EDISP
(English) Digital Signal Processing

Jacek Misiurewicz
e-mail: jmisiure@elka.pw.edu.pl
and
Mateusz Malanowski
e-mail: mmalanow@ise.pw.edu.pl
Institute of Electronic Systems
Warsaw University of Technology
Warsaw, Poland

October 3, 2011

General information

Lectures 2h/week, Tue, 14:15-16

Labs ≈4h/2weeks: Monday 8:15-12, room 022. See the schedule.
First meeting for all students – Monday 18 Oct, 9:15

Contact J. Misiurewicz, (jmisiure@elka.pw.edu.pl) room 447.
(also M. Malanowski (mmalanow@ise.pw.edu.pl)).

Web page *http://staff.elka.pw.edu.pl/~jmisiure/*
⟶ Slides on Monday evening! (usually ;-))

Homeworks Announced as a preparation for the tests.

Exams Two short tests within lecture hours (see the lab schedule) and a final exam during the winter exam session (TBA).

Scoring:

2x10%	=	20%	tests
6x5%	=	30%	lab + entry test (lab 0 – not scored)
		50%	final exam
2x2%	=	4%	extra for homeworks (maybe even more)

Short path `if [(score≥41)&&(tests≥15)&&(test2≥5)]; then score*=2; fi`

Books

base book The course is based on selected chapters of the book:

A. V. Oppenheim, R. W. Schafer, *Discrete-Time Signal Processing*, Prentice-Hall 1989 (or II ed, 1999; also previous editions: *Digital Signal Processing*).

free book A free textbook covering some of the subjects can be found here: `http://www.dspguide.com/pdfbook.htm` *The book is slightly superficial, but nice*

good book Edmund Lai, *Practical Digital Signal Processing for Engineers and Technicians*, Newnes (Elsevier), 2003

exercise book Vinay K. Ingle, John G. Proakis, *Digital Signal Processing using MATLAB*, Thomson 2007*Helps understand Matlab usage in the lab (but is NOT a lab base for us)*

Additional books available in Poland:

R.G. Lyons, Wprowadzenie do cyfrowego przetwarzania sygnałów (WKiŁ 1999)

Craig Marven, Gilian Ewers, Zarys cyfrowego przetwarzania sygnałów, WKiŁ 1999 [en: A simple approach to digital signal processing, Wiley & Sons, 1996]

Tomasz P. Zieliński, Od teorii do cyfrowego przetwarzania sygnałów, WKiŁ 2002

You may also buy/borrow a laboratory scriptbook for a Polish language course (Cyfrowe Przetwarzanie Sygnałów, red. A Wojtkiewicz, Wydawnictwa PW) – but our lab is different!

A schedule was here - see the webpage for an updated version!

What Is EDISP All About ;-)

Theory Discrete-time signal processing

Practice Digital signal processing

Application examples:

Filters Guitar effects, radar, software radio, medical devices...

Adaptive filters Echo canceller, noise cancellation (e.g. hands-free microphone in a car),...

Discrete Fourier Transform/FFT Signal analyzer, OFDM modulation, Doppler USG, ...

Random signals Voice compression, voice recognition....

2D signals Image processing, USG/tomography image reconstruction, directional receivers, ...

Upsampling/Interpolation CD audio output, ...

Oversampling CD audio D/A conversion (example)

Please have a look at the black/green-board.

Notice & remember some things:

- Upsampling
- Filtering (and what happens to the signal spectrum)
- Frequency response (frequency characteristics) of a filter

Signal classification

Continuous or Discrete **amplitude** and **time**.

