IDENTIFYING DATA				
Digital electronic systems				
Subject	Digital electronic systems			
Code	V12G330V01923			
Study programme	Grado en Ingeniería en Electrónica Industrial y Automática			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Optional	4th	1st
Teaching language	Spanish			
Department				
Coordinator	Rodríguez Andina, Juan José			
Lecturers	Fariña Rodríguez, José Quintáns Graña, Camilo Rodríguez Andina, Juan José			
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General description	It is an end-of-degree course, extending the study of Digital Electronics and Microcontrollers from the analysis in previous courses to design techniques. The main objective is for students to acquire design, analysis, simulation, optimization, test, and maintenance skills for digital electronic circuits based on reconfigurable devices (FPGAs) and microcontrollers. The course focuses on: - Standard serial communication peripherals and protocols, with emphasis on electrical behavior. - Capture and compare units for the generation of digital signals with timing information. High-speed outputs, pulse width modulation, measurement of frequency, period, or phase shift. - Low power consumption operating modes. - Numerical formats and arithmetic operators. - Hardware description languages (HDLs) for the specification of digital circuits. - Case studies of the design of digital electronic circuits based on microcontrollers and FPGAs for industrial control.			

Skills	
Code	
B3	CG3 Knowledge in basic and technological subjects that will enable students to learn new methods and theories, and provide them the versatility to adapt to new situations.
B4	CG4 Ability to solve problems with initiative, decision making, creativity, critical thinking and the ability to communicate and transmit knowledge and skills in the scope of industrial engineering in the field of Industrial Electronic and Automation.
C21	CE21 knowledge of the fundamentals and applications of digital electronics and microprocessors.
C24	CE24 Ability to design analog, digital and power electronic systems.
D2	CT2 Problems resolution.
D9	CT9 Apply knowledge.
D14	CT14 Creativity.
D17	CT17 Working as a team.

Learning outcomes			
Expected results from this subject	Training and Learning Results		
Dominate the skilled resources of a microcontroller for tasks of control of processes	B3 B4	C21 C24	D2 D9 D14 D17

Purchase skills for the modelling and synthesis of digital electronic circuits with languages of description of hardware (*HDL).	B4	C21 C24	D2 D9 D14
Dominate the technicians of implementation of digital systems complexes with circuits *reconfigurables	B4	C21 C24	D2 D9 D14 D17
Dominate and know use the methodologies and tools for the simulation, purification and verification of the operation of digital electronic circuits based in microcontrollers or devices *reconfigurables.	B4	C21 C24	D2 D9 D14

