TEACHING SCHEME

M.TECH PROGRAMME

MECHATRONICS AND ROBOTICS

PUNJAB TECHNICAL UNIVERSITY, JALANDHAR
for Batch 2012 onwards
## Detailed Syllabus and Other Conditions for the Proposed Course

### M.Tech. Mechatronics and Robotics

#### Schedule of Teaching

<table>
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<tr>
<th>Lecture</th>
<th>Tutorials</th>
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<th>Time</th>
<th>Theory</th>
<th>Viva</th>
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- **1st Semester**
  - **MER 500**: Advanced Mathematics for Engineers
  - **MER 501**: Design of Experiments
  - **MER 502**: Design of Mechatronics System
  - **MER 503**: Digital Control Engineering
  - **MER 504**: Microprocessor, Microcontroller And Embedded Systems
  - **MER 505**: Robotics
  - **MER 506**: Industrial Automation
  - **MER 507**: Digital Signal Processing and Applications
  - **MER 508**: MEMS and Nanotechnology
  - **MER 509**: Neural Network & Fuzzy Logic

- **2nd Semester**
  - **MER 520 LAB – I**
  - **MER 521 LAB – II**

#### Schedule of Examination

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- **1st Semester**: Satisfactory/not Satisfactory
- **2nd Semester**: Satisfactory
LAB

ROBOTICS LABORATORY
SENSORS LABORATORY
MECHATRONICS LABORATORY
INDUSTRIAL AUTOMATION AND PLC LABORATORY
DIGITAL SIGNAL PROCESSING LABORATORY
MICROPROCESSOR AND MICROCONTROLLER LABORATORY

THEORY ELECTIVE

Elective 1
Bridge Course
   a. MER 518 PRINCIPLES OF DESIGN OF MACHINE ELEMENTS OR
   b. MER 519 ELECTRONIC DEVICES AND CIRCUITS

Elective 2

MER 511 MODELING, SIMULATION AND ANALYSIS OF MANUFACTURING SYSTEMS
MER 512 DYNAMICS AND MECHANISM DESIGN
MER 513 DFM TECHNIQUES AND PRODUCT DESIGN
MER 514 COMPUTER CONTROL OF MANUFACTURING SYSTEMS
MER 515 DESIGN OF TRANSMISSION SYSTEMS
MER 516 ARTIFICIAL INTELLIGENCE
MER 517 ADVANCED CONTROL SYSTEMS
Fourier Transforms

Z -Transforms

Matrices And Linear System Of Equations
Solution of linear simultaneous equations by Gaussian elimination and its modification, Crout’s triangularization method, Iterative methods-Jacobins method, Gauss-Seidal method, Determination of Eigen values by iteration.

Conformal Mapping
Conformal mapping, linear transformations, Bi-linear transformations, Schwarz’s-Christoffel transformations.

Calculus Of Variations

Books Recommended:
1. Higher Engineering Mathematics - by Dr. B.S. Grewal; Khanna Publishers
2. Fourier Series and Boundary Values Problems - by Churchill; McGraw Hill.
3. Complex Variables & Applications - by Churchill; McGraw Hill.
4. Calculus of Variations - by Elsgole; Addison Wesley.
5. Calculus of Variations - by Galfand & Fomin; Prentice Hall.
**MER 501   DESIGN OF EXPERIMENTS**

**INTRODUCTION**
Strategy of experimentation, Some typical applications of experimental design, Basic principles, Guidelines for designing experiments, A brief history of statistical design, Using statistical design in experimentation.

**SIMPLE COMPARATIVE EXPERIMENTS**
Introduction, Basic statistical concepts, Sampling and sampling Distribution, Inferences about the Differences in means, randomized designs, Inferences about the Differences in means, Paired comparison Designs, Inferences about the Variances of Normal Distributions.

**RANDOMIZED BLOCK DESIGNS**
Randomized complete block design, Latin square design, Balanced incomplete block design.

**INTRODUCTION TO FACTORIAL DESIGN**
Basic definition and principles, Advantages of factorials, The two factor factorial design, General factorial design, Fitting response curves and surfaces, Blocking in a factorial design.

**FITTING REGRESSION MODELS**
Introduction, Linear regression models, Estimate of parameters in linear regression models, Hypothesis testing in multiple regression, Confidence intervals in multiple regression, Prediction of new response observations, Regression model diagnostics, testing for lack of fit.

