



EE482/682: DSP APPLICATIONS

INTRODUCTION



OUTLINE

- Intro to 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 in modern computation age
- Complexity
 - Can implement sophisticated tasks on specialized hardware
- Cost
 - Moore's Law for semiconductors, software development cycle and powerful packages (e.g. Matlab, Python)

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 current or real-time data
- 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

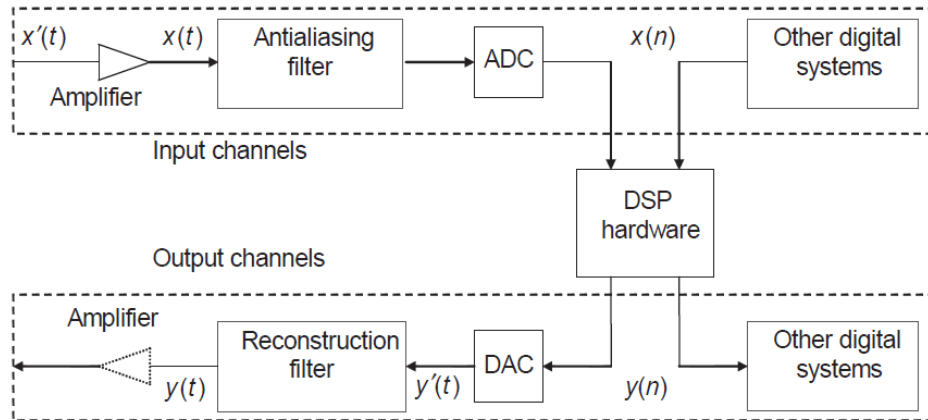


Figure 1.1 Basic functional block diagram of a real-time DSP system

- 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
- Analog signals are converted to electrical by a transducer
 - E.g. 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

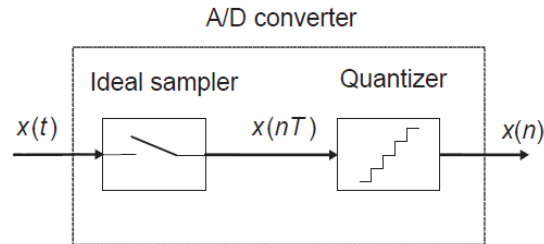


Figure 1.2 Block diagram of an ADC

- 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 - $f_n = 2f_M$

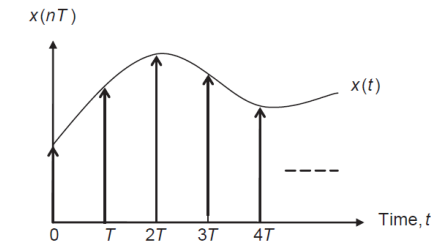
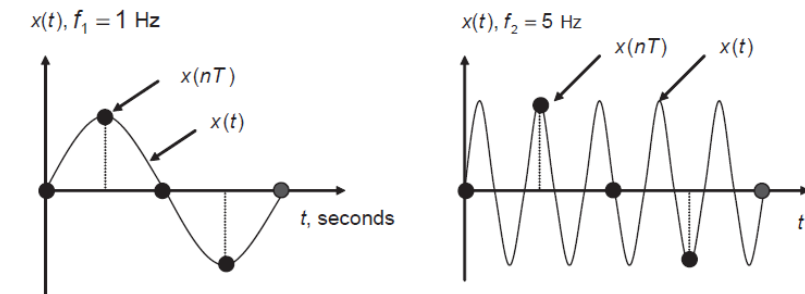
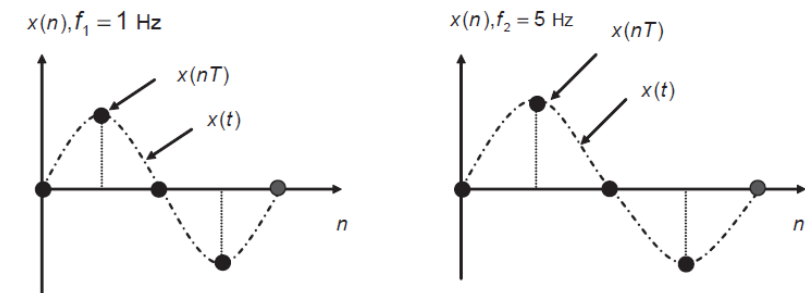


Figure 1.3 Sampling of analog signal $x(t)$ and the corresponding discrete-time signal $x(nT)$



(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.

