

## Course guide

### 340607 - SIDI-R2010 - Digital Systems

**Last modified:** 17/05/2023

**Unit in charge:** Vilanova i la Geltrú School of Engineering  
**Teaching unit:** 710 - EEL - Department of Electronic Engineering.

**Degree:** MASTER'S DEGREE IN AUTOMATIC SYSTEMS AND INDUSTRIAL ELECTRONICS (Syllabus 2012). (Optional subject).

**Academic year:** 2023    **ECTS Credits:** 5.0    **Languages:** Catalan, Spanish, English

#### LECTURER

---

**Coordinating lecturer:** Mariano López-García

**Others:** Mariano Lopez Garcia

#### PRIOR SKILLS

---

Basic knowledge on combinational and sequential systems. Moreover, it is necessary that students have general notions about synchronous and asynchronous systems.

#### REQUIREMENTS

---

Have successfully passed the course Fundamentals of electronics.

#### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

---

**Specific:**

1. CC05 - Analyzing and using microprocessors and microcontrollers as programmable digital devices within a electronical system
3. CB8 - Students will be able to integrate knowledge and handle complexity and formulate judgments from a incomplete or limited information, including reflecting on social and ethical responsibilities linked to the application of their knowledge and judgments
4. CB9 - Students can communicate their conclusions, knowledge and rationale underpinning these, to skilled and unskilled public in a clear and unambiguous way

**Transversal:**

2. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.
5. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

#### TEACHING METHODOLOGY

---

Learning method based on lectures, group and individual work, exercises and laboratory classes.

#### LEARNING OBJECTIVES OF THE SUBJECT

---

The basic objective of this course is to introduce the student in the design and the implementation of programmable digital systems and their applications. The subject concentrates in the design based on hardware description languages (HDL), making emphasis in their physical implementation.

## STUDY LOAD

Type	Hours	Percentage
Hours large group	22,5	18.00
Self study	80,0	64.00
Hours small group	22,5	18.00

**Total learning time:** 125 h

## CONTENTS

### Chapter 1.- Introduction to digital systems

#### Description:

- 1.1 Introduction.
- 1.2 Stages, criteria and alternatives of design.
- 1,3 Definition of basic concepts and software tools.
- 1,4 Examples of digital electronic systems applied to industrial applications.

#### Specific objectives:

This aim of this chapter is that students acquire a general vision on the design of digital systems and its applications. The concepts and the usual terminology is introduced, as well as some examples that help to define the particular contents of this course.

#### Related activities:

Reading of introductory chapters detailed in basic references.

#### Full-or-part-time: 3h

Theory classes: 3h

### Chapter 2.- Hardware alternatives in industrial applications.

#### Description:

- 2,1 Introduction.
- 2.2 Digital microprocessors and microcontrollers.
- 2.3 Digital processors of signal (DSP).
- 2.4 PLD (CPLD and FPGA)
- 2.5 Comparative of benefits: Complexity, price, speed, consumption, immunity to the noise, etc.

#### Specific objectives:

The objective of this chapter is to present the criteria useful for selecting the optimal hardware platform as solution to a specific problem of digital design. Different alternatives are presented, as well as the most important benefits and drawbacks offered by each of them. Emphasis in the diversity of solutions and its suitability based on the specific characteristics of each application.

#### Related activities:

Individual exercise related to the subject of this chapter.

#### Full-or-part-time: 5h

Theory classes: 5h

### Tema 3.- FPGAs: Basic concepts and internal architecture.

**Description:**

- 3.1 Introduction: technologies and vendors.
- 3.2 Basic elements: Multiplexors, flip-flops and Lookup tables.
- 3.3 Logic Cells: CLBs, LABs, Slices and distributed memory.
- 3.4 Hardware/software processors.
- 3.5 Relatge i ports d'entrada/sortida.

**Specific objectives:**

The main aim of this chapter is to describe the internal architecture of FPGAs by Xilinx and Altera. Besides, the student learns the most usual terminology employed by the main vendors of FPGAs and what are the main devices currently used in the market.

**Related activities:**

None.

**Full-or-part-time:** 4h

Theory classes: 4h

### Tema 4.- High level synthesis of digital systems.

**Description:**

- 4.1 Introduction: hardware description languages.
- 4.2 VHDL language.
  - 4.2.1 Basic examples and styles of description.
  - 4.2.2 Language syntactic elements. Sequential and concurrent programming.
  - 4.2.3 Description of data flow.
  - 4.2.4 Algorithmic behavioral description.
  - 4.2.5 Structural description.
  - 4.2.6 Packages and libraries.
- 4.3 Design examples.

**Specific objectives:**

In this chapter an introduction to VHDL language is performed. This basic tool of design allows describing complex digital systems by using a high-level description language. The main structures and styles of description are introduced, indicating the suited rules to achieve the design with best performance. The chapter finalizes presenting different examples of design, where the most important aspects are pointed out in order to obtain a correct synthesis.

