# Digital Signal Processing (DSP)

## Lecture 0
## Introduction to Digital Signal Processing

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# Course Topics

- Introduction to DSP and its applications
- Discrete Signals and their properties
- Discrete-Time Systems and their representations and properties
- Linear Time Invariant Systems (LTI) and their properties
- LTI system representation and realizations
- *Z*-Transform and its properties
- Relation between *Z*-Transform and Laplace transform
- LTI Discrete-Time Systems in the Z-Domain and Frequency domain
- Discrete-Time Fourier Transform
- Discrete-Time Fourier Series
- Introduction to digital filters
- Digital Filter Structures and realizations
- Design of IIR and FIR Digital Filters

# Course Reference Book

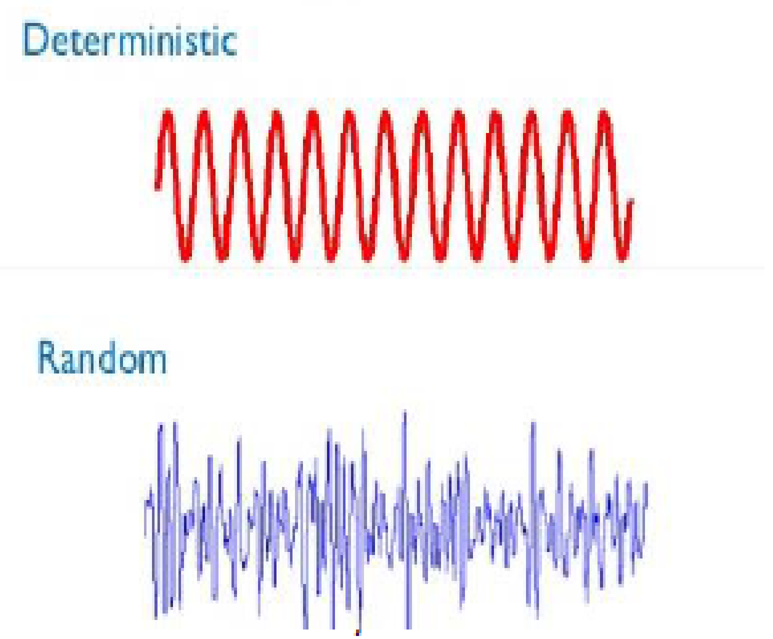
Proakis, D. Manolakis “Digital Signal Processing, 4th Edition” Pearson, 2014.

# Grading

| | |
|---|---|
| Final Exam | 50 |
| Mid-Term Exams | 30 |
| Year Work (Attendance, Assignments, Projects) | 20 |
| Total | 100 |

# What is Digital Signal Processing (DSP)*?

- **Digital:** operating by the use of discrete signals to represent data in the form of numbers
- **Signal:** a parameter (electrical quantity or effect) that can be varied in such a way as to convey information (deterministic vs. random)
- **Processing:** a series operations performed on the signal according to programmer instructions

