

# Course guide

## 2301213 - PDS - Power Devices and Systems

Last modified: 21/03/2024

**Unit in charge:** Barcelona School of Telecommunications Engineering  
**Teaching unit:** 230 - ETSETB - Barcelona School of Telecommunications Engineering.

**Degree:** MASTER'S DEGREE IN SEMICONDUCTOR ENGINEERING AND MICROELECTRONIC DESIGN (Syllabus 2024).  
(Optional subject).

**Academic year:** 2024    **ECTS Credits:** 4.0    **Languages:** English

### LECTURER

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**Coordinating lecturer:** Vellvehi Hernandez, Miquel

**Others:** Rebollo Palacios, José Andrés  
Pérez Tomás, Amador  
Jordà Sanuy, Xavier

### TEACHING METHODOLOGY

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Classroom lectures: 24 h  
Practical sessions: 6 h  
Practical sessions performed at IMB-CNM.  
Used simulation programs: Synopsis-Sentaurus / LT-Spice.

### LEARNING OBJECTIVES OF THE SUBJECT

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- Acquire basic knowledge on semiconductor physics for describing both the operation and the electrical-thermal characteristics of the main power semiconductor devices currently available in the market (e.g., diodes, MOSFETs, IGBTs, HEMTs), also taking into account the different types of semiconductor materials used: silicon and WBG semiconductors.
- Acquire basic knowledge on manufacturing technological processes used in power semiconductor devices.
- Be able to evaluate and identify the thermal problems associated with power semiconductor devices, their packages, as well as their possible cooling solutions.
- Be able to select the reliability and aging protocols used in power semiconductor devices more adequate for a given final application, as well as interpret their impact on converter design and lifespan.

### STUDY LOAD

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Type	Hours	Percentage
Self study	70,0	70.00
Hours small group	6,0	6.00
Hours large group	24,0	24.00

**Total learning time:** 100 h



## CONTENTS

### Physical Properties of Semiconductors

**Description:**

Introduction. Crystal structure. Energy bandgap and intrinsic carrier concentration. Energy band structure and carrier particle properties. Doped semiconductors. Carrier transport. Recombination-generation and carrier lifetime in non-equilibrium. Impact ionization. Basic equations of semiconductor devices.

**Full-or-part-time:** 2h

Theory classes: 2h

### pn Junctions

**Description:**

pn junction in thermal equilibrium. Current-voltage characteristics of pn junction. Blocking and breakdown characteristics of pn junction.

**Full-or-part-time:** 2h

Theory classes: 2h

### pin Diodes

**Description:**

pin diode structure. I-V characteristic of pin diode. Design and breakdown voltage of pin diode. Forward conduction behavior. Relationship between stored charge and forward voltage. Turn-on behavior of power diodes. Reverse recovery of power diodes.

**Full-or-part-time:** 1h

Theory classes: 1h

### Schottky Diodes

**Description:**

Energy band diagram of metal-semiconductor junction. Current-voltage characteristics of Schottky junction. Structure of Schottky diodes. Ohmic voltage drop of a unipolar device.

**Full-or-part-time:** 1h

Theory classes: 1h

### Bipolar Transistors

**Description:**

Function of bipolar transistor. Structure of power bipolar transistor. I-V characteristic of power transistor. Blocking behavior of power bipolar transistor. Current gain of bipolar transistor. Base widening, field redistribution, and second breakdown. Limits of silicon bipolar transistor. SiC bipolar transistor. Thyristor-like structures.

**Full-or-part-time:** 1h

Theory classes: 1h



### MOS Transistors

**Description:**

Operating principle of MOSFET. Structure of power MOSFETs. Current-Voltage characteristics of MOSFETs. Characteristics of MOSFET channel. Ohmic region. Compensation structures in modern MOSFETs (Superjunction). Temperature dependency of MOSFET characteristics. Switching properties of MOSFET. MOSFET switching losses. Safe operating area of MOSFET. Reverse diode of MOSFET. SiC field-effect devices: JFET and MOSFET.

**Full-or-part-time:** 3h

Theory classes: 3h

### IGBTs

**Description:**

Operating mode. I-V characteristic of an IGBT. Switching behavior of an IGBT. Plasma distribution in IGBTs. IGBTs with higher carrier charge density modules. Bidirectional blocking capability IGBTs. Reverse Conducting IGBTs (RC-IGBTs). Potential of IGBT

**Full-or-part-time:** 3h

Theory classes: 3h

### WBG / UWBG Materials and Related Power Devices

**Description:**

Related materials: SiC and GaN. SiC-based power devices: Schottky and pin diodes, JFET and MOSFET. GaN lateral power transistors. GaN vertical power transistors. Power devices based on UWBG materials.

**Full-or-part-time:** 4h

Theory classes: 4h

### Introduction to Power Device Manufacturing Technology

**Description:**

Complete conception process of a power device. Review of basic manufacturing technology processes. Example of a power device manufacturing process: Vertical double-diffused MOSFETs and IGBTs.

**Full-or-part-time:** 2h

Theory classes: 2h

### Packaging Technologies for Power Devices

**Description:**

Challenges faced by packaging technologies. Types of packaging. Physical properties of materials. Thermal simulation and thermal equivalent circuits. Parasitic electrical elements in power modules. Advanced packaging technologies.

**Full-or-part-time:** 3h

Theory classes: 3h



### Reliability and Testing for Verification

**Description:**

Higher reliability needs required in power devices. Different tests for reliability verification: high-temperature reverse bias, High-Temperature Gate Stress, temperature and humidity bias, high and low-temperature storage, temperature cycling and thermal shock, power cycling. Failures due to cosmic rays. Statistical evaluation of reliability test results. Other reliability tests.

**Full-or-part-time:** 2h

Theory classes: 2h

### Practical sessions

**Description:**

Practical sessions will be devoted to simulation for design, manufacturing, and electrical behaviour analysis of power devices, covering the following topics (6h):

1. Review of technological, physical, and electrical simulators.
2. Simulation of a technological process.
3. Physical analysis of electrical behaviour through simulation.
4. Correlation with models used in behavioural electrical simulators.

**Full-or-part-time:** 6h

Practical classes: 6h

## GRADING SYSTEM

Examination: course work (50%) plus exam (50%)

## BIBLIOGRAPHY

**Basic:**

- Lutz, J.; Schlangenotto, H.; Scheuermann, U.; De Doncker, R. Semiconductor power devices: physics, characteristics, reliability [on line]. 2nd ed. Cham: Springer International Publishing, 2018 [Consultation: 14/06/2024]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-70917-8>. ISBN 9783319709178.
- Baliga, B.J. Fundamentals of power semiconductor devices [on line]. 2nd ed. Cham: Springer, 2019 [Consultation: 14/06/2024]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-93988-9>. ISBN 9783319939889.
- Baliga, B.J. Modern power devices. New York: John Wiley & Sons, 1987. ISBN 0471637815.
- Iannuzzo, F. Modern power electronic devices: physics, applications, and reliability. Institution of Engineering and Technology, 2020. ISBN 9781785619175.