EEENG 479 : Digital Signal Processing (DSP)

Lecture #1 : Introduction

Prof. Mohab A. Mangoud
Professor of Wireless Communications (Networks, IoT and AI)
University of Bahrain, College of Engineering
Department of Electrical and Electronics Engineering
P.O.Box 32038- Kingdom of Bahrain
mmangoud@uob.edu.bh
http://mangoud.com

Administrative Issues

Instructor: Prof. Mohab Mangoud,

Room: 14-224
☎ 6261
💻 mmangoud@uob.edu.bh

Lecture hours: MW @ 9:30
Office hours:

- H from 1 till 4 pm at my office
- or by appointment (please feel free to contact me)

References

Text:

Sanjit K. Mitra, “Digital Signal Processing , A computer Based Approach”, McGraw-Hill, third edition, 2006. (this will be the major source)

required software:

The Mathworks, The Student Edition of MATLAB, latest (7) or next to latest release plus the Signal Processing Toolbox (extensive use will be made on this software)

Alternative Texts:

Digital Signal Processing: A Practical Approach by E. C. Ifeachor and B. W. Jervis, Prentice-Hall, 2nd edition, 2002

Course Website:

http://userspages.uob.edu.bh/mangoud

Main Objectives

Understanding the digital signal processing approach and <u>digital filter design</u> with a computer based approach

Covered Topics

- 20% Discrete-time signals, sequence operations, sampling
- 20% Discrete Fourier and Z-transforms, system function for linear shift-invariant systems
- 20% Design of Infinite Impulse Response (IIR) digital filters by transformation from analog filters: Impulse Invariance, Bilinear Transformation
- 20% Design of Finite Impulse Response (FIR) digital filters by Windowing, Frequency Sampling
- 20% Computer Aided Design of FIR and IIR digital filters by Criterion Minimization

Course grading

- Lab Assignments + HWs (15 %)
- Test 1 (15 %)
- Test 2 (15 %)
- Test3/ Project (15 %)
- Final Exam (40 %)

- **Honor Code**

  All submitted work should be your own and reflective of your own understanding of the material.

  OK to discuss assignments, techniques & codes of the others

  Not OK to just copy code or use portions from others' code

'We do not lie, cheat or steal nor tolerate those who do'

- **Attendance policy:**

class attendance not figure in your grade.

However, attendance has an enormous indirect impact, as you will be responsible for what is covered and taught in class.

Major Measurable Learning Objectives

- Having successfully completed this course, the student will be able to
  - Use Discrete Fourier Transform and Z transforms techniques for the analysis of arbitrary signals;
  - Evaluate the performance of a digital filter, in terms of its frequency response;
  - Design digital filters using transformation techniques from analog designs and windowing techniques;

Digital signal processing (DSP) is a central requirement of modern high-performance processors and fuels the portable, wireless revolution.

DSP in applications

- Speech

Speech coding (GSM, DECT, ..), Speech synthesis (text-to-speech), Speech recognition

