COURSE OUTLINE

(1) GENERAL

SCHOOL	ENGINEERING		
ACADEMIC UNIT	ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT		
LEVEL OF STUDIES	Undergraduate		
COURSE CODE	**ECE_ELE820**	**SEMESTER**	**8**
COURSE TITLE	VERY LARGE SCALE INTEGRATION (VLSI) SYSTEMS		

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	3	
Seminars / Practice exercises	1	
Laboratory		
Total	**4**	**5**
Add rows if necessary. The organisation of teaching and the teaching methods used are described in detail at (4).		

COURSE TYPE *general background, special background, specialised, general knowledge, skills development*	Specialised
PREREQUISITE COURSES:	No. Students are advised to have already attended the courses: fundamental electronics and digital circuits and systems
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 manufacturing process and design technology of integrated circuits exhibit very high growth rate. The feature size of CMOS manufacturing processes (i.e. the minimum dimension of a transistor that can be reliably built) is today lower than 30nm, and the complexity of the circuits have grown by orders of magnitude. These issues are major challenges for the manufacturers as well as the designers of VLSI integrated circuits and systems. The emphasis of the course is on CMOS technology and the course offers the essential knowledge for the design, fabrication and operation of CMOS devices and circuits. The main objectives of the course is to introduce basic issues on VLSI circuits and systems, to describe in a feasibly way the manufacturing process of integrated circuits, to present and analyse the operation of the basic devices that are used in digital integrated circuits, as well as the parameters that affects

their performance, to explain the influence of interconnections on the operation of integrated circuits, to offer the required skills to design CMOS logic gates and complex digital circuits (combinational and sequential) and to estimate their characteristics, and finally to present the design and implementation methodologies of digital integrated circuits and systems.

Keywords: VLSI circuits, VLSI systems, MOSFET, CMOS technology, digital integrated circuits.

Learning Outcomes

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

1. understand and describe the basic principles of CMOS integrated circuits and to describe their manufacturing process,
2. understand and analyse the structure and the operation of MOSFETs,
3. estimate the delay and the power dissipation of basic CMOS circuits,
4. design static and dynamic CMOS circuits at the transistor and physical (layout) layers, and analyse their operation,
5. design complex CMOS combinational and sequential circuits,
6. understand the basic parameters of interconnections in integrated circuits, as well as their influence on the operation and the characteristics of integrated circuits,
7. know the design and implementation methodologies of digital integrated circuits and systems.

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
- Decision-making
- Working independently
- Team Work
- Production of free, creative and inductive thinking

(3) SYLLABUS

The course lectures cover the following thematic areas:

1. Introduction to VLSI circuits and systems: brief history, integrated circuits and microprocessors, Moore’s law, evolution of integrated circuits complexity, frequency and energy dissipation, design hierarchy of integrated circuits, pros and cons of integrated circuits, quality metrics of digital circuits, cost and yield of integrated circuits, functionality and robustness, operating frequency and propagation delay, power and energy consumption, energy-delay product.

2. Manufacturing process of integrated circuits I: manufacturing of CMOS integrated circuits, silicon ingot and wafers, photolithography, manufacturing process steps of CMOS integrated circuits, design and fabrication of the CMOS inverter, design rules.

3. Manufacturing process of integrated circuits II: advanced manufacturing techniques of integrated

circuits, packaging of integrated circuits, mounting of integrated circuits on boards, multi-chip modules, MCMs, system-in-a-package.

4. MOSFET transistor I: introduction to the MOSFET, threshold voltage, operating regions of NMOS and PMOS transistors, NMOS transistor current computation, current expressions of NMOS and PMOS transistors, I-V characteristics, channel length modulation in MOSFETs.

5. MOSFET transistor II: short-channel effects (carriers' velocity saturation and mobility degradation, subthreshold conduction, DIBL effect, source and drain parasitic resistance, hot carriers effect, gate leakage), MOSFET equivalent resistance, MOSFET capacitances, simulation models for MOSFETs, process variations.

6. CMOS inverter I: introduction and basic characteristics of the CMOS inverter, static behavior of the CMOS inverter (transfer characteristic, switching threshold, noise margins), dynamic behavior of the CMOS inverter, capacitances of the CMOS inverter.

7. CMOS inverter II: CMOS inverter propagation delay and parameters that affect it, sizing the CMOS inverter for propagation delay reduction, inverter chain propagation delay, power and energy consumption of CMOS inverter, dynamic (capacitive) energy consumption, short-circuit energy consumption, leakage and static energy consumption, energy-delay product.