**TAGUCHI METHOD OF DESIGN OF EXPERIMENTS**
Concept design, Parameter design, Tolerance design, Quality loss function, Signal-to-Noise ratio, Orthogonal array experiments, Analysis of Mean(ANOM), Quality characteristics, Selection and testing of noise factors, Selection of control factors, Parameter optimization experiment, Parameter design case study.

**ANALYSIS OF VARIANCE (ANOVA)**
Introduction, Example of ANOVA process, Degrees of freedom, Error variance and pooling, Error variance and application, Error variance and utilizing empty columns, the F-test.

**BOOKS RECOMMENDED**
1. Design and Analysis of Experiments, Douglas C Montgomery, John Wiley
2. Statistical Design and Analysis of Experiments, John P.W.M., Macmillan,
3. Introduction to Linear Regression Analysis, Montgomery D.C., Runger G. C.,
MER 502 DESIGN OF MECHATRONICS SYSTEM

INTRODUCTION

SENSORS & TRANSDUCERS
Sensors and Transducers, Performance Terminology, (Displacement, Position & Proximity Sensors), (Velocity & Motion, Force, Fluid Pressure, Liquid Flow, Liquid Level, Temperature & Light Sensors), Selection of Sensors.

ELECTRONIC FUNDAMENTALS

ACTUATORS

SYSTEM MODELLING & CONTROL

MICROPROCESSOR & COMPUTER
Computer and Interfacing, Microcomputer Structure, Microcontrollers, Application of Microcontrollers, PLC.

DESIGN & MECHATRONICS
Designing, Possible Design Solutions, Case Studies of Mechatronic Systems.

REFERENCE BOOKS

PRINCIPLES OF CONTROLLERS
Review of frequency and time response analysis and specifications of control systems, need for controllers, continues time compensations, continues time PI, PD, PID controllers, digital PID controllers.

SIGNAL PROCESSING IN DIGITAL CONTROL
Sampling, time and frequency domain description, aliasing, hold operation, mathematical model of sample and hold, zero and first order hold, factors limiting the choice of sampling rate, reconstruction.

MODELING AND ANALYSIS OF SAMPLED DATA CONTROL LANGUAGE
Difference equation description, Z-transform method of description, pulse transfer function, time and frequency response of discrete time control systems, stability of digital control systems, Jury's stability test, state variable concepts, first companion, second companion, Jordan canonical models, discrete state variable models, elementary principles.

DESIGN OF DIGITAL CONTROL ALGORITHMS
Review of principle of compensator design, Z-plane specifications, digital compensator design using frequency response plots, discrete integrator, discrete differentiator, development of digital PID controller, transfer function, design in the Z-plane.

PRACTICAL ASPECTS OF DIGITAL CONTROL ALGORITHMS
Algorithm development of PID control algorithms, software implementation, implementation using microprocessors and microcontrollers, finite word length effects, choice of data acquisition systems, microcontroller based temperature control systems, microcontroller based motor speed control systems.

REFERENCE BOOKS

Simple stresses and strains: Concept of stress and strain (linear, lateral, shear and volumetric), Hook’s law. Elastic constants and their relationship. Generalized Hook’s law. Axial force diagram, stresses, strains and deformation in determinate and indeterminate homogeneous and composite bars under concentrated loads, self-weight and temperature changes.

Shear force and bending moment diagrams. Concept and definition of shear force and bending moment in beams due to concentrated load, UDL, uniformly varying loads and couples in determinate beams. Relation between SF, BM and intensity of loading, construction of SF, and BM diagrams for cantilevers, simple compound beams and bends.

Design concepts, material & process selection
Design concept, design process, types of design, factor of safety & design codes, materials and process selection.

Loads and stress in machine elements
Types of loads, static, shock, impact and fluctuating loads, types of stresses, tensile, compressive, direct and torsional shear, bending stresses, combined effect of direct, bending and torsional stresses,

Design of shaft based on torsional and lateral rigidity, combined loadings.

Spur Gears: Law of Gearing, Effect of Pressure angle and Centre Distance, Path of Contact, Arc of Contact, Contact Ratio, Interference and Undercutting, Minimum number of teeth to avoid interference, Design of Spur Gears, Selection of Type of Gears, Force Analysis, Gear tooth Failures, Selection of Materials, Beam Strength, Wear Strength, Effective Load Calculation, Dynamic Load, Gear Design for Maximum Power Transmitting Capacity. Bevel Gears: Force Analysis, Worm Gears: Force Analysis

Rolling Contact Bearings: Types, Static and Dynamic load Capacity, Stribeck’s Equation, Concept of equivalent load, Load life Relationship, Selection of bearing from Manufacturer’s Catalogue, Design for variable loads and Speeds, Bearings with Probability of Survival other than 90%, Lubrication and Mounting of bearing.

