ECE 412: Digital Control and Digital Filters

IN

Transform Methods

- Analyze causal processes via one-sided z-Transform (forward and inverse using tables)
- Understand properties of z-Transform, especially shifting in time and frequency, time-domain convolution versus frequency domain multiplication, and final value theorem for steady state analysis
- Understand use and properties of Discrete-Time Fourier Transform (DTFT) for frequency domain analysis of digital signals
- Understand sampling theorem in time domain and aliasing effects on frequency spectra.

Linear Systems

- Manipulate and solve ordinary difference equations (ODEs)
- Compute via transfer functions
- Compute time domain convolution
- Convert between the above system representations (ODE, transfer function, and convolution (via impulse response)

Continuous-Time Control Systems

- Understand Nyquist/Bode and Root Locus plots and their relation to stability analysis
- Analyze system stability using Routh Hurwitz test and gain and phase margins - Analyze closed-loop system steady state and transient response using classical tools (Nyquist/Bode/Root Locus/Final Value Theorem)
- Design Lag, Lead, Lag-Lead, PI, PD, PID controllers for an analog plant
- Formulate and solve state space systems, and switch to other representation (transfer function)
- Utilize Matlab and Simulink for controller analysis, simulation, and design

Filters

- Analyze n^{th} order RLC and Op Amp circuits and create a corresponding ordinary differential equation

Pre-requisites

- ECE 411

Concepts:
- Sampling and reconstruction for signals and systems
- Zero-order and first-order hold devices and frequency response
- Digital control systems and sampled signal flow graph method
- Time domain analysis of closed-loop control systems
- Stability analysis and stability margins (gain and phase) and their relation to Nyquist and Bode plots
- Pole/Zero Location and the Effects of Feedback (root locus plots)
- Controller Design via classical and modern methods
- State feedback and observer designs
- Bilinear and impulse invariant transformations
- Frequency Sampling method
- Design standard analog filters
- IIR and FIR digital filters and their designs

Applications:
- Time-domain and Z-domain analysis of closed loop sampled-data systems
- Stability analysis
- Digital controller design
- Numerical approximation and mappings from continuous to discrete-time
- Analog and digital filter design and implementation

Tools:
- Complex Algebra and Analysis
- Ordinary Difference Equations
- Series and sequences
- Z Transform, starred transform (and Discrete Time Fourier Transform), and modified Z transform
- Matlab and Simulink, plus Toolboxes (control, signal processing, symbolic)

OUT

Classic Closed-Loop Analysis

- Compute zero order hold equivalent system
- Map sampled data to equivalent digital system
- Understand mappings from s-plane to z-plane
- Compute transfer function of digital control systems with multiple loops
- Compute steady state performance for closed-loop systems via final value theorem
- Compute transient performance parameters
- Check stability via Jury's test, Nyquist/Bode plots, and/or root locus plot

State Space Representation

- Transform between ODE or pulse transfer function to state space representation
- Construct state and simulation diagrams (for implementation)
- Solve system of state space equations

Digital Controller Design

- Design lag, lead, and lag-lead controllers, PI, PD, and PID controllers for digital control
- Design controllers using Nyquist/Bode, root locus, and analytic approaches
- Design controllers via mapping from continuous time
- Design controllers via direct digital design
- Design controllers via state feedback method

Digital Filter Design

- Design Butterworth, Chebyshev, Elliptic, and Bessel filters
- Design low pass, high pass, band pass, and band stop filters
- Design filters via mapping from continuous time domain
- Understand how to implement IIR and FIR filters
- Understand basic approaches to direct digital filter design

Computer Aided Tools

- Perform all calculations above by hand (for simple systems)
- Perform all above calculations in Matlab