Contents

Topic	
Lesson 1: Introduction to microcontroller programming in C language	Basic concepts of the C language: data types, operators, functions, structures for program flow control. Programming of the Microchip PIC18 family of microcontrollers with XC8.
Lesson 2: Serial I/O in microcontrollers	Introduction to serial connection between processors. Synchronous communication. Asynchronous communication. Point-to-point connection (RS232). Serial bus (I2C). Basic structure of a serial I/O peripheral. Serial I/O peripherals in the Microchip PIC18 family of microcontrollers (USART and SSP). Application examples: asynchronous and synchronous.
Lesson 3: Capture and compare unit in microcontrollers	Temporal variables. Generation and measurement. Basic structure of a compare and capture peripheral. High-speed I/O. Pulse width modulation (PWM). Capture/Compare/PWM (CCP) peripherals in the Microchip PIC18 family of microcontrollers. Application and programming examples.
Lesson 4: Special operation modes.	Power consumption in digital processors. Low power consumption modes: the case of the Microchip PIC18 family of microcontrollers. Application and programming examples. Watchdog timing strategies: the case of the Microchip PIC18 family of microcontrollers. Application and programming examples.
Lesson 5: Memory organization	Memory hierarchy in digital processors. Cache memory: organization, basic structure, operation examples. Memory expansion in microcontrollers. Direct memory access (DMA)
Lesson 6: Arithmetic circuits	Numeric formats: signed/unsigned integers, fixed point, floating point. Precision. Multiplication and integer division: algorithms and functional blocks. Performance optimization. Floating point operations.
Lesson 7: Design of custom peripherals	Connection of peripherals to microcontrollers. Timer / counter: structure and applications. Serializer.
Lesson 8: Design examples: digital electronic systems for instrumentation and industrial control	Case studies
Lab session 1. Serial communication with microcontrollers. Connection to a display through the i2C bus.	Task 1: Study of serial MSSP unit of the PIC microncontroller. Task 2: Programming of a subroutine that sends data through the i2C bus. Task 3: i2C serial connection of an alphanumeric display with the PIC. Study of the control commands of the display. Task 4: Monitoring of the i2C bus with the Logic Analyzer (LA). Task 5: Create a program to write the "HELLO WORLD" welcome message in the display.
Lab session 2: User I/O control by means of a keyboard and a display.	Task 1: Connection of a matrix keyboard to the microcontroller through parallel port B. Task 2: Design and implementation of a keyboard exploration algorithm and a key-pressed decoder. Use the LEDs of the testing system to show the codes of the keys pressed. Task 3: Create a program to write in the display the keys pressed in the keyboard. Reserve one of them to make some control action.
Lab session 3: Open-loop PWM speed control of a dc motor	Task 1: Study of the compare/capture/PWM (CCP) unit of the microcontroller in PWM mode. Task 2: Create a program to initialize the CCP unit. Task 3: Open-loop motor speed control. Use of the A/D converter of the microcontroller to acquire the speed set point from a potentiometer in the testbed. Task 4: Connection of the PWM output to a L293 current amplifier. Visualization of the PWM signal in an oscilloscope and measurement of its average (dc) value .

Lab session 4: Speed measurement of a dc motor by means of a sensor that generates pulses of variable frequency	Task 1: Motor speed measurement by means of a pulse signal from a barrier optoelectronical sensor. Task 2: Create a program that implements a frequency-to-voltage converter using the microcontroller timers. Visualization of the measured speed in the LEDs of the testbed.
Lab session 5: Closed-loop PI speed control of a dc motor	Task 1: Create a closed-loop PI speed control program for the dc motor, based on the programs created in previous lab sessions. Task 2: Visualize in a display the speed set point, the error signal, and the output signal of the regulator (the input of the actuator). Task 3: Enter speed set points using the matrix keyboard.
Lab session 6. Design and implementation of a SPI serial communication unit for an A/D converter.	Task 1: Study of a control module for SPI serial communication and of the data format. Task 2: Design and implementation of an SPI control module for connection to an A/D converter. Task 3: Capture of an analog input signal with the A/D converter and the SPI serial interface. Visualization of input data with a 7-segment display. Task 4: Monitor the SPI port with the logic analyzer.
Lab session 7. Design and implementation of a SPI serial communication unit for a D/A converter.	Task 1: Design and implementation of an SPI control module for connection to a D/A converter. Task 2: Generation of an analog signal from digital data defined with external switches connected to the FPGA. Task 3: Monitor the SPI port with the logic analyzer.
Lab session 8. Design and modeling of a memory to implement a search table in an FPGA.	Task 1: Implementation of a search table containing digital samples of a signal to be reconstructed. Task 2: Generation of an analog signal using the search table and the D/A converter with the SPI module. Task 3: Visualize the generated signal with the digital oscilloscope.
Lab session 9. Implementation of a real-time processing system.	Task 1: With the hardware resources developed in previous sessions, create a bypass for an analog input signal (sample, hold, and reconstruction) and visualize in the oscilloscope both the analog input and output. Task 2: Implementation of a digital average filter to be added to the circuit of the previous task, creating a structure analog input - digital filter - analog output.

