Universidad de Alcalá

# TEACHING GUIDE

# Power Electronics

## Degree in
## Industrial Electronics and Automatics Engineering

## Universidad de Alcalá

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## Academic Year 2024/2025

3rd Year - 2nd Semester

Approved by the EPS School Board on June 14th, 2024

# TEACHING GUIDE

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|---|---|
| Course Name: | **Power Electronics** |
| Code: | **600017** |
| Degree in: | **Industrial Electronics and Automatics Engineering** |
| Department and area: | **Electrónica**<br>**Electronic Technology** |
| Type: | **Compulsory** |
| ECTS Credits: | **9.0** |
| Year and semester: | **3rd Year, 2nd Semester** |
| Teachers: | Por definir<br><br>https://www.uah.es/es/estudios/estudios-oficiales/grados/asignatura/Electronica-de-Potencia-600017/ |
| Tutoring schedule: | Consultar al comienzo de la asignatura |
| Language: | English |

# 1. COURSE SUMMARY

This course is intended for students in the third year of the Degree of Engineering Electronics and Industrial Automation, being imparted in the second semester. It involves the initiation of students in the discipline of power electronics basing on electricity and electronics previously studied subjects.

The contents of the course include the study of specific power devices and basic aspects of power electronic converters (DC / AC, DC / DC, AC / DC), including its most common topologies, operating modes, limitations, potential applications, etc.

The course follows a theoretical and practical approach, based on the systematic development of exercises and practical cases, as well as simulation and implementation of some of the power systems in the laboratory. The specific skills acquired in this course will be useful for both continuing with further studies in the field, and, also, for the professional development in such diverse fields as industrial automation, power systems, renewable energy generation and distribution electricity, etc.

Prerequisites and Recommendations

* Electrical and electronics circuits analysis.
* Common digital and analog electronic devices knowledge.
* Mathematics for engineering (ODE, Fourier and Laplace transform, linear algebra)
* Matlab/Simulink.

Students must come to exams with a document of identity (student card, ID card or passport).

Virtual Classroom (Blackboard platform) is used as a tool for student-teacher communication and as a repository for the different teaching materials and tasks. Each student has to upload a recent photograph on this platform at the beginning of the semester and maintain a valid email address.

It is recommended that the student follows a continuous study of the subject. It is also very important to respect the job submission dates.

# 2. SKILLS

### Basic, Generic and Cross Curricular Skills.

This course contributes to acquire the following generic skills, which are defined in the Section 3 of the Annex to the Orden CIN/351/2009:

**en_TR2** - Knowledge in basic and technological subjects, which enables them to learn new methods and theories, and gives them versatility to adapt to new situations.

**en_TR3** - Ability to solve problems with initiative, decision making, creativity, critical reasoning and to communicate and transmit knowledge, skills and abilities in the field of Industrial Engineering.

**en_TR4** - Knowledge to carry out measurements, calculations, assessments, appraisals, appraisals, studies, reports, work plans and other similar works.

**en_TR5** - Ability to handle specifications, regulations and mandatory standards.

**en_TR9** - Ability to work in a multilingual and multidisciplinary environment.

**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.

### Professional Skills

This course contributes to acquire the following professional skills, which are defined in the Section 5 of the Annex to the Orden CIN/351/2009:

**en_CEI4** - Applied knowledge of power electronics.

**en_CEI6** - Ability to design analog, digital and power electronic systems.

**en_CEI7** - Knowledge and capacity for modeling and simulation of systems.

### Learning Outcomes

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

* **RAEI6.** Analyze and design low power linear power supplies complying with electrical, thermal and energy efficiency parameters.

* **RAEI7.** Describe and explain the operation of the electronic switching devices and their typical applications.

* **RAEI8.** Use tools and analysis programs to support electronic designs and modelling of electronic circuits.

* **RAEI9.** Use bibliographic resources search tools related to the industrial electronics field.

* **RAEI10**. Explain the general concepts of power electronics.

* **RAEI11.** Describe the basic components of the power converters.

* **RAEI12**. Apply knowledge of electronics to solving technical problems.

* **RAEI13.** Model, simulate and design power electronics systems.