Figure 1.4 Example of the aliasing phenomenon

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)
 - $SQNR \approx 6B \text{ dB}$

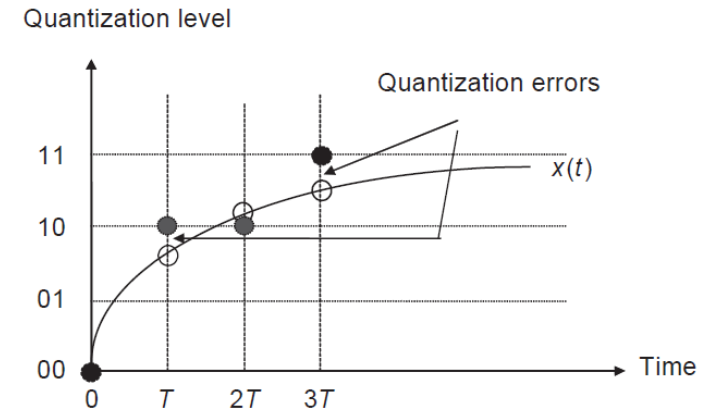


Figure 1.5 Digital samples using 2-bit quantizer

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

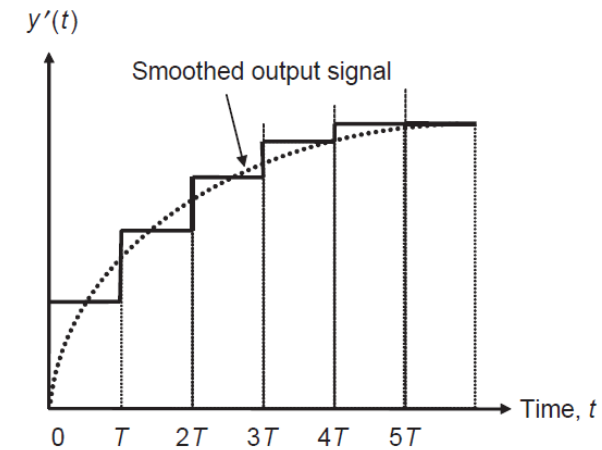
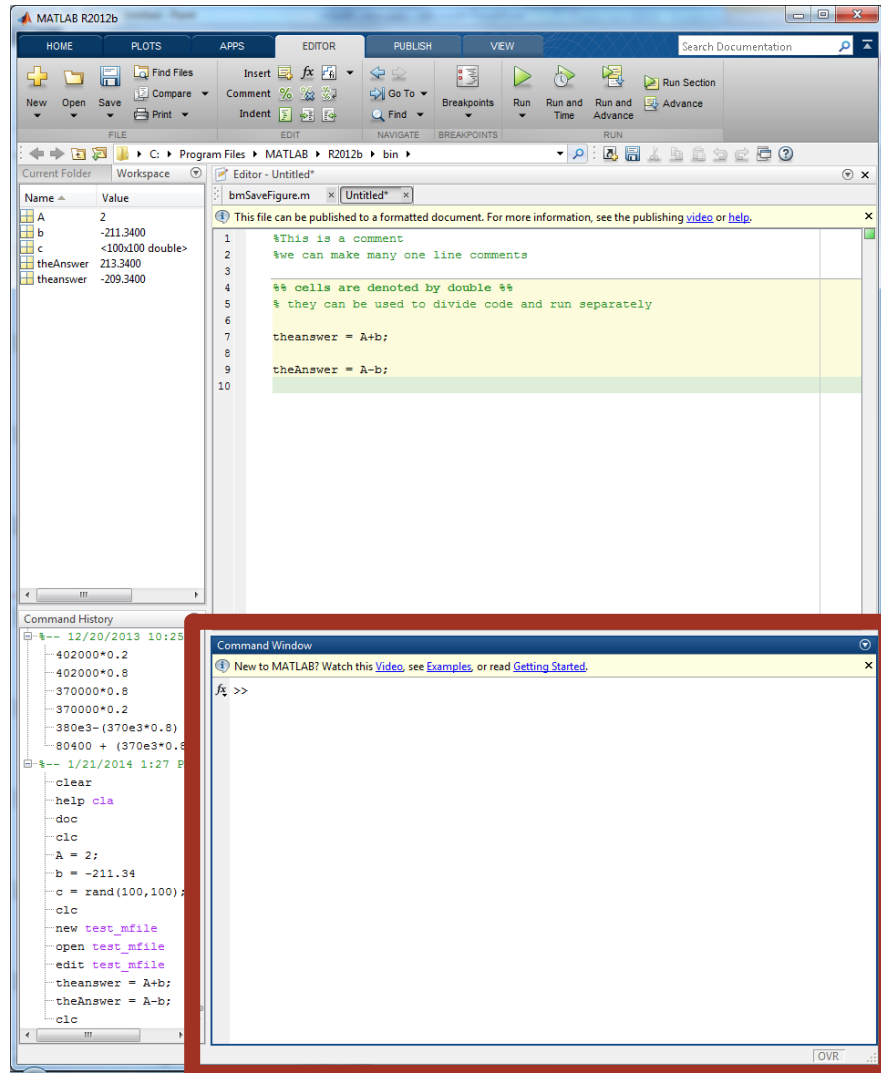


