EUROPEAN UNIVERSITY FOR CUSTOMISED EDUCATION

STUDY GUIDE

DECODING THE DIGITAL WORLD: PRINCIPLES AND APPLICATIONS OF DIGITAL SIGNAL PROCESSING

Organised by

University of the Peloponnese

1. IDENTIFYING DATA.	
· **Course Name.**	DECODING THE DIGITAL WORLD: Principles and Applications of Digital Signal Processing
· **Coordinating University.**	University of the Peloponnese
· **Partner Universities Involved.**	-
· **Course Field(s).**	Digital technologies
· **Related Study Programme.**	-
· **ISCED Code.**	0710 Engineering and engineering trades
· **SDG.**	Industry, innovation and infrastructure
· **Study Level.**	BA and MA
· **EUNICE Key Competencies**	[Indicate the Key Competencies required for the course.] • Green – strongly • Orange- moderately • Red – partially • Blank cell - not at all

Problem solving	strongly
Teamworking	moderately
Communication	moderately
Self-management	moderately
Cognitive flexibility	partially
Digital competence	strongly
Technical competence	strongly
Global intercultural competence	partially

Co-funded by the European Union

· Number of ECTS credits allocated.	3
· Mode of Delivery.	Online self-study
· Language of Instruction.	English
· Course Dates.	March 2026 – June 2026
· Precise Schedule of the Lectures.	Self-study program: 4 hours per week Synchronous 2 hours online sessions for student support: Sunday: 15 March, 29 March, 19 April, 10 May, 24 May 2026
· Key Words.	Digital Signal Processing, Systems and Signals, Filters, Transforms Fourier and Z, Digital filters
· Catchy Phrase.	Digital signal processing for beginners

· Prerequisites and co-requisites.	• Students must have attended an undergraduate course related to Signals and Systems. • Students must have the ability to communicate in English – Level B2 is required. • The study levels this course is available for BA and MA students.
· Number of EUNICE students that can attend the Course.	Total number of students: 40 Number of students per EUNICE partner: 4
· Course inscription procedure(s).	The standard EUNICE registration process will be applied for the course.

2. CONTACT DETAILS.	
· Department.	Electrical and Computer Engineering
· Name of Lecturer.	Dr Michael Paraskevas, Professor
· E-mail.	mparask@uop.gr
· Other Lecturers.	Michail Nanos, Mathematician & Informatics Engineer, MSc Nikos Spatiotis, Informatics Engineer, MSc, Phd candidate

3. COURSE CONTENT.
Discrete time signals, Fundamental discrete-time signals, characteristic parameters and operations between signals, Discrete-time systems and system function, Stable, causal, time-invariant discrete systems, Impulse response of a discrete system, Convolution in discrete time, Differential equations and their solution, The DTFT transform and its properties, Solving difference equations using DTFT, Inverse systems, Ideal frequency selection filters, Z-transform, transform properties and regions of convergence (ROC), Fractional forms of Z-transform, System transfer function, The discrete DFT transform, its properties and the FFT implementation, Circular convolution and ways of calculating

it, DFT implementation, Design of IIR and FIR digital filters, IIR and FIR filter design techniques.

4. LEARNING OUTCOMES.

At the end of the course students will be able:

- Describe the principles and operation of analog-to-digital conversion systems and design such systems based on specific requirements.
- Determine the impulse response of a Linear Time-Invariant (LTI) system given its linear difference equation.
- Select the most appropriate method for computing the output of an LTI system, depending on the available input and system data.
- Explain the role, significance, and differences between the Discrete-Time Fourier Transform (DTFT) and the Discrete Fourier Transform (DFT), and apply them in signal analysis.
- Relate the properties of the Z-transform to system behavior, including time delay and group delay, and use them for system characterization.
- Evaluate the stability and transient response of discrete-time systems through pole-zero analysis and Z-transform properties.
- Design, implement, and assess the performance of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) digital filters.

5. OBJECTIVES.

The purpose of this course is to familiarize students with the fundamental concepts, methods, and applications of Digital Signal Processing (DSP). The course covers the representation and analysis of discrete-time signals and systems, focusing on the computation of system responses through convolution and difference equations. Students will explore the definitions, properties, and applications of key transforms, including the Discrete-Time Fourier Transform (DTFT), the Discrete Fourier Transform (DFT), and the Z-transform.

