# FER – Teaching complex concepts

AQUILONIS d.o.o.

SREDNJA EKONOMSKA ŠOLA
IN GIMNAZIJA MARIBOR

SVEUČILIŠTE U ZAGREBU
FAKULTET ELEKTROTEHNIKE I RAČUNARSTVA

TARTU KUTSEHARIDUSKESKUS
ZAVOD ANTONA MARTINA SLOMŠKA MARIBOR

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ACTIVE LEARNING THROUGH IMPROVED INTERACTIVITY

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# Context

- University of Zagreb, Faculty of electrical engineering and computing

- 1st semester graduate elective course with ~50 students
  *Digital signal processing*

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# Motivation

- Contents include:
- time discrete signals and Fourier transformation
- introduction to DSP and digital filters
- continuous time-domain filters
- design of Finite Impulse Response (FIR) filters
- design of Infinite Impulse Response (IIR) filters
- Fast Fourier Transform (FFT)
- …

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# Methods

- *Ex chatedra teaching*
  *theoretical concepts*

- *Problem solving sessions*
  *exam problems*

- *Laboratory sessions*
  *practical implications*

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# Example – Drawing the DTFT spectrum

- To plot the DTFT spectrum
  of a discrete-time aperiodic signal $x[n]$:

  *1.* find the DTFT transformation of the signal $X(e^{j\omega})$
  *2.* find the magnitude spectrum $\left|X(e^{j\omega})\right|$
  *3.* find the phase spectrum $\angle X(e^{j\omega})$
  *4.* plot them separately on the $[-\pi, \pi]$ interval

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# 1. Find the DTFT transformation

- Let $x[n]$ be a discrete-time aperiodic signal
- Its DTFT is calculated as

$$X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n]e^{-j\omega n}$$

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# 1. Find the DTFT transformation

- For example, if *x[n]* = *[$\underline{1}$, 2, 1]*

  its DTFT is calculated as

$$X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n]e^{-j\omega n} = 1 + 2e^{-j\omega} + 1e^{-2j\omega}$$

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# 2. Find the magnitude spectrum $|X(e^{j\omega})|$

- Calculate the magnitude spectrum $\left|X(e^{j\omega})\right|$
- Use (a)simmetry to reduce the expression to sinus and cosinus if possible

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# 2. Find the magnitude spectrum $|X(e^{j\omega})|$

- For example, the magnitude spectrum of signal $x[n]$

$$|X(e^{j\omega})| = \left|1 + 2e^{-j\omega} + e^{-2j\omega}\right|$$
$$= \left|e^{-j\omega}\right| \cdot \left|e^{j\omega t} + 2 + e^{-j\omega}\right|$$
$$= |2 + 2\cos(\omega)\,| = 2|1 + \cos(\omega)|$$

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# 3. Find the phase spectrum $\angle X(e^{j\omega})$

- Calculate the phase spectrum of $x[n]$

- Unwrap the phase to $[-\pi, \pi]$ interval if it exceedes it

*What is the phase of a real number?*

*What is the phase of an imaginary number?*

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# 3. Find the phase spectrum $\angle X(e^{j\omega})$

- For example, the phase spectrum of *x[n]* is

$$\angle X(e^{j\omega}) = \angle\left(1 + 2e^{-j\omega} + e^{-2j\omega}\right)$$

$$= \angle\left(e^{-j\omega}[2 + 2\cos(\omega)]\right) = -\omega + \angle[2 + 2\cos(\omega)] = -\omega$$

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# 4. Plot the spectrum on the $[-\pi, \pi]$ interval

- Magnitude spectrum is always non-negative!
- Phase spectrum should be unwrapped to the $[-\pi, \pi]$ interval on the y-axis

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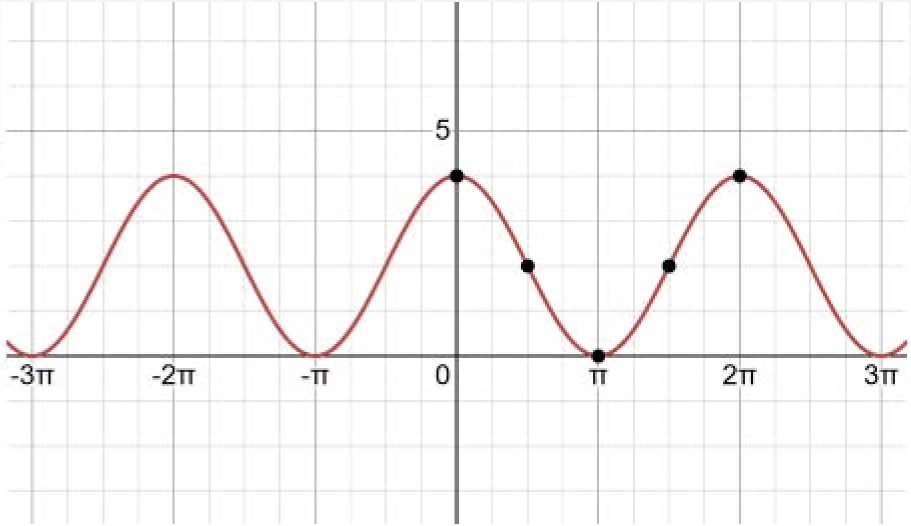
# 4. Amplitude spectrum $|X(e^{j\omega})$




— $|X(e^{j\omega})| = 2|1 + \cos(\omega)|$

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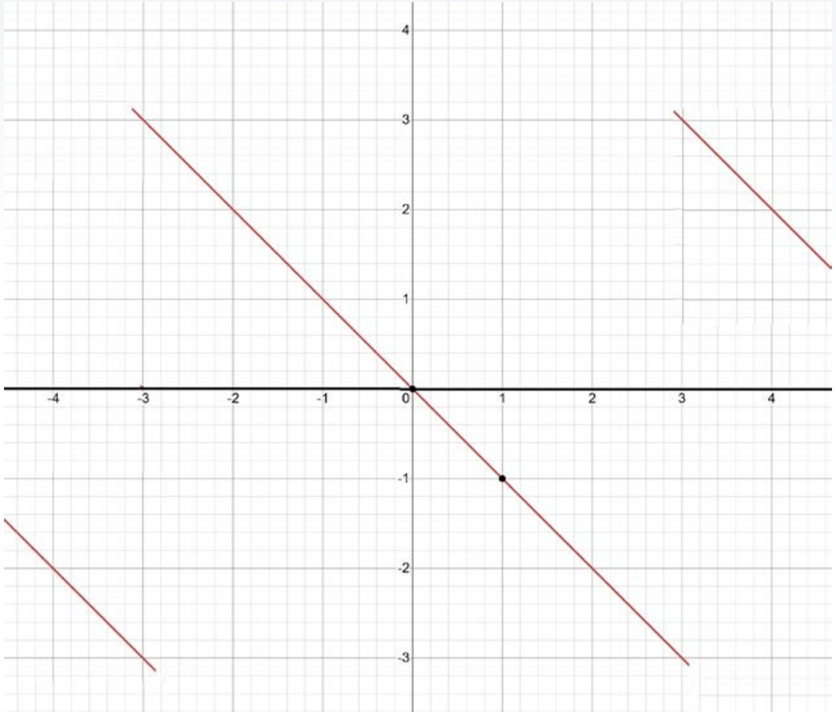
# 4. Phase spectrum $\angle X(e^{j\omega})$




- $\angle X(e^{j\omega}) = -\omega$

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# Issues

- *Poor prior knowledge (course prerequisite!)*
- *Poor working habits*

→ *The course has a reputation of being difficult among students*

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# Thank you for your attention!

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