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	31	48.05	79.05
Laboratory practical	18	40.95	58.95
Essay questions exam	2	10	12

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Lecturing	Explanation by the professor of the theoretical concepts of the course. For a better understanding of the contents and an active participation in the sessions, the students have to make a previous personal work on the bibliography proposed. In this way, students will be in position to ask questions, request additional explanations, or raise doubts. These can be addressed either during lectures or during the professor's office hours. For a better understanding of some concepts, practical examples will be presented aiming at increased participation of the students. Students must do personal work for consolidating concepts and develop the competencies targeted in each Session. Attendance to lectures will be monitored. The schedule and classroon will be as directed by the dean's office.
Laboratory practical	Application of the theoretical knowledge acquired by students. They will develop skills related to the design, simulation, debugging, and test of digital electronic circuits based on microcontrollers or FPGAs. The students will use electronic instrumentation for the analysis of the behavior of digital electronic circuits, as well as tools for design, simulation, and debugging of digital electronic circuits based on reconfigurable devices (FPGAs), and for programming, simulation and debugging of digital electronic circuits based on microcontrollers. For each lab session it will be specified the previous personal work to be carried out by the students, the tasks they have to accomplish in the session, and the items to be assessed for evaluation purposes, that students have to present in a report for each session. Lab sessions will be carried out at the Digital Electronics lab of the Department of Electronic Technology, according to the schedule defined by the dean's office. Students will work in groups. Attendance to the lab sessions will be monitored.

Personalized assistance

Methodologies	Description
Lecturing	Students can attend the professor's office hours for the course, that will be published in the web page of the course. During these sessions, students can ask questions or request clarifications regarding the concepts covered in lectures.
Laboratory practical	In addition to the assistance from the professor during lab sessions, students can attend the professor's office hours for the course to ask questions or request clarifications regarding the previous personal work or the evaluation reports.

Assessment

	Description	Qualification	Training and Learning Results
Laboratory practical	The qualification for the lab sessions will be calculated as the average of the following assessments: 1.- Attendance and accomplishment of the tasks corresponding to each lab session, including previous personal work and evaluation report. 2.- Written tests regarding the concepts to be learnt in the session. To pass the lab evaluation, students must get at least 50% of the maximum total score.	50	B4 C21 C24 D2 D9 D14 D17
Essay questions exam	This test will assess the knowledge acquired by students regarding the theoretical concepts explained in the lectures. One such test will be given at the end of the semester. To pass it, students must get at least 50% of the maximum total score.	50	B3 B4 C21 C24 D2 D9 D14

Other comments on the Evaluation

The final score of the course is calculated as the average of the scores from the lab sessions and the written test. To pass the course students must get at least 50% of the maximum total score. The average will only be applied as final score if students get at least 40% of the maximum total score for each part (lab sessions and written test). Otherwise, students will fail the course, and the numerical score will be calculated by multiplying the average by 0.71. This coefficient is obtained by dividing 4.99 (maximum score for failure) by 6.99 (maximum average that can be obtained when failing the course: [10+3.99]/2).

Failing students who passed one of the parts (lab sessions or written test) don't need to take it in the second call. The second call will consist of: - Written test regarding theoretical concepts and problem-solving ability. - Lab test, consisting of the realization of one of the tasks already carried out during the regular lab sessions of the course . The final score will be calculated using the same criteria as for the first call.Students not in "continuous evaluation" will have to take a written test regarding theoretical concepts and problem-solving ability, as well as lab test. Evaluation criteria are the same as above.Ethical commitment: student are expected to show a suitable ethical behavior. In case of non-ethical behavior (copy, plagiarism, use of unauthorized electronic devices, or other), it will be concluded that the student does not comply with the requirements to pass the course. In this case, the final score will be 0.0 (fail).

Sources of information

Basic Bibliography

John F. Wakerly, **Digital Design: Principles and Practices**, 4,

Fernando E. Valdes Pérez, Ramón Pallás Areny, **Microcontroladores. Fundamentos y aplicaciones con PIC**, 1,

Complementary Bibliography

Recommendations

Subjects that it is recommended to have taken before

Fundamentals of electronics/V12G330V01402

Digital electronics and microcontrollers/V12G330V01601

Electronic instrumentation 1/V12G330V01503

Other comments

To enrol in this course it is necessary for the students to have passed or be enrolled in all courses of previous years.