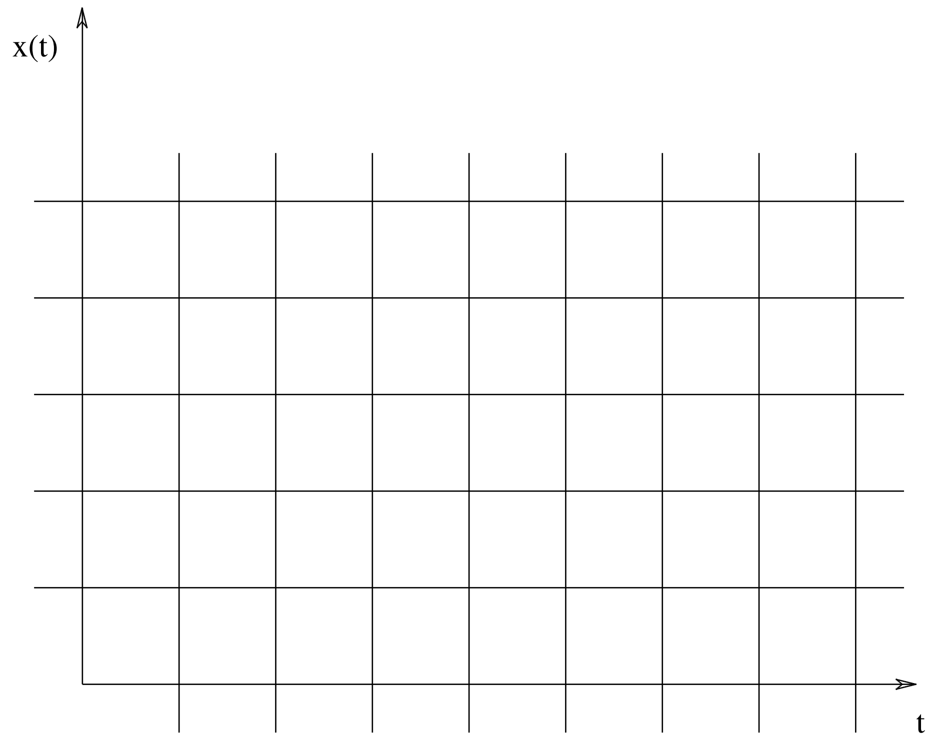
CA-CT $\longrightarrow$ "analog" signals

DA-CT $\longrightarrow$

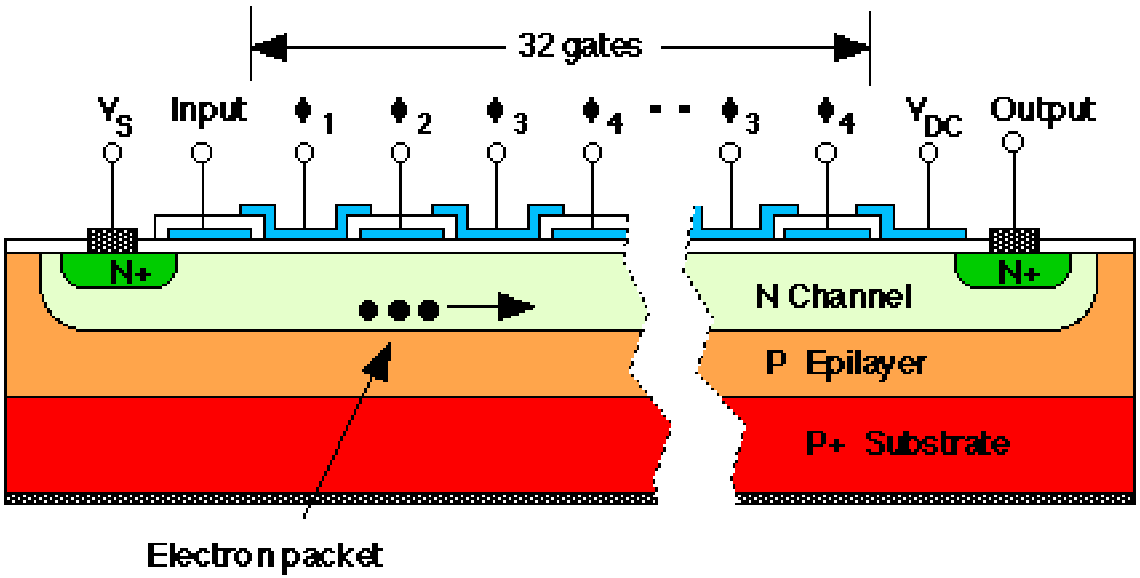
CA-DT $\longrightarrow$ CCD, SC, SAW devices

DA-DT $\longrightarrow$ digital devices

We'll speak mainly about DT properties; only in some subject DA will be of importance.