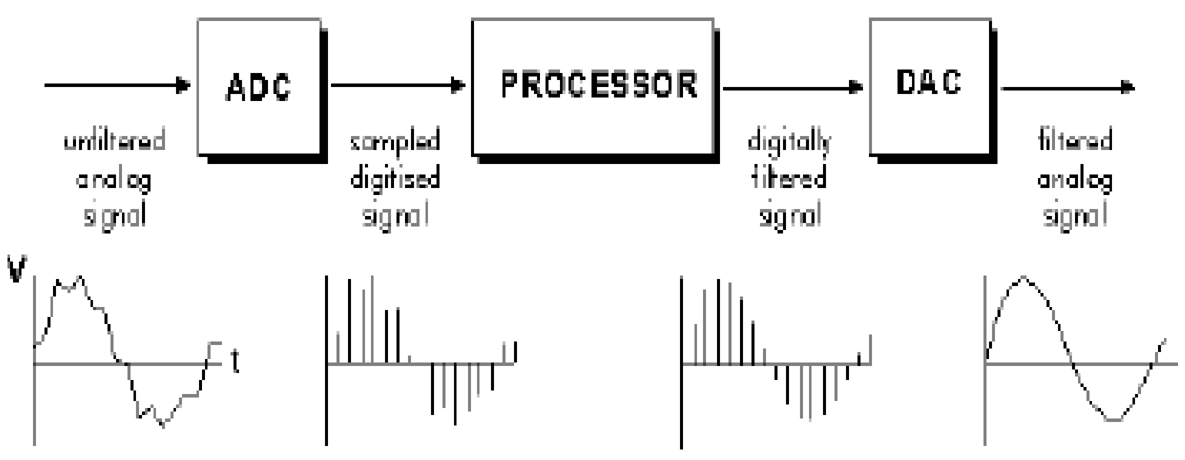



**DSP:** Changing (filtering) or analyzing information which is measured as discrete sequence of numbers

# Signal Filtering

Produces a new desired signal

- To **remove noise or interference** in the signal of interest
- To make the signal **more perceptually pleasing** to human beings




Courtesy of image to: http://www.cs.indiana.edu/~port/teach/541/sig.proc.html

A DSP System used for signal filtering

# Signal Analysis

- To learn and extract information about the input signal

Courtesy of image to: http://www.nhs.uk/Conditions/EEG/Pages/Introduction.aspx

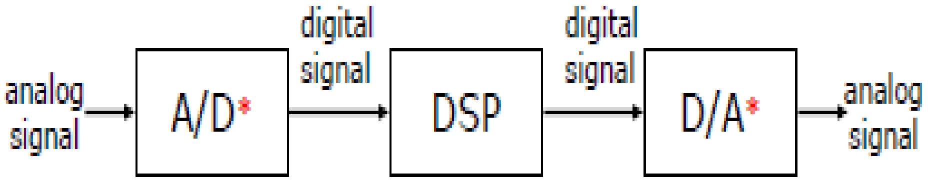
Electroencephalogram (EEG) signal can be analyzed to extract information that can help to:

- Diagnose number of brain lesions and localize the region of brain from which a seizure originates

