Universidad de Alcalá

TEACHING GUIDE

Embedded Systems

Degree in
Computer Engineering (GIC)

Universidad de Alcalá

Academic Year 2023/2024

3rd Year - 2nd Semester (GIC)

Approved by the School Board on June 12th, 2023

TEACHING GUIDE

Course Name:	**Embedded Systems**
Code:	**590010 (GIC)**
Degree in:	**Computer Engineering (GIC)**
Department and area:	**Automática** **Systems Engineering and Automation**
Type:	**Compulsory (GIC)**
ECTS Credits:	**6.0**
Year and semester:	**3rd Year - 2nd Semester (GIC)**
Teachers:	Antonio Da Silva Fariña Óscar Rodríguez Polo
Tutoring schedule:	Consultar al comienzo de la asignatura
Language:	English

1. COURSE SUMMARY

This subject, together with "Real Time Systems" and "Perception and Control", covers the subject of Systems Engineering. It is focused on embedded systems, the elements used for their construction, and the knowledge necessary to understand their operation, face their design and take decisions about their implementation. The subject begins with an introduction in which the main characteristics of the embedded systems are presented, and the main elements that form them are explained, together with the most important metrics that affect their development, as well as the different possibilities of implementation of their processing hardware.

After the introduction, the different design levels of the embedded system will be exposed, as well as the design and validation techniques used in order to improve the productivity and quality of the developed systems. Among the techniques explained, the co-design hardware-software will be described, through a use case, in order that the student can know the challenges and benefits of using it in the development of embedded systems.

Next, the concept of an embedded system architecture will be defined, and the most significant elements used in the structures that are part of the architecture will be described, as well as the functionality they provide, justifying their suitability to be part of this type of systems.

Finally, the development process of the embedded systems will be studied, defining the life cycle that includes its specification and validation, as well as the subsequent implementation and deployment of the system. A set of tools that facilitate the process will be also introduced.

Parallel to the theoretical exposition, the student will carry out practices to consolidate the acquired theoretical contents. In this sense, the student will develop, deploy and debug software on an embedded system hardware, and he also will use a simulation environment of an embedded system that involves hardware and software aspects. To support the laboratory, the basic hardware of an embedded system will be used first, implementing simple drivers that allow serial communication, interrupts management and the basic timing services. Subsequently, more advanced services will be used, that facilitate the programming of functions over time on a cyclical executive. Finally, the student will perform practices on multitasking systems, becoming familiar with the use of timing services, mutual exclusion mechanisms for access to shared resources, and synchronous and asynchronous communication mechanisms.

2. SKILLS

Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following basic, generic and cross curricular skills:

en_CG4 - Ability to define, evaluate and select hardware and software platforms for the development and execution of computer systems, services and applications, in accordance with the knowledge acquired as set out in section 5, annex 2, of resolution BOE-A-2009 -12977.

en_CG6 - Ability to conceive and develop centralized or distributed computer systems or architectures integrating hardware, software and networks in accordance with the knowledge acquired as set out in section 5, annex 2, of resolution BOEA-2009-12977.

en_CG8 - Knowledge of the basic subjects and technologies, which enable them to learn and develop new methods and technologies, as well as those that provide them with great versatility to adapt to new situations.

en_CG9 - Ability to solve problems with initiative, decision making, autonomy and creativity. Ability to know how to communicate and transmit the knowledge, skills and abilities of the profession of Computer Engineering Engineer.

en_CB1 - That students have demonstrated to possess and understand knowledge in an area of study that is based on general secondary education, and is usually found at a level that, although supported by advanced textbooks, also includes some aspects that involve knowledge from the forefront of their field of study.

en_CB2 - That the students know how to apply their knowledge to their work or vocation in a professional manner and possess the competencies that are usually demonstrated through the elaboration and defense of arguments and the resolution of problems within their area of study.

en_CB3 - That students have the ability to gather and interpret relevant data (usually within their area of study) to make judgments that include a reflection on relevant social, scientific or ethical issues.

en_CB4 - That students can transmit information, ideas, problems and solutions to both a specialized and non-specialized public.

en_CB5 - That the students have developed those learning skills necessary to undertake further studies with a high degree of autonomy.

en_TRU1 - Capacity of analysis and synthesis.

en_TRU2 - Oral and written competencies.

en_TRU3 - Ability to manage information.

en_TRU4 - Autonomous learning skills.

en_TRU5 - Team work.

Specific Skills

This course contributes to acquire the following specific skills:

en_CIC2 - Ability to develop specific processors and embedded systems, as well as develop and optimize the software of these systems.

en_CIC5 - Ability to analyze, evaluate and select the most suitable hardware and software platforms for the support of embedded and real-time applications.

en_CIC7 - Ability to analyze, evaluate, select and configure hardware platforms for the development and execution of computer applications and services.

Learning Outcomes

After succeeding in this subject the students will be able to:

RA1. Enumerate the specific characteristics of embedded systems and describe how they condition their development process.

RA2. Enumerate the specific design metrics of embedded systems.

RA3. Describe the role of the processing unit in the context of a complete embedded system with I/O and memory.

