Remote Sensing Laboratory
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Digital Signal Processing
Lecture 1

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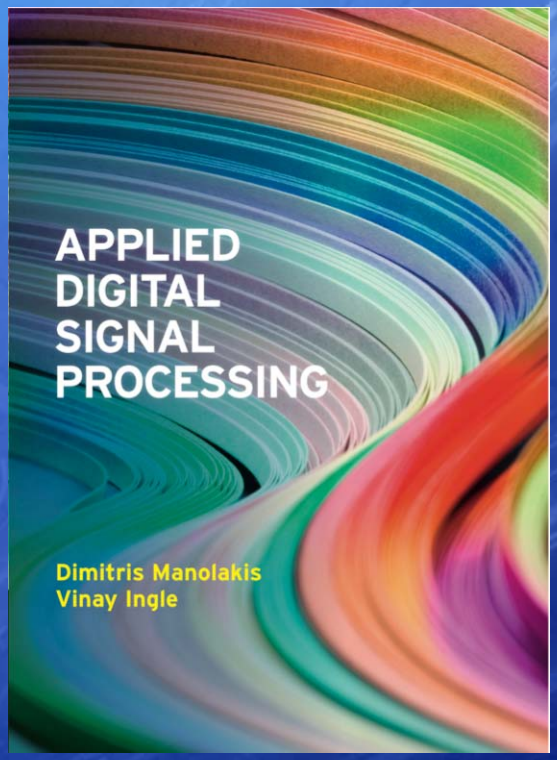
Course Textbook



Dimitris G. Manolakis and Vinay K. Ingle

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General Information

- ✓ Book suggestions:
  - Sanjit K. Mitra: *Digital Signal Processing: A Computer-Based Approach*, 4/e, University of California - Santa Barbara, McGraw-Hill Education, 2011.
  - Oppenheim and Schafer: *Discrete-Time Signal Processing, Prentice Hall Signal Processing.*
  - *Textbook: "The Scientist and Engineer's Guide to Digital Signal Processing", California Technical Publishing.*

- ✓ Grading: A written exam and an exam in PC lab by the use of Matlab The grade will be broken down as follows:
  1-A written exam: 80%
  2-An exam in the PC lab: 20%
- ✓ Web page of the lecture:
  http://rslab.disi.unitn.it/ (then go to the teaching page) or
  http://http://rslab-tech.disi.unitn.it/moodle/course/view.php?id=8

- ✓ Office hours: Monday 14.00-15.00 & Friday 14.00-15.00

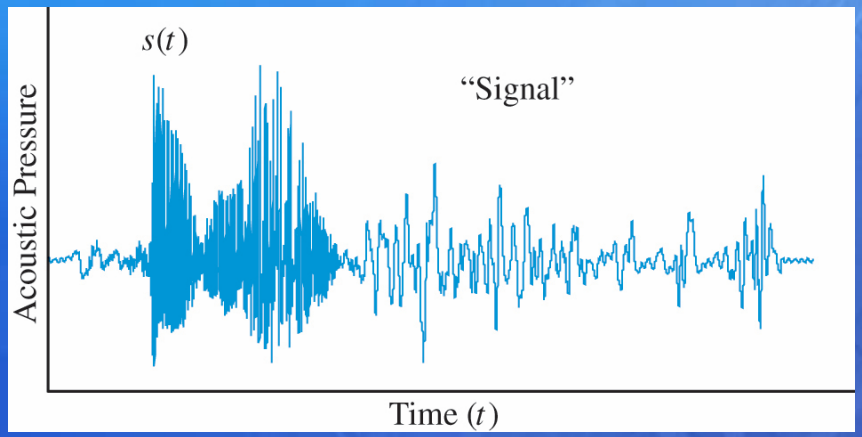
Content of the Lecture

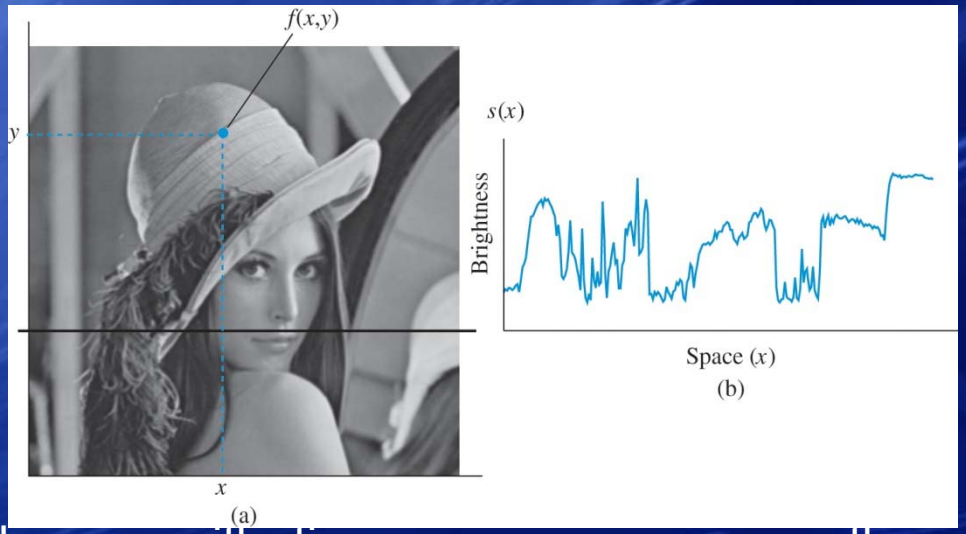
- ✓ Introduction to Digital Signal Processing
- ✓ Discrete Time Signals (characterization and classification of discrete time signals and elementary operations on them)
- ✓ Discrete Time Systems (classification of discrete time systems, analysis of discrete-time linear time-invariant systems, discrete-time systems described by difference equations) ---Lab1
- ✓ Frequency Analysis of Signals and Systems (discrete time Fourier transform, discrete Fourier transform, fast Fourier transform)--- Lab2
- ✓ Z-Transform Analysis of Signals and Systems (definition and properties of the z-transform, transfer function) --- Lab3
- ✓ Digital Filters Design (FIR digital filters- Lab4, IIR digital filters- Lab5)
- ✓ Lab 6: Speech recognition

What is Signal?

