

---

*In the name of Allah*

---

*the compassionate, the merciful*

---

# Signals & Systems

---

S. Kasaei

Sharif University of Technology

Room: CE 307

E-Mail: [skasaei@sharif.edu](mailto:skasaei@sharif.edu)

Home Page: <http://ce.sharif.edu>

<http://ipl.sharif.edu>

<http://sharif.edu/~skasaei>

---

# Course Syllabus

---

---

# Course Syllabus

- Lecture:  
Sundays & Tuesdays, 9:30-10:30, EE 8.

- Website:

<http://ce.sharif.edu/courses/85-86/1/ce242/>

Check this site often for important *announcements*, files needed for *computer exercises*, and the PDF versions of *handouts & homework*.

- Course Description:  
40-242 provides an introduction to signals & systems *fundamental principles & techniques*.

---

# Course Syllabus

- Topics include:  
Linear time-invariant systems, Fourier series representation of periodic signals, continuous-time Fourier transform, discrete-time Fourier transform, time & frequency characterization of signals & systems, sampling, Laplace transform, and Z transform.
- Prerequisites:  
Engineering Mathematical (22-035),  
Electrical Circuits (40-121).

---

# Course Syllabus

- Text Book:

1. *Signals & Systems*, by Alan V. Oppenheim & Alan S. Willsky, with H. Nawab, Prentice-Hall, 2<sup>nd</sup> Edition, 1997 (translated by Mr. Dayyani).  
[Additional topics might be included.]

2. *Digital Signal Processing*, by John G. Proakis & Dimitris G. Manolakis, Prentice-Hall, 3<sup>rd</sup> Edition, 1996.

- Written & Computer Exercises:

Written homework problems and computer exercises will be assigned over the course.

---

# Course Syllabus

- Exams:

There will be one *midterm* and one *final term exam*.

- Grading Policy:

Written & computer exercises: 3+2=5 pts.

Quiz: 2 pts. (1 pt. each)

Midterm exam: 4 pts. (hold at: 1385.8.30)

Final exam: 10 pts. (hold at: 1385.10.24, 14:30)

Class activities (participation, constructive questions, advanced problems): 2 pts.

Total: 23 pts.

---

# Course Syllabus

- Instructor Office Hour:  
*Sundays, 16:30-17:30, Room CE 307.*
- Teaching Assistants:  
*R. Dianat, N. Amini, H. Tajik & M. Khorramzadeh*
- Course E-Mail: [ce242@list.ce.sharif.edu](mailto:ce242@list.ce.sharif.edu)

---

Introduction  
to  
Signal & Systems

---

---

# Introduction

- Concept of signals & systems arise in a wide variety of fields including: communications, circuit design, acoustic, biomedical engineering, speech/image/video processing, ICT, and the forth.
- A signal represents the changes of a physical phenomenon (quantity) as a function of independent variables (usually time).
- In other words, a signal is a function of one or more independent variables that contains information about behavior (or nature) of some phenomenon.