The course also introduces essential concepts such as transfer functions, frequency response analysis, and the use of transforms for determining system behavior. System stability will be examined through pole-zero diagrams and related criteria. Finally, students will gain an understanding of digital filter design by studying the basic principles and characteristics of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters.

6. COURSE ORGANISATION.	
UNITS	
1.	**Signal Conversion from Analog to Digital - Discrete Time Signals** Ideal sampling, Uniform quantization, Quantization parameters, Coding, Reconstruction of analog signal from digital, Classification of discrete-time signals (Periodic and Non-Periodic, Even and Odd, Energy and Power, Causal and Anti-causal), Operations on discrete-time signals (Addition, Multiplication, Amplitude Scaling), Transformations of the independent variable (Time-shift, Time-inversion, Time-scaling), Fundamental discrete-time time signals (Unit step, Unit impulse, Unit slope), Analysis of discrete-time signals into unit impulses, Real exponential discrete-time sequence, Complex exponential discrete-time sequence, Sine sequence).

2.	**Discrete-time Systems, Convolutional Sum and Difference Equations** Introduction to discrete-time systems, Categorization of discrete-time systems (Causal, Static, Time-Invariant, Homogeneous, Linear, Stable, Invertible), Ways of describing discrete-time systems (Stage diagrams, Difference Equations, Convolutional sum), Recursive and Non-recursive systems, Study of systems with the convolution, Properties of convolution, Ways to calculate linear convolution (Analytic calculation, Graphical calculation, Table Method, Calculation with Toeplitz Table), Difference Equations, Solving Linear Difference Equations with Constant Coefficients (LDECC), Classification of systems according to the type of the impulse response, Asymptotic stability of LSI discrete-time systems.
3.	**Z-Transform and Study of discrete-time system using Z-transform** Z-Transform Definition (Direct and Inverse Z-Transform), Region of Convergence (ROC of sequences of infinite duration, ROC of sequences of finite duration), Relation of Z-Transform with Laplace Transform), One-Sided Z-Transform, Properties of Z-Transform (Linearity, Time Shift, Time Reversal, Time Scaling, Complex Frequency Scaling, Convolution Theorem, Z Field Derivation, Complex Conjugate, Signal Multiplication, Initial Value Theorem, Final Value Theorem), Poles and zeros of the Z-Transform, Calculate the Inverse Z-Transform using expansion in partial sums, Description of discrete-time system in Z-plane (Transfer Function, Relation between Transfer Function and Difference Equation, Frequency Response, Poles and Zeros of Transfer Function, All-Pole and All-Zero systems, Causality and Stability Theorems), Solution of Difference Equations.

4.	**Discrete-Time Fourier Transform (DTFT) and Discrete Fourier Transform (DFT)** Discrete Time Fourier Transform (DTFT), Properties of DTFT (Periodicity, Symmetry and Conjugation, Linearity, Time Reversal, Time Shift, Frequency Shift , Variation in Frequency, Convolution Theorem, Periodic Convolution, Correlation, Parseval Theorem), Inverse DTFT, Relation of DTFT to other Transforms (Fourier transform, Z transform), Sampling rate transformation (Up-sampling, Down-sampling), Discrete Fourier Transform (DFT), Twiddle Factors, Magnitude and Phase Spectra, Relation of DFT to other Transforms (DTFT Transform, Z Transform), DFT calculation with tables, DFT Properties (Linearity, Cyclic Convolution in Time, Cyclic Time Shift, Conjugation, Symmetry of DFT for Real Sequences, Symmetry of DFT for Complex Sequences, Periodic Sequence Expansion, Periodic Convolution, Cyclic Frequency Shift, Cyclic Convolution, Multiplication of Sequences, Parseval's Theorem), Relation of Cyclic Convolution to Linear, Calculate the Circular Convolution using DFT, Fast Fourier Transform, Strategy for building efficient DFT calculation algorithms (Decimation in Time, Decimation in Frequency), Properties of Frequency Response, DTFT Applications (Calculating Frequency Response, Solving Differential Equations, Designing Inverse Systems, System Connections).
5.	**Digital FIR and IIR Filters** Filter gain control, Minimum, Maximum, Mixed and Linear Phase filters, Ideal Frequency selective filters, Specifications of real digital filters, Finite Impulse Response (FIR) Filters, FIR Filters in time and frequency domains, FIR Filter as a delay line, Types of FIR linear phase filters, FIR Filter Design Methods (Window Method, Frequency Sampling Method, Equiripple (optimal) Method), Study of Window sequences (Rectangular, Triangular (Bartlett), Hanning, Hamming, Blackman, Kaiser), Infinite Impulse Response (IIR) Filters, IIR Filter Design (General IIR Filter design method, Individual IIR Filter design methods), Standard Low-Pass analog filter (Prototype Butterworth, Chebyshev I & II, and Elliptic Low-Pass Filters), IIR Filter design methods (Invariant Impulse Response, Bilinear Transform), Effect of finite word length on filter accuracy.

