UAB
Universitat Autònoma de Barcelona

Integrated System Design for Digital Processing

Code: 42839
ECTS Credits: 6

2024/2025

Degree	Type	Year
4313797 Telecommunication Engineering	OB	1

Contact

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Teachers

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Teaching groups languages

You can view this information at the end of this document.

Prerequisites

Knowledge on the following subjects is recommented:

Digital Signal Processing
Electronic Systems Design
Digital Sistemes and Hardware Description Languages
Electronic Systems and Applications

Objectives and Contextualisation

(This course has been updated for the year 2024-25)
The main objective of this course is to learn, understand and be able to design electronic systems for digital signal processing with the focus on integrated systems. These Systems are composed of integrated circuits that manage their computation and communication. The study of these integrated systems will be oriented to the usual digital signal processing architectures with the focus on applications of acoustics, audio and speech processing.
Different design methodologies will be used according to the level of abstraction (system, architecture, implementations). Hardware Description Languages (HDL) will be introduced. In order to implement such systems in the labs you will use electronic boards with FPGA reconfigurable devices.

Competences

- Be capable of using programmable logic as well as designing advanced electronic systems, both analogue and digital.
- Capacity for critical reasoning and thought as means for originality in the generation, development and/or application of ideas in a research or professional context.
- Capacity for working in interdisciplinary teams
- Knowledge of the hardware description languages for highly complex circuits
- Maintain proactive and dynamic activity for continual improvement
- Students should be capable of integrating knowledge and facing the complexity of making judgements using information that may be incomplete or limited, including reflections on the social and ethical responsibilities linked to that knowledge and those judgements
- Students should know how to apply the knowledge they have acquired and their capacity for problem solving in new or little known fields within wider (or multidisciplinary) contexts related to the area of study
- Students should know how to communicate their conclusions, knowledge and final reasoning that they hold in front of specialist and non-specialist audiences clearly and unambiguously

Learning Outcomes

1. Capacity for critical reasoning and thought as means for originality in the generation, development and/or application of ideas in a research or professional context.
2. Capacity for working in interdisciplinary teams
3. Design ASICs
4. Design integrated circuits using hardware description languages through ASICs and/or FPGAs
5. Knowledge of the hardware description languages for highly complex circuits
6. Maintain proactive and dynamic activity for continual improvement
7. Students should be capable of integrating knowledge and facing the complexity of making judgements using information that may be incomplete or limited, including reflections on the social and ethical responsibilities linked to that knowledge and those judgements
8. Students should know how to apply the knowledge they have acquired and their capacity for problem solving in new or little known fields within wider (or multidisciplinary) contexts related to the area of study
9. Students should know how to communicate their conclusions, knowledge and final reasoning that they hold in front of specialist and non-specialist audiences clearly and unambiguously
10. Use programmable digital logic.

Content

1. Introduction to Integrated System Design for Digital Processing
Fundamentals of Digital Signal Processing (Quantization, Sampling, Z-transform, Filer design, Digital Fourier Transform)
Microelectronic Design Methodologies for ASIC and FPGA

2. High-level Digital Signal Processing
Introduction to Acoustics and Spatial Audio
Introduction to Speech Sounds and Speech Processing
Source Filter Models
Speech Coding
Perceptual Models and Hearing Devices (Hearing Aids and Cochlear Implants)
Speech Enhancement and Source Separation Algorithms
Spatial Audio (Introduction to Vector Based Amplitude Panning and Ambisonics)

3. Adaptation for Implementation of Signal Processing Algorithms
Asynchronous sample rate conversion (ASRC)
Real time low latency processing (circular buffers)
Optimization of algorithms (Fast Fourier Transform - Radix algorithms)
Floating point to Fixed Point conversion Algorithms
Platforms and libraries for audio and hearing aid real time processing

4. Deployment on Integrated Systems
Integrated circuits structure: FPGAs
HDL Modelling, simulation and synthesis
Clock and Power Management
Verification and prototyping

Laboratories: Real-time Audio and Speech Digital Signal Processing on FPGA

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Laboratory Sessions	15	0.6	1, 2, 4, 5, 6, 7, 8, 9, 10
Lectures	30	1.2	1, 3, 4, 5, 6, 7, 8, 10
Type: Supervised			
Thematic Homework (Individual)	10	0.4	1, 6, 7, 8, 9
Type: Autonomous			
Laboratory activities preparation and reporting	20	0.8	1, 2, 4, 5, 7, 8, 10
Study	69	2.76	1, 3, 4, 5, 6, 7, 8, 10

The course will be mainly driven by the lectures, that will use adhoc material (presentations, documents, links, tools and other resources) available in the virtual campus (VC) of the UAB.

Students will deliver exercices on specific subjects (on the Virtual Campus).

Laboratory work will let the students to apply and experiment the concepts acquired on FPGA platforms widelly used in industry.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes

Inidividual Exercises	15%	1	0.04	1, 6, 7, 8, 9
Laboratory work reports	35%	1	0.04	1, 2, 4, 5, 6, 7, 8, 9, 10
Partial Evaluación (Part 1): Exam	25%	2	0.08	3, 4, 5, 7, 8, 9, 10
Partial Evaluación (Part 2): Exam	25%	2	0.08	1, 3, 6, 9

Student assessment uses continuous evaluation made up of the following assessments:

• Two partial exams for the each part of the course, which gives 25% of the final grade.
• Individual work in thematic exercises (delivered on the virtual campus), which accounts for 15% of the final grade
• Team work in the laboratory, scheduled in 5 sessions, with the obligation to deliver the corresponding individual reports. An evaluation above 5 is mandatory to pass the course. This activity contributes 35% to the final grade of the course.

