

EE482: Digital Signal Processing Applications

Spring 2014

TTh 14:30-15:45 CBC C222

Lecture 01

Introduction

14/01/21

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

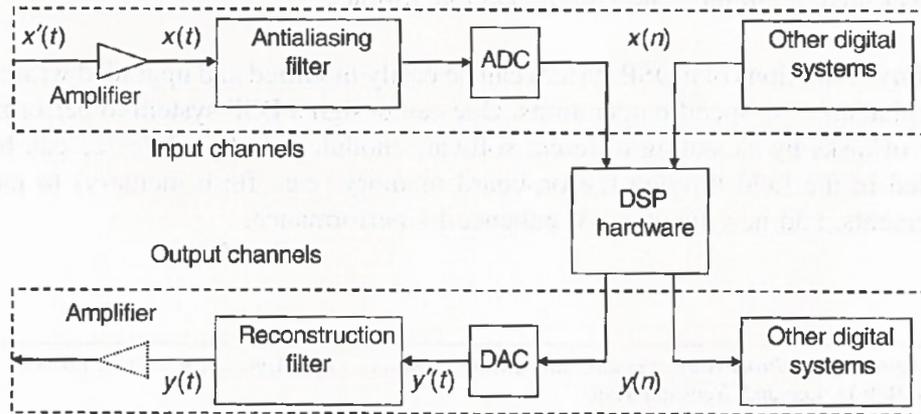


Figure 1.1 Basic functional block diagram of a real-time DSP system

- CT Analog signal
 - $x(t) \quad t \in \mathbb{R}$
- DT/digital signal
 - $x(n) \quad n \in \mathbb{Z}$
- ADC – analog to digital conversion
- DAC – digital to analog conversion
- 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
- Analog signals are converted to electrical by a transducer
 - Eg. Microphone

ADC - Sampling

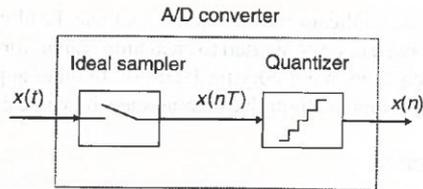


Figure 1.2 Block diagram of an ADC

- 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 - $f_s = 2f_M$

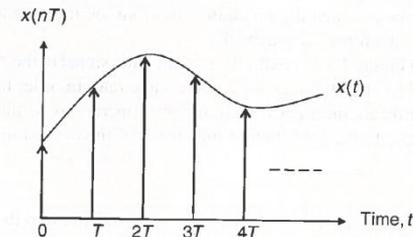
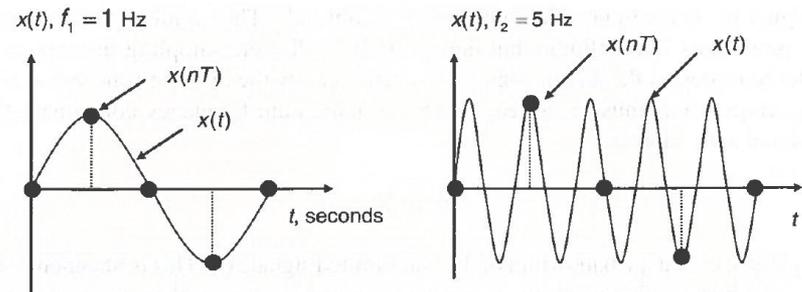
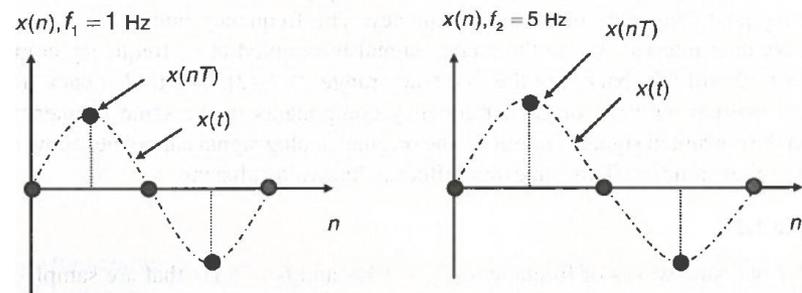


Figure 1.3 Sampling of analog signal $x(t)$ and the corresponding discrete-time signal $x(nT)$



(a) Original analog waveforms and digital samples for $f_1 = 1$ Hz and $f_2 = 5$ Hz.