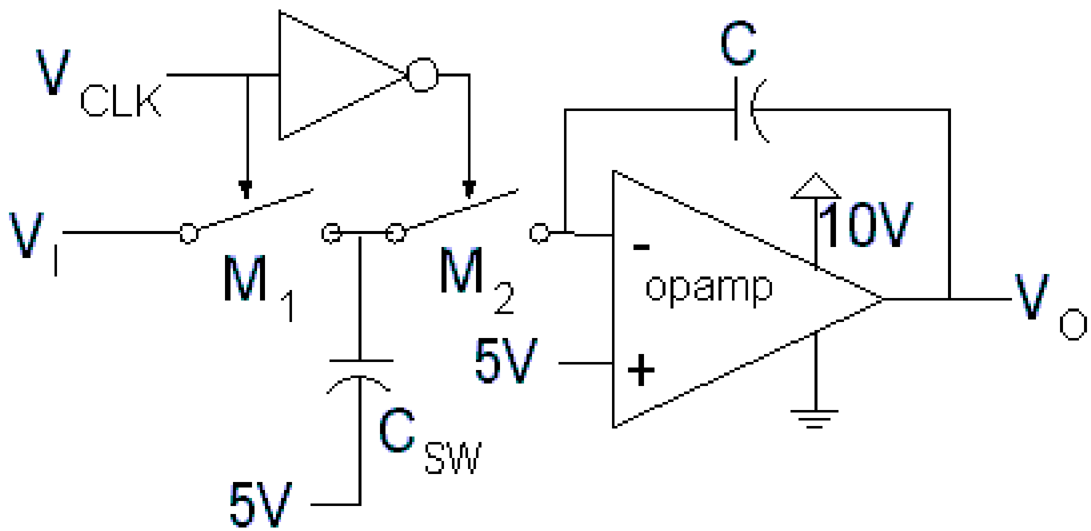
CCD device (side remarks)



Charge is transferred on the clock edge (discrete time!).

Clock is usually polyphase (2-4 phases).

SC device (side remarks)



DT signal representations

DT signal $\longleftarrow\!\longrightarrow$ a number sequence

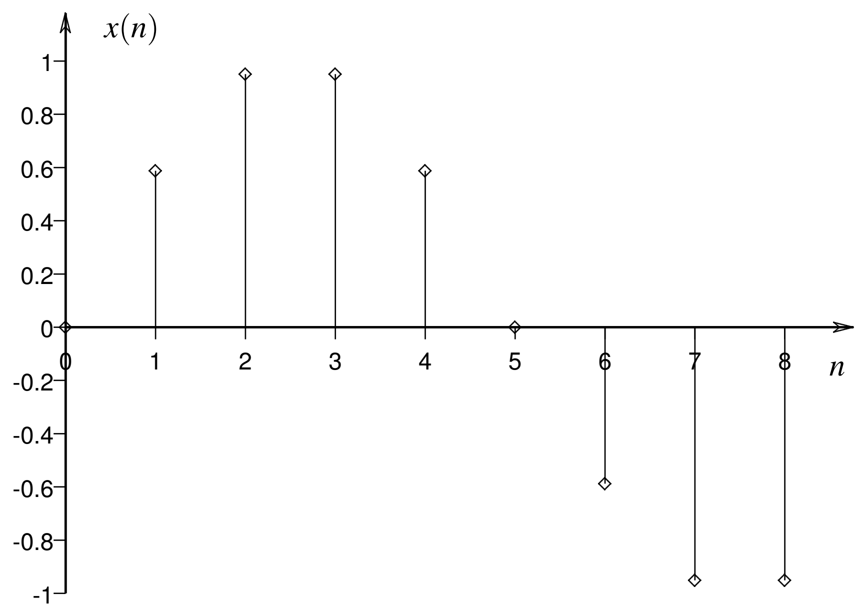
$$x[n] = \{x(n)\}$$

$x[n]$ is a number sequence (or ...)

$x(n)$ is a $n-$th sample

$\longrightarrow$ $x(n)$ is *undefined* for $n \notin \mathrm{I}$

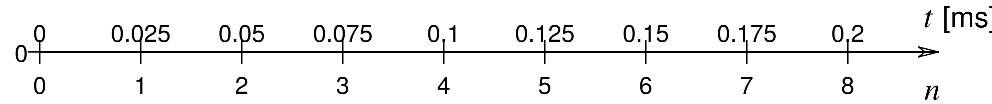
- it *may* come from sampling of analog signal
- but it may also be inherently discrete
- n may correspond to: time, space, ...



