Chapter 1:

Introduction to DSP

(Digital Signal Processing)

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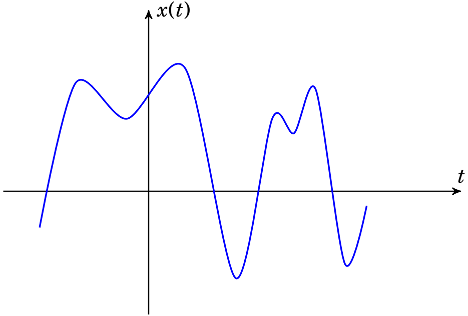
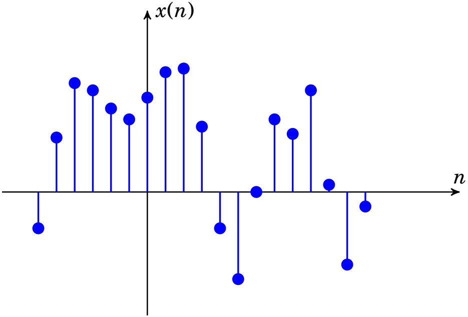
What is a signal?

- A signal is represented by a function x of independent variable t, that is $x(t)$. If the domain of t is the real line $\mathbb{R}$ then $x(t)$ is called a continuous-time signal or analog signal.

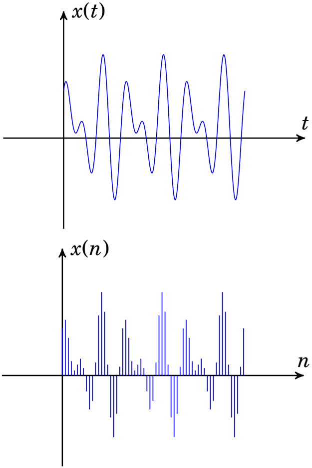


- If the domain is the set of integer number $\mathbb{Z}$ then $x(t)$ is called a discrete-time signal and is normally written as $x(n)$ where n is a positive integer number. In this case, the discrete-time signal is a sequence of values $\{\ldots, x_0, x_1, x_2, \ldots, x_k, \ldots\}$.

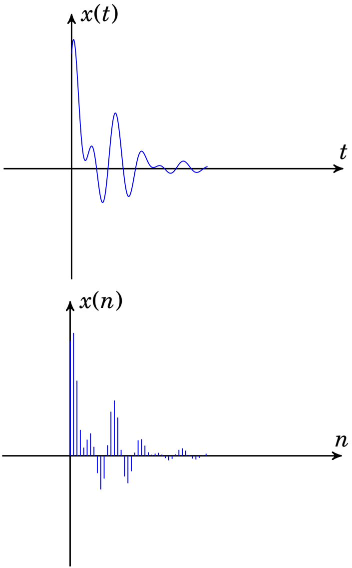


Types of Signals

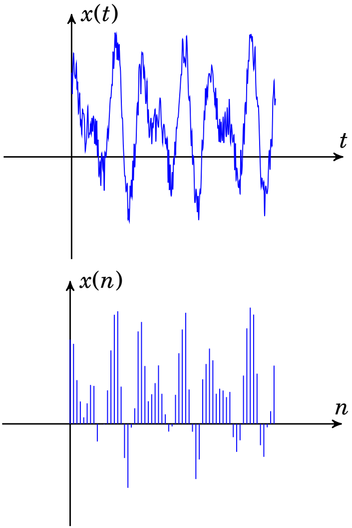
- Periodic signal



- Energy signal



- Random signal



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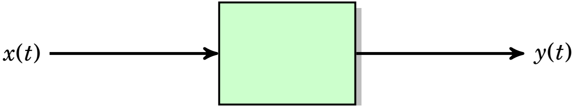
What is a system?

- Signals often pass through electric circuits (mechatronic systems, or physical systems...) to produce an output signal
- Systems: physical system, mechatronic system, production-line system, chemical reaction, ...
- System model: describes the relationship between inputs and outputs as mathematical equations



- $x(t)$: input signal
- $y(t)$: output signal
- The model contains all characteristics of a physical system,such as: linearity, time-invariance, stability, causality.