- ✓ A signal is a function of independent variables such as time, distance, position and temperature. Signals convey information in their patterns of variation.
- ✓ The manipulation of information carried by signals involves the acquisition, storage, transmission, and transformation of signals.
  - Speech signals - Characterize air pressure as a function of time at a point in space;
  - Electrocardiography signals-Characterize the electrical activity of the heart;
  - Seismic signals-Produced by the movement of rocks due to an earthquake, a volcanic eruption, or an underground explosion.
  - Video signals -Involves a sequence of images, called frames, and is a function of 3 variables: 2 spatial coordinates and time.

What is Signal?





Signals are physical quantities which vary with time, space, or some other variable(s) and convey information in their patterns of variation. They are mathematically represented by functions.

In this lecture, we will focus on a function of a single variable.

Types of Signals

- ✓ Types of Signals:
  - Natural (such as thunderstorm, lightening) and Synthetic (can be generated in the laboratory) Signals;
  - Continues Time or Discrete Time Signals;
  - Analog and Digital Signals;
  - Periodic and Non-Periodic Signals;
  - Energy and Power Signals;
  - Random and Deterministic Signals.

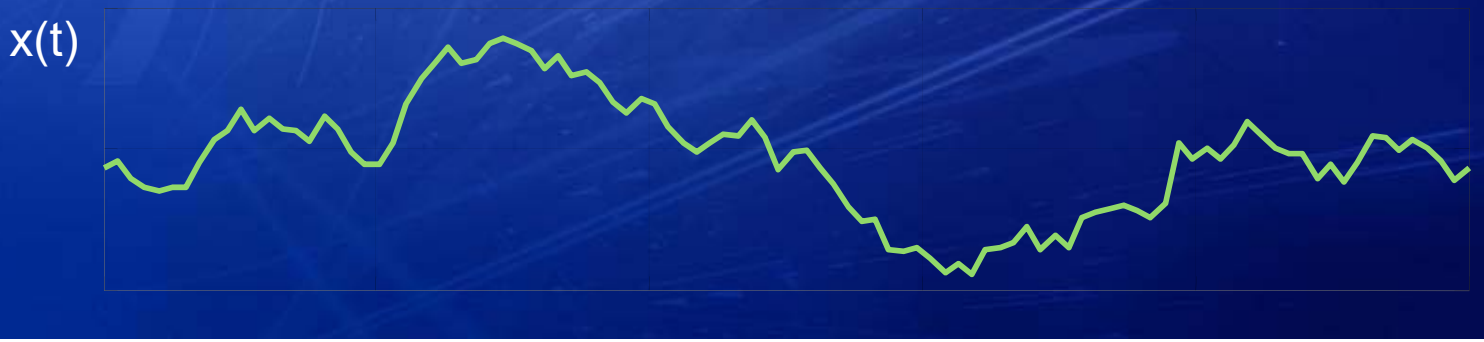
Continues Time Signals

Continues Time Signals :

✓ Continuous time signal is a signal that exists at every value of time t, e.g., voltage, velocity.

✓ The independent variable is a continuous variable. The amplitude of a continues-time signal may take any value from a continues range of real numbers.

✓ Continues time signals are also known as analog signals because their amplitude is analogous, i,.e., that is proportional to the physical quantity they represent.



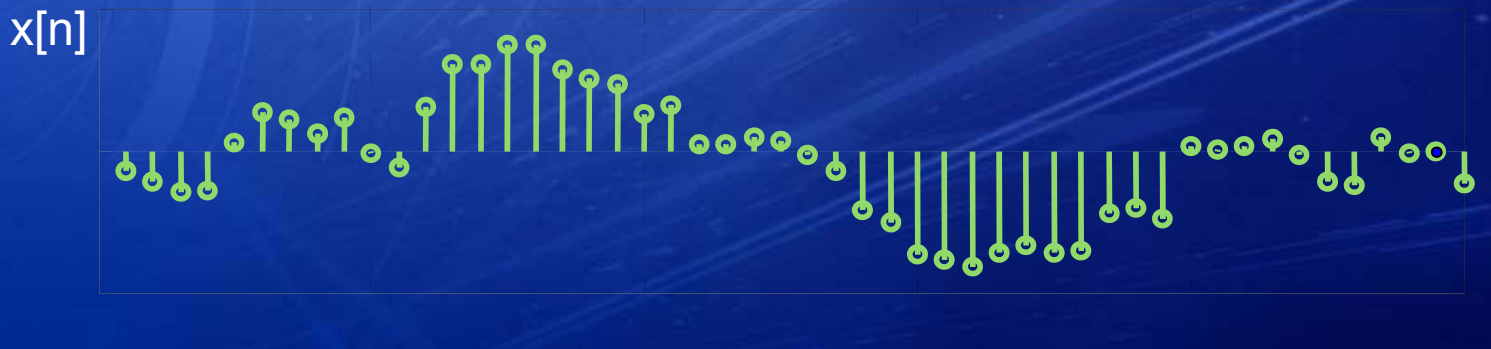
Discrete Time Signals

Discrete Time Signals :

- ✓ Discrete time signals is a signal defined only for discrete values of time, e.g. pixels, daily stock price.

