Digital Signal Processing

<table>
<tr><th>module title
module code</th><th colspan="2">level of module</th><th>year of study</th><th>semester/trimester when the module is delivered</th><th></th></tr>
<tr><td>Digital Signal Processing
EN-SplC 504-6</td><td colspan="2">1st (Undergraduate)</td><td>3rd</td><td>FALL</td><td></td></tr>
<tr><th rowspan="2">Name / e-mail of lecturer(s)</th><th colspan="2">Weekly Hours</th><th rowspan="2">ECTS</th><th rowspan="2">module type (comp., opt.)</th><th rowspan="2">mode of delivery (face to face, distance learning)</th></tr>
<tr><th>Lect.</th><th>Lab.</th></tr>
<tr><td>Prof. Maria RANGOUSSI
(mariar@teipir.gr)</td><td>4</td><td>2</td><td>6</td><td>compulsory</td><td>face to face</td></tr>
<tr><td>module web Page</td><td colspan="5">http://electronicstaff.teipir.gr/rangoussi/index.php/en/teaching/undergraduate-courses/digital-signal-processing/lectures.html</td></tr>
<tr><td>learning outcomes</td><td colspan="5">Upon successful completion of the course, the student possesses advanced knowledge, skills and competences that enable him/her to:
1. Describe general and specific DSP processes by block diagrams.
2. Select the appropriate form of digital system description, among alternatives, for the problem at hand.
3. Perform spectral analysis of digital signals and systems using simulation tools for the computation of the digital output signal.
4. Interpret the results of spectral analysis of digital signals and systems, so as to conclude on their characterization and classification.
5. Analyze signal processing problems under realistic application scenarios (processing of audiovisual / biomedical / telecom signals) and compose solutions (design digital systems) on the basis of methods taught in the course.
6. Collaborate with fellow students in a team, in order to thoroughly address complex DSP problems (analysis – synthesis) and to critically evaluate alternative solutions, leading to decisions as to the feasibility of hardware implementations.

Keywords: Discrete-time signals and systems, (auto-)correlation, finite / infinite impulse response, digital filters, direct form I and II, Discrete Fourier Transform, Fast Fourier Transform, spectral analysis.</td></tr>
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prerequisites and co-requisites:	None
recommended optional programme components	
module description	<u>*Lectures*</u> **UNIT I: Introduction** 1. General placement of the DSP subject in the field of study of the electronics and telecommunications engineer. Survey of major modern DSP applications, with emphasis on telecoms. Placement of the DSP course and connections with previous and next semester courses. 2. Basic mathematics background revisited (Laplace, Z and Fourier Transforms and Inverses). Discrete-time versus continuous-time signals and systems. Discrete Fourier Transform and Inverse, properties. 3. Simulation and graphics display of discrete-time signals and systems in Matlab. **UNIT II: A-to-D and D-to-A conversion** 1. Fundamental theorems and methods, electronic circuits, survey of contemporary hardware available (A/D and D/A convertors, DSP boards) and selection criteria. 2. Introduction to A/D and D/A devices and systems using modern hardware; application to speech and audio signals. Experimental acquaintance with the fundamental characteristics of A/D conversion and their impact on digital signal quality. **UNIT III: Elementary DSP functions and properties** 1. Instrumental DSP functions and their properties: convolution, (auto-)correlation); methods for their computation in the time and the frequency domains. 2. Use of simulation software for the computation and representation of the correlation and the convolution of digital signals / systems. **UNIT IV: The Discrete Fourier Transform (DFT) and its fast implementations (FFT)** 1. Discrete Fourier Transform, Fast Fourier Transform fundamentals. Algorithms for their computation and algorithmic complexity. Hardware implementations.

