Syllabus
2023 - 2024

GENERAL INFORMATION

Data of the subject	
Subject name	Electronic Systems
Subject code	DEAC-IMAT-225
Mainprogram	Grado en Ingeniería Matemática e Inteligencia Artificial
Involved programs	Grado en Ingeniería Matemática e Inteligencia Artificial [Second year]
Level	Reglada Grado Europeo
Quarter	Semestral
Credits	6,0 ECTS
Type	Obligatoria (Grado)
Department	Department of Electronics, Control and Communications
Coordinator	José Daniel Muñoz Frías and Jaime Boal Martín-Larrauri
Office hours	Arrange an appointment through email.

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DESCRIPTION OF THE SUBJECT

Contextualization of the subject

Prerequisites

Contribution to the professional profile of the degree

The tight integration of artificial intelligence with the physical environment, the so-called cyber-physical systems, is transforming multiple industries. This course covers the fundamentals of mixed analog/digital embedded systems, on which more advanced applications are built, such as mobile robots that increase the flexibility of manufacturing processes, autonomous vehicles, or power grid monitoring and control systems.

By the end of the course, students will be able to design systems composed of an analog signal acquisition and conditioning part, a digital processing module based on a Single Board Computer (SBC) programmed in Python, specifically a Raspberry Pi, and several actuators.

Prerequisites

Fundamentals of Python programming.

Course contents

Contents

Theory

1. Introduction to electronic systems

- Definition of embedded system.
- Elements of an embedded system: sensors, actuators, and processor.
- Real-time systems.

2. Circuit theory

- How to draw electronic circuits.
- Kirchoff's laws.
- Basic theorems: Thévenin, Norton, and superposition. Voltage dividers.
- Single-time-constant circuits. Filtering.

3. Digital input/output (GPIO)

- Basic input and output hardware: pushbuttons, switches, and LEDs.
- Management of higher power output devices: transistors and relays.
- Input and output handling on the Raspberry Pi: the GPIO Zero library.

4. Timers and PWM

- The time library.
- Delay generation.

- PWM signals. Applications.
- PWM signal generation with GPIO Zero.

5. A/D converter

- Basic concepts: sampling and quantization. Aliasing.
- The successive-approximations converter.
- The MCP3008 converter.
- Using the MCP3008 with the GPIO Zero library.

6. Operational amplifiers

- The operational amplifier in open loop configuration: comparator.
- The operational amplifier with negative feedback.
- Basic circuits with operational amplifiers: inverting, non-inverting, summing, and differential configurations.
- Voltage and current saturation.

7. Large variation resistive sensors

- Basic conditioning: voltage divider.
- Advanced conditioning with operational amplifiers.
- Linearization.

8. Modular programming and the scan loop

- Modular programming in Python.
- Embedded systems programming: tasks and the scan loop.

9. State machines

- Finite state machines.
- Software implementation of finite state machines.

10. DC motors

- Direct current motors.
- Transistor motor drivers.
- H-bridge motor drivers. The L293 bridge.
- Speed and position measurement: encoders.

11. Serial communications

- Advantages of serial versus parallel interfaces.
- Asynchronous communications: UART.
- Synchronous communications:
    - The I2C bus.
    - The SPI bus.

Laboratory

1. Soldering and first steps with the development system
In the first lab assignment, students will solder an expansion board for the Raspberry Pi designed at Comillas ICAI named iMAT HAT that uses both through-hole and surface mount (SMD) technology. Besides, the students will configure the Raspberry Pi to be able to connect via SSH and XRDP (remote desktop) and they will become familiar with the development environment that will be used during the course, Visual Studio Code.
2. Introduction to the laboratory
Students will learn how to use the instruments available in the laboratory (multimeters, oscilloscopes, wave generators...) by experimenting with simple circuits mounted on a breadboard.
3. Digital input/output (GPIO)
The LEDs and pushbuttons soldered on the iMAT HAT expansion board will be used to learn to drive the digital inputs and outputs of the Raspberry Pi. Special emphasis will be placed on the difference between level and edge detection.
4. Timers and PWM
Students will learn to implement synchronous tasks by waiting for time to elapse (polling) and using events (callbacks), as well as to generate Pulse Width Modulation (PWM) signals to control actuators such as servomotors.
5. A/D converter and sensor conditioning
An analog sensor will be calibrated and conditioned, its measurement will be digitalized by means of the analog-to-digital converter soldered on the iMAT HAT, and the value obtained will be used to control an actuator.
Project
In the final part of the course, all the modules previously developed in the laboratory will be integrated into a free-themed project. The chosen system will include at least one analog sensor to be conditioned, an actuator, and will use serial (e.g., to incorporate a digital sensor or actuator) or wireless communications (to send information to a server or a simple mobile application).

