EE/CPE 548 – Digital Signal Processing

Instructor Name
Hongbin Li

Instructor Contact Information
Department of Electrical and Computer Engineering, Stevens Institute of Technology
Phone: 201-216-5604; Email: hli@stevens.edu .

Office Hours
3-4 pm Monday and Wednesday

Text Book
Sanjit K. Mitra, Digital Signal Processing: A Computer Based Approach, 4th edition, McGraw Hill, 2010, ISBN ISBN 007736676X.

Prerequisites
Student should have taken an undergraduate-level course in signals and systems.

Course Description
Review of mathematics of signals and systems including sampling theorem, Fourier transform, z-transform, Hilbert transform; algorithms for fast computation: DFT, DCT computation, convolution; filter design techniques: FIR and IIR filter design, time and frequency domain methods, window method and other approximation theory based methods; structures for realization of discrete time systems: direct form, parallel form, lattice structure and other state-space canonical forms (e.g., orthogonal filters and related structures); roundoff and quantization effects in digital filters: analysis of sensitivity to coefficient quantization, limit cycle in IIR filters, scaling to prevent overflow, role of special structures.

Course Learning Outcomes
After completing this course, student will be able to

- know how to represent digital signals and systems in the time and frequency domains;
- Analyze digital signals and systems using analytical and computer tools;
- Design linear digital systems to meet given specifications.

Topics Covered Each Week

- Week 1: Time-domain representation of discrete-time signals; operations on sequences; upsampling and downsampling; energy, power, periodicity; discrete-time impulse/step signals, sinusoidal signals, and other basic discrete-time signals.
- Week 2: Sampling and aliasing; linearity, time invariance, causality, and stability; linear and time-invariant (LTI) systems; impulse response and step response; convolution sum;

cascade and parallel connections; stability and causality of LTI systems; finite-duration impulse response (FIR) and infinite-duration impulse response (IIR) systems; linear constant-coefficient difference equations and finite-dimensional LTI systems.

- Week 3: Discrete-time Fourier transform (DFTF), uniform convergence and mean-square convergence of DTFT, Gibbs phenomenon, DFTF of periodic signals, DFTF properties, DFTF computation by Matlab; eigenfunctions, frequency response, magnitude and phase response, phase and group delay, phase unwrapping; steady-state response of sinusoidal inputs.
- Week 4: Discrete-time processing of continuous-time signal, anti-aliasing filter, sampling and hold, quantization and round-off errors; effect of time-domain sampling in the frequency domain; reconstruction and interpolation; sampling of bandpass signals.
- Week 5: Discrete Fourier transform (DFT), fast Fourier transform; sampling in the frequency domain; circular shifting, circular convolution; linear convolution using DFT; block convolution; discrete cosine transform and Haar transform.
- Week 6: z-transform, region of convergence, z-transform and DFTF; rational z-transform, poles and zeros; inverse z-transform, partial fraction expansion, inverse z-transform by long division; transfer function; region of stability.
- Week 7: zero-phase, linear-phase, versus nonlinear-phase systems; linear-phase FIR transfer functions, Type 1-4 linea-phase FIR filters; zero distribution of linear-phase FIR filters.
- Week 8: Frequency selective filters; analysis of first- and second-order FIR and IIR filters; comb filters; allpass transfer functions, delay equalizer; minimum-phase and maximum-phase systems; inverse systems.
- Week 9: Digital filter structures, analysis and synthesis of digital systems; canonic and non-canonic structures; transpose operation; direct, cascade, and parallel forms; lattice structures.
- Week 10: Filter design specifications; Butterworth, Chebyshev, and Elliptic approximations; bilinear transform; IIR filter design; spectral transformation of IIR filters.
- Week 11: FIR filter design, least-square method, window-base method; fixed windows including rectangular, Hanning, Hamming, and Blackman windows; adjustable window functions including Kaiser and Dolph-Chebyshev windows.
- Week 12: Minimax filter design criterion, alternation theorem, Parks-McClellan algorithm; computer-based digital filter design.