L.EEC025 - Fundamentals of Signal Processing (FunSP)
2024/2025 – 1st semester

Lectures (T): **2 × 1 h/week (2 classes of ± 105 students each)**
Lab classes (PL): **2 h/week (9 classes of ± 18 students each)**

Week-by-week Lectures/PL planning (13 weeks)

Week 1, Sept 16-20, 2024

Lectures/videos:

- Curricular Unit presentation.
- Characterization and representation of discrete-time signals and systems.
- Linear and shift-invariant systems (LSI).
- Deterministic and discrete-time random signals.
- Special forms of the discrete-time convolution: the auto-correlation and the cross-correlation.

  - illustrative exercise solving

PL:

- Intro to Matlab, review of the discrete-time convolution.

Week 2, Sept 23-27, 2024

Lectures/videos:

- Introduction to the frequency-domain representation of discrete-time signals and systems.
- The discrete-time Fourier transform (DTFT). DTFT properties. DTFT transform pairs.
- The DTFT of the auto-correlation and of the cross-correlation.

  - illustrative exercise solving

PL:

- Organization of groups of 4 students for AD purposes (throughout the semester).
- Getting started with the STM32F7 Discovery kit (to be used in all FunSP Lab classes).

Week 3, Sept 30 – Oct 04, 2024

Distributed Assessment (AD)
→ VQ1 (discrete signals/systems, DFTF, AC/CC)
→ DSP Lab

Lectures/videos:

- Sampling and reconstruction of signals.
- Frequency-domain interpretation of sampling.
- The sampling theorem and aliasing.
- Discrete-time processing of continuous-time signals.

  - illustrative exercise solving

PL:

- **DSP Lab**: Generation on the STM32F7 kit of deterministic signals (LUT-based) and random signals. Viewing program output.

Week 4, Oct 07-11, 2024

Distributed Assessment (AD)
→ VQ2 (sampling / reconstruction of signals)
→ peer-to-peer (P2P) assessment

Lectures/videos:

- The direct Z-Transform. Causality and stability conditions.
- Information associated with the distribution of poles and zeros in the Z-plane.
- Z-Transform pairs.
- Characterization in the Z domain of FIR and IIR discrete-time systems (time permitting)

  - illustrative exercise solving

PL:

- **P2P** teaching/assessment.
- DSP Lab: Understanding sampling and reconstruction with the STM32F7 kit.

Week 5, Oct 14-18, 2024

Distributed Assessment (AD)
→ DSP Lab

Lectures/videos:

- The inverse Z-Transform. Z-Transform properties.
- The Z-Transform of the auto/cross-correlation functions.

  - illustrative exercise solving

PL:

- **DSP Lab**: Measuring the frequency response of a moving average filter running in real-time on the STM32F7 kit.

Week 6, Oct 21-25, 2024

Distributed Assessment (AD)
→ VQ3 (Z-Transform)
→ peer-to-peer (P2P) assessment

Lectures/videos:

- Characterization of LSI systems in the frequency-domain.
- Frequency-domain selectivity.
- Phase response, phase distortion and group delay.
- Inverse systems. All-pass systems.
- Minimum-phase systems, linear-phase and maximum-phase systems.

  - illustrative exercise solving

PL:

- **P2P** teaching/assessment.
- DSP Lab on “comparison between DMA-based and interrupt-based transfer of individual samples”.

FEUP week (Oct 28 – Nov 01)

Week 7, Nov 04-08, 2024

Lectures/videos:

- FIR linear-phase systems.
- Structures for the realization of IIR filters.
- Structures for the realization of FIR filters.

  - illustrative exercise solving

PL:

- DSP Lab: on "FIR and IIR comb filters".

Week 8, Nov 11-15, 2024

Distributed Assessment (AD)
→ VQ4 (LSI systems in the frequency-domain)
→ peer-to-peer (P2P) assessment

Lectures/videos:

- Design of IIR filters using the impulse invariance and bilinear transformation methods.
- Design of FIR filters using the window method and the MinMax optimization methods.

  - illustrative exercise solving

PL:

- **P2P** teaching/assessment.
- DSP Lab on "test of 2^{nd}-order IIR filters: an All-Pole and an All-Pass filter".

Week 9, Nov 18-22, 2024

Distributed Assessment (AD)
→ DSP Lab

Lectures/videos:

- The Discrete Fourier Transform (DFT). Analysis and synthesis equations.
- The DFT as a frequency-domain sampling of the DTFT.
- The circular/periodic properties of the DFT.
- Relationship between the circular convolution and the linear convolution.

  - illustrative exercise solving

PL:

- **DSP Lab:** on "design, realization and test of FIR filters".

Week 10, Nov 25-29, 2024

Distributed Assessment (AD)
→ VQ5 (IIR/FIR filter design & structures)
→ peer-to-peer (P2P) assessment

Lecture/videos:

- The computation of the DFT using the Fast Fourier Transform (FFT).
- The DFT-DIT and DFT-DIF algorithms.
- Programming of the FFT.

- Efficient FFT computation of real-valued signals.
- Fast FIR filtering in the frequency domain using the FFT (time permitting)
- The overlap-add and overlap-save methods (time permitting)

  - illustrative exercise solving

PL:

- **P2P** teaching/assessment.
- DSP Lab on "6th-order IIR band-stop filter".

Week 11, Dec 02-06, 2024

Distributed Assessment (AD)
→ VQ6 (DFT & IDFT)
→ DSP Lab

Lecture/videos:

- The computation of the auto/cross-correlation using the DFT/FFT.
- Introduction to spectrum estimation using the DFT/FFT.
- The periodogram, average spectrum, and spectrogram.

  - illustrative exercise solving

PL:

- **DSP Lab**: on "design and implementation of a discrete-time differentiator and Hilbert Transformer".

Week 12, Dec 09-13, 2024

Distributed Assessment (AD)
→ DSP Lab

Lecture/videos:

- Introduction to adaptive filtering.

  - illustrative exercise solving

PL:

- **DSP Lab**: on "FFT and power spectrum".

Week 13, Dec 16-20, 2024

Distributed Assessment (AD)
→ VQ7 (DFT filterbank. spectrog., adaptive filt.)

Lectures/videos:

- Applications of signal processing
- Course wrap-up and feedback

PL:

- DSP Lab on "system identification with adaptive filtering".