EVALUATION AND CRITERIA

Evaluation activities	Evaluation criteria	Weight
• Midterm • Final exam	• Understanding of the theoretical concepts. • Application of these concepts to problem-solving. • Critical analysis of the numerical results. • Written communication skills.	45 %
• Lab assignments • Lab exam	• Understanding of the theoretical concepts. • Application of these concepts to problem-solving. • Critical analysis of the experimental results. • Oral and written communication skills.	30 %

• Project	• Quality of the proposal. • Execution and quality of the final design. • Difficulty. • Working robustness. • Autonomy and problem-solving skills. • Oral and written communication skills.	25 %

Grading

Regular assessment

The weighting of each of the evaluation activities will be as follows:

- Theory (45%)
  - Midterm: 15%
  - Final exam: 30%
- Laboratory (55%)
  - Lab assignments: 15%
  - Lab exam: 15%
  - Project: 25%

The final grade will be computed according to these **restrictions**:

- The *examinations mark* will be the weighted average of the midterm, the final exam, and the laboratory exam, **provided that the final exam grade is greater than or equal to 4**. Otherwise, the examinations mark will be the minimum between the weighted average and the final exam grade.
- The *assignments mark* will be the weighted average of the lab assignments and the project.
- If the examinations mark is greater than or equal to 5 and the assignments mark is also greater than or equal to 5, the course grade will be obtained as indicated in the percentages above. Otherwise, the final grade will be the lower of the two marks.

Retake

A new final exam and another laboratory exam will be taken, the latter only if there was one in the regular assessment period and it does not have a passing grade. In case the assignments mark is lower than 5, the student will also carry out an individual project, which will be defended publicly at the latest on the day of the retake exam and whose grade will replace those of the lab assignments and the project. The marks of all those evaluation activities that do not have to be repeated will be preserved. The final grade will be computed as in the regular assessment period and according to the same restrictions.

Course rules

Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:

- Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.
- Regarding laboratory, absence from more than 15% of the sessions can result in losing the right to take the final exam of the regular assessment period and the retake. Anyway, unjustified absences to laboratory sessions will be penalized in the evaluation.

Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedures will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

WORK PLAN AND SCHEDULE

Activities	Date of realization	Delivery date
Midterm	Week 8	
Final exam	Regular examination period	
Lab sessions	Weekly	
Self-study of the concepts covered in the lectures	After each lesson	
Problem solving	Weekly	
Lab report writing		One week after the end of each session
Project development	From week 11	Last week
Midterm preparation	One week before the test	
Final exam preparation	April	

BIBLIOGRAPHY AND RESOURCES

Basic References

- Slides and notes prepared by the instructors (available in Moodle).

Complementary bibliography

- P. Scherz and S. Monk, *Practical Electronics for Inventors*, 4th Ed., McGraw Hill-Education, 2016. ISBN-13: 978-1-259-58754-2
- A. S. Sedra, K. C. Smith, T. C. Carusone, and V. Gaudet, *Microelectronic Circuits*, 8th Ed., Oxford University Press, 2020. ISBN-13: 978-0-190-85346-4
- P. Horowitz and W. Hill, *The Art of Electronics*, 3rd Ed., Cambridge University Press, 2015. ISBN-13: 978-0-521-80926-9
- E. Matthes, *Python Crash Course: A Hands-On, Project-Based Introduction to Programming*, 3rd Ed., No Starch Press, 2022. ISBN-13: 978-1-718-50270-3
- "The MagPi magazine" books, [Online]. Available: https://magpi.raspberrypi.com/books

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ELECTRONIC SYSTEMS: TENTATIVE WEEKLY SCHEDULE