EE482: Digital Signal Processing Applications

Spring 2014
TTh 14:30-15:45 CBC C222

Lecture 01
Introduction
14/01/21

http://www.ee.unlv.edu/~b1morris/ee482/
Outline

• Intro to real-time DSP
• Real-time DSP system components
• Matlab primer
Signals

• Continuous-time (CT or analog)
  ▫ Everyday signals from nature
  ▫ Defined continuously in “time” – at all time instances
  ▫ Infinite amplitude value resolution
  ▫ Can be processed using analog electronics (active and passive circuit elements)

• Discrete-time (DT)
  ▫ Only defined on particular set of “time” instances
  ▫ Sequence of numbers with continuous value range
  ▫ Used for theoretical study and mathematical convenience

• Digital
  ▫ Both discrete “time” and discrete amplitude values
  ▫ Processed with computers and DSP chips
What is DSP?

- Digital representation of signals (coding)
- Design and use of digital systems to
  - Analyze
  - Modify
  - Store
  - Transmit
  - Extract information
DSP Advantages

● Flexibility
  ▫ Software implementation for upgrades, multiple tasks, etc.

● Reproducibility
  ▫ Easier to repeat implementation, to store and transfer digital signals

● Reliability
  ▫ DSP hardware design is quite robust due to modern computation age

● Complexity
  ▫ Can implement sophisticated tasks on specialized hardware

● Cost
  ▫ Moore’s Law for semiconductors, software development cycle and powerful packages (Matlab)
DSP Disadvantages

- **Unnatural**
  - Our everyday signals come from analog processes
- **Physical limitations**
  - Bandwidth of DSP system limited by sampling rate, aliasing
- **Numerical effects**
  - Limited precision and dynamic range, quantization and arithmetic errors
Real-Time DSP Systems

• Non-real-time
  ▫ Signals that are stored in digital form
  ▫ Not necessarily for a current or real time

• Real-time
  ▫ Demands design to ensure tasks are completed within a given timeframe
  ▫ Typically expect this to be related to the current time

• Emphasis on real-time in this class
  ▫ Fun processing streaming data
  ▫ See bandwidth processing time relationship in Section 1.3.4
    • Faster processing means less available bandwidth
Real DSP System

CT Analog signal
- $x(t)$  \ $t \in \mathbb{R}$

DT/digital signal
- $x(n)$  \ $n \in \mathbb{Z}$

ADC – analog to digital conversion

DAC – digital to analog conversion

- Analog signals are converted to electrical by a transducer
  - Eg. Microphone

- Amplifier
  - Gain selected to match ADC
  - Often need auto gain control (e.g. white balance)

- Anti-aliasing filter
  - Deal with finite bandwidth of digital system

- Reconstruction filter
  - Interpolation between digital and analog signal
ADC - Sampling

- Sampling
  - \( x[n] = x(nT) \)
    - \( T \) – sampling period
  - Analog signal value extracted at fixed uniformly spaced times
- Shannon’s sampling theorem
  - \( f_s = \frac{1}{T} > 2f_M \)
  - Sampling frequency must be twice the bandwidth to avoid aliasing
  - Nyquist rate - \( f_s = 2f_M \)
ADC - Quantization

- Quantization
  - Amplitude value is represented by one of $2^B$ binary levels
  - Rounding – set value to closest quantization level
  - Truncation – replaces by value below it (chop bits)

- Quantization error/noise
  - Difference between quantized value and original value
  - Appears as random noise at output of converter
  - Signal-to-quantization-noise ration (QNR)
    - $SQNR \approx 6B$ dB

\[ SQNR \approx 6B \text{ dB} \]
Smoothing Filters

• DACs are zero-order-hold
  ▫ Keep fixed sample value until next sample

• Smoothing with low pass (LP) filter is done to remove high frequency components of “staircase”
  ▫ LP filter in reconstruction block

![Staircase waveform generated by DAC and the smoothed signal](image)
Matlab Primer

• See the web for many more tutorials and help

• Matlab has very good in program help
  ▫ Use the `help.m` and `doc.m` commands

• Go through tutorials
  ▫ Signal processing
  ▫ Image processing
Matlab Primer

- Command Window
  - Interactive interpreted area
  - The calculator space
Matlab Primer

- **Workplace**
  - Lists all variables in memory
    - All are currently available
Matlab Primer

- Editor
  - Build script files (m-files)
  - What makes Matlab so much more than a calculator

- M-files
  - Learn to write these, it will make your life much easier
  - Provides ability to document and re-run code quickly
  - Must submit for class assignments

- Note:
  - ; suppresses command window output
  - % is comment character
Matlab Primer

- Variables
  - Quick way to read contents of your workspace variables

- Useful for debugging
  - There is a debugger in Matlab!
  - Must write m-files to utilize this