	UNIT V: Linear Prediction 1. Introduction of the central notion of linear prediction in discrete-time systems, through the solution of linear problems of special forms. Prediction error and optimal prediction. System modeling. **UNIT VI: Modern Spectral Analysis** 1. Modern spectral analysis, parametric and non-parametric Spectral analysis of stationary and quasi-stationary signals: Fourier-based methods, examples. Spectral analysis of non-stationary signals: time-frequency and time-scale representations, examples. 2. Experimental application of spectral analysis methods in real signals, stationary or not. Use of simulation software for the representation of the spectra in order to comparatively evaluate the quality of the results. **UNIT VII: Introduction to digital filter design** 1. Major design methods for FIR and IIR filters. Window functions and windowing. Introduction to adaptive digital filters. 2. Design and application of digital filters in specific speech and audio processing scenarios. Experimental acquaintance with digital filters design and comparative evaluation of the quality of the results. *Laboratory* 1. TMS320C5505 Digital Signal Processor and the Integrated Development Environment “Code Composer Studio v.5” of Texas Instr. Inc. 2. Echo and reverberation 3. Sine waves generation 4. Alien voices generation 5. Dual tone multi-frequency signal generation 6. Comb digital filters 7. FIR digital filters 8. IIR digital filters 9. Adaptive filters 10. Adaptive filters applied to active noise reduction (ANR).

recommended or required bibliography:

Essential reading

1. HAYES, M., Digital Signal Processing, Schaum's Outline Series, 2nd Edition, Paperback 2011.
2. OPPENHEIM, A.V., SCHAFER, R.W., BUCK, J.R., Discrete-Time Signal Processing, Prentice-Hall, 1999.
3. PROAKIS, G., MANOLAKIS, D., Digital Signal Processing, Prentice-Hall, 3rd. ed., 1996.
4. TMS320C5505 USB Stick Teaching Materials, Texas Instruments – University Programme, 2010.

Recommended Books

1. HAYKIN, S., Adaptive Filter Theory, 4th Edition, Prentice-Hall, 2001.
2. PORAT, B., A course in Digital Signal Processing, Wiley, 1997.
3. PROAKIS, J., RADER, C.M., LING, F., NIKIAS, C.L., Advanced Digital Signal Processing, McMillan, New York, 1992.
4. KALOUPTSIDIS, N., THEODORIDIS, S., Adaptive System Identification and Signal Processing Algorithms, Prentice-Hall Intl., UK, 1993.
5. PORAT, B., Digital Processing of Random Signals, Prentice-Hall, New Jersey, 1994.
6. GOLD, B., MORGAN, N., Speech and Audio Signal Processing, Wiley, 2000.
7. QUATIERI, T. F., Discrete-time Speech Signal Processing, Prentice-Hall, 2000.
8. RABINER, L.R., SCHAFER, R.W., Introduction to Digital Speech Processing, Foundation & Trends in Signal Processing, 2007.

planned learning activities and teaching methods:

Learning Activities Plan

Learning activity	**Load (hours)**
Lectures	52
Laboratory experiments	26
Student technical report on lab part	32
Student technical report on lecture part (possibly as a team member)	30
Study and preparation for exam	40
TOTAL COURSE LOAD	***180***

Teaching Methods Employed

- Face to face teaching with the aid of power-point

	transparencies and multimedia (audio) material. • Simulation software for the simulation of digital processes in the lab. • Integrated Development Environment Software of the programming and running of applications on the TMS DSP dedicated hardware in the lab. • Teaching support and study material (lecture notes, lab notes, solved examples, solved past exams) through the course webpage. • Electronic communication with the students enrolled in the course, through the course webpage.
assessment methods and criteria:	Final course grade = Lectures part grade x 60% + Laboratory part grade x 40%, analyzed as follows: Final written exam covers all taught material. During the exam, students may consult a list of formulae provided by the examiner as a reminder. Students must prove mastery of the material through stating and interpreting definitions of all quantities, handling relations among quantities and solving of design problems based on specs. *Lectures part grade:* Homework assignments – 2 per semester (20%) Final written exam – 2 hours (80%) Final written exam covers all taught material. During the exam, students may consult a list of formulae provided by the examiner as a reminder. Students must prove mastery of the material through stating and interpreting definitions of all quantities, handling relations among quantities and solving of design problems based on specs. *Laboratory part grade:* Participation in all lab experiments and oral evaluation – (20%) Mid-term written test (40%) End-term written test (40%)
language of instruction:	English