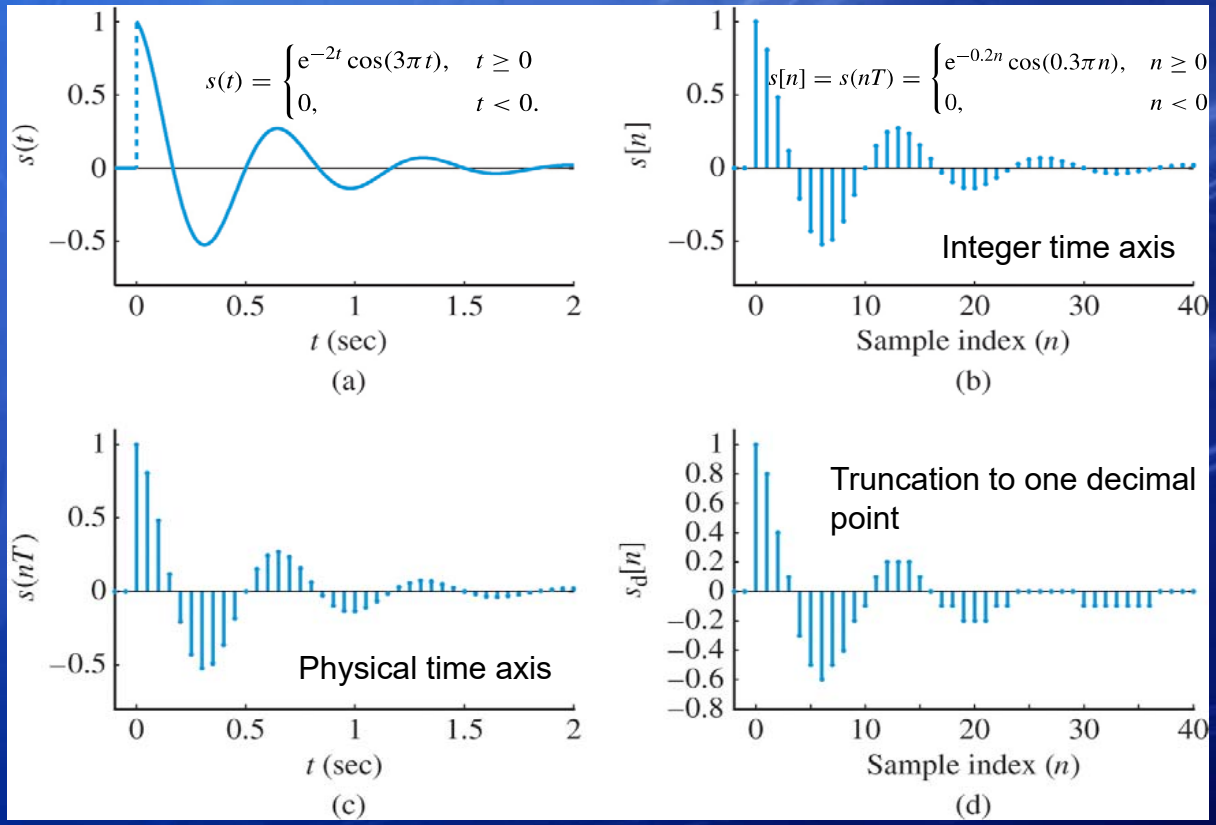
- ✓ It is denoted by x[n], where n is an integer value that varies discretely.

- ✓ A discrete time signal whose amplitude takes values from a finite set of real numbers is known as a digital signal. All signals stored on a computer or displayed on a computer screen are digital signals.



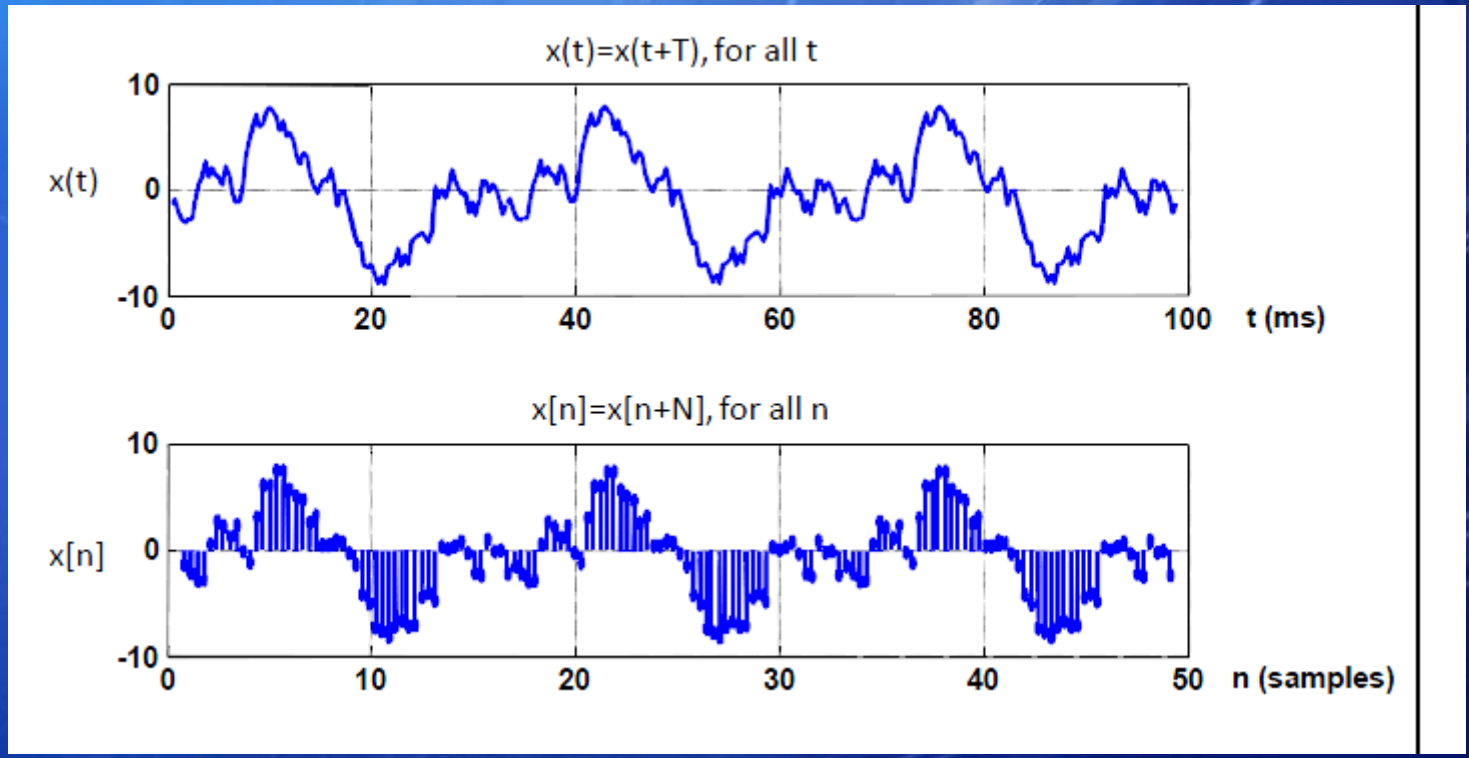
Analog/Digital Signals

- ✓ Continues/Discrete Time Signals:
  - All continues time signals are also analog signals.
  - If the amplitude and independent variable are both discretized, the signal is digital.