- Audio Signal Processing

Audio Coding (i.e: MP3), Audio synthesis

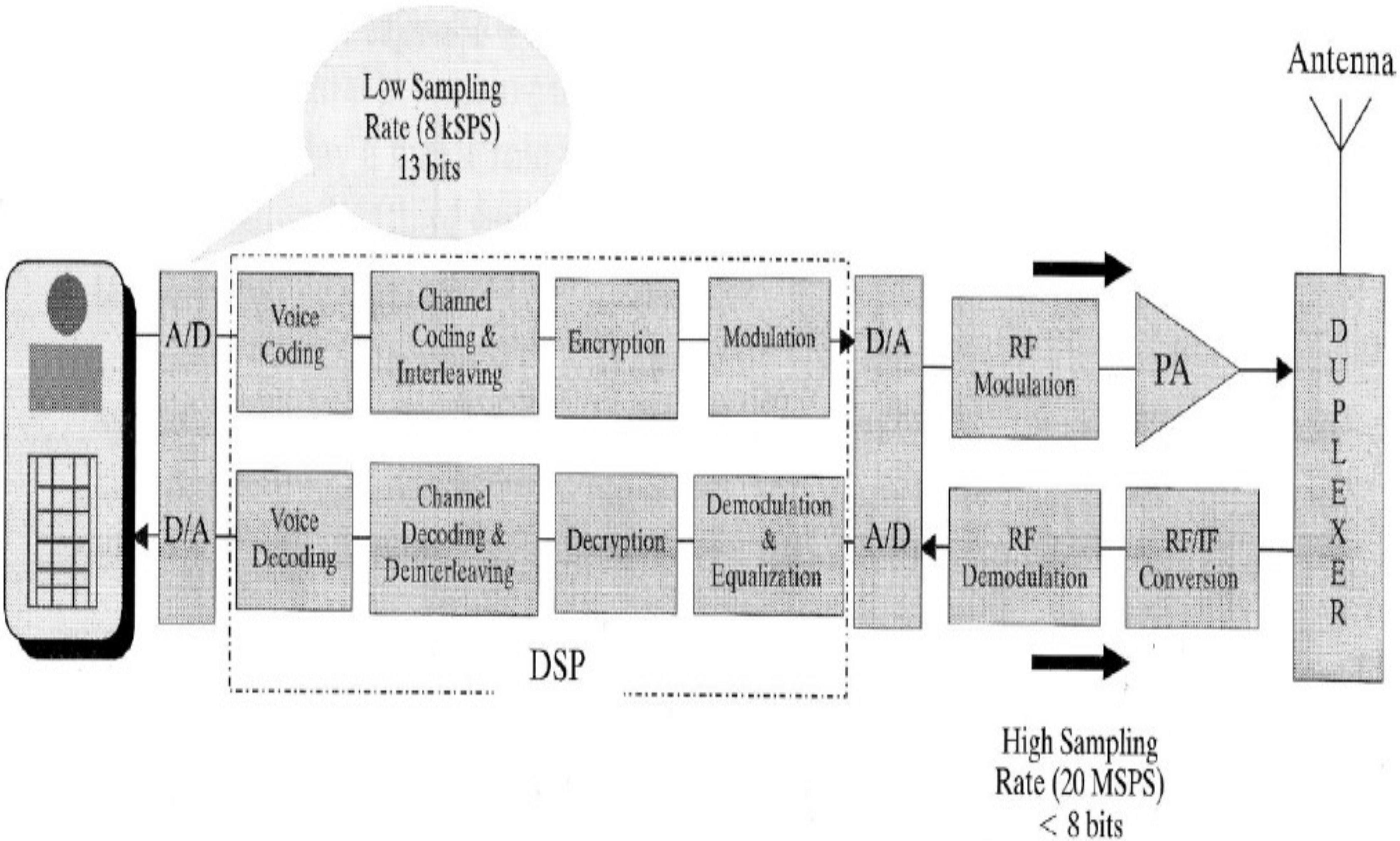
Editing, Automatic transcription, Dolby/Surround, 3D-audio,.

- Image/Video
- Digital Communications

Wireline (xDSL,Powerline), Wireless (GSM, 3G, WLAN, CDMA, MIMO-transmission,..)

Example DSP Applications

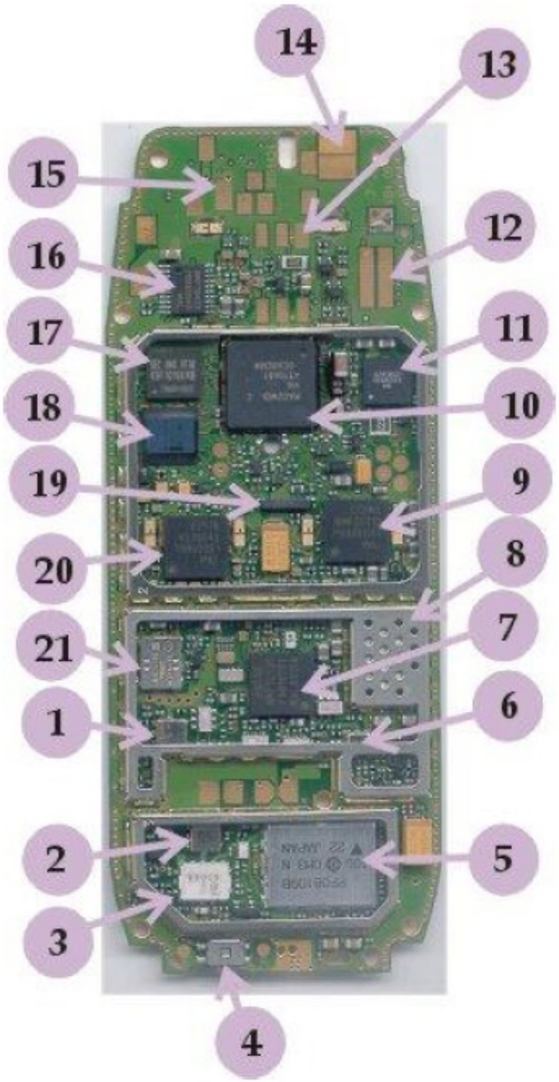
Mobile phones.