8. CMOS circuits interconnections: capacitance, resistance and inductance of interconnections, interconnection modeling techniques, lumped capacitance model, lumped RC model, Elmore delay, distributed rc line.

9. CMOS combinational circuits I: introduction to CMOS combinational circuits, static complementary CMOS logic, physical design of complementary CMOS gates, static characteristics of CMOS complementary logic, propagation delay of complementary CMOS logic gates, logic effort, energy consumption of complementary CMOS logic gates.

10. CMOS combinational circuits II: ratioed CMOS logic, pseudo NMOS logic, DCVSL logic, pass transistor logic, complementary pass transistor logic (CPL), SRPL logic, transmission gates logic, dynamic logic gates, domino logic, np-CMOS logic.

11. CMOS sequential circuits I: introduction to CMOS sequential circuits, memory elements (latches and registers), SR- and D-type static latches, multiplexer-based static latches, static master-slave edge-triggered registers, timing properties of static registers.

12. CMOS sequential circuits II: dynamic memory elements, dynamic transmission-gate edge-triggered registers, timing properties of dynamic registers, pseudo-static registers, C^2MOS (clocked CMOS) dynamic registers, true single-phase clocked (TSPC) latches and registers, optimization of synchronous sequential circuits by pipelining, pipelining implementation with dynamic latches, NORA-CMOS logic.

13. Design and implementation methodologies of digital integrated circuits and systems: abstraction levels of digital VLSI design, custom design, semi-custom design, standard cell design, standard cell design process steps, compiled cells and macro-cells, array-based circuit design and implementation, pre-diffused array structures (gate arrays, sea-of-gates), programmable array structures (PLAs, FPGAs), programmable interconnections, system-on-chip (SoC).

(4) TEACHING and LEARNING METHODS - EVALUATION

DELIVERY *Face-to-face, Distance learning, etc.*	Face-to-face in-class lecturing

<table>
<tr><td>USE OF INFORMATION AND COMMUNICATIONS TECHNOLOGY
Use of ICT in teaching, laboratory education, communication with students</td><td>• Slides (ppt) of the presentation of the theoretical part of the course, which will be available from the beginning of semester through e-Class.
• Combined use of projector (for slides) as well as of whiteboard.
• Homework assignment (project) at the semester mid-time.
• Support of teaching procedure through the e-Class platform (notification of the teaching procedure, distribution of slides, supplementary material, announcements, relative links and literature, provision of test and the final examination)
• Specialized software relevant to the course.</td></tr>
<tr><td>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 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.</td><td><table><tr><th>Activity</th><th>Semester workload</th></tr><tr><td>Lectures</td><td>39</td></tr><tr><td>Laboratory</td><td>13</td></tr><tr><td>Homework assignment</td><td>15</td></tr><tr><td>Study of lectures and bibliography</td><td>58</td></tr><tr><td>Course total</td><td>125 hours (5 ECTS)</td></tr></table></td></tr>
<tr><td>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.</td><td>Evaluation of theoretical part through final written exam that includes solving exercises, multiple choice questions, comparative evaluation of theory elements.
Homework assignment (project) regarding circuit design and simulation based on soecialized software.
The final grade is the weighted result of the grades of the theoretical part of the course and the project. The weights are defined and the beginning of each semester and they will be announced via e-Class.
The final exams are in Greek language. The examination process and the evaluation criteria are publicly available to the students through e-Class.</td></tr>
</table>

(5) ATTACHED BIBLIOGRAPHY

- Suggested bibliography:

1. J. M. Rabaey, A. Chandrakasan, B. Nikolic, Digital integrated circuits: A design perspective, Pearson, 2003.
2. H. N. Weste, D. M. Harris, CMOS VLSI design: A circuits and systems perspective, Addison-Wesley, 2005.
3. S. Kang, Y. Leblebici, CMOS digital integrated circuits: Analysis and design, McGraw-Hill, 2003.
4. J. Segura, C. Hawkins, CMOS electronics: How it works, how It fails, Wiley-IEEE, 2004.

5. Y. Tsividis, Operation and modeling of the MOS transistor, Oxford University Press, 2003.
6. Y. Taur, T. Ning, Fundamentals of modern VLSI devices, Cambridge University Press, 2009.

- Related academic journals:

1. IEEE Transactions on VLSI Systems
2. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems
3. IEEE Transactions on Circuits and Systems I & II
4. ACM Transactions on Design Automation of Electronic Systems
5. Integration, the VLSI Journal, Elsevier
6. Microelectronics Journal, Elsevier