Professor Brendan Morris, SEB 3216, brendan.morris@unlv.edu

# EE482: Digital Signal Processing Applications

Introduction

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

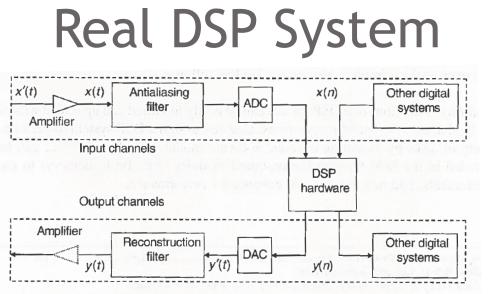
- Flexibility
  - Software implementation for upgrades, multiple tasks, etc.
- Reproducibility
  - Easier to repeat implementation, to store and transfer digital signals
- Reliability
  - DSP hardware design is quite robust due to modern computation age
- Complexity
  - Can implement sophisticated tasks on specialized hardware
- Cost
  - Moore's Law for semiconductors, software development cycle and powerful packages (Matlab)

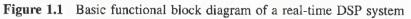
## **DSP** Disadvantages

- 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

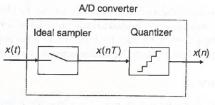


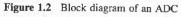


- CT Analog signal
  - x(t)  $t \in \mathbb{R}$
- DT/digital signal
  - x(n)  $n \in \mathbb{Z}$
- ADC analog to digital conversion
- DAC digital to analog conversion

- 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)
- Antialiasing 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 - 
$$f_n = 2f_M$$

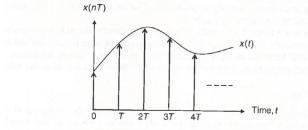
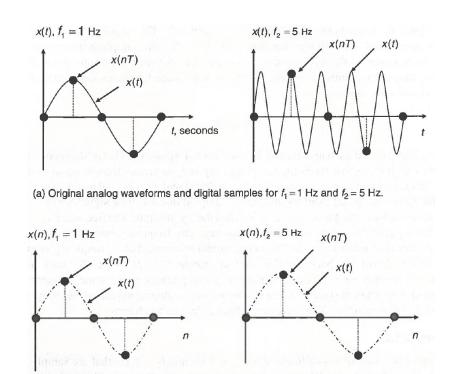


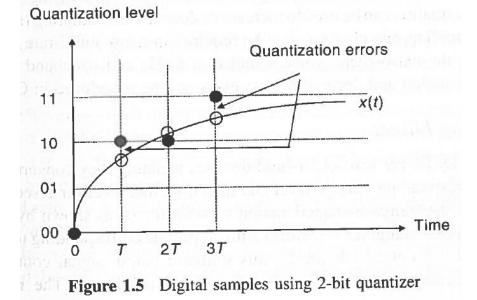
Figure 1.3 Sampling of analog signal x(t) and the corresponding discrete-time signal x(nT)



(b) Digital samples of  $f_1 = 1$  Hz and  $f_2 = 5$  Hz and the reconstructed waveforms.

# ADC - Quantization

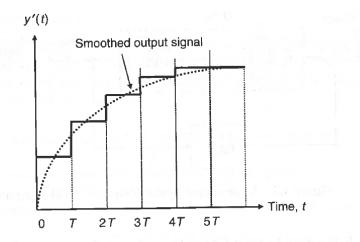
- Quantization
  - Amplitude value is represented by one of 2<sup>B</sup> binary levels
  - Rounding set value to closest quantization level
  - Truncation replaces by value below it (chop bits)
- Quantization error/noise
  - Difference between quantized value and original value
  - Appears as random noise at output of converter
  - Signal-to-quantization-noise ration(QNR)
    - $SQNR \approx 6B \text{ dB}$

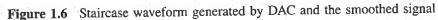


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# **Smoothing Filters**

- 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





- See the web for many more tutorials and help
  - <u>https://matlabacademy.mathworks.com/</u>
- Matlab has very good in program help
  Use the help.m and doc.m commands
- Go through tutorials
  - Signal processing
  - Image processing

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- Workplace
  - Lists all variables in memory
    - All Are currently available

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- 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

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- 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