# Limitations of Analog Signal Processing

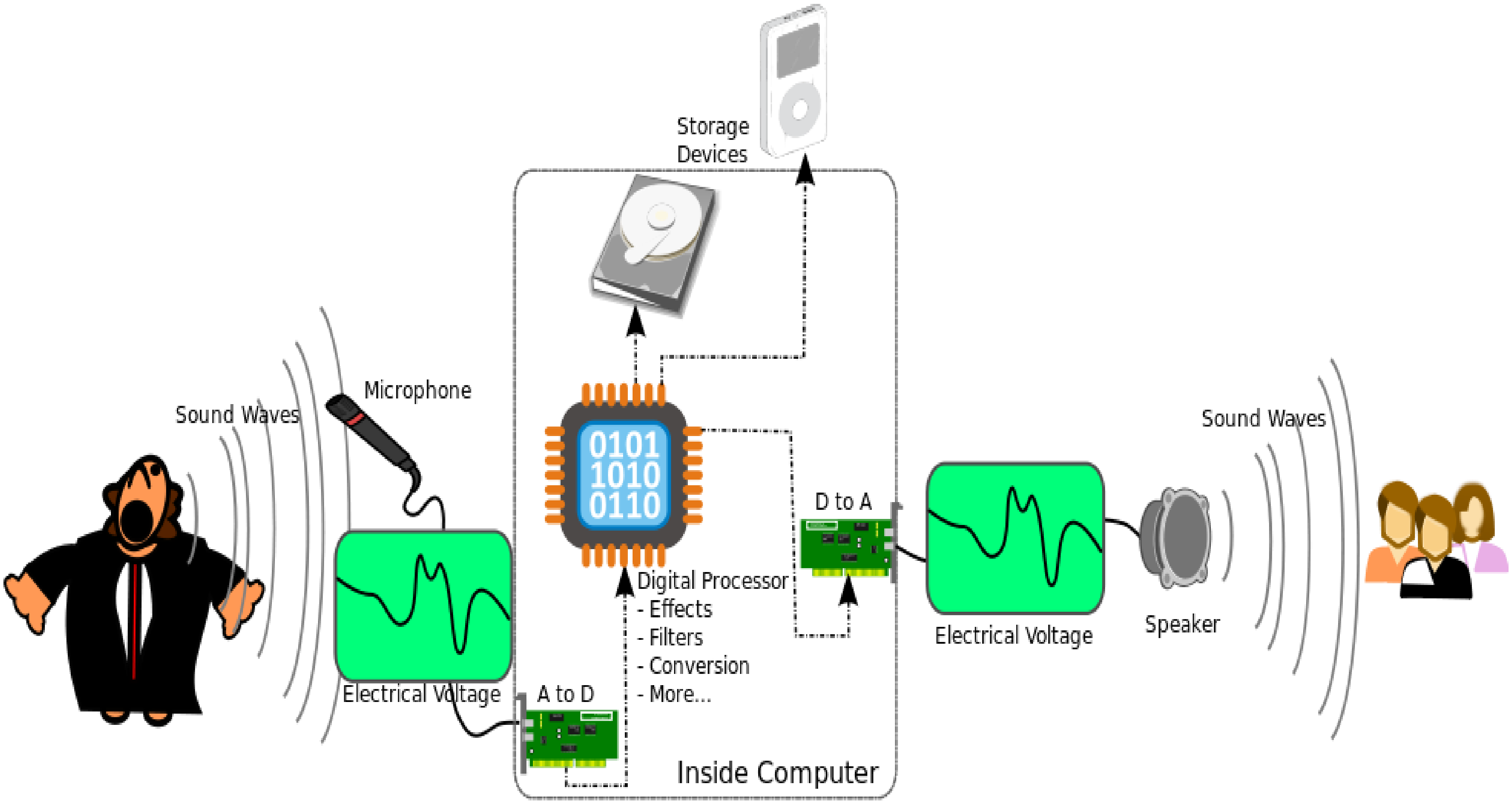

- Accuracy limitations due to
  - Component tolerances
  - Undesired nonlinearities
- Limited repeatability due to
  - Tolerances
  - Changes in environmental conditions (Temperature, Vibration)
- Sensitivity to electrical noise
- Limited dynamic range for voltage and currents
- Inflexibility to changes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

# A General Block Diagram of A DSP System



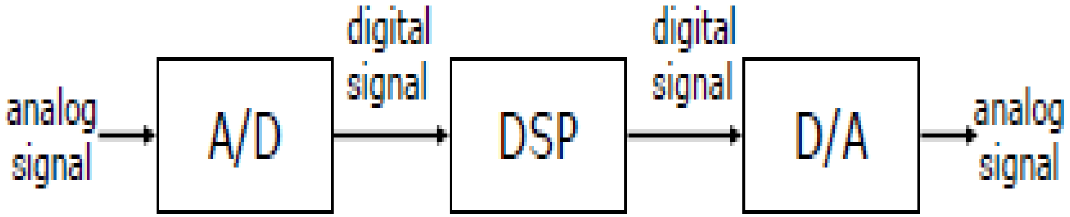

- Analog to digital (A/D) converter
- Digital Signal Processor (DSP)
- Digital to analog (D/A) converter

# Example



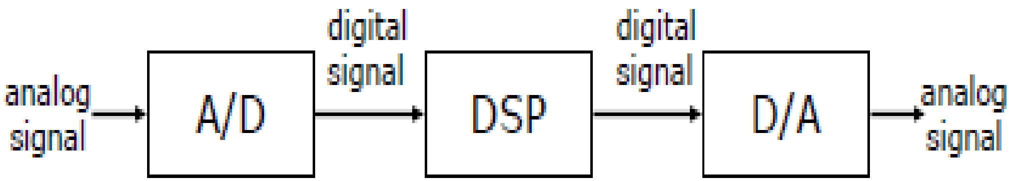
Storage
Devices
Sound Waves
Microphone
0101
1010
0110
Digital Processor
- Effects
- Filters
- Conversion
- More...
D to A
A to D
Electrical Voltage
Inside Computer
Electrical Voltage
Speaker
Sound Waves

# Disadvantages of DSP systems




- A/D and D/A blocks add complexity to the system and requires mixed-signal hardware
- Sampling and quantization causes loss of information
- Speed is limited by the clock frequency of the processors

