Course guide
2301214 - ETC - Emerging Technologies for Computing

Last modified: 30/05/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 1022 - UAB - (ANG) pendent.

Degree: MASTER'S DEGREE IN SEMICONDUCTOR ENGINEERING AND MICROELECTRONIC DESIGN (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 4.0 **Languages:** English

LECTURER

Coordinating lecturer: ANTONIO CALOMARDE PALOMINO

Others: Segon quadrimestre:
ANTONIO CALOMARDE PALOMINO - 10
ENRIQUE ALBERTO MIRANDA CASTELLANO - 10
XAVIER ORIOLS PLADEVALL - 10
FRANCESC PÉREZ MURANO - 10
ROSANA RODRIGUEZ MARTINEZ - 10
JOSE ANTONIO RUBIO SOLA - 10

LEARNING RESULTS

Knowledges:
KT01. Identify semiconductor devices, technological processes, the most appropriate microelectronic design tools, and relationships between these elements in order to integrate a given product or system into microelectronic technologies.
KT02. Describe the current state of scientific research and microelectronic industrial technology worldwide and their economic, social and environmental impact.
KT03. Describe the physical principles underlying current semiconductor devices in relation to their application, as well as their emerging trends, modelling and characterisation techniques.

Skills:
ST01. Design integrated devices, circuits and systems for new products according to their applications, taking into account sustainability and energy efficiency requirements.
ST04. Select appropriate sources of information from the scientific and technical literature, using appropriate channels, and integrate this information, demonstrating the ability to synthesise information, analyse alternatives and engage in critical debate.

Competences:
CT01. Design new devices and integrated systems that require the use of manufacturing techniques specific to microelectronic technologies or the use of microelectronic design tools.
CT03. Apply the processes of semiconductor engineering and microelectronic design to fields in diverse areas of science or engineering where integrated systems are required.
CT04. Generate questions and hypotheses, propose methodologies to address new research and innovation challenges, and demonstrate originality in approaching and solving problems requiring integrated solutions in microelectronic technologies.

TEACHING METHODOLOGY

Classroom lectures: 30h.
Place of demonstrations sessions: Visits to institutions with practical activity on diverse aspects of quantum computing, as for example, IMB-CNM, BSC and Qilimanjaro.

LEARNING OBJECTIVES OF THE SUBJECT

1. Acquire basic knowledge on the limitations of conventional computing technologies and how they can be complemented by emerging technologies based on neuromorphic and quantum computing circuits for specific applications.
2. Learn what in-memory computing means, its different fields of application, and how neuromorphic circuits with memristors are implemented.
3. Be able to design and simulate neuromorphic circuits based on memristors and CMOS neurons.
4. Acquire knowledge about the basics of quantum computing and its implementation through different physical devices, with special emphasis on spin qubits in semiconductors.
5. Be able to analyze the operation of devices and circuits for quantum computing

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	30.00
Self study	70,0	70.00

Total learning time: 100 h

CONTENTS

Emerging technologies for computing

Description:
Block 1. Neuromorphic and in-memory computing

1. Conventional computing technologies
Principles, state of the art and limitations. High performance systems and unaffordable power budget. The Von-Neumann wall.

2. Alternative technologies and Unconventional Computing Strategies
In-Memory Computing and Neuromorphic Computing. AI accelerators, emerging NVM, comparison of Memory for edge-AI.

3. The memristor, an emerging device
Memristor basics: the fourth element (Chua), the device found (HP). Materials in Metal-Oxides. Ideal memristor, fingerprints of memristors.
Device types and properties: Filamentary, ionic. Binary, multiple value. PCM, ReRAM, OxRAM. Memristor non-linear properties.
Memristor models: Behavioral, physic models.
Memristor based structures: Crossbars, 1R, 1T1R. NVMemories.

4. Applications of memristors for in-memory and neuromorphic computing
Neuromorphic computing with memristors: principles, synaptic crossbars. Neuron models and implementation. Learning strategies. SNN and DNN examples. Variability and stochasticity. Associative memories.
Logic gates with memristors: gate structures and logic design styles. Memristive memory logic design.
Examples of other applications of low and high precision: cryptography, combinatorial optimization problems, sparse coding, scientific computing.

Block 2. Quantum computing

5.- The second quantum revolution
From science to engineering. Basic concepts of quantum mechanics: wave function, energy quantization, superposition, entanglement, measurement, decoherence.

6.- Quantum technologies and computing basics
Quantum technologies. Qubits and quantum computing algorithms. Deutsch's and Jozsa's algorithms. Physical implementation of Qubits. Hamiltonians for quantum gates.

7. Physical implementation of quantum computing
Platforms for quantum computing: diamond, ion traps, photons, superconductors, semiconductors, hybrid. Semiconductor based quantum computing. Devices: quantum dots, single electron charges. Read-out methods. Fabrication Technologies.

8. Demonstrations sessions
Showcase sessions about different implementations of quantum computing.

Full-or-part-time: 100h
Theory classes: 30h
Self study : 70h

GRADING SYSTEM

Examination: exam (100%).

BIBLIOGRAPHY

Basic:
- Christensen, Dennis V.; Dittmann, Regina; Linares-Barranco, Bernabé ... [et al.]. "2022 roadmap on neuromorphic computing and engineering". Neuromorphic Computing and Engineering [on line]. Vol. 2 (2), 022501, 2022 [Consultation: 18/03/2024]. Available on: https://iopscience-iop-org.recursos.biblioteca.upc.edu/article/10.1088/2634-4386/ac4a83.- Indiveri, Giacomo; Liu, Shih-Chii. "Memory and Information Processing in Neuromorphic Systems". Proceedings of the IEEE [on line]. Vol. 103 (8), pp. 1379-1397, 2015 [Consultation: 18/03/2024]. Available on: https://ieeexplore-ieee-org.recursos.biblioteca.upc.edu/document/7159144.- Kitaev, Alexei Yu; Shen, Alexander H.; Vyalyi, Mikhail N.. Classical and quantum computation [on line]. American Mathematical Society, 2002 [Consultation: 02/05/2024]. Available on: https://www.ams.org/books/gsm/047/gsm047-endmatter.pdf. ISBN 0-8218-2161-X.
- Nielsen, Michael A.; Chuang, Isaac L. Quantum computation and quantum information. 10th ed. Cambridge: Cambridge University Press, 2010. ISBN 9781107002173.
- Gonzalez-Zalba, M; de Franceschi, S.; Charbon, E.; Meunier, T.; Vinet, M.; Dzurak, A.S.. "Scaling silicon-based quantum computing using CMOS technology: State-of-the-art, Challenges and Perspectives". Nature Electronics [on line]. Vol. 4 (12), pp. 872-884, 2021 [Consultation: 02/05/2024]. Available on: https://arxiv.org/abs/2011.11753.- Semiconductor spin qubits. Rev. Mod. Phys. 95, 025003(2023). doi.org/10.1103/RevModPhys.95.02500.