67229 - Modeling and Control of Power Electronic Systems

Información del Plan Docente

Academic Year	2017/18
Faculty / School	110 - Escuela de Ingeniería y Arquitectura
Degree	527 - Master's in Electronic Engineering
ECTS	5.0
Year	1
Semester	First semester
Subject Type	Optional
Module	---

1.General information

1.1.Introduction

1.2.Recommendations to take this course

1.3.Context and importance of this course in the degree

1.4.Activities and key dates

2.Learning goals

2.1.Learning goals

2.2.Importance of learning goals

3.Aims of the course and competences

3.1.Aims of the course

3.2.Competences

4.Assessment (1st and 2nd call)

4.1.Assessment tasks (description of tasks, marking system and assessment criteria)

5.Methodology, learning tasks, syllabus and resources

5.1.Methodological overview

The methodology followed in this course is oriented towards achievement of the learning objectives. A wide range of teaching and learning tasks are implemented, such as:

- Lectures, in which the theoretical basis of averaged switch modelling and Middlebrrok's theorems will be explained.
- Practice sessions where the students will solve problems and representative cases.
- Lab sessions will be carried out in small groups where students prepare computer simulations.

- Students are expected to participate actively in the class throughout the semester.

5.2.Learning tasks

The course includes the following learning tasks:

Classroom activities (2 ECTS: 50 hours)

- A01 **Lectures** (22 hours). Presentation of theoretical contents with representative examples. The contents are the concepts and fundamentals of averaged switch modeling and Middlebrrok's theorems. Student participation is encouraged through questions
- A02 **Practice sessions** (4 hours). Problems and cases related to the lectures' contents. Students are encouraged to work on the problems previously.
- A03 **Lab sessions** (15 hours). Sessions are structured in 5 sessions of 3 hours each. The instructions of the exercises will be available to students on the virtual platform.
- A06 **Tutorials** (9 hours). Tutoring of student assignments.

Autonomous work (3 ECTS: 75 hours)

- A06 **Student assignments** (20 hours). Activities related to lab work that the student can do individually or in group and that the teacher will propose throughout the teaching period. Its main format is a sheet of short questions students must solve.
- A07 **Study** (35 hours). It is aimed at monitoring the learning process, conducting practice sessions, exam preparation and tutorials.
- A08 **Evaluation tests** (20 hours).
  - 1) Midterm exam: exam to do at home to cover HW 1-4 and it is submitted one week later in class.
  - 2) Final exam: exam to do at home to cover HW 1-8 and it is submitted four days later in class.

5.3.Syllabus

The course will address the following topics:

- Topic 1. Introduction and simulation tools.
- Topic 2. Averaged switch modeling.
- Topic 3. Middlebrook's Extra Element Theorem.
- Topic 4. Middlebrook's feedback theorem.
- Topic 5. Equivalent circuit modeling of the discontinuous conduction mode.
- Topic 6. Peak and average current mode control.

Homework assignments

1. Homework Assignment 1

- **Averaged switch modeling problems**
  - Do problems 7.15 and 7.16 of the course textbook, second edition.
  - It is highly suggested to read Section 7.4 of the textbook before attempting problems 7.15 and 7.16. It is also suggested to read the notes posted in the Matlab/Simulink pages
- **Simulink problems**
- **Do the attached problems:**
  - Closed-loop output impedance of buck converter
  - Control-to-output transfer function of a buck-boost converter

2. Homework Assignment 2

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- **Extra Element theorem problems.** Do the following two problems:
  - The effect of capacitor equivalent series resistance (esr) on the transfer function of an R-L-C filter.
  - Analysis of the CCM buck-boost converter control-to-output transfer function Gvd(s) using the extra element theorem.

3. Homework Assignment 3

- **Extra Element theorem problems.** Do the following two problems:
  - Analysis and design of a CCM SEPIC.
  - Analysis of a flyback converter with input filter.

4. Homework Assignment 4

- **The n Extra Element Theorem.** Do the following problems:
  - Write the output impedance function of a damped filter circuit.
  - Write the control-to-output transfer function of a nonideal boost converter.