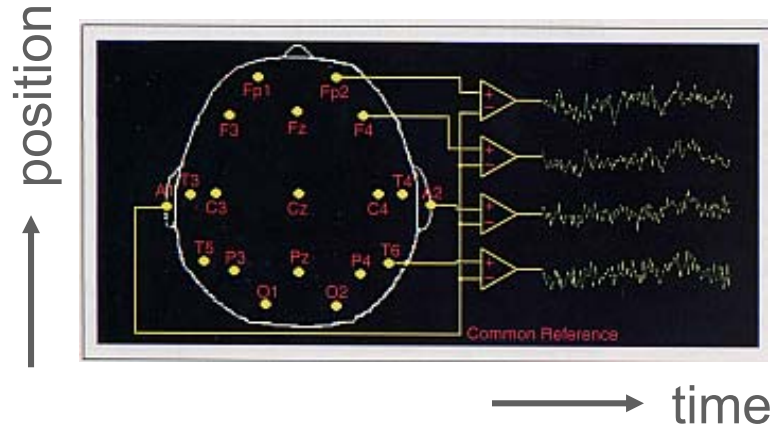
---

# Introduction

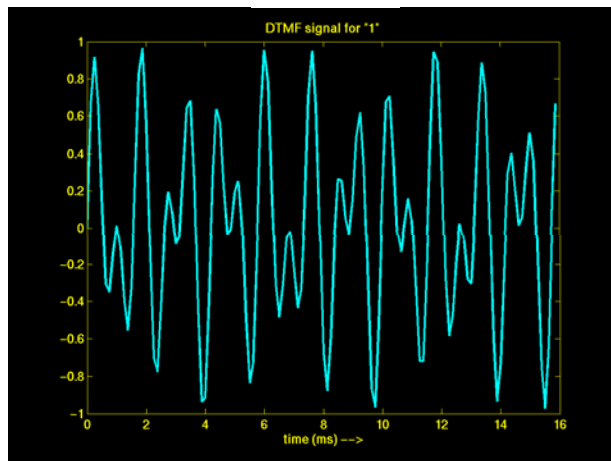
- Examples include speech, music, seismic, image, & video.
- A signal can be a function of one, two, or  $N$  independent variables.
  - **Speech** is a 1-D signal, as a function of **time**.
  - **Image** is a 2-D signal, as a function of **space**.
  - **Video** is a 3-D signal, as a function of **space & time**.

# Introduction

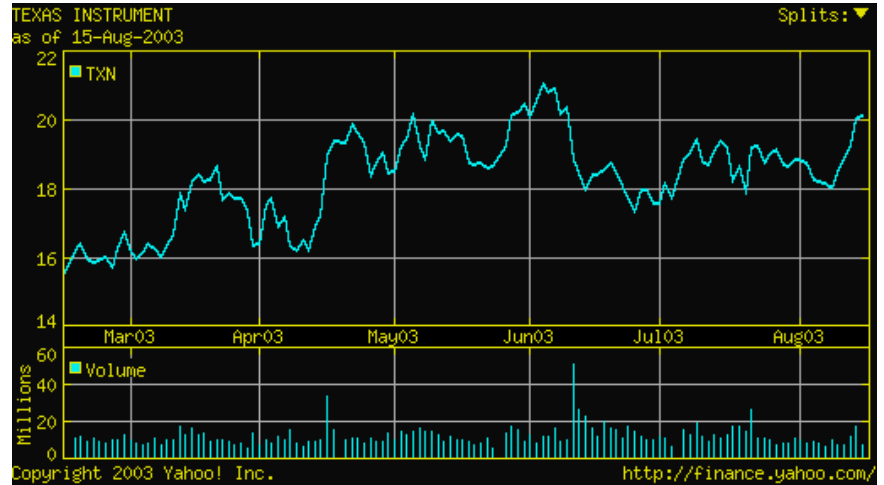
EEG



DTMF



Stock price & volume



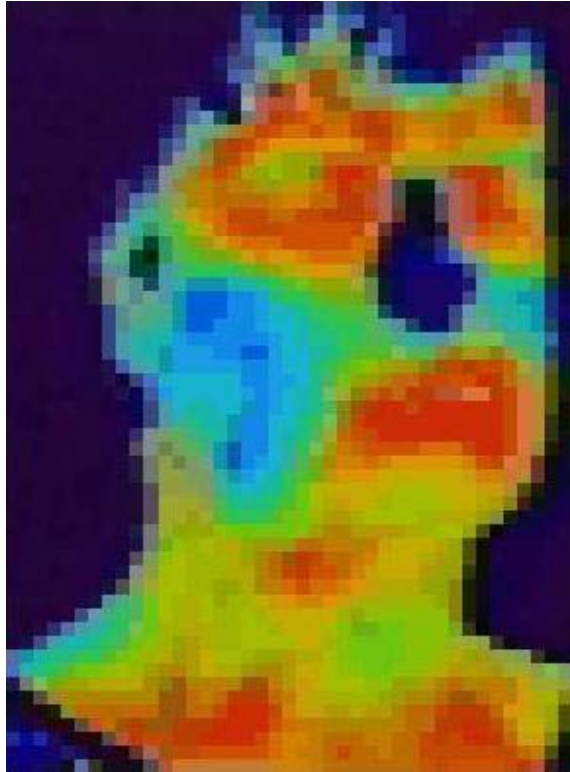
Video



time

time

# Introduction



Infrared image.



Angiography image.

---

# Introduction

- A system is defined as a physical device that performs an operation on a signal.
- A physical system in the broadest sense is an interconnection of components, devices, or sub-systems (e.g., automobile, human body).
- A system not only includes physical devices, but also software realizations of operations on a signal.

# Introduction

- System responds to a particular signal by producing another signal (or some desired behavior).



- When we pass a signal through a system, we say that we have processed the signal.
- A system can be viewed as a process in which the input signal is transformed by the system (or causes the system to respond in some way), resulting in other signal as the system output.