(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^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 ratio(QNR)
 - $SQNR \approx 6B$ dB

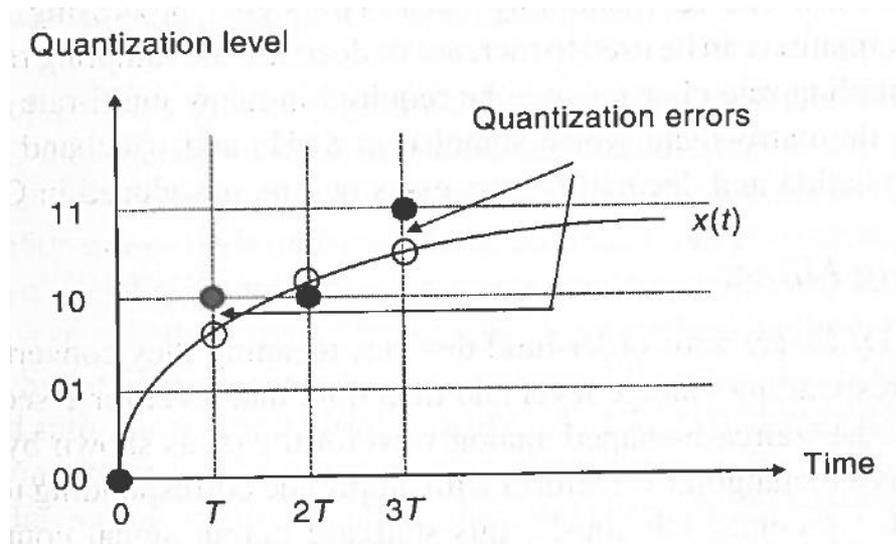


Figure 1.5 Digital samples using 2-bit quantizer

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

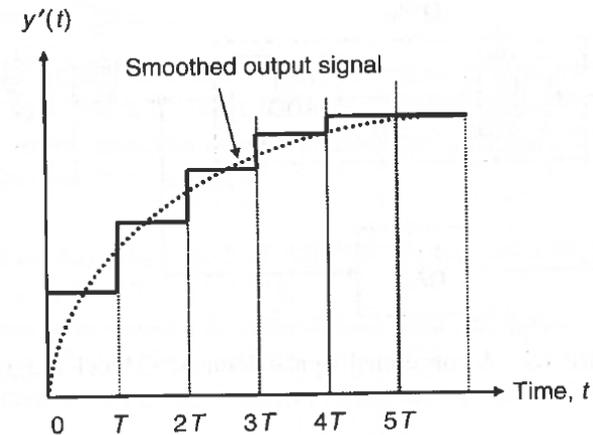
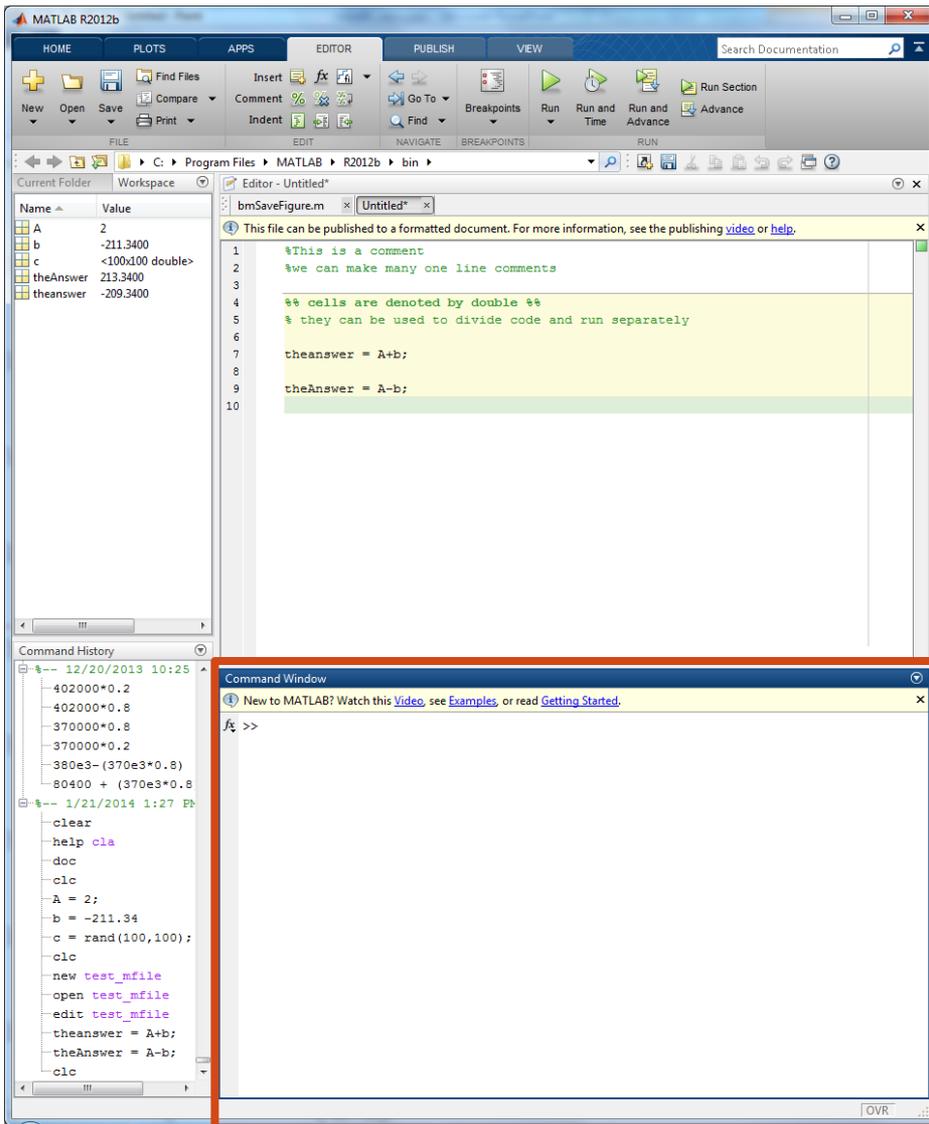


