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300022 - CSD - Digital Circuits and Systems

Coordinating unit: 300 - EETAC - Castelldefels School of Telecommunications and Aerospace Engineering

Teaching unit: 710 - EEL - Department of Electronic Engineering

Academic year: 2017

Degree: BACHELOR'S DEGREE IN NETWORK ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2009). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING/BACHELOR'S DEGREE IN NETWORK ENGINEERING (Syllabus 2015). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING/BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING (Syllabus 2015). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERINGS/BACHELOR'S DEGREE IN TELECOMMUNICATIONS SYSTEMS ENGINEERING - NETWORK ENGINEERING (AGRUPACIÓ DE SIMULTANEÏTAT) (Syllabus 2015). (Teaching unit Compulsory)
BACHELOR'S DEGREE IN AIRPORT ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN AIR NAVIGATION ENGINEERING (Syllabus 2010). (Teaching unit Optional)

ECTS credits: 6 Teaching languages: Catalan, Spanish, English

Teaching staff

Coordinator: Definit a la infoweb de l'assignatura.

Others: Definit a la infoweb de l'assignatura.

Prior skills

Students must have acquired a solid theoretical understanding of electronic technology and the accompanying practical skills developed during the subject Electronics for Telecommunications (1A).

Students should understand basic aspects of computer programming, which is the objective of the subjects Introduction to Computers (1A) and Programming Project (1B).

Students would also benefit from practices of generic skills developed in Semesters 1A and 1B, in particular team work, self-directed learning and spoken and written communication.

Degree competences to which the subject contributes

Specific:

1. CE 14 TELECOM. Capacidad de análisis y diseño de circuitos combinacionales y secuenciales, síncronos y asíncronos, y de utilización de microprocesadores y circuitos integrados.
2. CE 15 TELECOM. Conocimiento y aplicación de los fundamentos de lenguajes de descripción de dispositivos de hardware.(CIN/352/2009, BOE 20.2.2009.)

Generical:

3. PROJECT MANAGEMENT - Level 1: To know project management tools carrying out the different phases of the project established by the professor
4. EFFICIENT USE OF EQUIPMENT AND INSTRUMENTS - Level 1: Using instruments, equipment and software from the laboratories of general or basic use. Realising experiments and proposed practices and analyzing obtained results.

Transversal:

5. SELF-DIRECTED LEARNING - Level 1. Completing set tasks within established deadlines. Working with recommended information sources according to the guidelines set by lecturers.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 1. Planning oral communication, answering questions

properly and writing straightforward texts that are spelt correctly and are grammatically coherent.

7. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
8. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

Teaching methodology

The subject is based on cooperative learning (CL) and problem/project-based learning (PBL). Students work in base groups of three members for the whole semester with the goal of implementing the projects that have to be handed in before the due date following the quality criteria (rubrics) and the established methodology. Emphasis is given to what the student does, applying repetitively the same technique of problem-solving: specifications, planning, development, final verification of the project using simulation or laboratory training materials; and the detailed reviewing of the student's deliverables. The assignments force students to be active and to pay constant attention, as if they had to go to work to a company, which requires weekly quality results from them for the whole semester.

In classroom, the instructor discuses the specifications and sketches a general plan for the problem or project to be solved, with active discussion with the students on general issues. The laboratory session, lead by the students themselves within their respective cooperative groups, is devoted to the development of the problem and the testing of the circuits, while the instructor is kept aside to solve doubts when required. The session on directed academic activities is used as an extra support for problem solving and to give guidelines for the self-directed work out of the class: project management, task sharing, tutorials on the use of software or laboratory instrumentation, reviewing of the documentation, and group processing, etc. Let's remark that the weekly autonomous work out of class is essential to complete the assignments and prepare the projects' documentation.

In order to promote the use of English, this is the language used throughout the course, in class, in all the learning materials, in office tutoring time or email (teaching content through English).