However, the most popular interpretation is: periodic sampling in time.

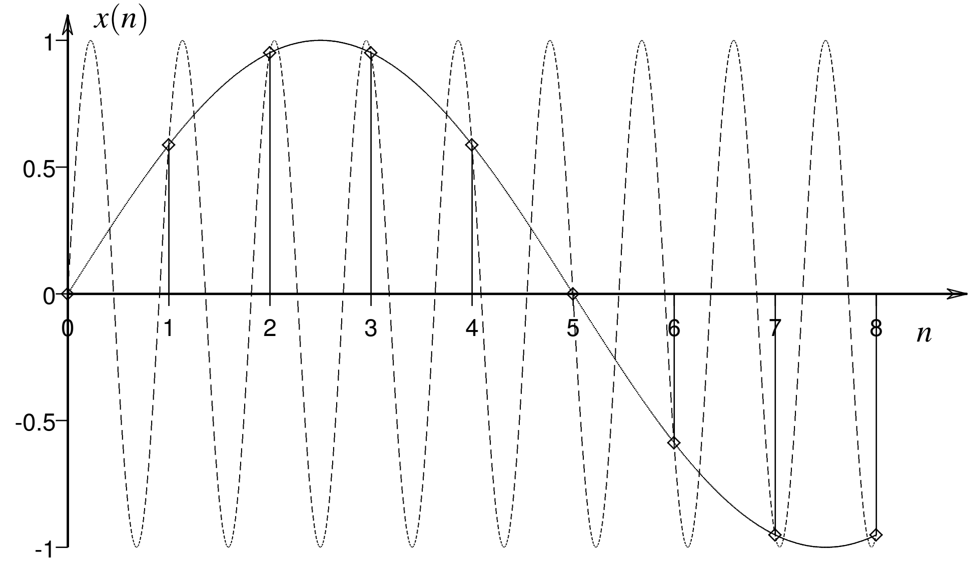
Periodic sampling

$$n \longleftarrow\longrightarrow n \cdot T_s$$



$$x(n) = x_a(nT_s)$$

$$n = t/T_s, \;\; T_s = 0.025 \text{ [ms]}$$



Misinterpretations

$\longrightarrow$ we do not know what is between points

a) $sin(n \cdot (1/5) \cdot \pi)$ or

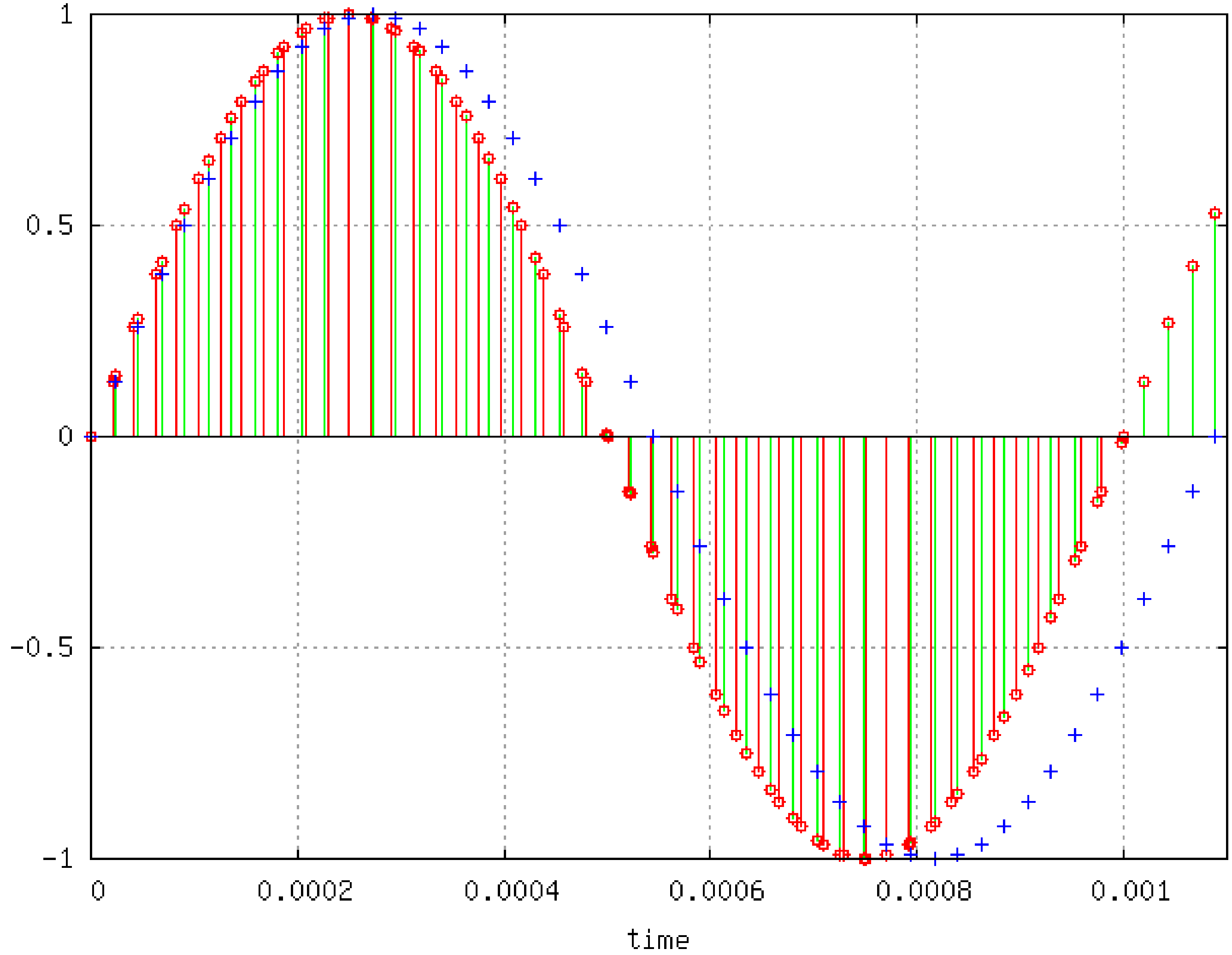
b) $sin(n \cdot (2 + 1/5) \cdot \pi)$?

We have to **know** which one to choose $\longrightarrow$ sampling theorem

Frequency in a DT signal

	CD audio system	DAT audio system
Sampling:	44100 Hz	48000 Hz
Nyquist:	22050 Hz	24000 Hz
t_s	22.676μs	20.833μs
1kHz: samples per period	44.1	48
1kHz: moved from CD to DAT	1kHz	48/44.1=1.0884 kHz

We need a good definition of frequency!


1
0.5
0
-0.5
-1
0
0.0002
0.0004
0.0006
0.0008