Figure 1.6 Staircase waveform generated by DAC and the smoothed signal

MATLAB PRIMER

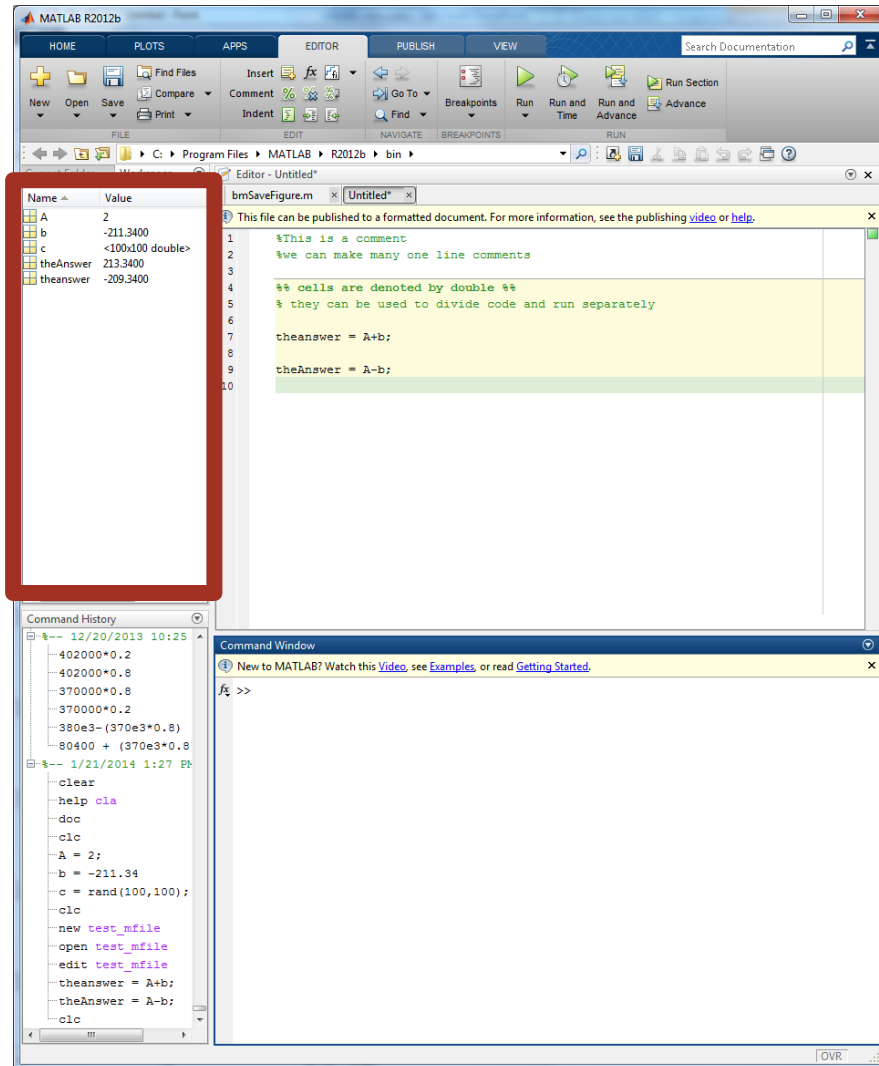
- See the web for many tutorials and help
 - <https://matlabacademy.mathworks.com/>
- Matlab has very good in program help
 - Use the help.m and doc.m commands
- Go through tutorials
 - Signal processing
 - Image processing

