael (2003) The Craft of Scientific Presentations, Springer.
6. Strunk Jr., William; E. B. White, (1999). The Elements of Style, Fourth Edition, Longman; 4th edition
7. L.J. Gurak & J.M. Lannon (2010). *Strategies for Technical Communication in the Workplace.* 2nd Ed. New York: Pearson Education, Inc.
8. Monippally, M. M., Pawar, B.S. (2010) Academic Writing: A Guide for Management Students and Researchers, Response Books.
9. V.R. Narayanaswami (2005). *Strengthen Your Writing*, 3rd ed. Hyderabad: Orient Longman Pvt. Ltd.

Course Outcome:

Learners will be able to:

CO1	Communicate to multiple professional audiences clearly and effectively through both written and verbal modes
CO2	Identify weaknesses in their own writing and apply appropriate revision processes to strengthen communication
CO3	Analyse rhetorical aspects of audience, purpose, and context to communicate technical information effectively in written, oral, and visual media.
CO4	Recognize structures or genres typically used in science and engineering, understand the processes that produce them, and the organizational and stylistic conventions characteristic of them, and apply this knowledge to their own

Mapping of Course Outcome with Programme Outcomes:

	PO1	**PO2**	**PO3**
CO1	1	2	2
CO2	2	1	3
CO3	3	2	2
CO4	2	3	3