LEARNING GUIDE

ADVANCED ELECTRONICS FOR SMART NODES

MÁSTER EN INGENIERÍA DE TELECOMUNICACIÓN

ACADEMIC YEAR	CODE	COURSE	CREDITS	TYPE	SEMESTER
2026-27	**93001371**	**1**	**5 ECTS**	**COMPULSORY**	**FIRST SEMESTER**

LANGUAGE
ENGLISH, SPANISH

ASSIGNED CENTER
E.T.S. DE INGENIEROS DE TELECOMUNICACION

ASSIGNED DEPARTMENT
INGENIERÍA ELECTRÓNICA

COORDINATOR

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REQUIRED PREREQUISITES

REQUIRED COURSES

—

RECOMMENDED PRIOR KNOWLEDGE

RECOMMENDED COURSES

—

OTHER RECOMMENDATIONS

- Analog electronics
- Digital electronics
- Handling of electronic instrumentation
- Microcontroller programming

RESULTS

RD-822/2021

Knowledge

KG1	Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

Skills

HG2	Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

Competences

CE12	Capacidad para utilizar dispositivos lógicos programables, así como para diseñar sistemas electrónicos avanzados, tanto analógicos como digitales. Capacidad para diseñar componentes de comunicaciones como por ejemplo encaminadores, conmutadores, concentradores, emisores y receptores en diferentes bandas
CG3	Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios
CE15	Capacidad para la integración de tecnologías y sistemas propios de la Ingeniería de Telecomunicación, con carácter generalista, y en contextos más amplios y multidisciplinares como por ejemplo en bioingeniería, conversión fotovoltaica, nanotecnología, telemedicina
CG4	Que los estudiantes sepan comunicar sus conclusiones ¿y los conocimientos y razones últimas que las sustentan¿ a públicos especializados y no especializados de un modo claro y sin ambigüedades
CT5	Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente
CG5	Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo
CT4	Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT3	Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas
CE14	Capacidad para desarrollar instrumentación electrónica, así como transductores, actuadores y sensores
CT1	Capacidad para comprender los contenidos de documentación en lengua inglesa
CT7	Capacidad para trabajar en contextos internacionales

DESCRIPTION

Advanced Electronics for Smart Nodes (EANI) is a course designed to train students in the complete development cycle of IoT nodes. The course approach is markedly experimental and evolutionary, structured in such a way that each practical session builds upon the achievements of the previous one, progressively guiding students from basic instrumentation to the consolidation of a smart system.

Throughout the course, the study of sensors in IoT nodes is addressed by analyzing transduction mechanisms, analog signal conditioning, and its digitization through the node's generic microcontroller, as well as the communication protocols of digital sensors. A central pillar of the course is optimization and energy efficiency. To this end, different power supply architectures are examined, along with the processor's consumption profiles in its various operating states, and environmental energy harvesting technologies are presented.

Students will learn to evaluate how hardware decisions (such as the choice of sensor, communication protocol, or power supply topology) directly impact the autonomy and overall performance of the node. Thus, upon completing the course, they will have acquired a comprehensive view of IoT node design. This knowledge prepares students to successfully tackle the subsequent course, *Design of IoT Environments*.

TOPICS

1. **Introducción a los nodos IoT. Ejemplos aplicación: medida calidad del aire**

2. **Sensors with analog output**

- 2.1. Microprocessor readout (ADC)

3. **Power management and power supply systems**

- 3.1. Linear and Switched-mode power supplies

4. **Sensors with digital output**

4.1. SPI and I2C protocols

4.2. Digital control. PWM

5. Power consumption and low-power processing

6. Energy harvesting

6.1. Introduction to Power Management Integrated Circuits (PMIC)

7. Validation and certification of smart nodes

ACTIVITIES

Assessment activity   Learning activity

Topic 1

WEEKS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	01h 10m	Classroom (scheduled)	Normal

TOPICS
T1

METHODOLOGY
Lecture

Topic 2

WEEKS
1 **2** 3 4 5 6 7 8 9 10 11 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	01h 10m	Classroom (scheduled)	Normal

TOPICS
T2

METHODOLOGY
Lecture

Topic 3

WEEKS

1 2 **3** **4** 5 6 7 8 9 10 11 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	02h 20m	Classroom (scheduled)	Normal