This slide is copied from the [1] lecture notes ELEC3600 R.Cendrillon, U.O. Queensland

Case Study 2

Inside the Nokia 3310



1. Dual SAW filter.
2. See 1.
3. Rx/Tx switch.
4. On/off switch.
5. Dual frequency power amplifier.
6. SAW filter.
7. Dualband direct-conversion transceiver.
8. Voltage-controlled oscillator.
9. Power management IC.
10. Microcontroller and DSP.
11. Battery charger.
12. Contact strips to Vibra motor.
13. Contacts to SIM connector.
14. Microphone contacts.
15. Various contacts to bottom connector, like power.
16. User interface IC.
17. 64 k × 16 SRAM.
18. 1 M × 16 Flash.
19. Crystal: 32.768 kHz.
20. Audio & I/Q codec.
21. Oscillator: 26 MHz.

This slide is copied from the [1]

What is a DSP?

A *digital signal processor (DSP)* is a microprocessor for digital signal processing (confusingly, also generally abbreviated as DSP).

- How do DSPs differ from other microprocessors?
- They are optimised towards signal processing:

e.g., they might have special instructions to assist digital filtering.

- Generally, they are *embedded* microprocessors.
  - They live in disk drives and mobile phones and car engines.
  - They are often designed to be frugal with power.
- They generally have a small number of different tasks to do:

e.g., in a particular application, a DSP might only perform a filtering task.

  - However, it has to do it *on time, every time!*
  - That is, DSPs have to perform in *real time*.
  - Therefore, they must have predictable execution times.

This slide is copied from the [1]

When to choose a DSP?

For a specific signal processing application, there are many options for implementation, of which DSPs are only one.

Analogue Signal Processing. In analogue signal processing, a circuit is constructed from analogue components such as amplifiers, resistors, inductors and capacitors.

Advantages: much higher bandwidths are possible than for DSP.

Disadvantages: only limited complexity is possible, limited reconfigurability, variability in component values, difficult design.

Application-Specific Integrated Circuits (ASICs). ASICs are custom-made chips that are produced *en masse* in a factory.

Advantages: higher bandwidths, lower power consumption, lower cost (in a big production run).

Disadvantages: high investment cost, limited reconfigurability, difficult design.

This slide is copied from the [1]

Field-Programmable Gate Arrays (FPGAs). FPGAs are 'digital breadboards on a chip' that can be reconfigured in firmware, *e.g.*, XILINX & ALTERA FPGAs.

Advantages: somewhat higher bandwidths.

Disadvantages: somewhat difficult design, somewhat higher cost.

Microcontrollers. Microcontrollers are microprocessors that are designed for general embedded applications, *e.g.*, MICROCHIP PIC.

Advantages: easy, flexible design, low cost, low power.

Disadvantages: generally lower bandwidth.

General-Purpose Microprocessors (GPPs). By general-purpose microprocessors, we mean the mainstream microprocessors that often form the CPU of desktop computers, *e.g.*, INTEL Pentium IV, MOTOROLA PowerPC.

Advantages: extensive software tools, slightly higher bandwidth.

Disadvantages: higher power, higher cost, more difficult PCB design, execution times difficult to predict.

This slide is copied from the [1]

What does a DSP do?