# Advantages of DSP




- Accuracy can be controlled by choosing word length
- Reproducibility of signals
  - Sensitivity to electrical noise is minimal
  - Easy to reconstruct signals at receiver
- Dynamic range can be controlled using floating point numbers
- Flexibility can be achieved with software or programmable hardware implementations
- Real time applications can be achieved in hardware/ optimized software
- Single chip implementation (systems on chip)
- Newly introduced functions can be developed
  - Non-linear and Time-varying operations
  - Adaptive filters
  - Mixed A/D signal processing
  - Multi-rate DSP
- Ease of multiplexing
- Modularity through usage of standard digital circuits/software algorithms
- Digital storage is cheap
- Digital information can be encrypted for security
- Price/performance and reduced time-to-market

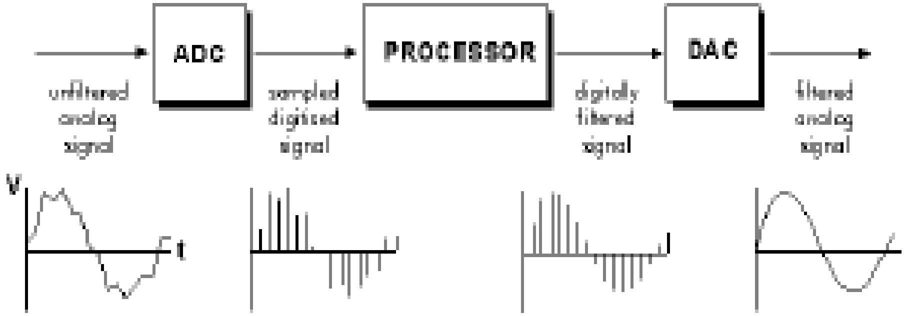
# DSP Applications*: Biomedical

- Analysis of biomedical signals, diagnosis, patient monitoring, and artificial organs monitoring
- **Example:** Electrocardiogram (ECG) provides information about the heart


Courtesy of image to:
http://www.lifebreath.org/diagnostic-testing/resting-ecg

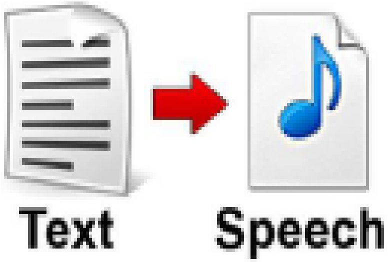
# DSP Applications: Speech Applications

- Noise reduction




- Speech recognition


- Text to speech systems



# DSP Applications: Communications

- Digital communication systems
  - VOIP, digital telephone

- Encoding and decoding information
  - Error correction and Encryption

# DSP Applications: Image Processing

- Image Enhancement

- Compression: JPEG uses Discrete-Cosine Transform (similar to Fourier Transform)

