COURSE OUTLINE

(1) GENERAL

SCHOOL	ENGINEERING		
ACADEMIC UNIT	ELECTRICAL AND COMPUTER ENGINEERING DEPT.		
LEVEL OF STUDIES	Undergraduate		
COURSE CODE	**ECE_K640**	**SEMESTER**	**6**
COURSE TITLE	DIGITAL SIGNAL PROCESSING		

INDEPENDENT TEACHING ACTIVITIES *if credits are awarded for separate components of the course, e.g. lectures, laboratory exercises, etc. If the credits are awarded for the whole of the course, give the weekly teaching hours and the total credits*	**WEEKLY TEACHING HOURS**	**CREDITS**
Lectures	2	
Seminars	1	
Laboratory	1	
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (4).	4	5

COURSE TYPE *general background, special background, specialised, general knowledge, skills development*	Special Background
PREREQUISITE COURSES:	
LANGUAGE OF INSTRUCTION and EXAMINATIONS:	Greek
IS THE COURSE OFFERED TO ERASMUS STUDENTS	Yes
COURSE WEBSITE (URL)	https://www.ece.uop.gr/

(2) LEARNING OUTCOMES

Learning outcomes

The course learning outcomes, specific knowledge, skills and competences of an appropriate level, which the students will acquire with the successful completion of the course are described.
Consult Appendix A
- *Description of the level of learning outcomes for each qualifications cycle, according to the Qualifications Framework of the European Higher Education Area*
- *Descriptors for Levels 6, 7 & 8 of the European Qualifications Framework for Lifelong Learning*

and Appendix B
- *Guidelines for writing Learning Outcomes*

The aim of the course is to introduce students to the basic concepts and techniques of digital signal processing, to analog-to-digital signal conversion and to design of digital signal processing methods in order to remove noise from signals. For this purpose, the concepts of discrete time signals and systems will be presented. It will be presented the calculation of the response of a linear and time invariant (LTI) system through convolution and equation of differences. Definitions and properties of DTFT, DFT and Z transformations as well as their applications also will be given. The concepts of Transfer Function, Frequency Response and system impulse response using DTFT and Z transformations will be presented. System stability will be studied by generating pole-zero diagrams. Finally, the basic concepts of FIR and IIR filter design concepts will be presented and the elaboration of thought signals will be extended with many applications in real time signals.

Keywords: discrete time signals, discrete time systems, convolution, linear difference equations with constant coefficients, Discrete Time Fourier Transform, Z transform, Discrete Fourier Transform, Fast Fourier Transform, cyclic convolution, digital IIR & FIR filters.

Learning outcomes

Upon successful completion of the course, students will be able to:

At the knowledge level:

1. Describe the characteristic parameters and properties of the discrete time signals.
2. Distinguish and recognize the elementary discrete time signals.
3. Recognize the different categories of discrete time systems, describe system connections, and classify systems according to the type of the impulse response.
4. Identify the most appropriate way to calculate the output of a linear and time invariant (LTI) systems.
5. Describe the methodology for calculating the frequency response of an LTI discrete time system.
6. Explain the effect of the poles of a discrete time system on its spectral response.
7. Explain the concept of circular convolution of a discrete time signal.
8. Describe the methodology for calculating cyclic and linear convolution using DTFT.
9. Explain the differences between ideal and real digital filters, as well as between IIR and FIR digital filters.

At the skill level:

1. Calculate the characteristic parameters of discrete time signals.
2. Calculate the output of LTI systems through convolution and the solution of difference equations.
3. Calculate the Discrete Time Fourier Transform, both by its definition and by using its properties.
4. Calculate the frequency response of a discrete time LTI system.
5. Use the DTFT transformation to calculate the frequency response, to resolve difference equations and to calculate inverse systems.
6. Calculate the direct and inverse Z transform and its region of convergence.
7. Calculate the Transfer Function of a LTI system using the Z transform.

10. Calculate the circular convolution.
11. Calculate linear convolution using overlap-add and overlap-save methods.
12. Draw a linear FIR filter with window, frequency sampling and equiripple methods.
13. Draw a linear IIR filter with the bilinear transformation and invariant impulse response methods.

At the level of abilities:

1. To produce the impulse response of a LTI system when the linear difference equation it is known.
2. Choose the most appropriate way to calculate the outputs of a LTI system depending on the data available to them.
3. Explain the significance and differences between DTFT and DFT transformations.
4. Describe the operation of analog to digital conversion systems and design such systems.
5. Connect the properties of Z transform with system functions, e.g. time delay and group delay.
6. To conclude about the stability and the transient behavior of systems using the Z transform.
7. Design and evaluate the FIR and IIR filter response.

General Competences

Taking into consideration the general competences that the degree-holder must acquire (as these appear in the Diploma Supplement and appear below), at which of the following does the course aim?

