EE 453 – Digital Signal Processing

Designation: EE elective course for electrical engineering majors.

University Bulletin Description:
EE 453: (3) Design of FIR and IIR filters; DFT and its computation via the FFT; applications of the DFT; filter implementation; finite arithmetic effects.
Prerequisite: EE 351.

Prerequisites by Topics:
1. Understanding sampling and reconstruction in both the time and frequency domains.
2. Understanding linear time-invariant systems, system properties, the convolution sum, and properties of convolution.
3. Understanding the system frequency response, magnitude response and phase response
4. Understanding the Z-transform and its application to identifying system properties, solving difference equations, and determining the frequency response of a system.
5. Understanding MATLAB as a tool for signal processing.

Textbook/Required Materials:
Digital Signal Processing: A Computer-based Approach, 3E, Mitra, S., McGraw Hill, 2005

Learning Outcomes:
This course introduces students to the fundamental techniques and applications of digital signal processing. Through lectures, homework, and laboratory experiments, students should be able to do the following upon completion of this course:
1. Design digital filters through pole-placement techniques.
2. Design digital IIR filters by designing prototypical analog filters and then applying analog to digital conversion techniques such as the bilinear transformation.
3. Design digital FIR filters using the window method.
4. Use a computer to design digital filters via the frequency sampling approach and the Remez exchange algorithm (Parks-McLellan filter).
5. Implement digital filters in a variety of forms: direct form I and II, parallel, and cascade, and then analyze their sensitivity to finite precision effects such as input quantization, coefficient quantization, and multiplication roundoff.
6. Analyze signals using the discrete Fourier transform (DFT).
7. Understand circular convolution, its relationship to linear convolution, and how linear convolution can be achieved via the discrete Fourier transform.
8. Understand the Decimation in time and frequency FFT algorithms for efficient computation of the DFT.
9. Alter the sampling rate of a signal using decimation and interpolation.
10. Direct form I and II, parallel, cascade, and lattice filter structures and their sensitivity to finite precision input, arithmetic, and coefficient quantization.

Topics:
1. Introduction: DSP objectives, DSP applications, EE351 review (7 classes)
2. Pole-zero filter design methods (4 classes)
3. IIR Filter design methods (8 classes)
4. FIR filter design methods (5 classes)
5. Computer-based filter design methods (1 class)
6. Digital filter structures and finite precision effects (3 classes)
7. Calculation of the Discrete Fourier Transform (DFT) and relationship to the Fourier Transform (6 classes)

8. Fast Fourier Transform: decimation in time and frequency algorithms (3 classes)
9. Digital filtering via the DFT (3 classes)
10. Multirate DSP: sampling rate conversion; efficient structures; applications (2 classes)

Class/Laboratory Schedule:
Three 50-minute lectures per week and three 2-hour laboratories during the semester.

Computer usage:
MATLAB is used in nearly all homework assignments to design and analyze the various digital filters covered in the course. MATLAB is also used to perform DFT analysis and sample-rate conversion.

Laboratory Projects/Assignments:
Three 2-hour DSP laboratory experiments are a required part of this course. Laboratory experiments are conducted using MATLAB/Simulink interfaced with the Texas Instruments 6713 DSK digital signal processing board. The experiments explore: i) sampling; ii) IIR filter design and its use in removing various types of noise, iii) FIR filter design and its use in building a graphic equalizer.

Contribution to Meeting the Requirements of Criterion 5. Curriculum:
This course contributes to both the engineering topics and design components.
This course introduces students to DSP design and analysis techniques that are core knowledge for DSP engineers, and which serve as solid grounding for graduate level work in DSP. Sustainability and economic issues are discussed in the context of advantages of DSP over analog signal processing, in the development of filter structures, and in efficient methods for decimation and interpolation filtering. Economic issues are also introduced via discussion of mainstream applications (e.g. CD, touch-tone phone, image and video compression) that have contributed to growth in the consumer electronics industry.

Relationship to Program Outcomes:
O.1.1. Graduates will possess mathematics skills necessary for electrical engineering.
O.1.3. Graduates will have attained computer proficiency.
O.2.3. Graduates will understand the basic concepts of linear systems and how they interact with continuous-time signals.
O.3.1. Graduates will have in-depth technical knowledge in one or more areas of specialization.
O.3.2. Graduates will have practical understanding of the major electrical engineering concepts and demonstrate application of their theoretical knowledge of the concepts.
O.4.2. Graduates will develop an appreciation of continuing educational and professional development.
O.5.1. Graduates will have good teamwork skills.
O.5.2. Graduates will possess good oral and written communication skills.
O.6. Graduates will appreciate their role as engineers in society.

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