RA4. Describe how the peripherals enable the interaction of the processing unit with the working environment of an embedded system.

RA5. Identify the implementation alternatives of an embedded system and be able to select the most suitable one according to the design metrics marked as objective.

RA6. Identify the design levels of an embedded system and describe the most significant techniques used to develop them.

RA7. Define the concept of architecture of embedded systems and describe the process followed for its specification and validation.

RA8. Be able to explain the design of an embedded system.

RA9. Be able to program an embedded system and describe how high-level language becomes executable code.

RA10. Be able to use compilers and developing environments suitable for embedded systems.

3. CONTENTS

Contents Blocks	Total number of hours
Introduction to embedded systems.	10 hours
Design and validation techniques for embedded systems.	16 hours
Embedded systems architecture and design elements.	18 hours
Development process and environments for embedded systems.	12 hours

4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

4.1. Credits Distribution

Number of on-site hours:	60 hours (56 hours on-site + 4 exams hours)
Number of hours of student work:	90
Total hours	150

4.2. Methodological strategies, teaching materials and resources

Theory sessions (big groups)	• Exposition and/or concepts reviews • Oral presentations and other activities
Practical Sessions(small groups)	• Exposition and/or review of practical concepts. • Lab sessions: they are focused on consolidate the theoretical concepts previously explained, and on practising with software and hardware tools that assist in the understanding of the subject and in the acquisition of relevant skills for the professional future. • Oral expositions and other activities
Individual, group and online office hours	• Solving student questions • Support to autonomous learning

5. ASSESSMENT: procedures, evaluation and grading criteria

Preferably, students will be offered a continuous assessment model that has characteristics of formative assessment in a way that serves as feedback in the teaching-learning process.

5.1. PROCEDURES

The evaluation must be inspired by the criteria of continuous evaluation (Learning Assesment Guidelines, LAG, art 3). However, in compliance with the regulations of the University of Alcalá, an alternative process of final evaluation is made available to the student in accordance with the Learning Assesment Guidelines as indicated in Article 10, students will have a period of fifteen days from the start of the course to request in writing to the Director of the Polytechnic School their intention to take the non-continuous evaluation model adducing the reasons that they deem convenient. The evaluation of the learning process of all students who do not apply for it or are denied it will be done, by default, according to the continuous assessment model. The student has two calls to pass the subject, one ordinary and one extraordinary.

Ordinary Call

Continous Assessment:

The competences acquired by the student are assessed during the whole learning process by means a series of summative tests distributed throughout the course, which allow the student to acquire the compentencies progressively.

This evaluation guarantees early feedback in the learning process of the student and allows teachers, coordinators and other elements of the Quality Assurance System to get a global traceability, with the possibility of intervention in case of being advised by certain indicators or situations.

The evaluation of the part related to the practices will be done at the end of its corresponding block

In order to be eligible for continuous evaluation, the student must have attended 80% of the laboratory classe

Extraordinary Call

The procedure will be the same as that described for the assessment by means of a final exam in the ordinary call.

5.2. EVALUATION

EVALUATION CRITERIA

The assessment criteria measure the level in which the competences have been acquired by the student. For that purpose, the following are defined::

CE1: The student has acquired knowledge about metrics and embedded systems design techniques.

CE2: The student has acquired knowledge about the development process of embedded systems.

CE3: The student shows the ability to apply and integrate the contents to problems, scenarios or case studies related to the subject

CE4: The student shows capacity and initiative to develop software for embedded systems and use specific development environments of this type of systems.

CE5: The student demonstrates the ability to argue and reasoning about designs of embedded systems.

CE6: The student overcomes the tasks assigned.

CE7: The student shows interest in the contents and the work assigned.

CE8: The student demonstrates interest, clarity and rigor in the presentation of ideas and reasoning.

GRADING TOOLS

The performance of the students will be assessed for their work, knowledge and skills acquired and the improvement of their learning process.

The continuous assessment instruments will consist of the fulfilment of continuous assessment activities proposed by the teacher for each of the topics.

The proposed activities, their contents and timing, will be communicated to the student during the presentation class or at the end of the corresponding content block. These activities comprise:

- **PEI**: Intermediate Assessment Tests (Pruebas de Evaluación Intermedia, PEI). During the course, an exam will be carried out, the content of which will focus on the topics covered. The contents and timing of the exam will be set during the first days of class
- **PL**: Lab Tests (Pruebas de Laboratorio, PL). These tests consist on expansions or variations of the practices carried out that must be resolved by the students.
- **En**: Deliverables (Entregable, En). A group work will be delivered. This group work will be accompanied, in addition, by a work memory and it also will be presented in class.
- **PEF**: Final Assessment Test (Prueba de Evaluación Final, PEF). It consists of a written test, at the end of the teaching period, that requires the solving of a set of problems.

