L.EEC025 - Fundamentals of Signal Processing (FunSP)
2023/2024 – 1st semester

Lectures: 2 h/week (2 classes of ± 105 students each)
Lab classes: 2 h/week (10 classes of ± 21 students each)

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

Week 1, Sept 11-15, 2023

Lecture/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.

  o illustrative problem solving

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

Week 2, Sept 18-22, 2023

Lecture/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.

  o illustrative problem 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 25-29, 2023

Distributed Assessment (AD)
→ VQ1
→ DSP Lab

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

  o illustrative problem solving

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

Week 4, Oct 02-06, 2023 (note: 05 Oct holiday)

Distributed Assessment (AD)
→ VQ2

Lecture/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)

  o illustrative problem solving (time permitting, as only ½ lecture will take place due to the holiday)

PL:

- Understanding sampling and reconstruction with the STM32F7 kit.

Week 5, Oct 09-13, 2023

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

Lecture/videos:

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

  o illustrative problem solving

PL:

- **P2P** teaching/assessment.
- Measuring the frequency response of a moving average filter running in real-time on the STM32F7 kit.

Week 6, Oct 16-20, 2023

Distributed Assessment (AD)
→ VQ4
→ peer-to-peer (P2P) assessment

Lecture/videos:

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

  o illustrative problem solving

PL:

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

Week 7, Oct 23-27, 2023	Distributed Assessment (AD)
	→ VQ5
	→ DSP Lab

Lecture/videos:

- Minimum-phase systems, linear-phase and maximum-phase systems.
- FIR linear-phase systems.
- Structures for the realization of IIR filters.
- Structures for the realization of FIR filters.

  o illustrative problem solving

PL:

- Lab on "FIR and IIR comb filters".

FEUP week (Oct 30 – Nov 03)

Week 8, Nov 06-10, 2023	Distributed Assessment (AD)
	→ VQ6
	→ DSP Lab

Lecture/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.

  o illustrative problem solving

PL:

- Lab on "test of 2nd-order IIR filters: an All-Pole and an All-Pass filter".

Week 9, Nov 13-17, 2023	Distributed Assessment (AD)
	→ VQ7
	→ peer-to-peer (P2P) assessment

Lecture/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.

  o illustrative problem solving

PL:

- **P2P** teaching/assessment.
- Lab on "design, realization and test of FIR filters".

Week 10, Nov 20-24, 2023	**Distributed Assessment (AD)** → **VQ8** → **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)

  o illustrative problem solving

PL:
- **P2P** teaching/assessment.
- Lab on "design and implementation of a discrete-time differentiator and Hilbert Transformer".

Week 11, Nov 27 – Dec 01, 2023 (note: 01 Dec holiday)	**Distributed Assessment (AD)** → **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.

  o illustrative problem solving

PL:
- Lab on "6th-order IIR band-stop filter".

Week 12, Dec 04-08, 2023 (note: 08 Dec holiday)	**Distributed Assessment (AD)** → **DSP Lab**

Lecture/videos:
- Adaptive filtering.

  o illustrative problem solving

PL:
- Lab on "FFT and power spectrum".

Week 13, Dec 11-15, 2023	Distributed Assessment (AD) → DSP Lab

Lecture/videos:
- Applications of signal processing
- Course wrap-up and feedback

PL:
- Lab on "system identification with adaptive filtering".