Figure 1.6 Staircase waveform generated by DAC and the smoothed signal

Matlab Primer

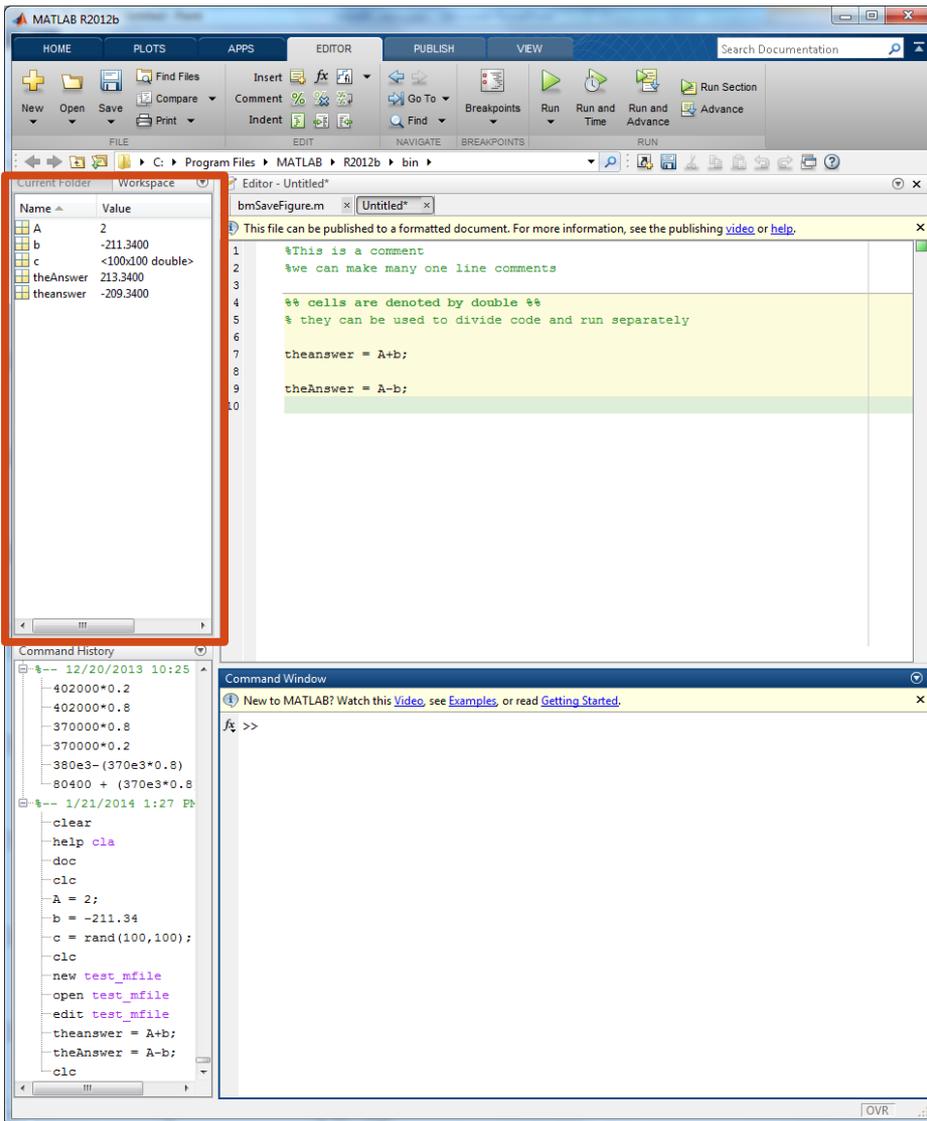
- See the web for many more tutorials and help
 - http://www.mathworks.com/academia/student_center/tutorials/
- Matlab has very good in program help
 - Use the `help.m` and `doc.m` commands
- Go through tutorials
 - Signal processing
 - Image processing