Introduction to Mechanical Vibrations, Importance of the Study of Vibrations, Elements of a Vibratory System, Examples of Vibratory Motion, Terms used in Vibratory Motion, Degrees of freedom and Examples of Degrees of freedom, Discrete and Continuous system, Types of Vibrations, Types of Free Vibrations.

Reference Books:

**MER 519 ELECTRONIC DEVICES AND CIRCUITS**

**Basic Semiconductor and Diodes:** Intrinsic and extrinsic semiconductors, diffusion and drift currents, p-n junction under open-circuit, reverse bias and forward-bias conditions, p-n junction in the breakdown region, ideal diode, terminal characteristics of junction diode, Load-line analysis of diode circuits, half wave rectifier and full wave rectifiers, Clippers and Clamps, capacitive filters, RC and LC filter, voltage multipliers. Principles, construction and characteristics of Zener diodes, Light Emitting Diodes, Schottky Diode, Varactors


**Integrated Circuit and Operational-Amplifiers:** Introduction to IC’s, Op-Amps, Op-Amp Characteristics, Feedback, Different feedback configurations, Current- to-voltage converter and voltage-to-current converters, voltage and current amplifiers, mathematical operations using Op-Amp: summing, differentiation and integration, Comparators and Schmitt trigger

**Oscillators and Active Filters:** Oscillations, Feedback oscillator Principles., RC phase shift oscillator, Wien bridge oscillator, Hartley oscillator, Colpitts oscillator, Crystal oscillators, frequency stability, Active Filters (1st order) with low pass, high pass, band pass, band stop and all pass. Pin configuration of 555 timer, 555 timer as Oscillator: monostable, bistable and astable multivibrator.


**Suggested Readings/ Books:**
- Boylestad, Robert L. Electronic Devices and Circuit Theory, Pearson Education
- Floyd Thomas L., Electronic Devices, Pearson Education
• Gayakwad, Ramakant A. OP-AMPS and Linear Integrated Circuits, Prentice Hall of India
• Malvino Albert Paul and Bates David, Electronic Principles, edition 7th, Tata McGraw Hill
• Millman Jacob, Integrated Electronic Devices and Circuits, Tata McGraw Hill.

MER 520 Lab-I

Max. Marks: 100
Time Allowed: 4hrs
One lab /field/industrial oriented project /problem will be allocated to each student related to the subjects related to the subjects taught in 1st semester.
Microprocessor 8086 Architecture - BIU and EU, Registers, Pin Diagram, Memory addressing, Clock Generator 8284, Buffers and Latches, Maximum and Minimum Modes.

Addressing Modes, Instruction set of 8086, Assembly Language Programming, Assemblers, Procedures, Macros, Interrupts, 8086 Based Multiprocessor Systems - Coprocessors (8087 NDP), Closely and Loosely Coupled Multiprocessor Systems (8089 IOP).

Interfacing Chips- IC 8155 (Static Ram with I/O Ports and Timer), 8755 (EPROM with I/O Ports), 8251A (USART), 8255A (Programmable Peripheral Interface), 8253/8254 (Programmable Interval Timer/Counter), 8257 (DMA Controller), 8259A (Programmable Interrupt Controller).


Embedded Systems-Introduction, Classification, Processors, Hardware Units, Software Embedded into System, Applications and Products of Embedded Systems, Structural Units in Processor, Memory Devices, I/O Devices, Buses, Interfacing of Processor Memory and I/O Devices, Case Study of an Embedded System for a Smart Card.

Text Books
1. B. B. Brey: The Intel Microprocessors, Architecture, Programming and Interfacing, Pearson Education.
3. D. V. Hall: Microprocessors and Interfacing, TMH.
5. V. Deshmukh: Microcontroller (Theory and Application), TMH.
MER 505  INDUSTRIAL ROBOTICS

ROBOT FUNDAMENTALS
Robot components, robot classification and specification, Work envelopes, Other basic parameters of robots.