Students answer an anonymous questionnaire to evaluate the course development and lecturer performance, with the aim of detecting dysfunctions and good ideas for future improvements.

Learning objectives of the subject

On completion of the subject, students will be able to:
- Work in cooperative teams to: specify, organise, develop and verify projects, track the study time and timetable and solve team conflicts.
- Obtain materials for self-directed study from libraries and internet to solve the course assignments and problems of a similar complexity (preference should be given to materials in English).
- Report and document their work using handmade sketches, graphics, pictures, tables, word processing software, project management applications and other software following the quality criteria stipulated in the subject guides.
- Maintain and publish an electronic portfolio (ePortfolio) for the cooperative work group, which should contain a selection of assignments, projects carried out, an appraisal of the course content and a personal evaluation of their progress towards the desired learning outcomes.
- Analyse, simulate and design logic functions using diagrams, schematics, Boole Algebra, Espresso algorithm (minilog), WolframAlpha, Proteus-ISIS, VHDL, and electronic design automation tools (EDA).
- Explain the basic technological features of digital circuits: voltages, noise levels, tri-state, propagation delays, power consumption, etc.
- Implement combinational circuits and sequential systems (finite state machines, FSM) for the programmable logic devices like CPLD and FPGA available in the laboratory training boards, based on hierarchical structures of components, using VHDL and the EDA tools associated with the design flow.

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- Design, simulate and implement an advanced digital system of medium complexity based on a datapath (data registers and ALU) and a control unit (FSM).
- Classify commercial microcontrollers considering architecture and processing capability, explain their most usual applications in the context of small embedded systems, and describe the integrated development environment (IDE) comprising hardware and software associated to the design process proposed by a given vendor.
- Design, simulate and implement projects based on microcontrollers using C language, the FSM coding style, basic I/O techniques (polling and interrupts), and the IDE tools supplied by a given vendor (Microchip, Atmel, Texas Instruments, etc.)
- Give an oral presentation of a project designed in the course, preparing all the necessary materials and following the template instructions.

Study load

Total learning time: 150h	Hours large group:	26h	17.33%
	Hours medium group:	0h	0.00%
	Hours small group:	26h	17.33%
	Guided activities:	14h	9.33%
	Self study:	84h	56.00%

Content

Chapter 1: Combinational circuits	Learning time: 44h Theory classes: 8h Laboratory classes: 8h Guided activities: 4h Self study : 24h

Description:
- Number systems, logic and basic arithmetic operations, information codes.
- Logic functions (Boolean Algebra, logic gates, minterms, maxterms, sum of products (SoP), product of sums(PoS), truth table).
- Simplification of logic functions (Espresso algorithm - Minilog).
- Electrical characteristics of digital circuits technology: logic levels, noise margins, propagation delay, power consumption, three-state outputs.
- Basic combinational standard logic (multiplexers, decoders, etc.) and arithmetic blocks (adders, comparators, etc.)
- VHDL design flow for combinational circuits in sPLD/CPLD and FPGA programmable devices: specifications, planning, synthesis, functional and gate-level simulation using VHDL test benches. Use of commercial EDA tools for electrical simulation (SPICE-based Proteus-ISIS), design and synthesis (Altera Quartus, Xilinx ISE, Lattice ispLEVER - Diamond, etc.), and VHDL simulation (Lattice ActiveHDL, Altera ModelSim, Xilinx ISim, etc.).

Related activities:
- Problems in Chapter 1.
- Individual test of basic knowledge (IT1)
- ePortfolio. Group processing, project documents and files, class notes, exams solutions and voluntary improvements regarding the indications in the correction.

