EE 411 Advanced Control System (3-1-2:5)

Continuous time Systems in State-Space

Introduction of State-Space, modelling of dynamic systems, State Diagram, Linear Transformation of state variables, State-Space representation in Canonical forms: Diagonal, Controllable, Observable, & Jordan Diagonal canonical form. Conversions between State Space and Transfer Functions model.

State transition matrix, properties of State Transition Matrix, computation of State Transition Matrix by Laplace transform approach, solution of Homogeneous and Non-homogeneous State equation of continuous time invariant systems.

Concepts of Controllability, Observability, Stabilizability & Detectability. Design of state variable feedback, Regulator design via pole placement method, determination of full state feedback gain using Direct-comparison method, controllable canonical form method and Ackermann's formula. state observers, Design of Full order state observers, reduced order State observers.

Digital Control Systems

Basic structure of computer control system. Digital signals and coding: Data conversion and Quantization. Sampling process and data hold operation. Zero Order Hold (ZOH) and First Order Hold (FOH). Sampling Theorem, Frequency folding.

Z-domain Analysis of Discrete-time system: Pulse transfer function. Pulse transfer function of ZOH. Z-transfer function of open loop and closed loop system. Block diagram. Transient and steady state response of discrete time systems. Steady state accuracy and error constants.

Mapping between s and z plane. Stability analysis: Characteristic equation. Bilinear Transformation and Routh-Hurwitz Criterion, Jury's test. Effect of sampling rate on stability. Frequency response of discrete time systems. Discrete Nyquist stability criterion. Digital Compensator Design.

State variable analysis of Digital Control Systems: State space representation of time-invariant difference equations and Z- Transfer function, State space representation of sampled continuous time systems, State diagram of discrete data system with ZOH. Solution of Discrete-Time State Equations.

Non-Linear Control System

Introduction, Common physical nonlinearities. Jump resonance, The Phase-Plane analysis: singular points, Phase portrait, Limit Cycle, Qualitative behaviour at near equilibrium points, Jacobian linearization of second order systems, Construction of phase trajectories –Isocline method, δ method, Stability of non-linear system by Phase-Plane method.

The Describing Function analysis, Harmonic Linearization, derivation of Describing Function of typical nonlinearities, existence of limit cycles, Stability analysis by describing function method.

Lyapunov's Stability Analysis: Stability definitions- local stability, asymptotic stability, asymptotic stability in large, Instability, Lyapunov's stability criterion, Lyapunov function, sign definiteness of scalar functions, Sylvester,s criterion, Lyapunov's Direct method for linear systems, construction of Lyapunov function, asymptotic stability of nonlinear systems with feedback.

List of Experiments:

1. Familiarization of MATLAB control system toolbox and MATLAB-SIMULINK toolbox for state variable analysis in continuous time. Obtaining transfer function from state variable model and vice versa. Obtaining step response and initial condition response for a given system.
2. Familiarization and use of MATLAB control system toolbox for Digital Control System.
3. Design and study of state variable feedback control system via pole placement method and determination of full state feedback gain using Direct-comparison method, and Ackermann's formula
4. Design of full order observer based feedback control system and study of actual state variable and estimated state variable response for a given system.
5. Study of step response with a nonlinear element introduced into the forward path of 2nd order unity feedback control systems
6. Study of phase plane trajectory and determination of limit cycle of common nonlinearities.
7. Study of Describing function analysis of a closed loop electronic relay control system with adjustable hysteresis and dead zone and display of phase plane diagram on CRO
8. To study the discrete-time version of the PID controller, and to implement classical tuning rules for the digital control system.

Text Books:

1. Gopal M, "Digital Control and State Variable Methods", TMH
2. H. K. Khalil., "Nonlinear Systems", Prentice Hall

References:

1. Nagrath I.J., Gopal M, "Control System Engineering", New Age International
2. Nise N.S., "Control System Engineering", Wiley India
3. Kuo B.C., "Digital Control Systems", Oxford India Edition
4. Ogata K., "Discrete time Control Systems", PHI