ROBOT MECHANICS

Trajectory planning - joint space trajectories: Cubic polynomials, Higher-order polynomials, Linear function with parabolic blends. Cartesian space trajectories: Positional transition, Rotational Transition. Trajectory Planning vs. path planning.

ROBOT ACTUATORS
Characteristics of actuating systems, Drives - electric, hydraulic, pneumatic and their relative merits. Speed reduction

ROBOT SENSORS
Robot sensors, sensor classification, micro-switches, proximity sensors, photo-electric sensors, rotary position sensors, sensor usage and selection, sensors and control integration.

ROBOT END-EFFECTORS
Types, grippers, gripper, force analysis, tool selection, process tooling.

IMAGE PROCESSING AND ANALYSIS
Image acquisition, histogram of images, thresholding, connectivity, noise reduction, edge detection, segmentation, Image analysis - object recognition, depth measurement with vision systems, stereo imaging.

ROBOT PROGRAMMING AND APPLICATIONS
Programming methods using Teach-pendent, on-line or off-line technique, Space position programming, motion interpolation.

REFERENCES:

- Introduction to Robotics by J.J. Craig, Pearson Education
- Robotics: Control, sensing, vision and intelligence by KS Fu, P Gonzalez, CSG Lee, McGraw Hill
Automation of assembly lines
Concept of automation, mechanization and automation

Automation using hydraulic systems.
Design aspects of various elements of hydraulic systems such as pumps, valves, filters, reservoirs, accumulators, actuators, intensifiers etc. Selection of hydraulic fluid, practical case studied on hydraulic circuit design and performance analysis. Servo valves, electro hydraulic valves, proportional valves and their applications.

Automation using pneumatic systems

Various Number Systems

Simple Logic Operations:
Logic Circuits with AND, OR, XOR operations in electro-mechanical applications, Series and Parallel logic circuits.

Components of a PLC:
Chassis of a PLC, Power supply module, Input module, Output module, CPU.

Understanding Ladder Diagrams:
Programming contacts, Addressing contacts, Wiring diagrams, Ladder diagrams, Ladder diagram rules, Instructions to examine ON and examine OFF

Programming a Ladder Diagram:
Use of RSLogix software for ladder diagram programming, Setting up RSLogix for Allen-Bradley SLC 500 PLC, Hands-on wiring of input devices to input modules, Hands-on wiring of output devices to output module, Simple PLC programs to solve logical problems,

REFERENCES:
Groover, M.P., CAD/CAM- Prentice Hall
6. Programmable Logic controllers Principles and Application John w. Webb, Ronald A Reis
SIGNALS AND SYSTEMS
Basic elements of digital signal processing – Concept of frequency in continuous time and discrete time signals – Sampling theorem – Discrete time signals. Discrete time systems – Analysis of Linear time invariant systems – Z transform – Convolution and correlation.

FAST FOURIER TRANSFORMS

IIR FILTER DESIGN

FIR FILTER DESIGN

FINITE WORD LENGTH EFFECTS

TEXT BOOK

REFERENCES


REFERENCES:

Reference Books:
1. “System Simulation”- Gordon, PHI.
2. “System Simulation with Digital computer” – Deo, PHI


5. Autonomous Systems with Hologomic and Non Holonomic Constraints, Application to Systems with very small Displacements and to Impulsive Motion.


Text Books:

Reference Books:
2. A. R. Holowenko, Dynamics of Machinery, John Wiley and Sons.
4. Erdman and Sandoor, Advanced mechanism design, Analysis & Synthesis Vol 1 & Vol 2, PHI.
INTRODUCTION: General principles for manufacturability, Basic Principles of designing for economic production, Process capability, Feature tolerance and surface finish.

DESIGNING FOR MACHINING: Parts cut to length, Screw machine products, machined round holes, molded parts, parts produced by planning, shaping and slotting, broached parts, ground parts, rolled burnished parts, gears.

REVIEW OF DESIGN CONSIDERATION: in formed metal components, non-metallic parts, design for heat treatment and economical deburring.

MECHANICAL ASSEMBLY: Application of selective assembly, deciding the number of groups – examples, design recommendations for different fastening arrangements, automatic assembly control of axial play in assemblies.

INTRODUCTION TO PRODUCT DESIGN: Definition of Product Design; design by evolution, design of innovation; essential factors of product design; production consumption cycles; the morphology of design (The seven Phases).