The final exam allows students to assess the achievement of skills in a single exam or to recover any partial assessments that had a mark lower than 3.5. That is also the minimum mark requered for any of the parts to pass the course and the average mark of both exams is not below 5.

A weighted final grade of not lower than 5 is required to pass the course.

In order to obtain MH, students will need to have an overall qualification higher than 8.5 with the limitations of the UAB (1 MH/10 students). As a reference criterion, they will be assigned in descending order.

Plagiarism will not be tolerated either in exams or in individual activities on the Virtual Campus. In this case, the available tools will be used to verify it. All students involved in plagiarism will be automatically suspended. A final grade of no more than 30% will be assigned.

The student will receive a grade of "Not Evaluable" if:
- the student has not been able to be evaluated in the laboratory due to not attendance or not deliver the corresponding reports without justified cause.
- the student has not carried out a minimum of 50% of the activities proposed.
- the student has not taken the final exam.

Repeating students will be able to "save" their grade in lab but not in the rest of the activities.

Bibliography

Digital Speech Processing

- Peter Vary, Rainer Martin, Digital Speech Transmission: Enhancement, Coding and Error Concealment, John Wiley & Sons Inc, 2006. (New issue to appear during 2024).
- L.R. Rabiner and W. Schafer. 2007. Introduction to digital speech processing. http://cronos.rutgers.edu/~lrr/dsp%20design%20course/final_speech_paper_1_2008.pdf
- Xuedong Huang, Alex Acero, Hsiao-Wuen Hon, Spoken Language Processing: A Guide to Theory, Algorithm, and System Development, ISBN: 0130226165, Prentice Hall, 2001.

Acoustics and 3D Audio

- Jens Blauert, Spatial Hearing: The Psychophysics of Human Sound Localization (Revised Edition), DOI: https://doi.org/10.7551/mitpress/6391.001.0001, ISBN electronic: 9780262268684, , The MIT Press, 1996.
- Franz Zotter, Matthias Frank, Ambisonics: A Practical 3D Audio Theory for Recording, Studio Production, Sound Reinforcement, and Virtual Reality, ISBN 3030172066, Springer, 2019.

- Agnieszka Roginska, Paul Geluso, The Art and Science of Binaural and Multi-Channel Audio, ISBN 9781138900004, Routledge, 2017.

Psychoacoustics

- Brian Moore, An introduction to the Psychology of Hearing, 6th Edition, BRILL ACADEMIC PUB, 2006.Link: https://www.finearts.uvic.ca/~aschloss/course_mat/MUS%20511/articles/An%20Introduction%20to%20the
- Hugo Fastl, Eberhard Zwicker, Psychoacoustics, Facts and Models, ISBN 978-3-540-23159-2, DOI https://doi.org/10.1007/978-3-540-68888-4, Springer-Verlag Berlin, 2007.

Hearing Aids and Cochlear Implants

- Harvey Dillon, Hearing Aids, ISBN 3131289414, Thieme, 2010
- Graeme Clark, Cochlear Implants: Fundamentals and Applications (Modern Acoustics and Signal Processing), ISBN 0387955836, Springer, 2013.

Integrated and Embedded Systems:

- Edward A. Lee and Sanjit A. Seshia, Introduction to Embedded Systems, A Cyber-Physical Systems Approach, Second Edition, MIT Press, ISBN 978-0-262-53381-2, 2017.Available at https://ptolemy.berkeley.edu/books/leeseshia/releases/LeeSeshia_DigitalV1_08.pdf
- Vaibbhav Taraate, Digital logic design using Verilog : coding and RTL synthesis, Springer, ISBN 978-981-16-3198-6, 2022. Available at on-line through your UAB account https://bibcercador.uab.cat/
- I. Grout "Digital Systems Design with FPGAs and CPLDs"
- P. Bricaud, M. Keating : "Reuse Methodology Manual for System-On-A-Chip Designs"
- H.J.M. Veendrick "Nanometer CMOS: from ASICS to BASICS", 2ª edición, Springer. 2017. Available at on-line through your UAB account https://bibcercador.uab.cat/

Software

The electronic design tools (EDA) associated with Intel-Altera FPGA boards used in laboratories that enable:
- Specification of digital systems in HDL languages
- Building SoC architectures for RISC processors (ARM, NIOS)
- Logical and physical synthesis of HDL
- Downloading HW and SW code from the PC to the FPGA
- Execution of the algorithm in the FPGA

Intel Altera's DE1_SoC board will be used as the SoC-FPGA platform.

Students will have free access, upon request, to courses on industrial EDA tools (CADENCE) useful for their curriculum and training, mainly for subjects 3 and 4.
https://www.cadence.com/content/dam/cadence-www/global/en_US/documents/training/learning-maps.pdf

Language list

Information on the teaching languages can be checked on the CONTENTS section of the guide.