## 3. CONTENTS

| Contents Blocks | Total number of hours |
|---|---|
| **Chapter 0: Introduction** (1h in Big Group-BG)<br>Lesson 0: Introduction to the subject. | 1 hour |
| **Chapter 1: Introduction to Power Electronics** (6h BG, 3h Small Group-SG)<br>Lesson 1: Introduction to Power Electronics.<br>Lesson 2: Electrical Circuit Review. | 9 hours |
| **Chapter 2: Electronic Devices for Power Electronics** (4h BG, 3h SG)<br>Lesson 3: Power Electronic Devices. | 7 hours |
| **Chapter 3: Switched DC/DC converters**. (11h BG, 12h SG)<br>Lesson 4: Introduction to DC/DC conversion. Step-down converter.<br>Lesson 5: Step-up and Step-down-step-up converters.<br>Lesson 6: Full-bridge converter.<br>Lesson 7: Flyback converter, Forward converter and converters with bidirectional magnetic core excitation. | 23 hours |
| **Chapter 4: Uncontrolled and Controlled AC/DC converters**. (10h BG, 9h SG)<br>Lesson 8: Single-phase diode rectifiers.<br>Lesson 9: Three-phase diode rectifiers.<br>Lesson 10: Thyristor rectifiers. | 19 hours |
| **Chapter 5: DC/AC converters**. (10h BG, 12h SG)<br>Lesson 11: Single-phase DC/AC converters.<br>Lesson 12: Three-phase DC/AC converters. | 22 hours |

# 4. TEACHING - LEARNING METHODOLOGIES. FORMATIVE ACTIVITIES.

## 4.1. Credits Distribution

| | |
|---|---|
| Number of on-site hours: | 86 hours (81 hours on-site + 5 exams hours) |
| Number of hours of student work: | 139 |
| Total hours | 225 |

## 4.2. Methodological strategies, teaching materials and resources

The teaching strategy of the course is divided into 3 sections: classroom learning, learning in small groups and finally the working sessions in the laboratory.

**Sessions of large group in the classroom:**

Working sessions in the classroom, in large groups, will consist of lectures where the main concepts of the theory of circuits will be presented. The aim is to introduce students to the theoretical foundations of circuit analysis in a guided and reflective way. The understanding of these concepts will culminate with the use of them in both the laboratory and the problem solving sessions in small groups.

Teaching materials will be essential to create reflective learning environments, where students and teachers can undertake a critical analysis that allows the student to autonomously relate concepts.

The order of presentation of the contents will evolve from the simple to the complex, in order to avoid a high degree of abstraction that might cause a student lack of interest in the course. In any case, it is very convenient, during the working sessions in the classroom, to establish linkages with other subjects in the curriculum, and to provide possible experience on the contents, which will help to attract students' attention and will encourage their interest in the subject.

# 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

Continuous Assessment:

The main assessment tools will be:

1. Worksheets (HT). Solving practical problems individually or in small groups.

2. Laboratory Deliverable (L). Performance of laboratory practices and delivery of the corresponding reports. The evaluation will consider systematic observation, where the teacher will record the main difficulties and skills observed in each student, and the realization of a single memory by practice, by each of the groups of students who have done it.
3. Intermediate Assessment Tests (PEI1, PEI2). Performing written tests focused on both practical and theoretical aspects of the subject.

Students must attend 100% of the laboratory sessions and deliver the corresponding reports to all laboratory practices. Recovery sessions will be enabled for those students who have not attended any of the sessions and justify it documentarily.

Assessment through final exam:

In the case of evaluation by means of a final exam, the evaluation elements to be used will be the following:

1. A reduced version of the laboratory deliveries

2.- A final test focused on theoretical and practical aspects of the subject.

**Extraordinary Call**

There are two situations:

a. Students who followed, during the course, a continuous assessment procedure will keep the mark of the passed practical parts making a theoretical-practical exam for the parts they did not pass.

b. The remaining students will comply with the final assessment considerations.

According to current regulations and because the experimental lab skills are considered essential for the acquisition of the objectives of the course, attendance at all laboratory sessions and overcoming the mandatory practices is considered an essential element of the assessment, in both continuous and final modalities (regulations governing the evaluation processes learning models approved by the Governing Council of 24 March 2011, Article 6, paragraph 4). For this reason, the laboratory exercises are common and essential in both types of evaluation: continuous and final.