0.001
time

DT signal frequency concept

Continuous time cosine:		Discrete time cosine:	Normalized…
$x_a(t) = \cos \omega t$	$\omega \in \mathrm{R}$	$x(n) = \cos \omega n t_s$	…time: $n = t/t_s$
$\omega = 2\pi f$		$x(n) = \cos 2\pi f\, n \frac{1}{f_s}$	…frequency: $f_n = \frac{f}{f_s}$
		$x(n) = \cos \theta n$	…ang. freq.: $\theta = 2\pi \frac{f}{f_s}$
$T = \frac{1}{f} = \frac{2\pi}{\omega}$	$\leftarrow$ period ? $\rightarrow$	$N_0 = \frac{1}{f_n} = \frac{2\pi}{\theta}$	
$x(t) = x(t + kT)$		$x(n) = x(n + kN)$	
		$x(n+N)$ defined only if $N \in \mathrm{I}$	
Always	$\leftarrow$ periodic $\rightarrow$	only if $N_0 = N/M$ (!!)	

Normalized angular frequency θ: interval of 2π may be assumed as $[0, 2\pi)$ or $[-\pi, \pi)$.

$$\cos n(\theta + k \cdot 2\pi) = \cos(n\theta + n \cdot k \cdot 2\pi) = \cos n\theta$$

Periodicity example