---

# Introduction

- Voltage & current (as a function of time) in an electrical circuit are examples of signals.
- A circuit is an example of a system; which responds to applied voltage & current.
- When an automobile driver depresses the accelerator pedal, the automobile responds by increasing the speed  
[system: automobile, input: pressure on the accelerator pedal, response: automobile speed].

---

# Introduction

- **System:** computer program, **input:** digitized signal, **respond:** output signal/description.
- **System:** camera, **input:** light from different sources & reflected from objects, **respond:** photograph.
- **System:** robot arm, **input:** control inputs, **respond:** arm's movement.
- The **method** (or set of rules) for implementing the **system** by a program, is called an **algorithm**.

---

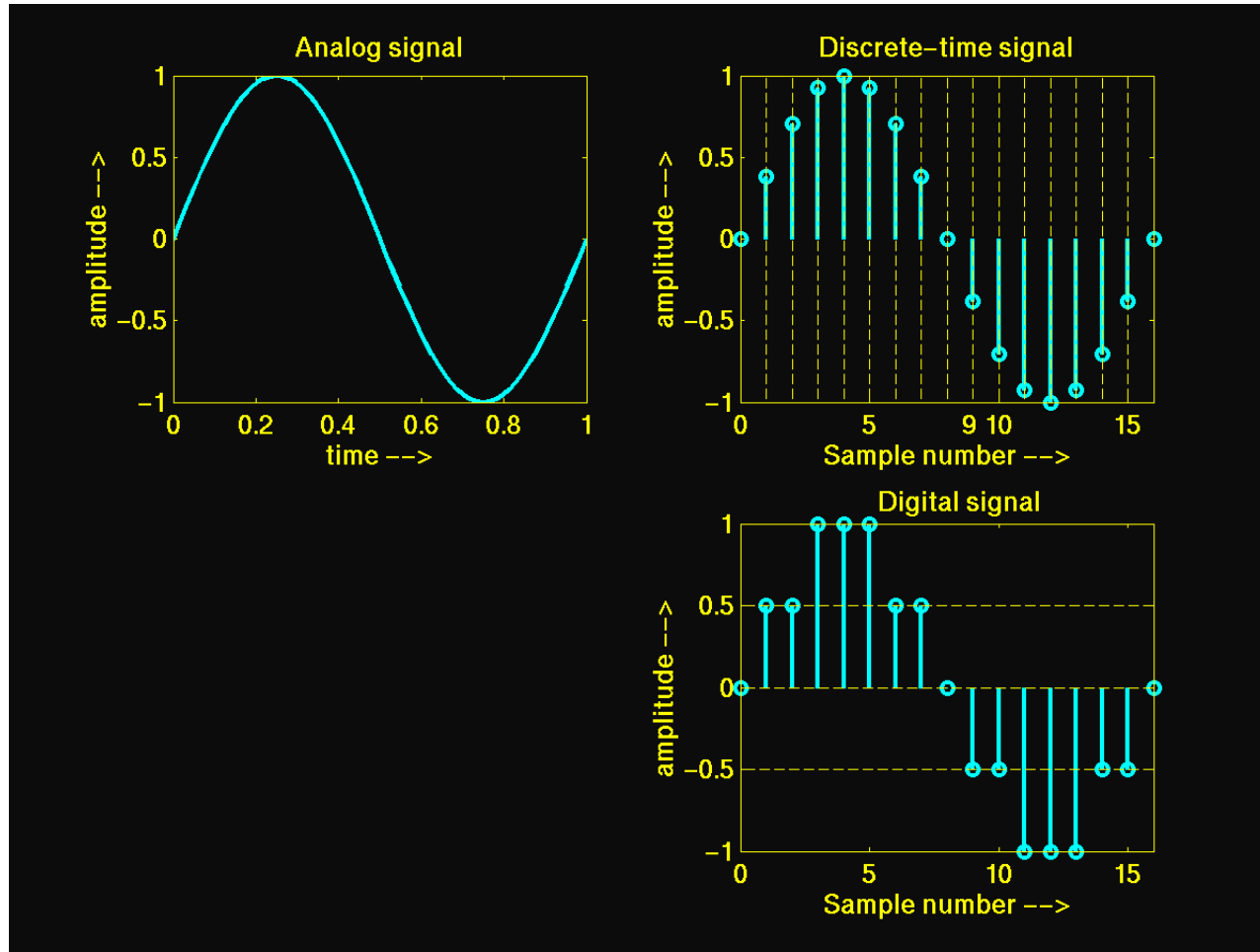
# Introduction

- We might be interested in:
  1. Characterizing a presented system to understand how it will respond to various inputs [circuit analysis].
  2. Designing a system to process signals in particular way [image restoration & compression].
  3. Extracting specific pieces of information from signals [future behavior prediction, classification, description].
  4. Controlling the characteristics of a given system [control system design].