a)continues time signals; b) and c) discrete-time signals, d) digital signals

Periodic Signals



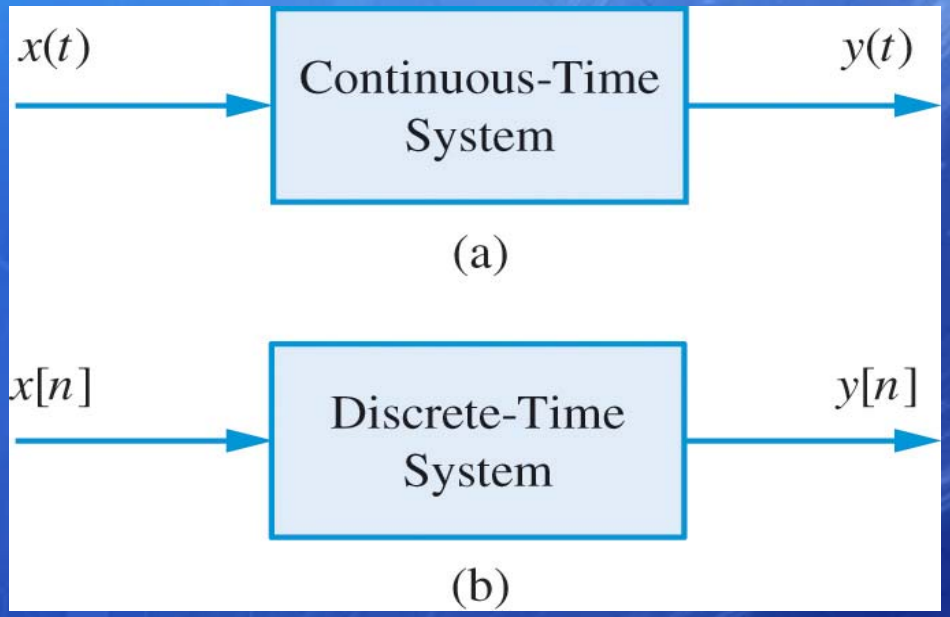
Other Types of Signals

- ✓ Energy and Power Signals:
  - If signal's energy is finite, the signal is an energy signal.
  - If signal's power is finite (but not zero) and energy is infinite , the signal is a power signal.
  - If signal's energy and power are infinite, the signal is neither energy nor power signal.
- ✓ Deterministic and Random Signals:
  - Deterministic signals can be described by mathematical functions. These functions can often take the form of explicit mathematical formulas.
  - Random signals can not be described by mathematical functions and are studied using the concepts and techniques from the theory of probability and statistics.

Systems

- ✓ A system is defined as a process where a signal called input is transformed into another signal called output.
- ✓ A continues time system is a system which transforms a continues-time input signal into a continues time output signal. The physical implementation of a continues time system is known as an analog system.
- ✓ A discrete time system is a system which transforms a discrete-time input signal into a discrete time output signal. The physical implementation of a discrete time system can be done either software or hardware. In practice every discrete time system has to be implemented by a digital system.