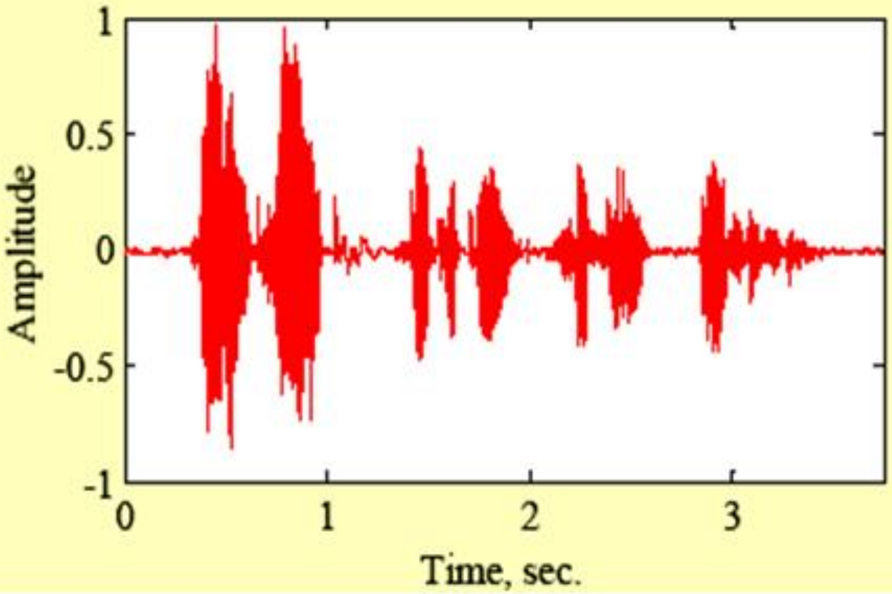
43K

13K

3.5K

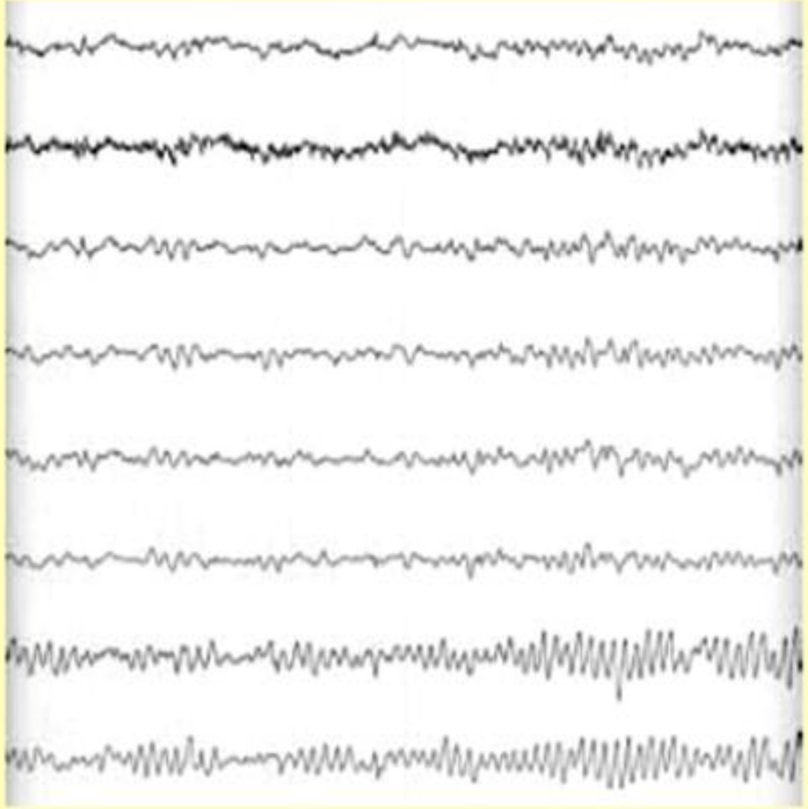
# Examples of Typical Signals

- **Speech and music signals** - Represent air pressure as a function of time at a point in space
- Waveform of the speech signal "I like digital signal processing" is shown below




- **Electrocardiography (ECG) Signal** - Represents the electrical activity of the heart
- A typical ECG signal is shown below

- **Electroencephalogram (EEG) Signals** - Represent the electrical activity caused by the random firings of billions of neurons in the brain



- Black-and-white picture - Represents light intensity as a function of two spatial coordinates

$I(x,y)$

- Video signals - Consists of a sequence of images, called frames, and is a function of 3 variables: 2 spatial coordinates and time


Frame 1


Frame 3


Frame 5


Video

Click on the video

# Classifications of Signals

**There are 5 main classifications of signals:**

1- The signal can be continuous x(t) or discrete x(n) based on the nature of the independent variables : (n= 0, ±1, ± 2, ….) for discrete and (…< t <…) for continuous.

This course will be focused on discrete time signals x(n), where n= 0, ±1, ± 2, ….

2- The signal can be either a real valued function or a complex-valued function.

3- The signal can be either

scalar signal :generated by single source

**or**

multi-channel signal (vector signal) :generated by multiple sources

4- The signal can be either
One-Dimensional (1-D) : function of a single independent variable
**or**
Multi-Dimensional (M-D): function of more than one independent variable

**Examples:**

- Speech signal is 1- D
- Image signal is 2-D (the 2 independent variables are the 2 spatial variables)

Note: A color image signal is composed of three 2-D signals representing the three primary colors: Red, Green, and Blue (RGB)

5- The signal can be either
Deterministic: can be uniquely determined by a mathematical expression or rule or table
**or**
Random: can not be predicted ahead of time)