DESIGN OF PRODUCTION METAL PARTS: Produce ability requirements in the design of machine components; forging design; pressed component design; casting design; design for machining case; design powder metallurgical parts; expanded metals and wire forms.

OPTIMIZATION IN DESIGN AND HUMAN ENGINEERING CONSIDERATIONS IN PRODUCT DESIGN: Introduction; Siddal classification of product design approaches; optimization by differential calculus; Langrange multipliers; linear programming; geometric programming; Johonson’s method of optimization; Human Engineering-Introduction; the design of controls; the design of displays; man/machine information exchange.

VALUE ENGINEERING AND PRODUCT DESIGN: Introduction; Historical perspective; Nature and measurement of value; Importance of value; the value analysis plan.

Text Books:

Reference Books:
Computer Control of Manufacturing Systems


Interpolators for manufacturing systems: DDA Integrator, DDA Hardware Interpolator, CNC software Interpolators, Reference word CNC interpolators, The concept of reference word interpolators, Tusten Method.

Control Loops of NC Systems: Introduction, Control of Point-to-point Systems, Control loops in Contouring Systems, Mathematical Analysis, operation of a two axis system.


Manufacturing system simulation: Introduction, Types of simulation, Need and elements of simulation, Simulation methodology.


Computer integrated Manufacturing systems: Introduction, Modern manufacturing, Sequence of functions in CIM, Elements of CIM system, CIM data base management system, CIM related standards, Guide lines for CIM development, Benefits of CIM.

Flexible manufacturing systems: Introduction, Elements of FMS, Classification and Types of FMS, FMS work stations, Lay out configurations, Petrinets, modeling with Petrinets.

Text Books:

Reference Books:
MER 515      DESIGN OF TRANSMISSION SYSTEMS

DESIGN OF FLEXIBLE POWER TRANSMISSION SYSTEMS
V belts and pulleys - Flat belts and pulleys - Wire ropes and pulleys - Link chains and pulleys – Transmission chains and Sprockets-Silent chains - Ribbed V belts.

SPUR GEARS

HELICAL BEVEL AND WORM GEARS

DESIGN OF GEAR BOXES
Geometric progression - Standard step ratio - Ray diagram, kinematic layout -Design of sliding mesh gear box - Constant mesh gear box.

CLUTCHES AND BRAKES
Internal Expanding Rim Clutches and Band Brakes - External - Contracting Rim Clutches and Band Brakes - Type Clutches and Brakes. Frictional contact Axial clutches, cone clutches and brakes - Energy Considerations. Temperature Rise - Friction Materials.

REFERENCES:
INTRODUCTION TO FUZZY LOGIC

FUZZY LOGIC APPLICATIONS

INTRODUCTION TO ARTIFICIAL NEURAL NETWORKS

OTHER ANN ARCHITECTURES

RECENT ADVANCES

REFERENCES:
MER 517     ADVANCED CONTROL SYSTEMS

STATE SPACE ANALYSIS
State Space Representation, Solution of State Equation, State Transition Matrix, Canonical Forms – Controllable Canonical Form, Observable Canonical Form, Jordan Canonical Form.

CONTROLLABILITY AND OBSERVABILITY
Tests for controllability and observability for continuous time systems – Time varying case, minimum energy control, time invariant case, Principle of Duality, Controllability and observability form Jordan canonical form and other canonical forms.

DESCRIBING FUNCTION ANALYSIS
Introduction to nonlinear systems, Types of nonlinearities, describing functions, describing function analysis of nonlinear control systems.

PHASE-PLANE ANALYSIS
Introduction to phase-plane analysis, Method of Isoclines for Constructing Trajectories, singular points, phase-plane analysis of nonlinear control systems.

STABILITY ANALYSIS
Stability in the sense of Lyapunov., Lyapunov’s stability and Lyapunov’s instability theorems. Direct method of Lyapunov for the Linear and Nonlinear continuous time autonomous systems.

MODAL CONTROL
Effect of state feedback on controllability and observability, Design of State Feedback Control through Pole placement. Full order observer and reduced order observer.

CALCULUS OF VARIATIONS

OPTIMAL CONTROL

TEXT BOOKS:

REFERENCE BOOKS:
   Control Systems Engineering by I.J. Nagarath and M.Gopal, New Age International (P) Ltd.

24
Max. Marks: 100
Time Allowed: 4hrs
One lab /field/industrial oriented project /problem will be allocated to each student related to the subjects related to the subjects taught in 1st semester.