DAY 1  INTRODUCTION TO SYSTEMS AND MODELLING

9.00  Introduction

The Need For Control
- What Is Control?
- Feedback Control
- Benefits Of Feedback Control
- Drawbacks Of Feedback Control

9.30  Linear Systems And Transfer Functions

The Integrator
- Gain And Phase Characteristics
- What Are They And Why Use Them?
The Laplace Transform
- Introduction To Transforms
- Use Of The Laplace Transform
- Laplace Transform Of Integrator
The First-Order Transfer Function (Or The Simplest Servo In The World!)
- Closed-Loop Transfer Function
- First-Order Transient Response
- Frequency Response
The Second-Order Transfer Function
More General Transfer Function Properties
- Zeros
- Poles
- Examples
- Definition Of Gain And Phase

11.00 Frequency Response Analysis

Advantages Of Frequency Response Analysis
The Bode Diagram
- Bode Plots Of Integrators
- Bode Plots Of Poles
- Bode Plots Of Zeros
- The Complete Transfer Function
The Nichols Chart
- Nichols Chart Representation Of Integrators
Nyquist Plot Representation of Poles and Zeros

13.00 Linear Modelling and Simulation

What is Modelling
- Objectives of Modelling
- How do you get a Plant Model
- Fundamentals of Modelling
What is Simulation
- Simulation Tools
Modelling Examples
13.30 Hands-On Session - Introduction to MATLAB & SIMULINK

14.45 Hands-On Session - Modelling for Control Design

16.00 Physical Components of Servomechanisms

Principles Of DC Motors
Explanation Of Terms Used To Describe Components Of DC Motors
Fleming's Left-Hand Rule For Torque Generation
Torque Constant Of A DC Motor
Fleming's Right-Hand Rule And Back-Emf Constant
Relationship Between Torque And Back-Emf Constant
Stationary Torque Characteristics
Functions Of Brush And Commutator
Pole And Neutral Zone
Relationship Between Motor And Generator
Relationship Between Motor, Generator And Brake
Calculation Of Servomotor Characteristics
Static Characteristics
Practical Limitations For Static Parameters
Installation Issues
Higher Order Motor Transfer Functions

Gears
Benefits Of Use Of Gears
Gear Types
Features Associated With The Use Of Gears
System Parameter Relationships In The Presence Of Gears
Criteria For Selection Of Gear Ratio/Maximisation Of Performance

Bearings
Bearing Design
Assembly Of Ball Bearings
Angular Contact Ball Bearings
Duplex-Pair Configuration
Benefits Of Bearing-Mounted Systems
Bearings Considerations/Limitations Within Tracking/Stabilisation System
Measures To Prevent Degrading Bearing Performance

Gyrosopes
Gyrosopic Motion
Types Of Gyroscope
Comparison Of Fogs And Dtgs /Benefits Of Fogs
Latest Gyroscopic Devices

Other Servomechanism Position Sensors
Resolvers
Variations On Synchros And Resolvers
Rotary Inductosyns
Uses Of The Rotary Inductosyn
Encoders
Comparison Of Different Position Sensors
Velocity Measurement/Tachogenerators
Drive Electronics

Basic Servo-Amplifiers
Characteristics Of Linear Servo-Amplifiers
Configuration Of Current-Controlled Pwm Servomotor

**DAY 2  CLASSICAL CONTROL DESIGN**

**09.00 Fundamentals of Control Design**

Tracking Performance
Control Accuracy
- Final Value Theorem
- Step Position Input Error
- Other Cases
Stability
- System Behaviour Based On Pole Position
- Gain And Phase Margins
- Gain Margin
- Phase Margin
Disturbance Rejection
Noise Immunity

**10.00 Hands-On Session - Control Fundamentals**

**11.00 Root Locus and Lead-lag Compensation**

Root Locus Technique
- Learning Objectives
- History
The Root Locus
- Root Locus for an Integrator
- Second Order System Root Locus
- Higher Order System Root Locus
- Location of Roots and Dynamic Response of the System
- Example
- Theory
Modulus Condition
Argument Condition
Some Useful Rules
Example
- Effect of Compensation
- Conclusion
Controller Design Using Lead-Lag Compensation
Justification For Dynamic Controllers
Classical Controllers And Design Methods
Frequency Responses Of Lead-Lag Compensators
Lead Compensation Design
Lag Compensation Design

**13.15 Hands-On Session - Root Locus and Lead-Lag**

**14.00 PID Controllers**

Introduction To PID Control
Motivation
Limitations
Generic Equations
PID Parameterisation
Proportional Term
  First-Order Plant
  Second-Order Plant
Integral Term
  Introduction
  First-Order Plant
Derivative Term
  Introduction
  Implementation
  First-Order Plant
  Second-Order Plant
Equivalence Of PID And Lead-Lag Controller Characteristics

15.30  Hands-On Session - PID Tuning

16.15  Implementation Issues and Nonlinearities

  Implementation Aspects
  Bumpless Transfer
  Derivative Filtering
  Integral Windup
  Graphical Representation
    -Antiwindup Mechanisms
  Practical Non-linearities
    Coulomb and Static Friction
    Deadband
    Backlash
    Saturation
    Quantisation

DAY 3  PRACTICAL ISSUES IN SERVOMECHANISM CONTROL

09.00  Discrete-Time Systems Modelling and Control
  Digital Control
  Modern Control Systems
  Sampling
  Spectra Of Sampled Signals
    Aliasing
  Difference Equations
  The Z-Transform
  Mapping Between Z-Plane And S-Plane
  Some Intuitive Appreciation
    Impulse Response Of Integrator (Impulse Invariant Transform Example)
  The DAC Reconstruction Process
  Total Z-Transform Of Sampled Plant Function
  Sampled-Data Control Systems Analysis
  Frequency Response Analysis
  Design Of Digital Compensators
    Continuous Domain Approach
    Direct Digital Design
    Example

10.45  Hands-On Session - Discrete Time Systems
13.00 Servomechanism Testing

Servo Testing

Servomotor Tests

Back-EMF Test
Armature Resistance and Inductance Test
Torque Test

Mechanism Tests

Inertia Testing
  - Torsional pendulum method
  - Torque versus acceleration test
  - Frequency response testing

Friction Testing

Torsional Stiffness Testing
  - Static deflection measurement
  - Dynamic frequency response test

Friction Testing

Torsional Stiffness Testing
  - Static deflection measurement
  - Dynamic frequency response test

14.00 System Identification

System Identification Application
System Identification Procedure
On-line and Off-line Identification
  - Off-line
  - On-line

Methods of Identification
  - Non-parametric methods
  - Parametric methods

Non-parametric Models and Identification Methods
  - Transient analysis
  - Frequency analysis (swept sine test)
  - Spectral analysis (FFT/PRBS)
  - Correlation analysis

Parametric Models and Estimation Methods

15.15 Real-life Design Example

Servomechanism with motor, load, gear and position sensor