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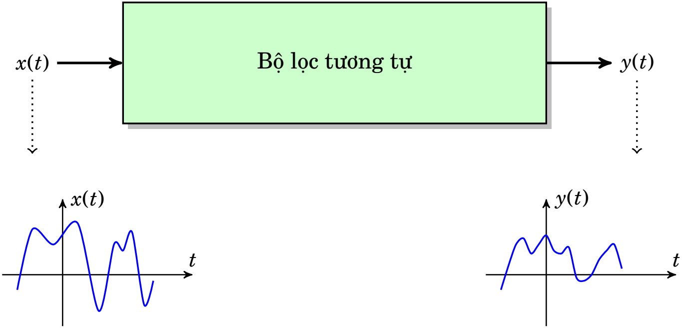
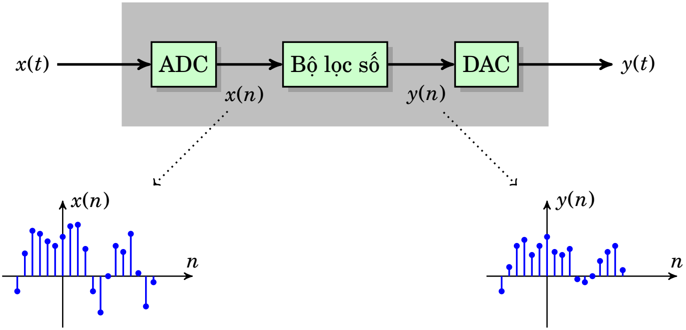
Signal Processing

- We're particularly interested in systems which we design
- signal processing: we want to design a system to extract meaningful information of the input signal $x(t)$
- Definition of signal processing from the IEEE Signal Processing Society.
- We only concentrate on a typical area of signal processing, called filtering. A filter suppresses unwanted components (interference) out of a signal.

- The concept of filter was well developed around the time of the World War II, called analog filtering.



- In the 60's of the last century, researchers used computers to convert the analog filters into algorithms so that the computers could execute. These algorithms are called digital filters.



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Applications of Digital Signal Processing

- Space: Image compression, Image quality improvement, Analysis smart sensors by radiosondes...;
- Medicine: medical imaging (CT,MRI, ultrasound, ...), EEG, ECG, ...; storage and medical information retrieval;
- Commerce: Image/audio compression, film special effects, video-conferencing, ...;
- Telephone: Voice/data compression, echo cancelation, signal multiplexing, filtering, ...;
- Military: radar, sonar, navigation, secure communication;
- Industry: mineral exploitation, process monitoring and control, quality inspection, CAD design, ...;
- Science: Earthquake measurement/analysis, data acquisition, spectral analysis, modeling and simulation.
  (*YouTube clip about applications of signal processing*)

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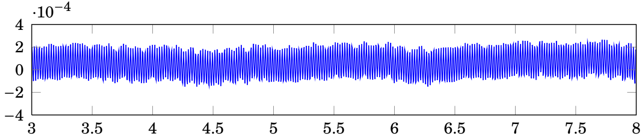
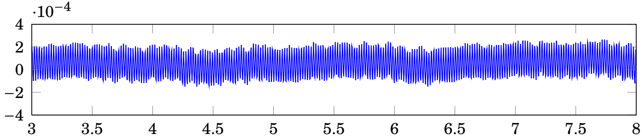
Example: EEG pre-processing

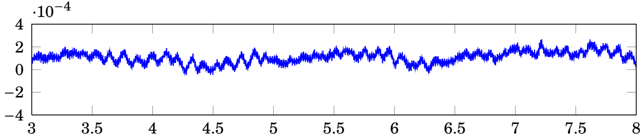
- Electroencephalogram (EEG) signal: measured in Volt; Sampling rate 256 Hz, with 2048 samples.

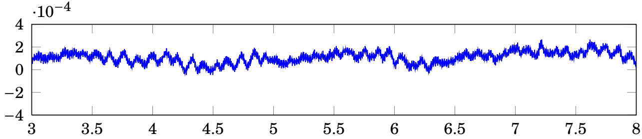


- It can be seen clearly that, we can't extract the meaning information from the signal because of effect of the powerline frequency of 50 Hz.

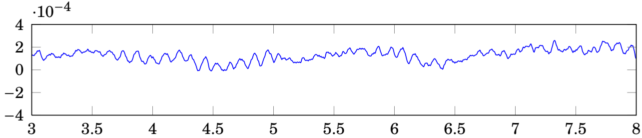


- The 50 Hz frequency was suppressed by a 50-Hz band-stop filter.

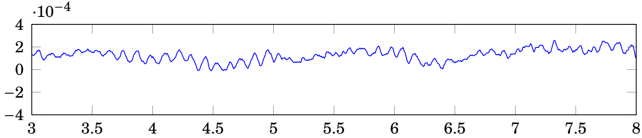




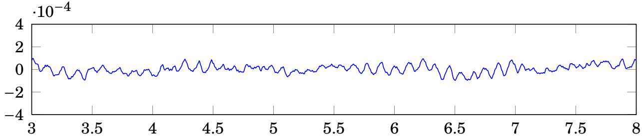
- Brain signals normally have frequencies of interest only up to 70 Hz. Frequencies above 70 Hz can be removed by passing the signal through a low-pass filter with the cutoff frequency of 70 Hz.