Systems



$$y(t) = \int_{-\infty}^{t} x(\tau)\mathrm{d}\tau$$

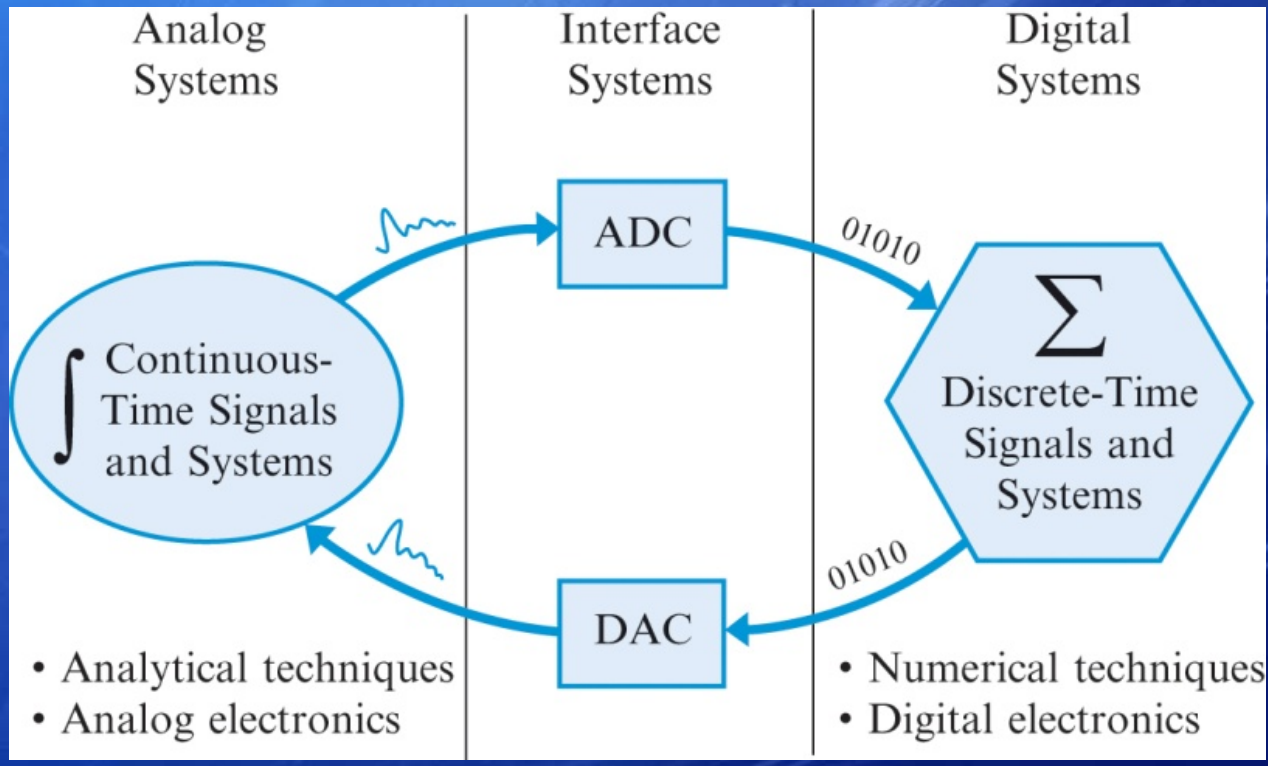
Integrator

$$y[n] = \sum_{k=-\infty}^{n} x[k]$$

Accumulator

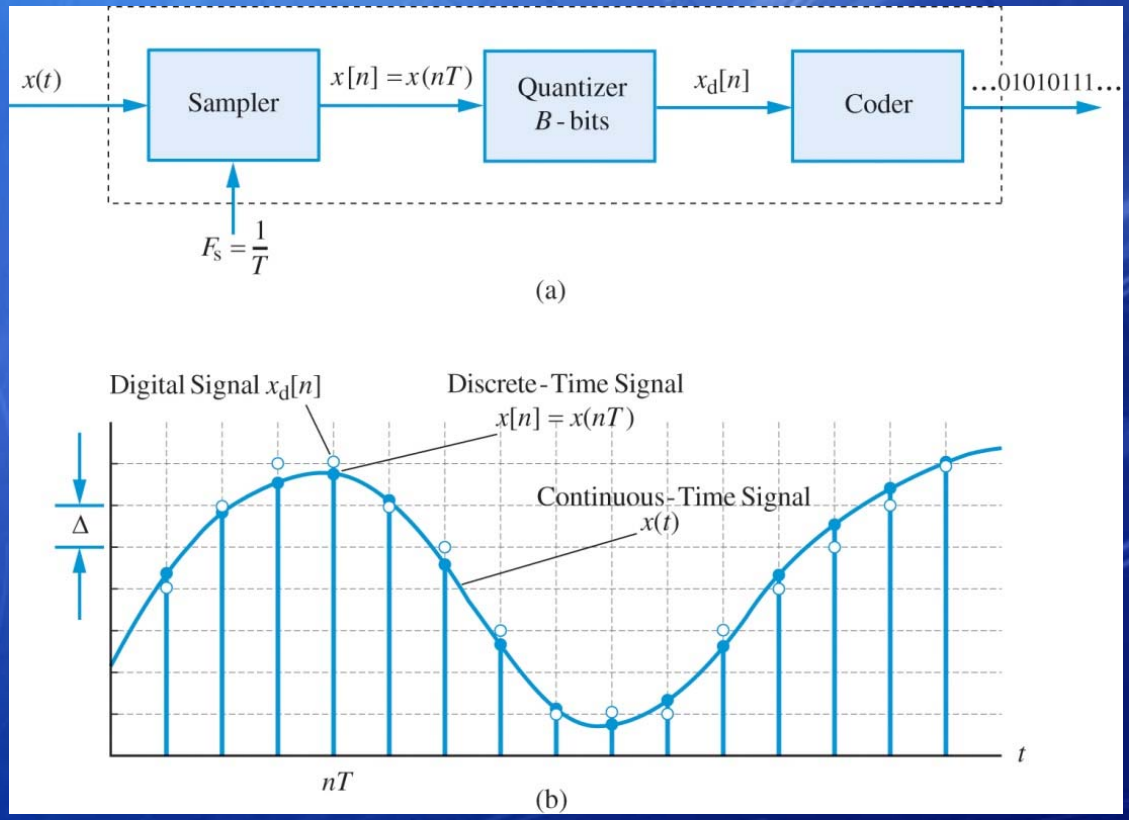
A system is a transformation or operator that maps an input signal to an output signal ("black-box" approach).

Systems


Analog Systems
Interface Systems
Digital Systems
ADC
01010
Continuous-Time Signals and Systems
Discrete-Time Signals and Systems
01010
DAC
• Analytical techniques
• Analog electronics
• Numerical techniques
• Digital electronics