# Introduction

- Information in a signal is contained in a pattern of variations in some form.
- Signals can be classified into four different categories depending on the characteristics of independent variables (time) & values they take, as:
  1. Continuous-time [e.g. speech] (& continuous-valued → analog signal),
  2. Discrete-time [e.g. daily average temperature],
  3. Continuous-valued,
  4. Discrete-valued (& discrete-time → digital signal).

# Introduction



---

# Introduction

- Mathematical analysis & processing of signals requires the availability of a mathematical description for the signal, called the signal model.
- Continuous & discrete signals can be of random or deterministic type.
- Any signal that can be uniquely described by an explicit mathematical expression, a table of data, or a well-defined rule is called deterministic.

---

# Introduction

- **Deterministic** term is used to emphasize that **all** past, present, & future values of the signal are **known precisely**, without any uncertainty.
- In **practice**, there are signals that either cannot be described to any reasonable degree of **accuracy** by explicit mathematical **formulas**, or such a description is **too complicated** to be of any practical use.
- Such signals **evolve** in time in an **unpredictable** manner & are referred to as **random** signals.

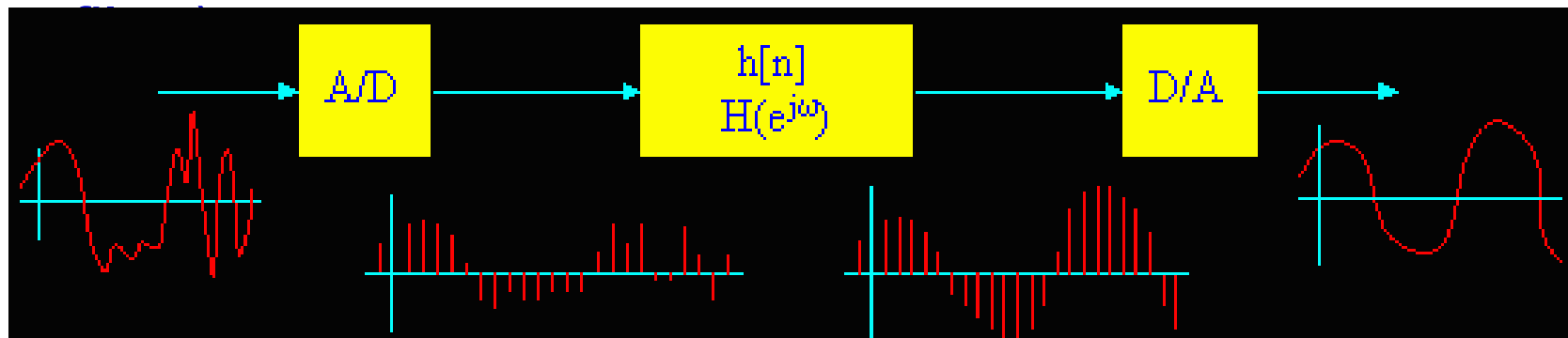
---

# Introduction

- This provides motivation for the analysis & description of random signals using statistical techniques instead of explicit formulas.
- The mathematical framework for the theoretical analysis of random signals is provided by the theory of probability & stochastic processes.
- In general, signal & system analysis is constantly evolving & developing in response to new problems, techniques, & opportunities.

# Typical DSP System Components

- **Input** the analog low-pass filtered signal (anti-aliasing filter).
- Analog-to-digital converter (**ADC**).
- Digital computer or digital signal processor (**DSP**).
- Digital-to-analog converter (**DAC**).
- **Output** the low-pass filtered signal (anti-imaging filter).



---

# DSP System Components

- Analog input signal is filtered to be a band-limited signal by an input low-pass filter.
- Signal is then sampled & quantized by an ADC.
- Digital signal is processed by a digital circuit, often a computer or a digital signal processor.
- Processed digital signal is then converted back to an analog signal by a DAC.
- The resulting step waveform is converted to a smooth signal by a reconstruction filter called an anti-imaging filter.