MATLAB PRIMER



- Command Window
 - Interactive interpreted area
 - The calculator space

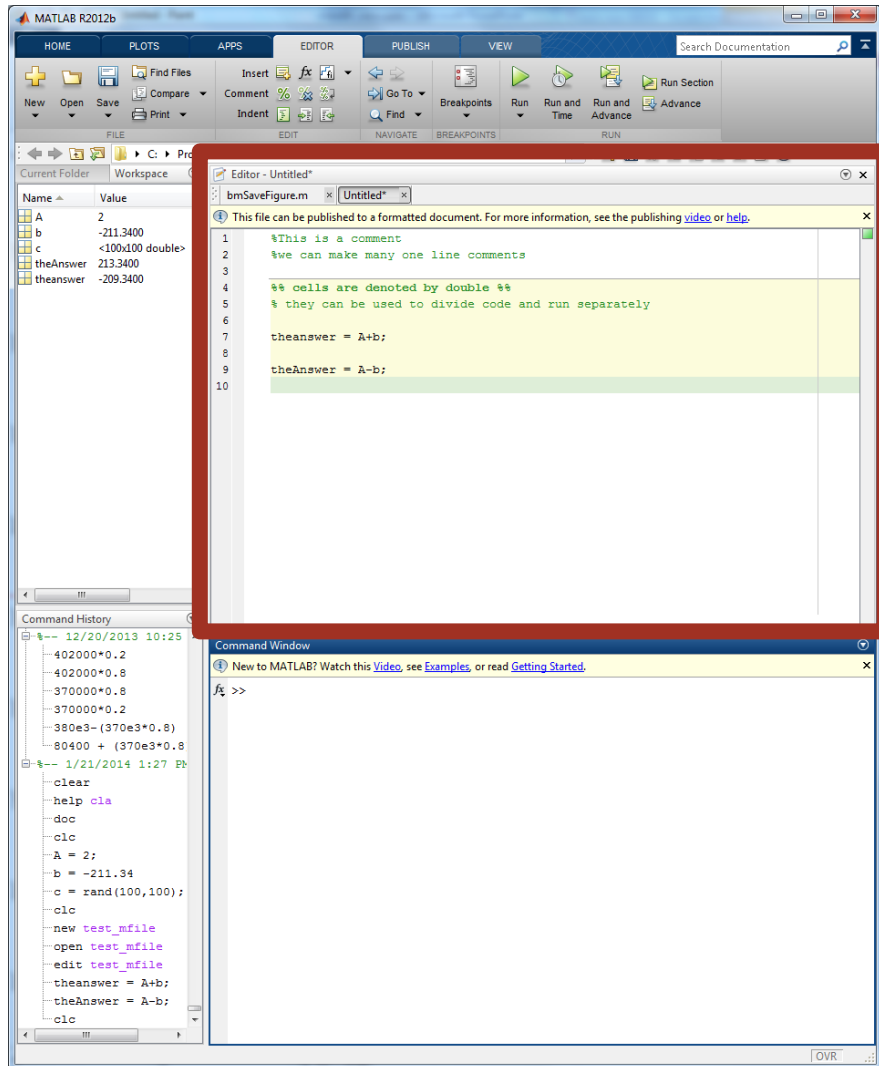
MATLAB PRIMER



■ Workspace

- 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