Interface Systems

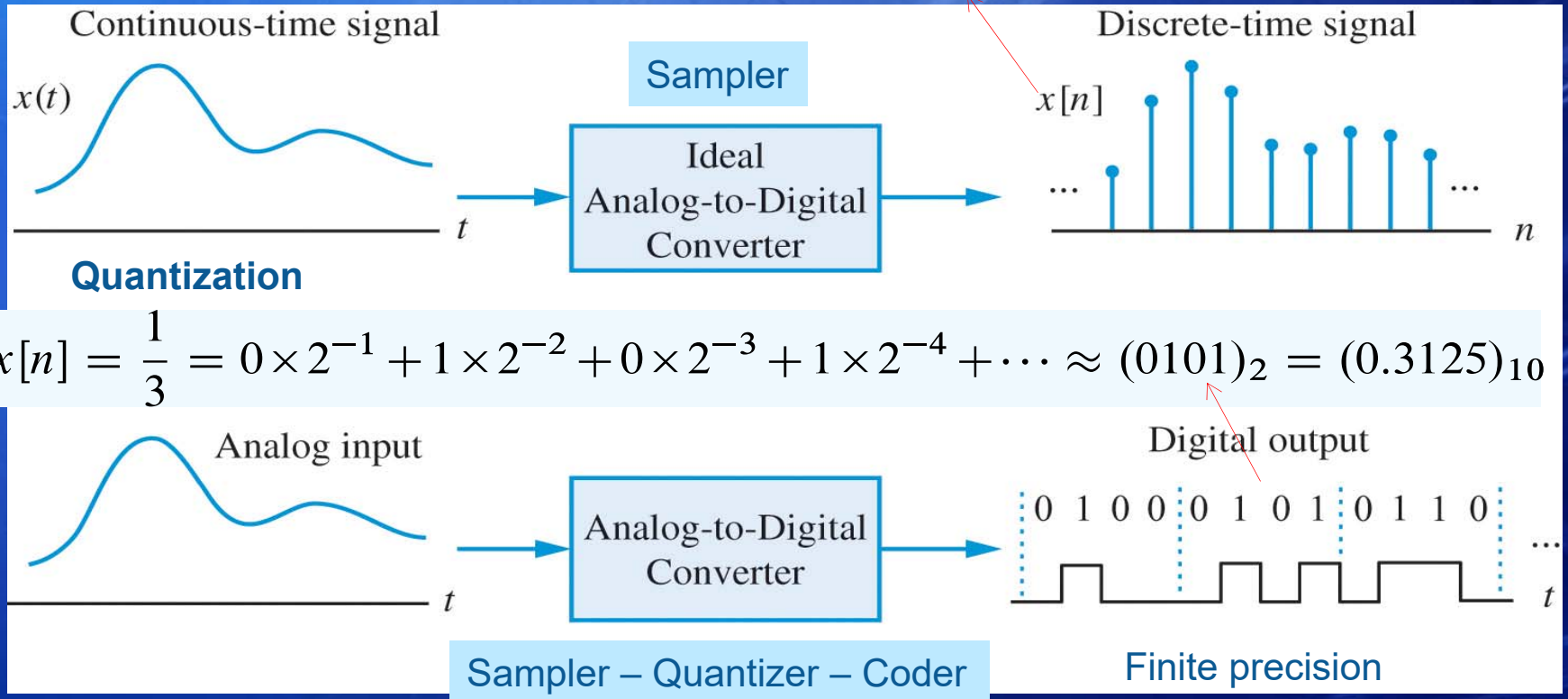
- ✓ Analog-digital interface systems are



a) Block diagram of the analog to digital conversion process, b) examples of signals involved in the process

Analog-to-Digital Conversion

Sampling $x[n] = x(nT) = \frac{1}{3} = 0.333333\cdots$ Infinite precision



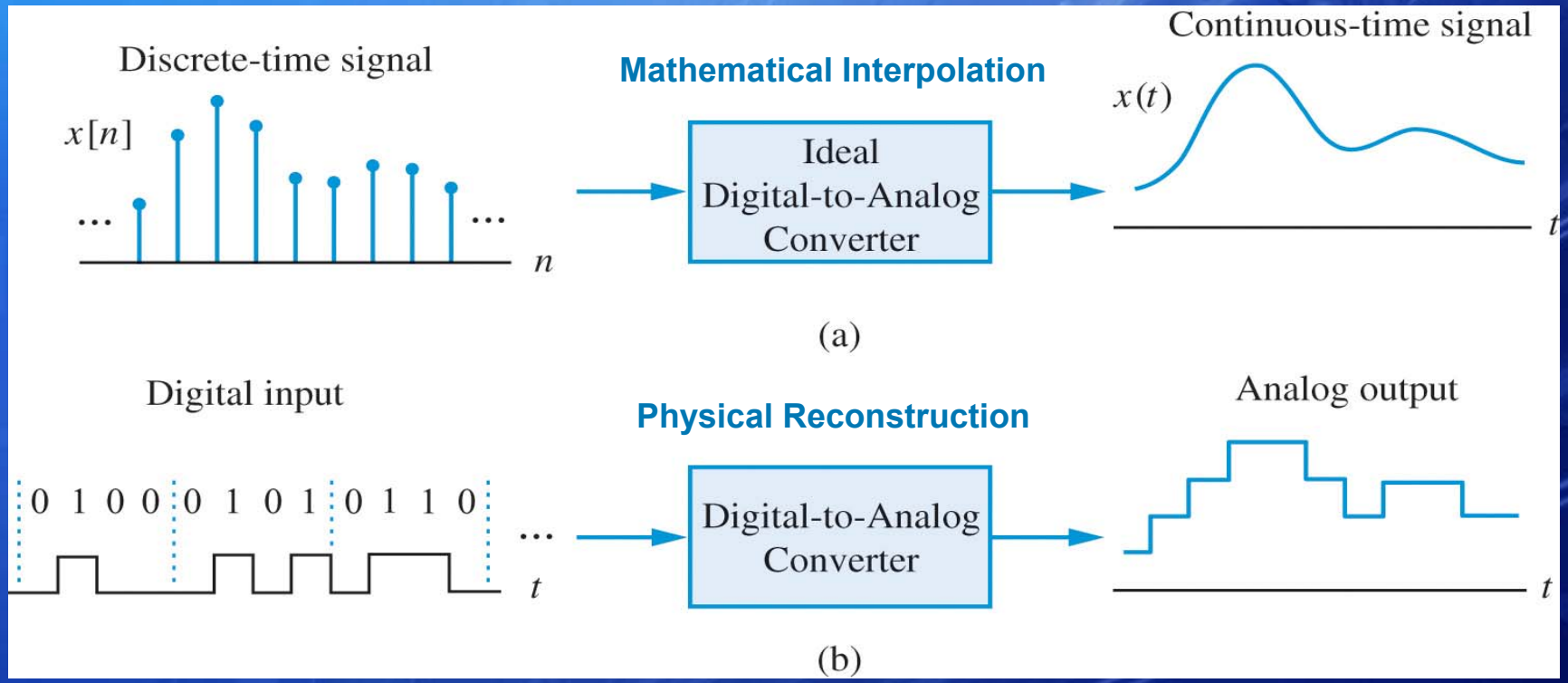
Quantization

$$x[n] = \frac{1}{3} = 0\times 2^{-1} + 1\times 2^{-2} + 0\times 2^{-3} + 1\times 2^{-4} + \cdots \approx (0101)_2 = (0.3125)_{10}$$