TOPICS

T3

METHODOLOGY

Lecture

Topic 4

WEEKS

1 2 3 4 **5** **6** **7** 8 9 10 11 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	03h 30m	Classroom (scheduled)	Normal

TOPICS

T4

METHODOLOGY

Lecture

Topic 5

WEEKS

1 2 3 4 5 6 7 **8** **9** **10** 11 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	03h 30m	Classroom (scheduled)	Normal

TOPICS

T5

METHODOLOGY

Lecture

Topic 6

WEEKS

1 2 3 4 5 6 7 8 9 10 **11** 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	01h 10m	Classroom (scheduled)	Normal

TOPICS

T6

METHODOLOGY

Lecture

topic 7

WEEKS
1 2 3 4 5 6 7 8 9 10 11 **12** 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	01h 10m	Classroom (scheduled)	Normal

TOPICS
T7

METHODOLOGY
Lecture

Laboratory work

WEEKS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 E

FORMAT	TOTAL DURATION	LOCATION	GROUP
In-person	28h 10m	Laboratory	Normal

TOPICS
T1 **T2** **T3** **T4** **T5** **T6** **T7**

METHODOLOGY
Laboratory assignments

Laboratory exam

WEEKS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 **E**

FORMAT	TOTAL DURATION	LOCATION	ASSESSMENT	WEIGHT	MINIMUM GRADE
In-person	01h 00m	Laboratory	Progressive, Global, Retake (Extraordinary)	40%	4

TOPICS
T1 **T2** **T3** **T4** **T5** **T6** **T7**

METHODOLOGY
Problem-solving exam

ASSESSED OUTCOMES
HG2 **CE12** **CT1** **CG5** **CE14** **CT3** **CT4**

Theory test

WEEKS

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 **E**

FORMAT	TOTAL DURATION	LOCATION	ASSESSMENT	WEIGHT	MINIMUM GRADE
In-person	02h 00m	Exam Classroom	Progressive, Global, Retake (Extraordinary)	60%	4

TOPICS

T1 T2 T3 T4 T5 T6 T7

METHODOLOGY

Written exam

ASSESSED OUTCOMES

KG1 CE14 CE15 CG3 CT1 CE12 CT7

Lab report

WEEKS

1 2 3 4 5 6 7 8 9 10 11 12 13 **14** 15 E

FORMAT	TOTAL DURATION	ASSESSMENT	WEIGHT	MINIMUM GRADE
Not in person, without teacher	01h 00m	Progressive	10%	0

TOPICS

T1 T2 T3 T4 T5 T6 T7

METHODOLOGY

Work in group

ASSESSED OUTCOMES

CG3 CG4 CT4 CT5 CT7 CT1 KG1

WEEKLY SCHEDULE

Assessment activity   Learning activity   ● Week with activity   E Exam period

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	E
Topic 1	●															
Topic 2		●														
Topic 3			●	●												
Topic 4					●	●	●									
Topic 5								●	●	●						

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	E
Topic 6											•					
topic 7												•				
Laboratory work	•	•	•	•	•	•	•	•	•	•	•	•	•			
Laboratory exam																•
Theory test																•
Lab report														•		

ASSESSMENT CRITERIA

General criteria

The assessment techniques for this course are designed to objectively verify whether the students have acquired the necessary knowledge, specific core competencies, and intended learning outcomes. Regardless of the chosen assessment modality, a minimum overall score of 5.0 points is required to pass the course.

Assessment criteria for the regular exam period. Progressive assessment

Assessment criteria

Designed to maximize active, evolutionary learning and consistent work throughout the semester. The final grade will be calculated using the weighted sum of the following activities:

- Theory test (60% of the final grade): A written test in the classroom.

Condition: A **minimum grade of 4.0 out of 10** is required to qualify for the weighted average.

- Laboratory Exam (40% of the final grade): An individual exam at the laboratory workbench.

Condition: A **minimum grade of 4.0 out of 10** is required to qualify for the weighted average.

- Laboratory Report (Up to +10% additional / Bonus): Submission at the end of the semester of an integrated technical report, completed in pairs, that groups the documentation and critical analysis of all the laboratory sessions. This document serves as the student's personal "study notebook."

Application: It will be evaluated from 0 to 1 point and added directly to the final overall grade, **provided that the minimum passing grades for both the theoretical and practical exams have been met**.

To pass the course via Continuous Assessment, the weighted average of the exams (plus the report bonus) must be equal to or higher than 5.0 out of 10.