**Related activities:**

Set of exercises with and without solution. Individual work: first program in VHDL based on a combinational system.

**Full-or-part-time:** 5h

Theory classes: 5h

### Tema 5.- VHDL language oriented to synthesis and simulation.

**Description:**

- 5.1 Basic restrictions and structures.
  - 5.1.1 Combinacional logic.
  - 5.1.2 Sequential logic.
- 5.2 Synchronous and asynchronous systems.
- 5.3 Description of Finite state machines (FSM).
- 5.4 Simulation and testbench.

**Specific objectives:**

The chapter has several objectives. Firstly, it is intended that students assimilate certain rules and styles of programming, which facilitate the design and avoid errors in the synthesis process. It is pointed out descriptions devoted to obtain combinational and sequential circuits. Likewise, a significant part of this chapter is dedicated on the design of synchronous and asynchronous systems, emphasizing, by means of some examples, the common problems that usually arise along with their resolution. On the other hand, VHDL language is also presented as a simulation tool for digital circuits. Some elements that have only meaning in simulation are also introduced: delays, testbench, etc.

**Related activities:**

Exercise devoted to describe a digital system of medium-complexity, whose resolution is based on a finite state machine.

**Full-or-part-time:** 6h

Theory classes: 6h

### Laboratory

**Description:**

- Practice 1. Introduction to Xilinx software tools and VHDL language (2 sessions)
- Practice 2. Design and implementation of a digital chronometer (2 sessions)
- Practice 3. Implementation of an accelerator hardware included in an embedded system (2 sessions).

**Specific objectives:**

The basic goal of practical or laboratory classes is the experimental verification of those concepts or knowledge acquired in lectures. These classes help to strengthen and to improve the assimilation of theoretical concepts related to VHDL and digital systems of medium complexity. The software tools provided by Xilinx were chosen to perform the experiments as well as the hardware boards of Digilent for programming FPGAs and CPLDs.

**Related activities:**

None

**Full-or-part-time:** 20h

Practical classes: 20h

## ACTIVITIES

### 3.- Design of a combinational circuit in VHDL

**Description:**

First individual exercise.

**Full-or-part-time:** 3h

Theory classes: 3h



## 2.- Finite state machine

**Description:**

Second individual exercise.

**Full-or-part-time:** 3h

Theory classes: 3h

## 3.- Implementation of a trigonometric function

**Description:**

Third individual exercise.

**Full-or-part-time:** 3h

Theory classes: 3h

## 5.- Oral presentation

**Description:**

Oral presentation at classroom.

**Full-or-part-time:** 1h

Theory classes: 1h

## GRADING SYSTEM

The qualification includes all the work carried out throughout the course, marks of one or more tests and laboratories. In particular, the qualification is obtained as:

$$\text{Nota final} = C1 \cdot 0.2 + C2 \cdot 0.6 + C3 \cdot 0.2$$

C1= Mark of individual (group) work and class presentations.

C2= Mark of theory test.

C3= Mark of practices (laboratory).

## EXAMINATION RULES.

None.

## BIBLIOGRAPHY

**Basic:**

- Eugenio Villar [et al.]. VHDL: lenguaje estándar de diseño electrónico. Madrid [etc.]: McGraw-Hill, 1998. ISBN 8448111966.
- Pardo Carpio, Fernando ; Boluda Grau, José A. VHDL: lenguaje para síntesis y modelado de circuitos. 3a ed. Madrid: Ra-ma, 2011. ISBN 9788499640402.
- Pérez López, Serafín Alfonso [et al.]. Diseño de sistemas digitales con VHDL. Madrid: International Thomson, 2002. ISBN 8497320816.
- Maxfield, Clive. The design warriors guide of FPGAs: devices, tools, and flows [on line]. 2004. Boston: Newnes, 2004 [Consultation: 20/02/2024]. Available on : <https://www.sciencedirect-com.recursos.biblioteca.upc.edu/book/9780750676045/the-design-warriors-guide-to-fpgas>. ISBN 0750676043.



**Complementary:**

- Ashenden, Peter J. The Designer's guide to VHDL [on line]. 3rd ed. Burlington: Morgan Kaufmann, 2008 [Consultation: 20/02/2024]. Available on : <https://www-sciencedirect-com.recursos.biblioteca.upc.edu/book/9780120887859/the-designers-guide-to-vhdl>. ISBN 9780120887859.
- Brown, Stephen D [et al.]. Field-programmable gate arrays. Boston: Kluwer Academic Publishers, 1992. ISBN 0792392485.
- Chang, Henry [et al.]. Surviving the SOC revolution [Recurs electrònic] : a guide to platform-based design [on line]. Boston: Kluwer Academic Publishers, 1999 [Consultation: 29/03/2022]. Available on: <https://link.springer.com/book/10.1007/b116290>. ISBN 0306476517.