## 5.2. EVALUATION

### EVALUATION CRITERIA

The evaluation process aims at assessing the extent and depth of the student's acquisition of skills raised in the subject. Consequently, the evaluation criteria to be applied in the various tests that are part of the process, ensure that the student has the appropriate level in the following knowledge and skills:

Theoretical contents:

* CE1: The student understands and knows the concepts and main ideas of each of the topics.
* CE2: The student knows how to relate theoretical contents to practical cases.
* CE3: The student develops ideas consistently.
* CE4: The student is able to solve the problems in a comprehensive way.
* CE5: The student has synthesis capacity.
* CE6: The student is careful and rigorous in his/her approach when making presentations.

Practical contents:

* CE7: The student succeeds in the interpretation of data, practical problems and practical experiments.
* CE8: The student successfully performs power system simulations.
* CE9: The student relates theory to practice properly.
* CE10: The student correctly makes laboratory experiments.

* CE11: The student is rigorous in making and interpreting measurements and results.
* CE12: The student presents consistent practical works within the available time.
* CE13: Knows how to work in teams.

## GRADING TOOLS

The work of the student is graded in terms of the assessment criteria above, through the following tools:

1. Ordinary call
    a. Continuous assessment, with four assessment exams or works (PEI1, PEI2, ML1, ML2).
    b. Final assessment (PEF, PL)
2. Extraordinary call. Final assessment (PEF, PL)

## GRADING CRITERIA

### Ordinary call

**1) Continuous assessment:**

Students will be evaluated by continuous assessment throughout the semester. The type of tests to be performed and the percentages by weight of such evidence on the final grade is:

a) Laboratory sessions: Compulsory attendance. The sessions cover the knowledge acquired in the theoretical part of the course. Problems or practical cases that link theory with practice will also be resolved. There are two marks: the first comprises the assessment of activities carried out until mid-course (ML1), the second those made in the second half of the course (ML2). Each mark, ML1 and ML2, represents, the 25% of the final grade of the student (50% overall). For each of the sections the following evaluation resources are used:

i) Worksheets (HT): In order to promote the ongoing monitoring and formative student feedback, students grouped in pairs or individually, have to deliver after each lab session a worksheet in which the main results are stated.

ii) Lab. Deliverable (E): After each lab. half (E1 for the first, E2 for the second), students will deliver a document describing all analysis, simulations and problems.

iii) Laboratory tests (PL): Individual practical cases to solve using simulation tools.

The mark in each of the halves, ML1 and ML2, is the average mark of the deliverables together with a continuous evaluation mark, pondered by the laboratory tests PL1 and PL2.

b) Mid-term evaluation tests (PEI), divided into two terms: the first comprises the tests until mid-course (PEI1: 25% of the final grade of the student); the second covers made from mid to end of the year (PEI2: 25% of the final grade of the student). These tests consist of questions (analysis and/or synthesis) regarding specific aspects of the syllabus covered by the lectures and exercises.

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 |
|---|---|---|---|---|
| TR2, TR3, TR4, TR5, TR9 CEI4, CEI6, CEI7 | RAEI6, RAEI7, RAEI9, RAEI10, RAEI11, RAEI12 | CE1, CE2, CE3, CE4, CE5, CE6 | PEI1<br>PEI2 | 25%<br>25% |
| TR2, TR3, TR4, TR5, TR9 CEI4, CEI6, CEI7 | RAEI6, RAEI8, RAEI9, RAEI12, RAEI13 | CE7, CE8, CE9, CE10, CE11, CE12, CE13 | ML1<br>ML2 | 25%<br>25% |

**2) Final assessment:**

Students have to pass two exams:

a) Theoretical-practical tests (PEF, 70%) widely covering the different subject contents. Mark will be NO PRESENTED if this test is not done.

b) Laboratory test (PL, 30%) to evaluate the student work during the compulsory lab sessions.