Activities

- Laboratory exam (40%)
- Theory test (60%)
- Lab report (10%)

Assessment criteria for the regular exam period. Global assessment

Assessment criteria

- Theory test (60% of the final grade): A written test in the classroom.

Condition: A **minimum grade of 4.0 out of 10** is required to qualify for the weighted average.

- Laboratory Exam (40% of the final grade): An individual exam at the laboratory workbench.

Condition: A **minimum grade of 4.0 out of 10** is required to qualify for the weighted average.

To pass the course via Global Assessment, the final weighted average of both exams must be equal to or higher than 5.0 out of 10. The additional bonus for the laboratory report is not applicable to this modality.

Activities

- Laboratory exam (40%)
- Theory test (60%)

Assessment criteria for the retake (extraordinary) exam period

Assessment criteria

Students who do not manage to pass the course during the ordinary examination period will have access to an extraordinary examination period structured as follows:

- Theory test (60% of the final grade): A written test in the classroom.

Condition: A **minimum grade of 4.0 out of 10** is required to qualify for the weighted average.

- Laboratory Exam (40% of the final grade): An individual exam at the laboratory workbench.

Condition: A **minimum grade of 4.0 out of 10** is required to qualify for the weighted average.

To pass the course in the Extraordinary Assessment, the weighted average of both exams must be equal to or higher than 5.0 out of 10. Grades for each individual block will be carried over if they were successfully passed (minimum grade of 4.0) during the ordinary assessment period.

Activities

- Laboratory exam (40%)
- Theory test (60%)

RESOURCES

Web

https://moodle.upm.es/titulaciones/oficiales/login/login.php
Classroom slides, scripts of the practical sessions and additional guides.

https://docs.espressif.com/projects/esp-idf/en/v6.0.1/esp32c6/get-started/index.html

Bibliography

S. Franco, Design with Operational Amplifiers and Analog Integrated Circuits, 4ª ed. Nueva York, NY, EE. UU.: McGraw-Hill, 2015. ISBN: 978-0-07-802816-8.

J. M. Rabaey, Low Power Design Essentials. Springer, 2009. ISBN: 978-0-387-71713-5

N. Batra and S. Goyal, IoT Fundamentals with a Practical Approach, 1st ed. Boca Raton, FL, USA: CRC Press, 2024. Available: https://doi.org/10.1201/9781003307488

Y. Khan and M. R. Yuce, Eds., Internet of Things (IoT): Systems and Applications. Singapur: Jenny Stanford Publishing, 2019.ISBN 978-0-429-39908-4

Equipment

PCB with microcontroller and external components (sensors, actuators, etc), oscilloscope, power supply, signal generator, multimeter.

SUSTAINABLE DEVELOPMENT GOALS

3 GOOD HEALTH AND WELL-BEING

Good Health and Well-being

4 QUALITY EDUCATION

Quality Education

7 AFFORDABLE AND CLEAN ENERGY

Affordable and Clean Energy

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Industry, Innovation and Infrastructure

11 SUSTAINABLE CITIES AND COMMUNITIES

Sustainable Cities and Communities

OTHER INFORMATION

The course contributes directly and actively to the Sustainable Development Goals (SDGs) in the following ways:

- SDG 3: Good Health and Well-being: Through the study of applications such as indoor air quality detection, which can contribute to the reduction of illnesses caused by indoor atmospheric pollution, as well as applications in telemedicine or bioengineering.
- SDG 4: Quality Education: Autonomous learning is promoted (through unguided competencies) in advanced instrumentation and engineering techniques, equipping students with cutting-edge technical skills highly demanded for technological entrepreneurship and high-tech research.
- SDG 7: Affordable and Clean Energy: The core of the course lies in energy efficiency, achieved through the study of low-power processing, the design of high-efficiency power supplies, and an introduction to Energy Harvesting.
- SDG 9: Industry, Innovation, and Infrastructure: It enhances scientific research and industrial technological capability by introducing the regulations, validation, and certification processes essential for transforming a laboratory prototype into a robust commercial product that can be integrated into smart infrastructures.
- SDG 11: Sustainable Cities and Communities: The designed smart nodes enable real-time monitoring of the urban environment with minimal energy cost and environmental impact, facilitating the smart and sustainable management of the buildings and cities of the future.