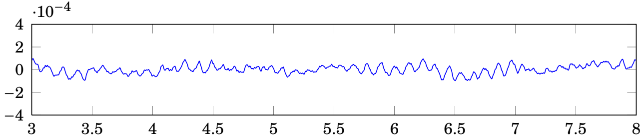


- Moreover, trends in the EEG signals(as upward, downward, slip-up, slip-down...) are often at low frequencies

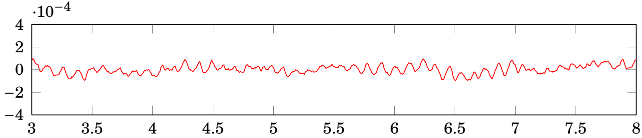


- The trends are removed by using a high-pass filter with the cutoff frequency of 1 Hz.





- Since the filtered signal has frequencies up to 70 Hz, while the sampling rate is 256 Hz, we can re-sample the signal so as to have the sampling rate to 140 Hz (twice the highest frequency of 70 Hz) by a multi-rate filter to reduce the number of samples, hence improve the processing time on the signal.
- In the example, the original signal has 2048 samples and the re-sampled signal has only 1120 samples.



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Subject objectives and structure

Objectives:

1. Analyze the filtering role of a linear time-invariant (LTI) discrete-time system;
2. Study design methods for LTI filters which satisfy given frequency requirements.

Structure:

- Low-pass, high-pass, band-pass and band-stop filters will be studied in Chapter 5 (IIR Filter Design) and Chapter 6 (FIR Filter Design);
- Multi-rate filters will be studied in Chapter 7.

Content

Digital Signal Processing Technology

- Nowadays, we have designed small computers specialize in signal processing that are better, cheaper than normal computers. The computers are called **Digital Signal Microprocessors** (DSμP)
- Digital Signal Processing DSμP is a special microprocessor which is designed to optimally execute a numerous number of complicated operations that was very useful to solve signal processing algorithms. The basis operators are **multiply-accumulate**. Moreover, DSμP need to read input data and write output data quickly because of time-response. In conclusion, if we want to have a good DSμP, it must have a suitable structure and be different from normal microprocessors.

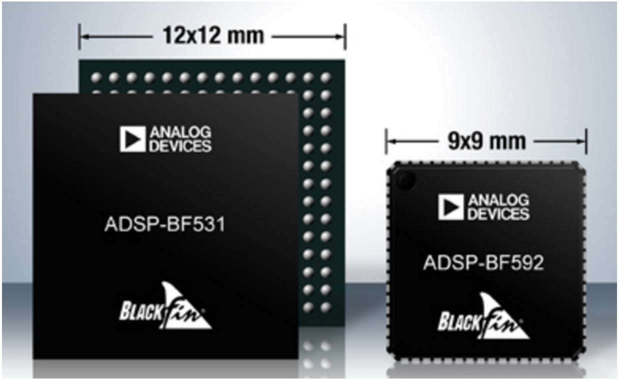
- DSμPs mostly execute operations with Fixed Point, because the structure of multiplier is quite simple but calculate quicker than Floating point. Moreover, the calculations with Fixed point have an acceptable accuracy for most of the applications in the field of Digital Signal Processing. Absolutely, in some special cases required high computing accuracy, we must use a DSμP with Floating point such as microprocessor TMS320C67x made in Texas Intruments
- Devices used DSμP as modem, mobile phone,TV, the most important factor is processing speed. Normally, programs often run a few hundred line containing loops. To ensure quality of system, coders use Assembly programming language and analysis below by below system operations to control the program. However, if DSμP have a complicated structure, it's really difficult to optimize program so manually. In that cases, we can

use C/C++ to code, and hope that C/C++ compiler will give us a good result. Furthermore, we can monitor system operations and adjust commands to have a better result. Moreover, Matlab have some tools to code DSμP.

- Selection programming languages depend on some typical factors such as operation complexity, processing speed, cost of components, system development tools of production company DSμP.
- Currently, there are many companies present different structure DSμPs, integrated or non-integrated ADC and DAC with different costs from a few hundreds dollar.s Microchip, Analog Devices v Texas Instruments are 3 typical companies

- TMXE320AV110PBM

- ADSP-BF592



12x12 mm
ANALOG DEVICES
ADSP-BF531
9x9 mm
ANALOG DEVICES
ADSP-BF592

- dsPIC microcontroller