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 |
|---|---|---|---|---|
| TR2, TR3, TR4, TR5, TR9 CEI4, CEI6, CEI7 | RAEI6, RAEI7, RAEI9, RAEI10, RAEI11, RAEI12 | CE1, CE2, CE3, CE4, CE5, CE6 | PEF | 70% |
| TR2, TR3, TR4, TR5, TR9 CEI4, CEI6, CEI7 | RAEI6, RAEI8, RAEI9, RAEI12, RAEI13 | CE7, CE8, CE9, CE10, CE11, CE12, CE13 | PL | 30% |

For both cases, continuous or final assessment, students are considered to have passed the subject (demonstrating the acquisition of skills of theoretical and practical) following the final assessment if the following requirements are met:

* They have successfully passed the assessment of the skills related to the labs or problems and practical assumptions. It is understood that a student acquires these skills successfully if he has attended the lab and its rating on average for all the related tests is, at least, 35% of the maximum score obtainable.
* They have successfully passed the assessment of skills related to theoretical and practical tests. It is understood that a student has successfully acquired these skills if his score in average in all the related tests is at least 35% of the maximum qualifying.
* The final weighted score assessment tests is equal to or greater than 5 out of 10.

In the event of failure to pass any of the parts (theoretical tests and laboratory), the student will receive a numerical grade equal to the weighted average of all the continuous assessment tests, always below 5 points.

If only one or none of the parts are assessed, the student will receive a mark of "Not Presented".

**Extraordinary call**

For both continuous and final assessment, the relationship between the criteria, instruments and rating is the same as in the ordinary exam, as described above.

1) Continuous assessment: Students who, having participated in the process of continuous assessment have not achieved a final grade higher than 5 out of 10 in the ordinary call may keep the marks of the passed parts and attend only for the failed ones in the extraordinary exam.

Students who do not pass the laboratory practices and problems, or practical cases, in the ordinary call, can make specific theoretical and practical tests to demonstrate the acquisition of those skills and competencies.

2) Final assessment: The assessment and marking procedure is equal to the ordinary one.

# 6. BIBLIOGRAPHY

## 6.1. Basic Bibliography

Material prepared by the lecturers of the subject [see web].

N. Mohan, T. M. Undeland y W. P. Robbins. "Power Electronics: Converters, Applications, and Design". Ed. John Wiley&Sons, Inc. 2002. ISBN: 0-471-58408-8.

This book is the main reference for the subject. It covers nearly all the topics and is also valid as a complementary reference

A. Barrado, A. Lazaro. "Problemas de Electr¢nica de Potencia". Ed. Pearson - Prentice Hall. 2007. ISBN: 9788420546520

Good solved-problems book. In Spanish.

Bin Wu."High-Power Converters and AC Drives". Wiley & IEEE Press, 2006. ISBN-13978-0-471-73171-9. http://www.ee.ryerson.ca/~bwu/publications.html

This book is used for the SVM description covered in Lesson 12.

## 6.2. Additional Bibliography

R. W. Erickson, D. Maksimovic. "Fundamentals of Power Electronics". Second Edition. Ed. Springer Science+Business Media Inc. 2001.ISBN: 0-7923-7270-0
http://ecee.colorado.edu/~pwrelect/book/SecEd.html. [Available third edition].

Well-known reference book for power electronic converters analysis and design from the equilibrium and dynamical point of view.

Daniel W. Hart. "Introduction to Power Electronics?.Ed. Prentice Hall. Edición internacional, 1997. ISBN: 0-13-180415-4. http://diamond.gem.valpo.edu/~dhart/
(Disponible también edición en castellano).

Good reference book.

Further reading

C. P. Basso. "Switch-Mode Power Supplies Simulations and Practical Designs". McGraw-Hill Professional Engineering. ISBN: P/N 978-0-07-150859-9 of set 78-0-07-150858-2.

D.G. Holmes, T.A. Lipo. "Pulse Width Modulation for Power Converters. Principles and Practice". IEEE Press Series on Power Engineering. ISBN: 0-471-20814-0.

D.O. Neacsu. "Power-Switching Converters. Medium and High Power". CRC Taylor & Francis.ISBN-10: 0-8247-2625-1.

Access to the Library to check the bibliography

## 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.