LEARNING RESOURCES AND TOOLS.
The learning resources and tools that will be utilized for the delivery of the course are the following: • PowerPoint lectures (5 sets, 500 slides) • Solved Examples (5 sets, 50 exercises) • Tutorials for the hands-on lab using Matlab (60 solved examples) • Auto-evaluation quizzes (15 sets, 500 questions) • Supporting training material (docx, pdf and html formats) • Relevant videos from Internet given that no IP constraints exist.
PLANNED LEARNING ACTIVITIES AND TEACHING METHODS.
The planned learning activities and teaching methods are the following: • Lectures by faculty members of the university • Individual or group assignments Moreover, a forum will be used to facilitate the communication between students, as well as between students and the teachers.

7. ASSESSMENT METHODS, CRITERIA AND PERIOD.
Students are assessed in the course either by prepare an assignment or by participating in the final exam. Students can choose one of the two ways. • ASSIGNMENT - The course assignment is optional. Each assignment is prepared in groups of 1-2 students. For each assignment, each group must submit a report (8-10 pages of text in .doc, .docx, .odt, .pdf file types) and any supporting material used (e.g. documents), to the e-learning platform by Sunday, June 21, 2026, at 10:59 pm CET. The report will be evaluated for the accuracy and completeness of its content, the sources used, and the structure and organization of the text. • FINAL EXAM - On Sunday, June 14, 2026, time 6:00-7:00 p.m. CET, students will answer a 60-minute online quiz consisting of 20 questions. COURSE GRADE - The overall course grade is the grade of the assignment or the grade of the final exam, depending on the way each student chooses to be assessed.
OBSERVATIONS.

8. BIBLIOGRAPHY AND TEACHING MATERIALS.

MOOCs

- Paolo Prandoni and Martin Vetterli, Ecole Polytechnique Federale de Lausanne (EPFL)
    - "Digital Signal Processing 1: Basic concepts and algorithms",
    - "Digital Signal Processing 2: Filtering"
    - "Digital Signal Processing 3: Analog vs Digital"
    - "Digital Signal Processing 4: Applications"
- MIT OpenCourseWare — 6.341: Discrete-Time Signal Processing
- edX — "Fundamentals of Digital Signal Processing" (ETH Zurich)

Open Access Books

- "Signal Processing for Communications", by Paolo Prandoni and Martin Vetterli
- "Think DSPv" by Allen B. Downey
- "The Scientist and Engineer's Guide to Digital Signal Processing", by Steven W. Smith

Books

- Chaparro L.F., «Signals and Systems Using Matlab», Academic Press, Elsevier, 2nd edition, 2015.
- Hsu H. «Signals and Systems», (Schaum's Outlines), McGrawHill, 3rd edition, 2013.
- Ingle V.K., Proakis J.G, «Digital Signal Processing using MATLAB», Brooks Cole, 2000.
- Lathi B.P., Green R., «Essentials of Digital Signal Processing» Cambridge University Press, 2014.
- Lavry D., «Sampling Theory for Digital Audio», Lavry Engineering Inc., online edition.
- Oppenheim A.V., Schafer R.W., Buck J.R., «DiscreteTime Signal Processing», PrenticeHall, 1999.
- Prandoni P., Vetterli M., «Signal Analysis for Communications», EPF Press, online edition, 2008.
- Proakis J.G., Manolakis D.G., «Digital Signal Processing: Principles, Algorithms and Applications», 4th edition, Prentice Hall, 2007.
- Vetterli M., Kovacevic J., «Foundations of Signal Processing», Cambridge University Press, 2014.