Common DSP Algorithms

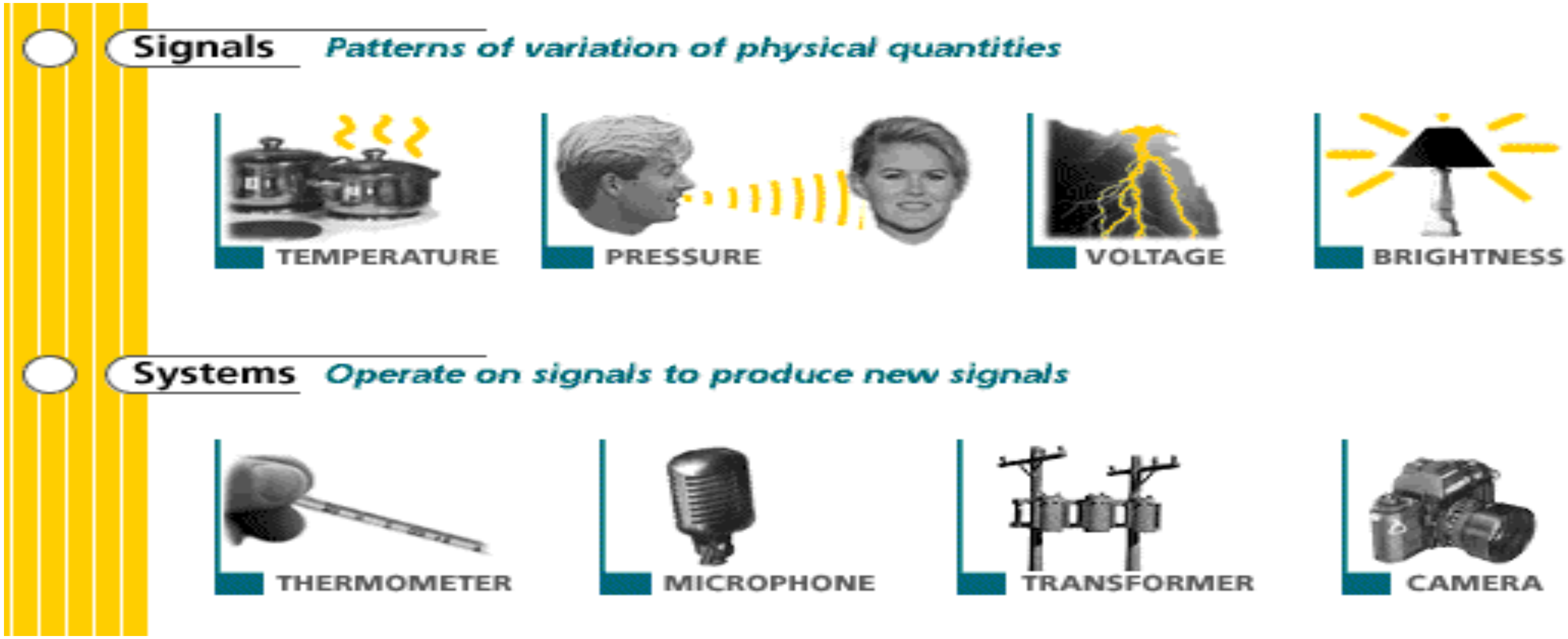
Although the total amount of code for a particular application may be thousands of lines, it often turns out that, for most of its time, a DSP executes fairly simple, but time-consuming, algorithms.

Algorithm	Formula
FIR/Convolution	$y[n] = h[n] * x[n] = \sum_{k=0}^{N} h[k]x[n-k]$
IIR/Difference equation	$y[n] = \sum_{k=0}^{M} b_k x[n-k] - \sum_{k=1}^{N} a_k y[n-k]$
DTFS (FFT)	$\tilde{X}[k] = \frac{1}{N} \sum_{n=0}^{N-1} \tilde{x}[n] e^{-j2\pi kn/N}$
Discrete Cosine Transform	$\tilde{X}[k] = \tilde{c}[k] \sum_{n=0}^{N-1} \tilde{x}[n] \cos\left[\frac{2\pi k(2n+1)}{2N}\right]$

This slide is copied from the [1]

An Overview of Digital Signal Processing

http://www.techonline.com/community/tech_group/dsp/course/13086



Signals and systems are the two most fundamental concepts in digital signal processing, as well as in many other disciplines. Signals are patterns of variation of physical quantities such as temperature, pressure, voltage, brightness, etc.

Ex.: microphones convert air pressure to electrical current and speakers convert electrical current to air pressure.

Introduction Ch 1, 2.0-6
discrete-time signals and systems,

Signals

- Continuous time vs. discrete time
- 1-D signals and 2-D signals (images)
- Concept of *sampling*
- *Signals can be represented by mathematical functions*