Search for, analysis and synthesis of data and information, with the use of the necessary technology
Adapting to new situations
Decision-making
Working independently
Team work
Working in an international environment
Working in an interdisciplinary environment
Production of new research ideas

Project planning and management
Respect for difference and multiculturalism
Respect for the natural environment
Showing social, professional and ethical responsibility and sensitivity to gender issues
Criticism and self-criticism
Production of free, creative and inductive thinking
……
Others…
…….

- Search for, analysis and synthesis of data and information, with the use of the necessary technology
- Adapting to new situations
- Working independently
- Team Work
- Working in an international environment
- Production of new research ideas.
- Project planning and management
- Criticism and self-criticism
- Production of free, creative and inductive thinking

(3) SYLLABUS

Summary

Discrete time signal. Elementary discrete time signals, characteristic parameters and operations between signals. Discrete time systems and system function. Stable, causal, time invariant system. Impulse response of a discrete time system. Linear convolution in discrete time. Difference equations and their solution. DTFT transform and its properties. Equation difference solution based on DTFT. Reverse systems. Ideal filters. Z transform, properties and region of convergence (ROC). Fractional forms of Z transform. System transfer function. The Discrete Fourier Transform, its properties and the implementation of FFT. Circular convolution and ways to calculate it. DFT implementation using overlap add and overlap save methods. Design of IIR and FIR digital filters.

Lectures:

1. **Analog to Digital Signal Conversion**: Periodic and uniform sampling, Quantization, Uniform quantization, Quantization parameters, Coding, Converting digital signal to analog.
2. **Discrete Time Signals**: Introduction, differences between analog and digital processing techniques, digital signal production, Elementary discrete time signals, Periodic and symmetrical discrete time signals, The concept of frequency.
3. **Discrete Time Signals**: Transformations of the independent variable, analysis in unit impulse functions, characteristic parameters.
4. **Discrete Time Systems**: Introduction and classification of discrete time systems, Analysis techniques of LTI systems (convolution method, difference equations), Convolution theory, properties and calculating methods.
5. **Discrete Time Systems**: Difference equations, methods to solve difference equations, classify discrete times systems according to the type of the impulse response.
6. **Discrete Time Fourier Transform** (DTFT): Definition, properties and applications of DTFT (Frequency Response calculation, Difference Equation solution, Reverse Systems calculation).
7. **Frequency Response**: The concept of frequency response, Frequency response properties, Digital filters, frequency selection ideal filters, interconnection of LTI systems (filters).
8. **Z Transform**: Definition of Z transform, Region of Convergence (ROC), Useful pairs of Z transform, properties of Z transform. Fractional forms of Z transform, Poles and zeros, Effect of poles on the temporal and spectral behavior of causal signals, LTI system transfer function.
9. **Discrete Fourier Transform (DFT)**: Definition and properties of DFT, Circular shift and circular convolution, Circular convolution vs. linear convolution, Linear convolution calculation using DFT (overlap-add and overlap-save methods), Fast Fourier Transform (FFT).
10. **Digital FIR Filters**: Design of FIR digital filters using window, sampling frequency and equiripple methods.
11. **Digital Filters IIR**: Design of IIR digital filters, bilinear transformation and invariant impulse response methods.
12. **Spectral signal analysis**: Self-correlation function estimation, periodic chart, Blackman-Tukey spectrum estimator, parametric modeling, AR, MA parameters, AR methods, linear process prediction, applications in geoelectric signals.
13. **Multidimensional signals**: Applications of digital signal processing with emphasis on real-time signals (geoelectric potential signals), environmental signals and other parameters in areas such as geophysics, tomography. Digital signal processing applications with emphasis on medical signals and images, Elements of digital audio signal processing techniques with applications.

Laboratories

The laboratory part of the course includes practical exercises that aim at the application and consolidation of the knowledge of the theory and concern:

1. **Analog to Digital Conversion**: Production of a digital signal through sampling, quantization, coding, Reconstruction of an analog signal.
2. **Discrete Time Signals**: Introduction, simple operations of discrete time signals (time reversal, time shift, time escalation), Elementary signals (impulse sequence, unit step sequence, ramp sequence, Characteristic parameters (mean, RMS value, energy, power).
3. **Discrete Time Systems**: Properties of discrete time systems (causality, superposition, homogeneity, linearity, etc), system interconnections, Calculation of convolution using MATLAB. Difference equations, Solve difference equations with linear coefficients, Classify systems according to the type of impulse response.
4. **Z Transform**: Definition of Z transform, Calculation of direct and reverse Z transform.
5. **Discrete Fourier Transform (DFT)**: Definition and calculation of direct and reverse DFT, Calculation of circular convolution using DFT. Frequency response calculation.
6. **Digital Filters Design**: Design FIR digital filters using window, sampling frequency and equiripple methods, Design IIR digital filters, bilinear transformation and invariant impulse response methods.

Attendance of laboratory exercises is mandatory.

