

EDISP

(English) Digital Signal Processing

Jacek Misiurewicz

e-mail: jmisiure@elka.pw.edu.pl

Institute of Electronic Systems
Warsaw University of Technology
Warsaw, Poland

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General information

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

Labs \approx 4h/2weeks: Monday 8:15-12, room 022. See the schedule.

First meeting for all students – Monday 15 Oct, 9:15

Labs start with an “entry test”!!!

Contact J. Misiurewicz, (jmisiure@elka.pw.edu.pl) room 447.

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 \geq 41)&&(tests \geq 15)&&(test2 \geq 5)]; then score* = 2; fi`
 “if” conditions are evaluated once, before re-doing tests etc.

Books

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

A. V. Oppenheim, R. W. Schaffer, *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**.

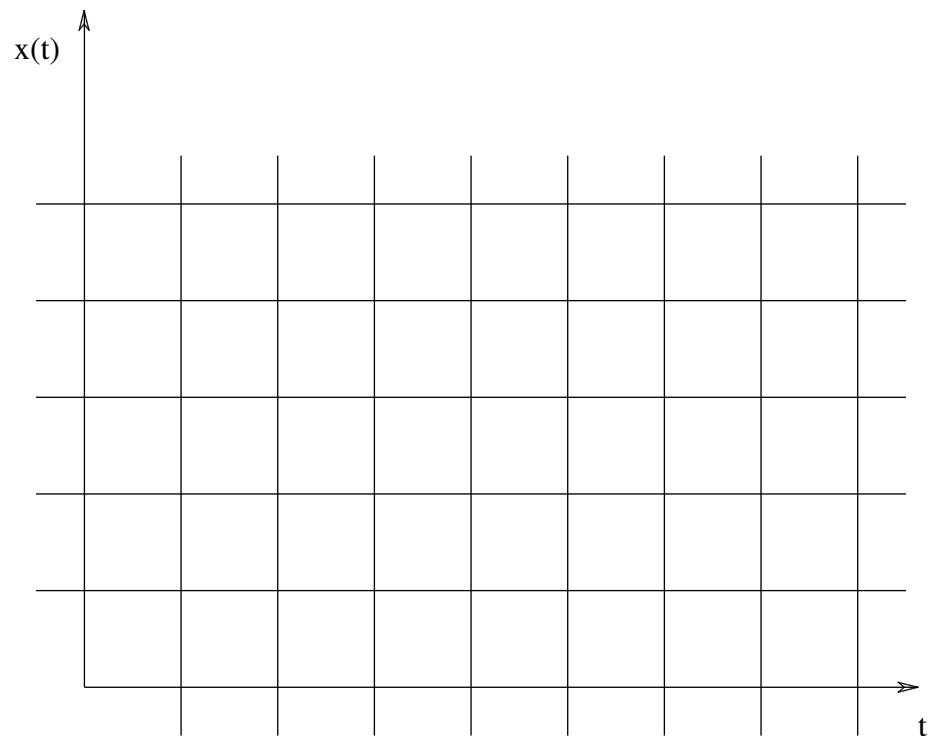
CA-CT → “analog” signals

DA-CT →

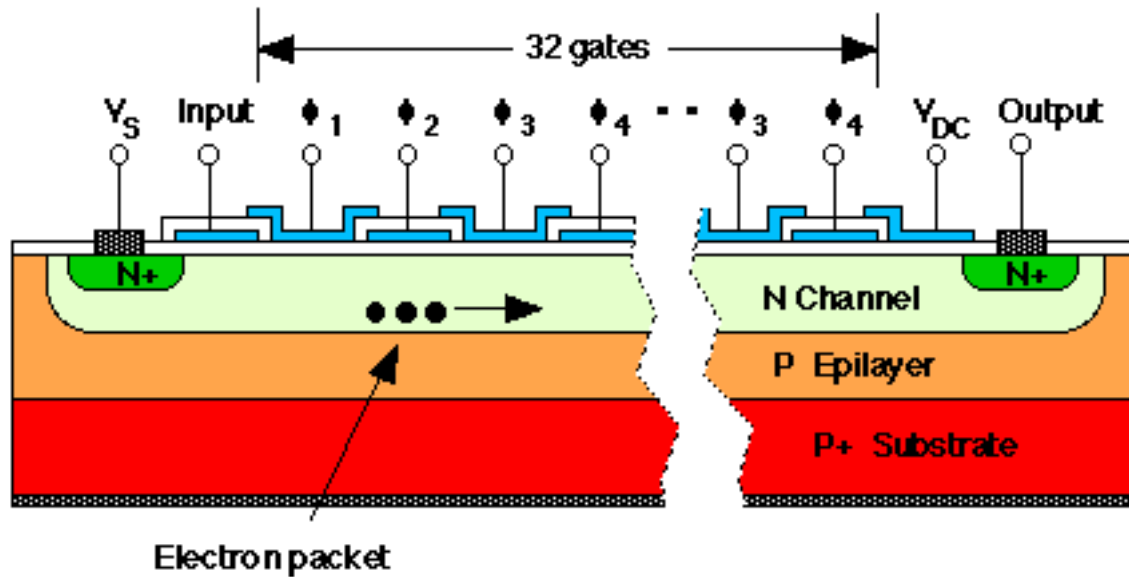
CA-DT → CCD, SC, SAW devices

DA-DT → digital devices

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

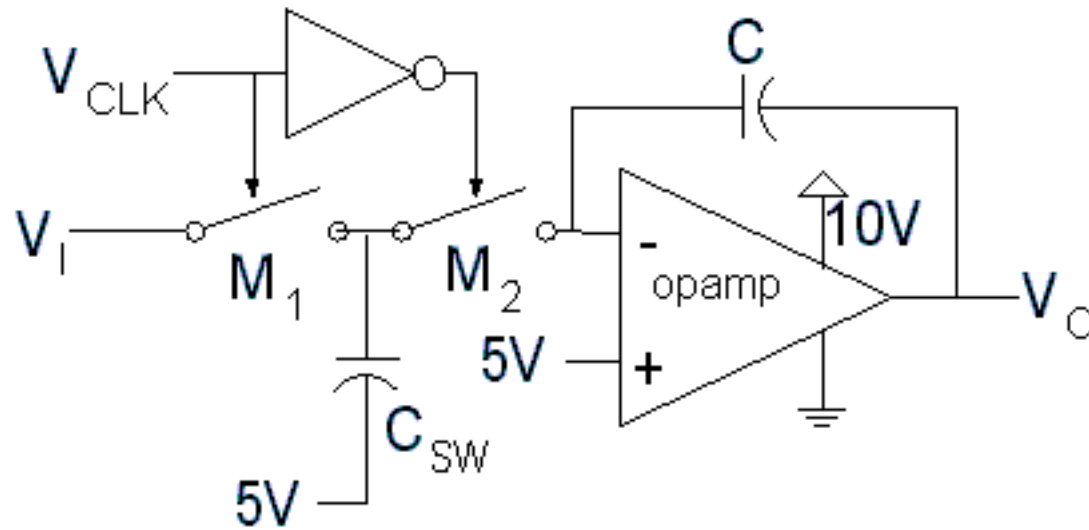


CCD device (side remarks)



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 \longleftrightarrow a number sequence

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

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

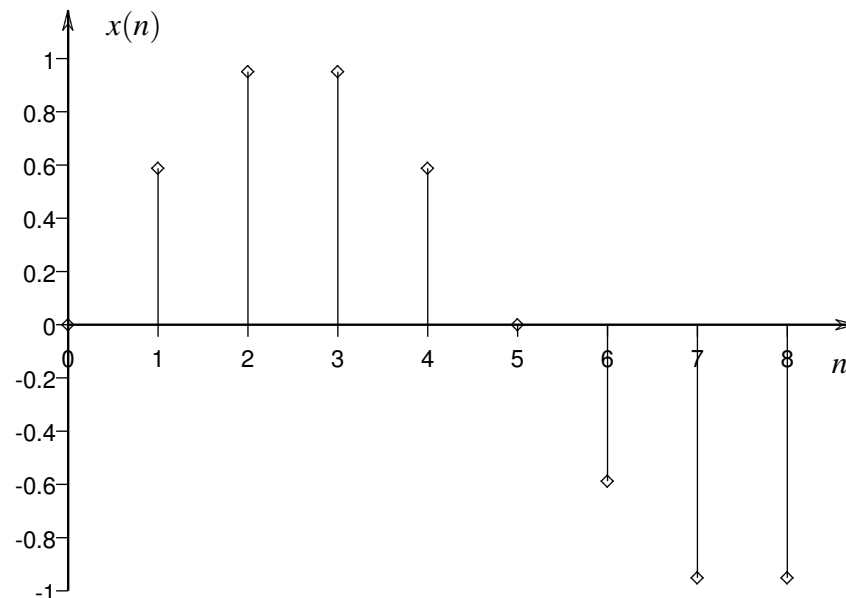
$x(n)$ is a n -th sample

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

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

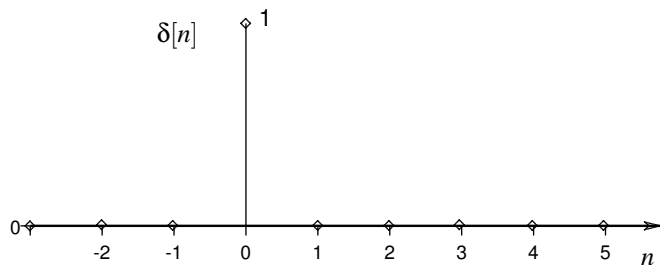
...