---

# Advantages of DSP

## ■ **Versatility**

- ❑ Digital systems can be **reprogrammed** for other applications.
- ❑ Digital systems can be ported to **different hardwares**.

## ■ **Repeatability & stability**

- ❑ Digital systems can be **easily duplicated**.
- ❑ Digital systems do not depend on strict **component tolerances**.
- ❑ Digital systems' responses do not **drift with temperature**.

---

# Advantages of DSP (contd)

## ■ **Simplicity**

- ❑ Some processes can be done more **easily** digitally than with analog systems (e.g., linear-phase filters).
- ❑ **Security** can be introduced by encryption/scrambling.
- ❑ Digital signals can be easily **stored** (on different types of media) without deterioration.

---

# Applications of DSP

## ■ **Speech Processing**

- ❑ Noise filtering
- ❑ Coding (Compression)
- ❑ Recognition
- ❑ Synthesis
- ❑ Sampling rate changes

## ■ **Music**

- ❑ Recording, playback, & manipulation (mixing, special effects)
- ❑ Synthesis

---

# Applications of DSP

## ■ Image Processing

- ❑ Enhancement/Restoration
- ❑ Coding (compression)
- ❑ Pattern recognition
- ❑ Object tracking
- ❑ Retrieval

## ■ Multimedia

- ❑ Transmission of sound, still images, motion pictures
- ❑ Digital TV
- ❑ Video conferencing

---

# Applications of DSP

## ■ **Communication**

- ❑ Encoding & decoding of digital communication signals
- ❑ Detection
- ❑ Equalization
- ❑ Filtering
- ❑ Direction finding
- ❑ Echo cancellation

## ■ **Radar & Sonar**

- ❑ Target detection, position, & velocity estimation
- ❑ Tracking

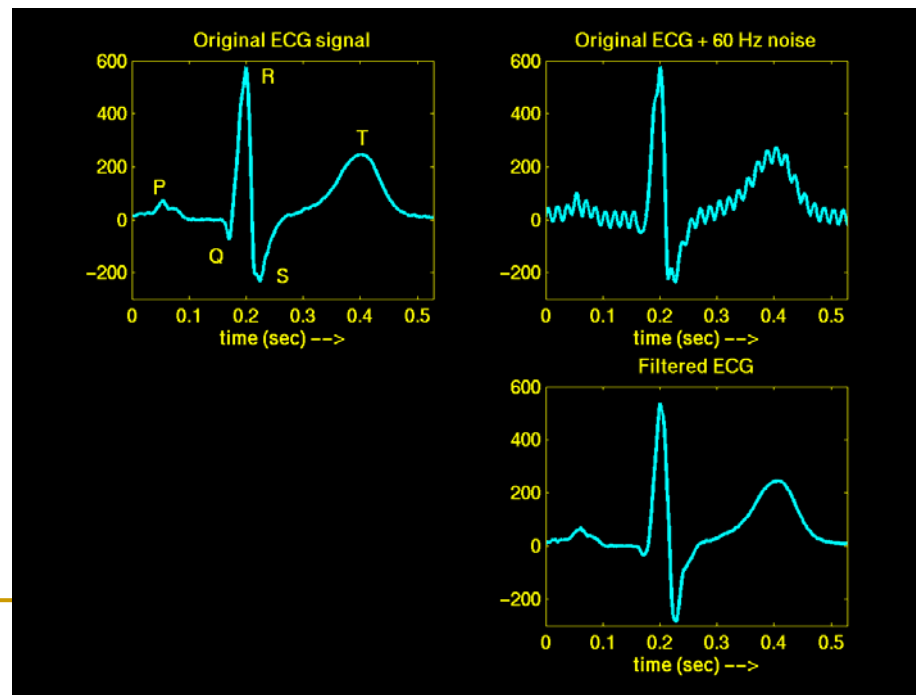
---

# Applications of DSP

- **Biomedical Engineering**
  - ❑ Analysis of biomedical signals
  - ❑ Diagnosis
  - ❑ Patient monitoring
  - ❑ Preventive health care
  - ❑ Artificial organs

# Filtering Example

- Signals are usually a mix of “useful” information & noise.
- How do we extract the useful information?
  - Filtering is one way.



---

# Useful Links

- For a good tool to exercise the concepts thought in each chapter refer to:
  - Johns Hopkins University:  
<http://www.jhu.edu/~signals/index.html>

---

*The End*

