



Code: IINF/01A

Credits: 9

Matter: MicroElectronics

Main language of instruction: Italian

Other language of instruction: English

Teaching Staff

Head instructor

Prof. Andrea Orsini - andrea.orsini@unicusano.it

Introduction

1. Objective of the course :

The Microelectronics course aims to provide students with the fundamentals of microelectronic design of digital circuits, from the single elementary unit to the design of digital architectures with low-to-medium complexity features. The course introduces the basic concepts of the various design and development phases of an integrated circuit commonly used in digital electronics design, with particular emphasis on dynamic problems and the study of transients. The E-tivities associated with the course develop the skills needed to formulate design problems through the use of CAD tools that support the design process itself..

Objectives

2. Course Structure:

1. Review and in-depth study of the behavior of BJTs and MOSFETs
2. CMOS Inverters
3. Static Logic and its Optimization
4. Other Types of Logic
5. Microfabrication Processes, Interconnections, and Packaging
6. Static and Dynamic Latches and Registers, Memories
7. 32/64-bit Processing Circuitry
8. CAD Tools for Synthesis, Placement, and Interconnection
9. Dynamic Behavior Simulation Software

Competencies:

- A. Knowledge and understanding.



By the end of the course, students will have demonstrated understanding of the behavior of a CMOS inverter depending on the geometric design parameters and the ability to derive a simplified model of the device in the switching state from simulations or measurements.

Furthermore, students will acquire knowledge of the operation of the main digital logic structures: complementary CMOS, pseudo-nMOS, transmission gate, and dynamic. Finally, students will acquire methods for designing and simulating the behavior of low-complexity digital circuit blocks.

B. Applying knowledge and understanding.

Students will be able to apply their knowledge of solid-state electronics (particularly silicon) to analyze digital integrated circuits and to determine the optimal layout of the various functional blocks within a microelectronic chip. They will also be able to implement simple computational codes to solve static and dynamic problems in digital signal logic. Furthermore, through the activities, students will acquire the ability to create digital gates within the Electric-VLSI software and simulate circuits at the schematic level based on their characteristics within LTSPICE.

C. Making judgements.

Upon completion of the course, students will be able to size the layout of individual transistors within the chip according to project specifications and to create electrical interconnection schemes that are robust to noise and have optimized delay times when designing the chip as a whole system. Students will also have developed the critical ability to interpret design layouts for the purposes of microelectronic fabrication on silicon wafers.

D. Communication skills.

At the end of the course, the student will have developed a correct and comprehensible scientific language that will allow him to express clearly and unambiguously the technical knowledge acquired in the field of digital integrated circuit theory.

E. Learning skills.

At the end of the course, the student will have developed the ability to apply the knowledge acquired to the design of digital circuits that have as their object the analysis, transmission and reception of data on microchips.

Syllabus

3. Programme of the course:

Subject 1. Recalling Physics of Diodes and Transistors.

Basic concepts of diodes and MOSFET transistors: Depletion, Static and Dynamic Behavior, Subthreshold Currents.

Subject 2. Microfabrication

Fabrication Technologies, complete CMOS process, main packaging techniques, model on-chip interconnections (Concentrated and Distributed Models), high-frequency issues and the transmission-line model

Subject 3. CMOS Inverter

Fundamental characteristics of a CMOS inverter, transfer curve and noise margins. Inverter dynamic behavior, input and output capacitances, optimized design for signal propagation time purposes, dynamic and static power consumption, inverter's Figures of Merit.

Subject 4 – Combinational Logic Gates

- Will be able to construct complementary static logic gates
- Will be familiar with ratio and pass-transistor logic
- Will be able to construct dynamic logic gates
- Will be able to analyze speed and power consumption, as well as robustness and signal integrity
- Will be familiar with the cross-talk problem and the performance limits of CMOS circuits
- Will receive the essential concepts of reduced logic circuits
- Will be familiar with design methodologies for current signals and single-chip networks

Subject 5. Logic Circuit Layout & Simulation (E-tivity 1-2)

E-tivities have a learning as well as an assessment purpose. This means that the Learning Outcomes stated in the module are not achieved through lectures, but exclusively through independent study and solving the proposed case studies. E-tivities always require the use of the virtual classroom forum and consist of discussions of theoretical topics and exercises.

Learning Outcomes

By the end of the module, students will be able to:

- understand the technical terminology of software used to design a simple integrated layout;
- evaluate the most appropriate method for connecting transistors;
- create their own integrated circuit using "Electric VLSI";
- understand the HSPICE simulation software;
- simulate using continuous-signal or discrete-signal methods;
- build high-level simulation models.



Subject 6. Sequential Logic Gates

Essentials of latches and static registers, dynamic registers and anti-clock skew design technologies, sequential circuits through pipeline design, Schmitt trigger, design of pulse generators and digital oscillators, pulsed and sense-amplifier registers, timing systems, clock skew and jitter, clock distribution technologies.

Subject 7. Logic and Arithmetic Blocks

architecture of an ALU, Optimized adder circuits, multipliers, barrel and logarithmic translators, trade-off between speed and power consumption of an ALU

Subject 8. Semiconductor Memories

Types of digital memory, essential peripheral circuits, timing and control of a digital memory, power consumption during access and retention, schema of the evolution of semiconductor memories, trade-off between speed and power consumption of a memory.

Evaluation system and criteria

The examination consists of a quiz test with 80 questions (40 questions on subjects 2-4 and 40 questions on subjects 6-8).

In addition, two e-tivities, consisting of microchip design and simulation, are available. These need to be sent to the instructor in advance of the examination. Each e-tivity counts as a separate evaluation to be averaged with the exam grade.

Bibliography and resources

4. Materials to consult

Notes written by the instructor are available in Italian. The notes cover the course contents and examination program.

5. Recommended bibliography

Suggested readings are:

1. J.M. Rabaey, A. Chandrakasan e B. Nikolic Circuiti integrati digitali. L'ottica del progettista. Ediz. MyLab. Second edition. EAN: 9788891918093 Pearson,2020.