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



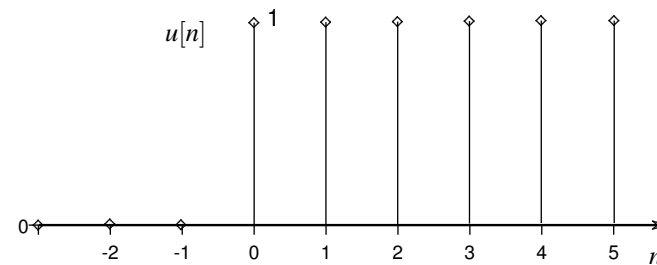
Number sequence (or DT signal) operations; basic sequences

operation	notation	definition
sum	$z[n] = x[n] + y[n]$	$\forall n \ z(n) = x(n) + y(n)$
scale	$z[n] = \alpha \cdot y[n]$	$\forall n \ z(n) = \alpha \cdot y(n)$
shift	$z[n] = x[n - n_0]$	$\forall n \ z(n) = x(n - n_0)$
difference	$z[n] = x[n] - y[n]$	$\forall n \ z(n) = x(n) - y(n)$
product	$z[n] = x[n] \cdot y[n]$	$\forall n \ z(n) = x(n) \cdot y(n)$
scalar product	$c = \langle x[n], y[n] \rangle$	$c = \sum_n x(n) \cdot y^*(n)$



Unit sample sequence (DT impulse)

$$\delta[n] = u[n] - u[n - 1]$$



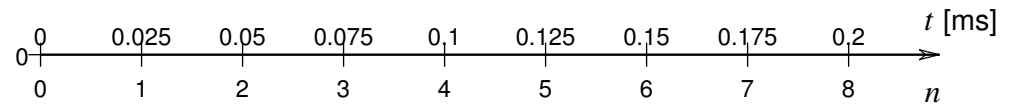
Unit step sequence

$$u[n] = \sum_{k=0}^{\infty} \delta[n - k]$$

Periodic sampling

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

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



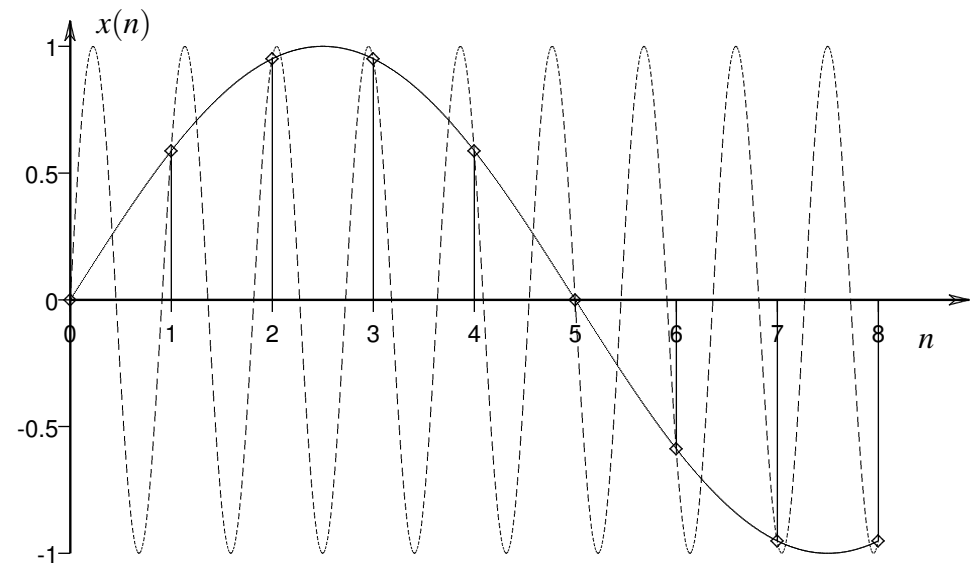
$$n = t/T_s, \quad T_s = 0.025 \text{ [ms]}$$