Sampler – Quantizer – Coder

Finite precision

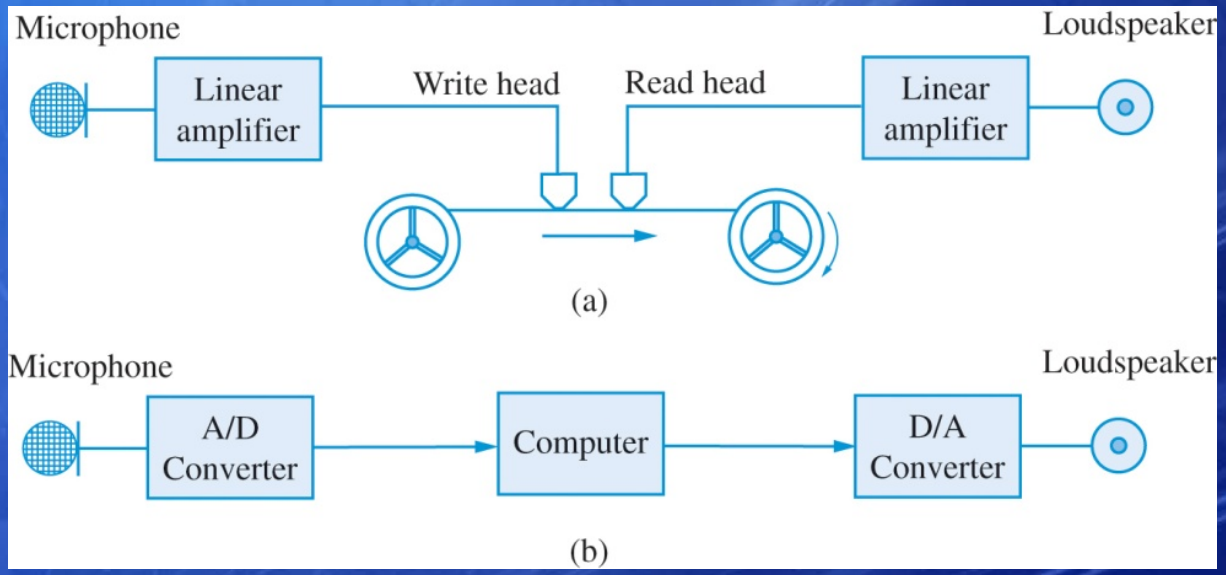
Digital-to-Analog Conversion



Digital Signal Processing

More Analog Signal Processing is required to smooth the edges

Analog-Digital Systems



(a) an analog audio recording system using magnetic tape
(b) a digital recording system using a personal computer

Why we should study signals?

Reason: A signal carries information.

- ✓ Objective of signal processing is to extract the useful information carried by the signal, and modify the signal in a desirable form, e.g., multiplexing, de-multiplexing, noise filtering.
  - Methods for information extraction depend on the type of signal and the nature of the information being carried by the signal.
  - Signal Processing can be 1) Analog; 2) Digital; 3) Mixed
  - Digital signal processing is much more convenient and accurate than analog signal processing, whereas most of the natural signals are analog.
  - Thus, mixed processing can be required.

Why Digital Signal Processing (DSP)

1-If the signal is digital, DSP is the natural choice.

2-Evenif the signal is analog, one may prefer DSP since:

- less sensitive to the component tolerances and environmental changes and thus they are more stable and provide higher precision;
- easier to store: digital signals are easily stored on magnetic media without deterioration or loss of signal.
- much more flexible in reconfiguring the digital signal processing operations simply by changing the program. Reconfiguration of an analog system usually involves a redesign of the hardware followed by testing and verification to see that it operates correctly.
- Sampling rate can be different in different parts of the processor.

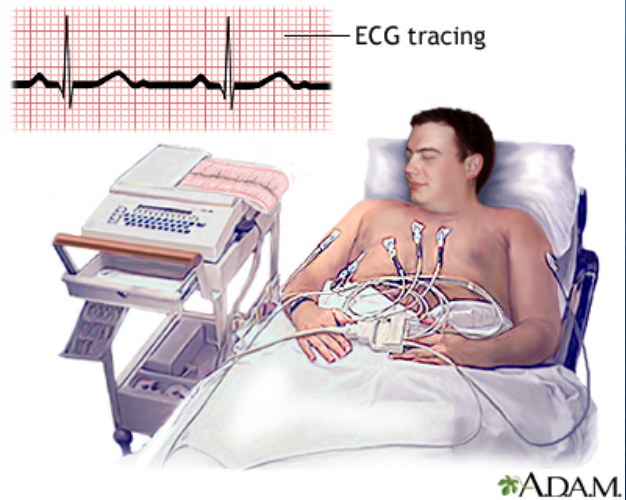
✓ However the DSP has some disadvantages:

- Sampling causes loss of information; Quantization and round off errors;
- A/D and D/A requires mixed signal hardware (increased complexity);

Some Application Areas of DSP

1-Biomedical Applications: analysis of biomedical signals to diagnose and monitoring patients:

- electrocardiogram (ECG) signal: show information about the situation of the patient's heart;
- electroencephalogram (EEG) signal: show information about the activity of the brain.



source:http://umm.edu/health/medical/ency/articles/electrocardiogram

source: http://www.npr.org/2011/06/02/136882002/looking-for-early-signs-of-autism-in-brain-waves

Some Application Areas of DSP

2-Communication Applications:

- telephony – transmission of information in digital form via telephone lines, modem technology, mobile phones;
- encoding and decoding of the information sent over a physical channel to optimize transmission or to detect or correct errors in transmission.