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face to face in class and in the laboratory. Distance learning support via e-Class system
USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY *Use of ICT in teaching, laboratory education, communication with students*	• Slides (ppt) for teaching the theoretical part, which have been posted since the beginning of the semester in the e-Class. • Laboratory guides for the laboratory part (one for each laboratory exercise), which have been posted on the e-Class since the beginning of the semester. • Solutions to laboratory exercises (posted after each laboratory exercise). • Support of learning process through the e-Class platform (for notification of the course operating regulations, for distribution of slides, supplementary material, announcements, links and bibliography, for the conduct of the intermediate and final examination of the laboratory part, etc.). • Specialized software for mathematical calculations Octave for the laboratory part freely available to each student. • Recorded video-lectures.
TEACHING METHODS *The manner and methods of teaching are described in detail.* *Lectures, seminars, laboratory practice, fieldwork, study and analysis of bibliography, tutorials, placements, clinical practice, art workshop, interactive teaching, educational*	(see table below)

Activity	*Semester workload*
Lectures	26 (=13×2)
Seminars	13 (=13×1)
Laboratory Exercises (in Lab)	12 (=6x2)
Projects (homework)	18 hours
Lecture & bibliography study (at home)	23 hours

visits, project, essay writing, artistic creativity, etc. *The student's study hours for each learning activity are given as well as the hours of non-directed study according to the principles of the ECTS*	<table><tr><td>Preparing for Final Exam</td><td>30 hours</td></tr><tr><td>Final Exam</td><td>3 hours</td></tr><tr><td></td><td></td></tr><tr><td></td><td></td></tr><tr><td>***Course Total***</td><td>***125 hours (5 ECTS)***</td></tr></table>
STUDENT PERFORMANCE EVALUATION *Description of the evaluation procedure* *Language of evaluation, methods of evaluation, summative or conclusive, multiple choice questionnaires, short-answer questions, open-ended questions, problem solving, written work, essay/report, oral examination, public presentation, laboratory work, clinical examination of patient, art interpretation, other* *Specifically-defined evaluation criteria are given, and if and where they are accessible to students.*	A. Assessment of Theoretical Part: • Intermediate exam (30%), which includes solving exercises and multiple-choice questions with graded difficulty. • Written final exam, that includes solving exercises, multiple choice questions and comparative evaluation of theory elements, graded difficulty. B. Evaluation of Laboratory Part: • Oral examination during laboratory exercises (30%) • Intermediate exam (30%) which includes solving exercises • Written final exam (40%) which includes solving exercises. <u>Remarks</u>: • The final grade results from the weighting of the theory and laboratory grades with weights of 60% and 40%, respectively. • The evaluation is done in the Greek language The evaluation process and evaluation criteria are published on the course's website in the e-Class.

(5) ATTACHED BIBLIOGRAPHY

- Suggested bibliography:

In Greek

1. A. Yfantis, G. Oikonomou, Signal Analysis and Processing, Ion Publications, 2002.
2. M. Paraskevas, Signals and Systems with MATLAB (Continuous and Discrete Time), Tziola Publications, 2018
3. A. Yfanti, G. Oikonomou, Signal Analysis and Processing, Ion Publications, 2002.
4. S. Loutridis, "Processing of Analog and Digital Signs", Tziola Publications, 2017.
5. A. Margaris "Signals and Systems of Continuous & Discrete Time", Tziola Publications, 2012.
6. S. Theodoridis, K. Berberidis, L. Kofidis, "Introduction to Signal and Systems Theory", Typothito Publications, 2003.
7. S. Fotopoulou, “Digital signal processing: Basic concepts and applications”, Inspiration Publications, 2010.
8. G. Syrkou, “Digital signal processing: Introduction, theory and applications”, G. Syrkou Publication, 2000.
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10. A. V. Oppenheim, R. W. Schafer, “Digital Signal Processing”, Founta Publications, 2012.
11. M. Hayes, “Digital Signal Processing”, Tziola Publications, 2000.
12. G. Moustakidis, “Basic techniques of digital signal processing”, Tziola Publications, 2003.
13. A. Yfanti, Ch. Theocharatou, V. Tsaggari, “Notes of the Laboratory of Digital Signal Processing”, Technological Educational Institute of Patras, 2005.
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16. Hayes Monson H., “Digital Signal Processing”, Tziola 2000 Publications.
17. L.Chaparro, "Signals and Systems Using MATLAB", Elsevier, 2011
18. V.Ingle, J.Proakis, "Digital Signal Processing Using MATLAB", Bookware Companion Series
19. J. G. Proakis, D. G. Manolakis, “Digital signal processing: Principles, algorithms and applications”, Prentice Hall, 2006.
20. S. K. Mitra, “Digital signal processing: A computer-based approach”, McGraw-Hill, 2011.
21. U. Zolzer, “Digital audio signal processing”, Wiley, 2008.
22. A. Antoniou, “Digital filters: Analysis, design and applications”, McGraw-Hill, 2004.
23. D. Schlichtharle, “Digital filters: Basics and design”, Springer, 2000.
24. B.P. Lathi, “Signal Processing and Linear Systems”, Berkeley-Cambridge, 1998.
25. N.Kalouptsidis, "Signal Processing Systems: Theory and Design", John Wiley