Matlab Primer



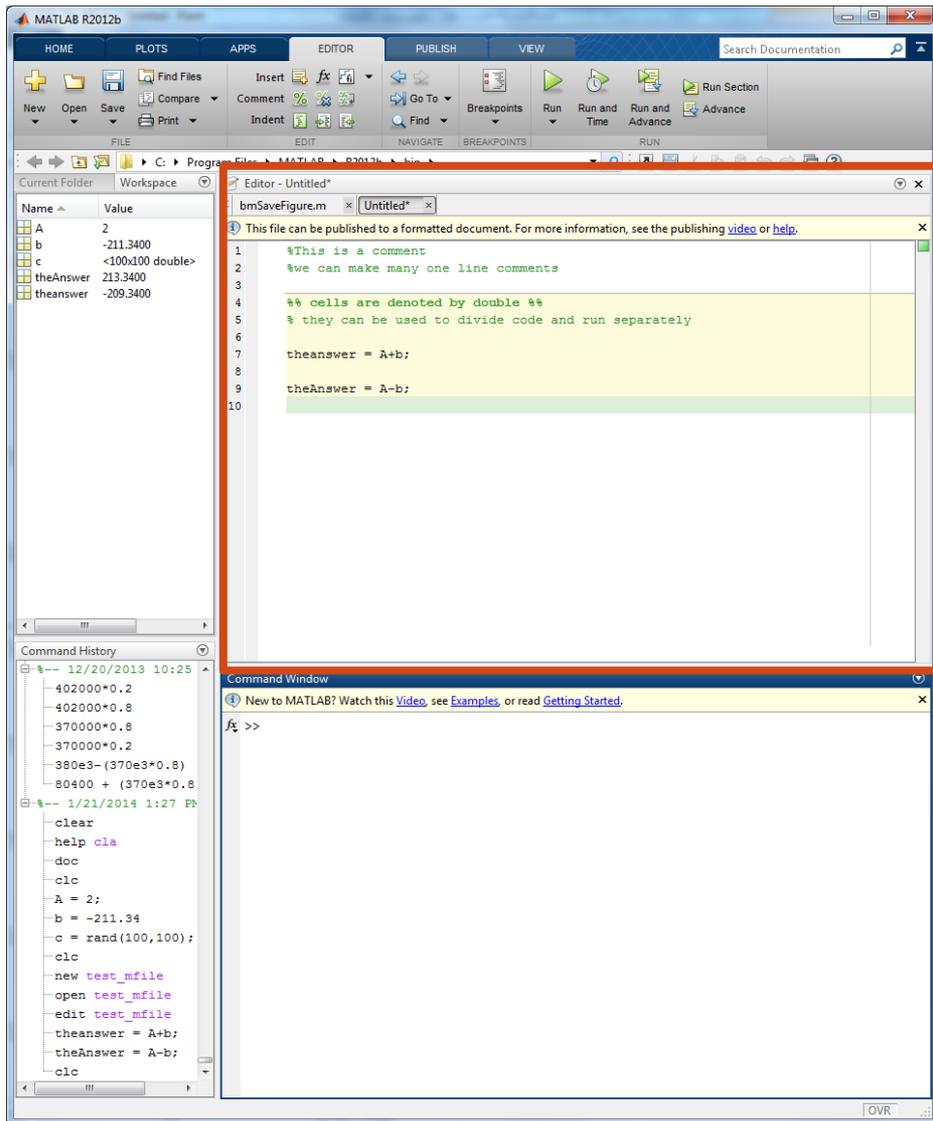
- Command Window
 - Interactive interpreted area
 - The calculator space

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

The screenshot shows the MATLAB R2012b environment. The workspace on the left contains variables: A (2), b (-211.3400), c (<100x100 double>), theAnswer (213.3400), and theanswer (-209.3400). The 'Variables - c' window is open, showing a 20x9 matrix of double values. The Command History window shows the following commands:

```

12/20/2013 10:25
> 402000*0.2
> 402000*0.8
> 370000*0.8
> 370000*0.2
> 380e3-(370e3*0.8)
> 80400+(370e3*0.8)
1/21/2014 1:27 PM
> clear
> help cla
> doc
> clc
> A = 2;
> b = -211.34
> c = rand(100,100);
> clc
> new test_mfile
> open test_mfile
> edit test_mfile
> theanswer = A+b;
> theAnswer = A-b;
> clc
  
```

- 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