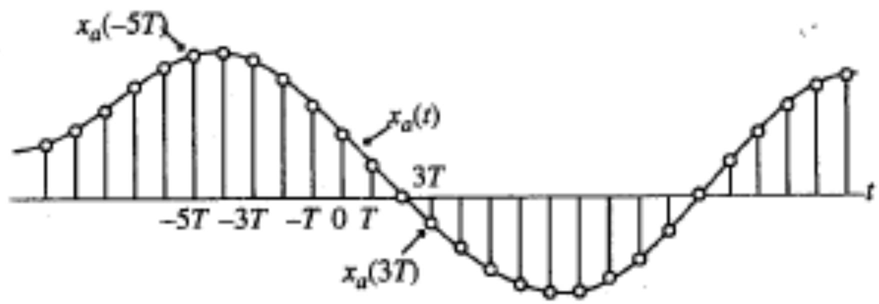
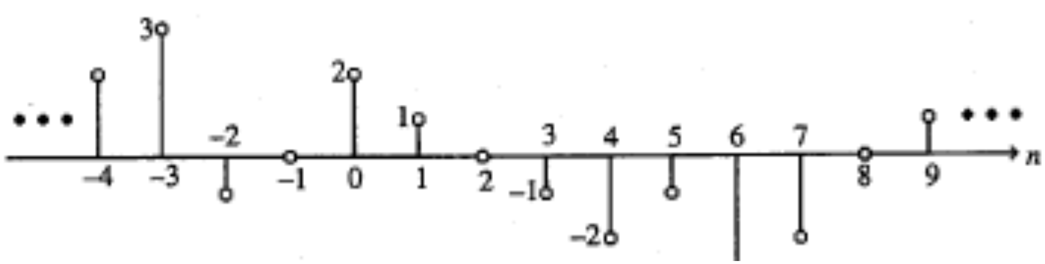


Figure 2.2: Sequence generated by sampling a continuous-time signal $x_a(t)$.



$$x[n] = x_a(t)|_{t=nT} = x_a(nT), \qquad n = \ldots, -2, -1, 0, 1, 2, \ldots \qquad (2.2)$$

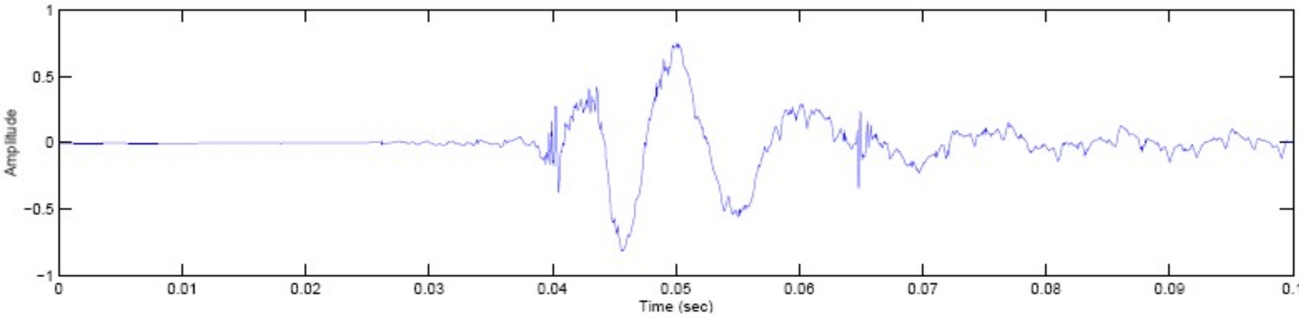
Signals

We take the definition from HvV, p. 1:

A signal is formally defined as a function of one or more variables that conveys information on the nature of a physical phenomenon.

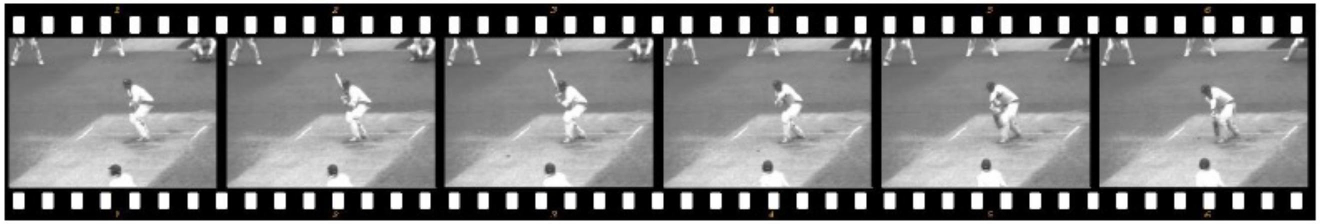
The number of independent variables is the *dimensionality*, *e.g.*:

A 1-dimensional signal: **audio**. (Independent variable: time.)



A 2-dimensional signal: a **still image**. (Independent variables: spatial dimensions.)

A 3-dimensional signal: a **video sequence**. (Independent variables: space & time.)



This slide is copied from the [1]