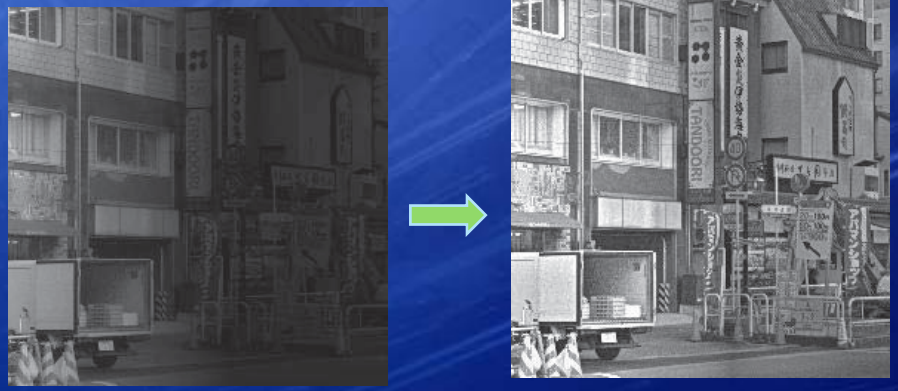
3-Speech Applications:

- Speech enhancement and noise reduction: reducing background noise in the sequence produced by a sensing device (microphone);
- speech recognition: distinguishing between various speech sounds;
- synthesis of artificial speech: text to speech systems.

Some Application Areas of DSP

4-Image Processing:

- content based image retrieval –browsing, searching and retrieving images from achieves;
- compression - reducing the redundancy in the image data to optimize transmission /storage.
- image enhancement:



Shahan C. Nercessian, Karen A. Panetta, and Sos. S. Agaian, Non-Linear Direct Multi-Scale Image Enhancement Based on the Luminance and Contrast Masking Characteristics of the Human Visual System, IEEE Transactions on Image Processing, vol. 22, No. 9, September 2013

Some Application Areas of DSP

5-Music Application:

- Recording;
- Playback;
- Manipulation (mixing, special effects)

6-Multimedia:

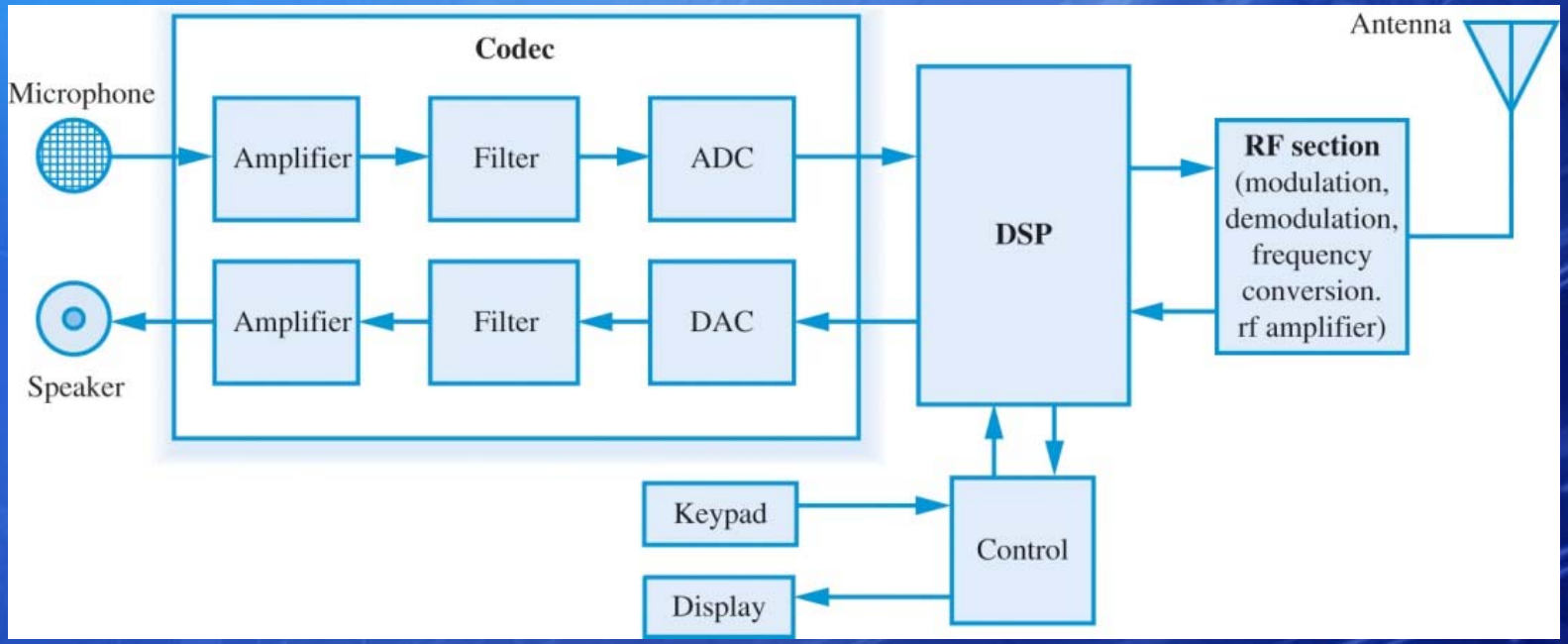
- digital TV ;
- video conferencing;
- video restoration.

Some Application Areas of DSP

7-Remote Sensing:

- Agriculture (e.g., precision farming, crop mapping, monitoring of shifting cultivation, crop diseases detection and monitoring).
- Forestry (e.g., forest mapping, clear-cut monitoring and planning, burned areas detection, forest biomass, forest density).
- Monitoring of urban areas and antrophic infrastructures (e.g. urban growth, building detection, road network extraction, abusive building detection).
- Monitoring of water resources (detection, estimation, quality).
- Monitoring snow and ice.

Some Application Areas of DSP



Simplified block diagram of a digital cellular phone

The DSP processor performs several functions as: speech compression/decompression, error detection/correction, signal strength and quality measurements, co-channel interference cancellation, encryption.

Next Lecture

- ✓ Discrete Time Signals
  - characterization and classification of discrete time signals;
  - elementary operations on them.