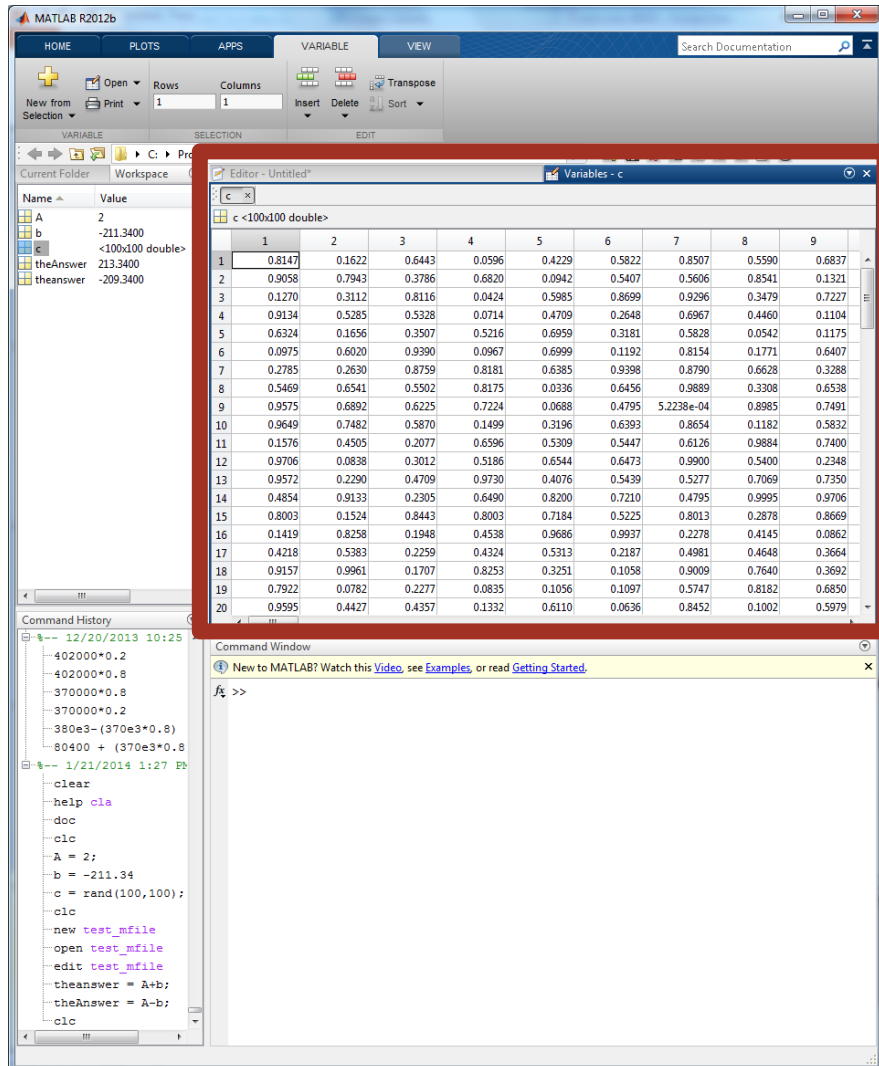
■ M-files

- 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!
 - Use the keyboard shortcuts (F5 run, shift-F5 stop, F10 step, F11 step-in)
 - Must write m-files to utilize this
- Ctrl+c to kill running code