EE 351M Digital Signal Processing

Course Details

- Objective
  - Establish a background in Digital Signal Processing Theory
- Required Text
  - Discrete-Time Signal Processing,
  - Prentice Hall, 2nd Edition
  - Alan Oppenheim, Ronald Schafer, John Buck
- Grading
  - Midterm #1: 20%
  - Midterm #2: 20%
  - Homework: 20%
  - Final: 40%
- Homework: Due to beginning of Wednesday Classes
  - Problems
  - MATLAB assignments

Useful References

- Text Books
  - DSP First A Multimedia Approach
    - James McClellan, Ronald Schafer, Mark Yoder
  - Digital Signal Processing, A Computer Science Perspective
    - Jonathan Stein
  - A Course in Digital Signal Processing
    - Boaz Porat
- Web Sites
  - Matlab Tutorial
    - http://www.utexas.edu/cc/math/tutorials/matlab6/matlab6.html

DSP is Everywhere

- Sound applications
  - Compression, enhancement, special effects, synthesis, recognition, echo cancellation,…
  - Cell Phones, MP3 Players, Movies, Dictation, Text-to-speech,…
- Communication
  - Modulation, coding, detection, equalization, echo cancellation,…
  - Cell Phones, dial-up modem, DSL modem, Satellite Receiver,…
- Automotive
  - ABS, GPS, Active Noise Cancellation, Cruise Control, Parking,…
- Medical
  - Magnetic Resonance, Tomography, Electrocardiogram,…
- Military
  - Radar, Sonar, Space photographs, remote sensing,…
- Image and Video Applications
  - DVD, JPEG, Movie special effects, video conferencing,…
- Mechanical
  - Motor control, process control, oil and mineral prospecting,…

Course Outline

- Introduction to Digital Signal Processing
- Sampling of Continuous-Time Signals
  - Periodic (Uniform) Sampling (4.1)
  - Frequency-Domain Representation of Sampling (4.2)
- Discrete-Time Signals and System
  - Discrete-Time Signals: Sequences (2.1)
  - Discrete-Time Systems (2.2)
  - Linear Time-Invariant Systems (2.3)
  - Properties of Linear Time-Invariant Systems (2.4)
  - Linear Constant-Coefficient Difference Equations (2.5)
  - Freq. Domain Representation of Discrete-Time Signals (2.6)
  - Representation of Sequences by Fourier Transforms (2.7)
  - Symmetry Properties of the Fourier Transform (2.8)
  - Fourier Transform Theorems (2.9)
  - Reconstruction of a Bandlimited Signal from Its Samples (4.3)

Course Outline

- The Z-Transform
  - Z-Transform (3.1)
  - Properties of the Region of Convergence of the z-Transform (3.2)
  - The Inverse Z-Transform (3.3)
  - Z-Transform Properties (3.4)
- Transform Analysis of Linear Time-Invariant Systems
  - The Frequency Response of LTI Systems (5.1)
  - Constant-Coefficient Difference Equations (5.2)
  - Frequency Response for Rational System Functions (5.3)
  - Relationship between Magnitude and Phase (5.4)
  - All-Pass Systems (5.5)
  - Minimum-Phase Systems (5.6)
- Filter Design Techniques
  - Design of Discrete-Time IIR Filters from Continuous-Time Filters (7.1)
  - Design of FIR Filters by Windowing (7.2)
  - Optimum Approximation of FIR Filters (7.4)

Course Outline

- Structures for Discrete-Time Systems
  - Block Diagram Representation (6.1)
  - Signal Flow Graph Representation (6.2)
  - Basic Structures for IIR Systems (6.3)
  - Transposed Forms (6.4)
  - Basic Structures for FIR Systems (6.5)
  - Finite Precision Numerical Effects (6.6)
  - Effects of Coefficient Quantization (6.7)
  - Effects of Round-Off Noise in Digital Filters (6.8)
- The Discrete-Fourier Transform
  - Discrete Fourier Series (8.1)
  - Properties of the Discrete Fourier Series (8.2)
  - The Fourier Transform of Periodic Signals (8.3)
  - Sampling the Fourier Transform (8.4)
  - The Discrete Fourier Transform (8.5)
  - Properties of the DFT (8.6)
- Computation of the Discrete-Fourier Transform

Signal Processing

- Humans are the most advanced signal processors
  - speech and pattern recognition, speech synthesis,…
- We encounter many types of signals in various applications
  - Electrical signals: voltage, current, magnetic and electric fields,…
  - Mechanical signals: velocity, force, displacement,…
  - Acoustic signals: sound, vibration,…
  - Other signals: pressure, temperature,…
- Most real-world signals are analog
  - They are continuous in time and amplitude
  - Convert to voltage or currents using sensors and transducers
- Analog circuits process these signals using
  - Resistors, Capacitors, Inductors, Amplifiers,…
- Analog signal processing examples
  - Audio processing in FM radios
  - Video processing in traditional TV sets

Limitations of Analog Signal Processing

- Accuracy limitations due to
  - Component tolerances
  - Undesired nonlinearities
- Limited repeatability due to
  - Tolerances
  - Changes in environmental conditions
    - Temperature
    - Vibration
- Sensitivity to electrical noise
- Limited dynamic range for voltage and currents
- Inflexibility to changes
- Difficulty of implementing certain operations
  - Nonlinear operations
  - Time-varying operations
- Difficulty of storing information

Digital Signal Processing

- Represent signals by a sequence of numbers
  - Sampling or analog-to-digital conversions
- Perform processing on these numbers with a digital processor
  - Digital signal processing
- Reconstruct analog signal from processed numbers
  - Reconstruction or digital-to-analog conversion

- Analog input – analog output
  - Digital recording of music
- Analog input – digital output
  - Touch tone phone dialing
- Digital input – analog output
  - Text to speech
- Digital input – digital output
  - Compression of a file on computer

Pros and Cons of Digital Signal Processing

- Pros
  - Accuracy can be controlled by choosing word length
  - Repeatable
  - Sensitivity to electrical noise is minimal
  - Dynamic range can be controlled using floating point numbers
  - Flexibility can be achieved with software implementations
  - Non-linear and time-varying operations are easier to implement
  - Digital storage is cheap
  - Digital information can be encrypted for security
  - Price/performance and reduced time-to-market
- Cons
  - Sampling causes loss of information
  - A/D and D/A requires mixed-signal hardware
  - Limited speed of processors
  - Quantization and round-off errors