Chapter 2: Sequential systems	Learning time: 50h Theory classes: 8h Laboratory classes: 8h Guided activities: 4h Self study : 30h

Description:
- The concept and specification of a sequential system: symbol, state diagram, timing diagram, functional description.
- Asyncrhonous 1-bit memory cells (RS and D latches). Application to timer and clock circuits, and massive semiconductor memories.
- 1-bit synchronous memory circuits (flip-flops JK, D, and T).
- General structure of a synchronous finite-state machine (FSM): state register, outputs and next state logic.
- VHDL design flow for sequential systems in sPLD/CPLD and FPGA programmable devices: specifications, planning, synthesis, functional and gate-level simulation using test benches. Use of commercial EDA tools (described in the previous chapter).
- Standard sequential systems: counters, data and shift registers.
- Concept and architecture of an advanced digital system of medium complexity based on a datapath (data registers and ALU) and a control unit (FSM).
- Specification, planning, development, simulation and prototyping of a simple dedicated processor (serial adder or multiplier, matrix keypad decoder, asynchronous serial communication transmitter or receiver, real-time clock, programmable timer, etc.)
- Characterisation and measurements: delays, maximum operational frequency, power consumption, etc. of synchronous sequential systems.

Related activities:
- Problems in Chapter 2.
- Individual test of basic knowledge (IT2)
- ePortfolio. Group processing, project documents and files, class notes, exams solutions and voluntary improvements regarding the indications in the correction.
- Project oral presentation.

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Chapter 3: Microcontrollers	Learning time: 56h Theory classes: 10h Laboratory classes: 10h Guided activities: 6h Self study : 30h

Description:

- Introductory chapter on the use and design of applications with commercial microcontrollers.
- The central process unit (CPU). Microprogrammed digital system (logic functions with memories) capable of performing multiple operations with the same hardware.
- The evolution of a dedicated processor towards the architecture of a microprocessor system (processing unit, data and program memory, and peripherals).
- The microcontroller. Integrating in a single chip a microprocessor system and peripherals.
- Architecture of a commercial 8-bit microcontroller: PIC16F/18F, ATmega from Microchip, MPS430 from Texas Instruments, etc. Comparison with other platforms (Arduino, Raspberry Pi, etc.)
- Microcontroller design flow, integrated development environment (IDE), source code, C compiler, virtual laboratory Proteus-VSM simulation, training boards, prototyping.
- Programming in FSM style for a deeper understanding of the concepts in previous chapters, standardisation of the source code for easy error detection -debugging-, and self-assessment.
- Polling of level-sensitive signals, and edge detection using interrupts, driving digital outputs.
- Peripherals: counters and timers. The concept of real-time and the use of a crystal quartz oscillator as system clock and time base.
- Other peripherals: A/D converter, PWM module, LCD display, EEPROM, USART, I2C and ASPI, etc.

Related activities:

- Problems in Chapter 3.
- Individual test of basic knowledge (IT3)
- ePortfolio. Group processing, project documents and files, class notes, exams solutions and voluntary improvements regarding the indications in the correction.
- Project oral presentation.

Planning of activities

Problems and projects	Hours: 118h Theory classes: 18h Laboratory classes: 26h Guided activities: 10h Self study: 64h

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Description:

Problems and projects become the most significant activities in CSD, carrying the learning of the specific content and practising cross-curricular skills at the same time. They deal with the design of digital systems and have a duration of one or two weeks. Problems are solved in cooperative base groups through all the class sessions with the guidance of the instructor and also out-of-class study time.
The CL and PBL methodologies imply that students have to attend classes and laboratories with regularity for achieving a good comprehension of the subject content. In the session on directed academic activity, the focus is set: on problem reviewing and correction so that the project can meet the quality standards; in tutoring group behaviour and monitoring their study time so that they can follow the schedule; in arbitration and conflict resolution if necessary, etc.
The written documentation of the project includes the annotation of the study time required to complete it, the description and distribution of tasks among the group members, a proposal of self-assessment, and the signature statement to reflect a fair participation of each group member.

Let's remark that the sequence of PBL problems is organised to be solved in a chain, like when climbing a ladder, constructing the knowledge step by step. They cannot be solved randomly by students with no initial experience in digital systems. Furthermore, students are encouraged to help each other in order to attain maximum performance, implying that they have to study together taking into account the guidelines discussed in class. Thus, it is not recommended dropping a chapter or the subject temporarily to come back later. The only possible way is to follow the established sequence handing in the materials for correction before the due date, to allow reviewing and discussion, and in this way the next problem in the series can be solved better.