GRADING CRITERIA

In the ordinary call-continuous assessment the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CG8, CIC5	RA1-RA6	CE1	PE1	20%
CG4, CG6, CIC2, CIC7	RA9-RA10	CE4,CE6,CE7	PL1	15%
CG4, CG6, CIC2, CIC7	RA9-RA10	CE4,CE6,CE7	PL2	15%
CG4, CG6, CIC2, CIC7	RA9-RA10	CE4,CE6,CE7	PL3	10%
CG4, CG6, CG8, CG9, CIC2, CIC5	RA1-RA8	CE2, CE3, CE5, CE7, CE8	PEF	40%

In the ordinary call-final evaluation, the relationship between the competences, learning outcomes, criteria and evaluation instruments is as follows.

Skill	Learning Outcomes	Evaluation criteria	Grading Tool	Contribution to the final mark
CG4, CG6, CG8, CG9, CIC2, CIC5, CIC7	RA1-RA10	CE1, CE2, CE3, CE4, CE5, CE6,CE7, CE8	PEF	100%

Extraordinary call

In the case of the extraordinary call, the same percentages that have been established in the case of the evaluation by means of a final exam will be maintained.

6. BIBLIOGRAPHY

6.1. Basic Bibliography

- Frank Vahid and Tony Givargis. Embedded System Design: A Unified Hardware/Software Introduction. John Wiley & Sons; ISBN: 0471386782. 2002. El libro describe conceptos básicos de sistemas empotrados, las métricas empleadas en su diseño y las alternativas de implementación. Se analizan las técnicas arquitectura de un sistema empotrado en la que se integra el hardware de procesamiento, el software, los periféricos, la memoria, etc. Se tratan algunos ejemplos de estudio y se presentan soluciones de diseño de alto nivel basadas en tareas concurrentes y en la especificación del comportamiento mediante máquinas de estados.
- David E. Simon. An Embedded Software Primer. Addison-Wesley, 1999. El libro presenta los fundamentos hardware y software necesarios para desarrollar un sistema empotrado. En él se describen las distintas técnicas empleadas en su resolución, profundizando en aquellas basadas en la utilización de un sistema operativo de tiempo real. Los contenidos son adecuados para tener una visión de conjunto de este tipo de sistemas e introduce nociones básicas sobre herramientas

de desarrollo y depuración.

- Arnold S. Berger. Embedded Systems Design: An Introduction to Processes, Tools and Techniques. CMP Books; 1st edition (December 15, 2010). El libro aborda desde el punto de vista práctico el diseño de sistemas empotrados. Centra sus contenidos en las características técnicas de las distintas alternativas y herramientas, tanto hardware como software, que se emplean en el desarrollo y depuración de este tipo de sistemas. Tammy Noergaard. Embedded Systems Architecture: A Comprehensive Guide for Engineers and Programmers. Editorial Newnes. 2013. Este libro también cubre ampliamente la temática de los sistemas empotrados. Los temas tratados son: elementos hardware, sistema operativo, lenguajes ensambladores y de alto nivel, redes y casos de estudio.

6.2. Additional Bibliography

- Jack Ganssle. The Art of Designing Embedded Systems. Newnes. 2008. Libro que refleja la experiencia de un desarrollador de sistemas empotrados. Resulta de especial utilidad una vez que se han adquirido los fundamentos teóricos y comienzan los primeros trabajos prácticos del alumno.
- Chris Rowen. Engineering the Complex SOC: Fast, Flexible Design with Configurable Processors. Ed. Prentice Hall PTR. 2004. Es un libro que cubre de un modo unificado el diseño de SOC para procesadores configurables y extensibles. Aborda temas como cogeneración hardware/software, particionado, comunicaciones y sistemas con varios procesadores.
- Richard Zurawski. Embedded Systems Handbook (Industrial Information Technology). 2009. Es un libro que cubre la temática de los sistemas empotrados de un modo amplio enfatizando en nuevas tendencias y tecnologías sin olvidarse de los fundamentos. Cubre todos los aspectos ligados a los sistemas empotrados tanto desde la perspectiva del software como de la del hardware. Entre ellos citaremos sistemas de tiempo real, seguridad, system-on-chip y network-on-chip, redes, etc. También incluye ejemplos y aplicaciones en el campo industrial, automoción y sensores inteligentes.
- Axel Jantsch. Modeling Embedded Systems and SoC's: Concurrency and Time in Models of Computation (The Morgan Kaufmann Series in Systems on Silicon). Ed. Morgan Kaufmann. 2003. El libro se centra en la presentación de técnicas de modelado para sistemas empotrados. Cubre típicos como máquinas de estado, redes de Petri o modelos de computación síncronos. También aporta ejemplos reales de uso de estas técnicas.
- David C. Black, Jack Donovan. SystemC: From the Ground Up. Ed. Springer. 2010. SystemC proporciona un conjunto de extensiones a C++ que permite el desarrollo rápido de sistemas hardware/software. Este libro se centra en aspectos prácticos del lenguaje para modelar sistemas reales. El amplio surtido de ejemplos y de programas disponibles de forma gratuita permite al lector una rápida introducción a SystemC.

Disclosure Note

During the evaluation tests, the guidelines set out in the Regulations establishing the Rules of Coexistence of the University of Alcalá must be followed, as well as the possible implications of the irregularities committed during said tests, including the consequences for committing academic fraud according to the Regulation of Disciplinary Regime of the Students of the University of Alcalá.