Misinterpretations

→ we do not know what is between points

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

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

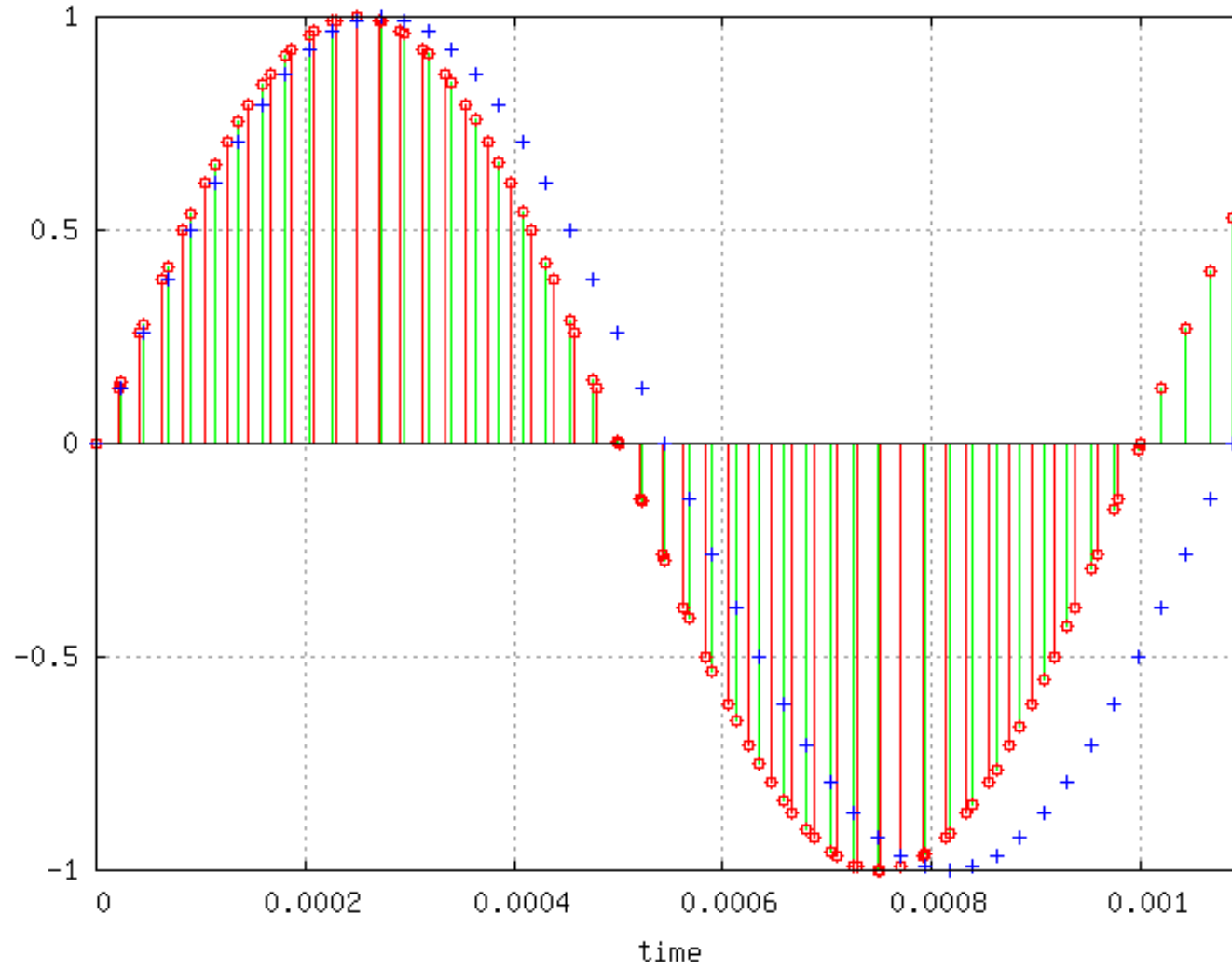


We have to **know** which one to choose → sampling theorem

Frequency in a DT signal

	CD audio system	DAT audio system
Sampling:	44100 Hz	48000 Hz
Nyquist:	22050 Hz	24000 Hz
t_s	22.676 μ s	20.833 μ s
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!



DT signal frequency concept

Continuous time cosine:

$$x_a(t) = \cos \omega t \quad \omega \in \mathbb{R}$$

$$\omega = 2\pi f$$

$$T = \frac{1}{f} = \frac{2\pi}{\omega} \quad \leftarrow \text{period ?} \rightarrow$$

$$x(t) = x(t + kT)$$

Always \leftarrow periodic \rightarrow

Discrete time cosine:

$$x(n) = \cos \omega n t_s$$

$$x(n) = \cos 2\pi f n \frac{1}{f_s}$$

$$x(n) = \cos \theta n$$

$$N_0 = \frac{1}{f_n} = \frac{2\pi}{\theta}$$

$$x(n) = x(n + kN)$$

$x(n + N)$ defined only if $N \in \mathbb{I}$
only if $N_0 = N/M$ (!!)

Normalized...

... time: $n = t/t_s$

... frequency: $f_n = \frac{f}{f_s}$

... ang. freq.: $\theta = 2\pi \frac{f}{f_s}$

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