Finally, let's say that the proposed problems "work"; all of them can be mounted in prototyping boards like kits, and the students can experiment with them in the simulators or the laboratory. They are nearer the "real world" than academy, with the aim of motivating and showing the applicability of this subject in everyday life. Digital systems are everywhere. For instance, students learn on 7-segment or LED matrix displays, data multiplexers, matrix keyboards blocked with a secret key, timers, real-time clocks, programmable systems to control motors or traffic lights, data transmission subsystems, simple calculators, and other circuits of similar complexity. The designs solve the projects using programmable logic devices and VHDL, or microcontrollers and C language. In a way that alternative technological solutions can be easily compared.

A list of example concepts included in the proposed designs is:

- P1. Analysis of basic circuits using logic gates.
- P2. Standard combinational circuits.
- P3. Arithmetic circuits.
- P4. Combinational circuits with multiple components in a hierarchical architecture.

- P5. Simple 1-bit memory cells: latches and flip-flops.
- P6. Finite state machines (FSM).
- P7. Standard sequential components: registers and counters.
- P8. Dedicated processor with datapath and control unit.

- P9. Basic I/O in a microcontroller system.
- P10. Interrupts and FSM style in C language.
- P11. Peripherals: LCD. Project with multiple source files. Software drivers.
- P12. Peripherals: Timers, A/D, etc.

Support materials:

Study materials (lecture notes, example solutions from previous years, etc.), electronic circuit simulator, standard digital electronics laboratory equipment, EDA software and demonstration boards for design with PLD/FPGA and microcontrollers.

Qualification system

Assessment is based on the criteria defined in the subject's infoweb.

Regulations for carrying out activities

In this subject there are no classic exams. Assessment is continuous for all the course duration and is carried out in every activity, which contribute to the final mark by a given percentage.
Most of the work done by students, which has to be handed in before the established due date, is assessed and has a score. The grade given to each activity is set using rubrics that indicate the items and their respective weight to be considered.
To do whichever activity, including the individual tests of basic knowledge, students can use any kind of resource like class notes, computers, calculators. However, the validity of any deliverable handed in may require a personal interview with the instructor.
As said before, it is mandatory to hand in project solutions before the due date. Furthermore, team members have to fairly and honestly participate in project development and reporting, and have to be responsible of anything handed in in their name. Instructors will encourage continuous discussion with cooperative groups on anything related with the projects and their assessment, because it is understood that the act itself of assessment contributes enormously to achieve the learning of the specific content and the cross-curricular skills associated to this subject.
This assessment scheme allows any student that cannot follow, for a major reason, the established timetable, ask for an alternative schedule of due dates which requires an equivalent amount of study time (ECTS).
The subject allows personal tutoring time in office and by email, accepting that exclusively the institutional address of the type "nom.cognoms@estudiant.upc.edu" is used. Email is used here as another useful mechanism to favour the development of professional skills.

Bibliography

Basic:

Roth, C.; Kurian, L. Digital system design using VHDL. 2a ed. Thomson International, 2008. ISBN 0495244708.

Brown, Stephen D.; Vranesic, Zvonko G. Fundamentals of digital logic with VHDL design. 2nd ed. Boston: McGraw-Hill, 2005. ISBN 0071244824.

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Barnett, R. H.; Cox, S.; O'Cull, L.. Embedded C programming and the Atmel AVR. New York: Thomson Delmar Learning, 2006. ISBN 1418039594.

Reese, Robert B. Microprocessors : from assembly language to C using the PIC18Fxx2 [on line]. Massachusetts: Da Vinci Engineering Press, 2005Available on: <http://site.ebrary.com/lib/upcatalunya/detail.action?docID=10228177>. ISBN 1584503785.