5. Homework Assignment 5

- **The Feedback Theorem and Feedback loop simulation.** Do the following two problems:
  - Use of the feedback theorem to analyze a transconductance amplifier circuit
  - Simulation of a closed-loop SEPIC

6. Homework Assignment 6

- **Discontinuous conduction mode.** Do the following problems:
  - Problem 11.3
  - Problem 11.4
  - Problem 11.6
  - Additional 11.6(d): modify your answer to part (c), accounting for inductor high frequency dynamics.
  - Do the attached DCM Flyback simulation problem.

7. Homework Assignment 7

- **Current mode control.** Do the following two problems:
  - Problem 12.2 of the textbook.
  - Design of the compensator of a closed-loop CPM buck regulator based on the simple model.

8. Homework Assignment 8

- **Current mode control, HF model**
  - Analysis and simulation of a CPM Regulator:
  - Evaluation of a compensator design
  - Simulation
  - Compensator redesign based on the more accurate model
  - Response to a step change in load current
- **The contents developed in the problems solving are:**
  - 1 Problem 6.45 Modeling and control of a buck converter
  - 2 Problem 6.46 Modeling and control of a bidirectional buck converter
  - 3 Problem 6.48 Modeling and control of a boost converter
  - 4 Problem 6.49 Modeling and control of a flyback converter

5.4.Course planning and calendar

Further information concerning the timetable, classroom, office hours, assessment dates and other details regarding this course, will be provided on the first day of class or please refer to the EINA website.

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Provisional course planning:

Week 1: Introduction

- Introduction tocourse.
- Presentation of ideas.
- **Simulation tools**
  - Matlab/Simulink tutorial.
  - LTspice tutorial.

Week 2: Averaged switch modeling and simulation

- Section 7.4 and Appendix B.
- Averaged models of main converters.
- Scheme of isolated converters.

Week 3:

- Introduction to Middlebrook's Extra Element Theorem.
- Appendix C.
- EET SEPIC analysis example, Zd.
- Homework assignment 1.

Week 4:

- Introduction to Middlebrook's Extra Element Theorem.
- Appendix C.
- EET SEPIC analysis example, Zn.
- Homework assignment 2.

Week 5:

- Middlebrook's n-Extra Element Theorem.
- Homework assignment 3.
- Lab session 1.

Week 6:

- Middlebrook's Feedback Theorem.
- Measurement point of transfer functions.
- Analysis of feedback circuits using null double injection techniques (examples)
- Homework assignment 4.

Week 7:

- Dynamic modeling and simulation of converters operating in discontinuous conduction mode.
- Chapter 11 and Appendix B.
- Homework assignment 5.
- Lab session 2.

Week 8:

- How changing the operating mode leads to substantial changes in small-signal transfer functions.
- Current Programmed Control. Introduction.
- Midterm exam.
- Student presentation of problem 6.45

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Week 9:

- Current Programmed Control.
- Student presentation of problem 6.46
- Lab session 3.

Week 10:

- Current Programmed Control. Chapter 12 and Appendix B.
- Basic circuit and slope compensation.
- Student presentation of problem 6.48
- Homework assignment 6.

Week 11:

- Sampled-data modeling of current programmed converters (Supplementary notes).
- Zero Order Hold: Transfer Function.
- Detailed small-signal analysis.
- Simulation.
- Effects of current mode control on basic transfer functions.
- Student presentation of problem 6.49
- Homework assignment 7.

Week 12:

- Current mode control.
- Homework assignment 8.

Week 13: Current mode control.

Week 14: Final exam.

5.5.Bibliography and recommended resources

- Erickson, Robert W.. Fundamentals of power electronics / Robert W. Erickson, Dragan Maksimovic . - 2nd ed., 6th print. New York: Springer, 2004
- Problemas de electrónica de potencia / coordinación y revisión técnica Andrés Barrado Bautista, Antonio Lázaro Blanco. - [Reimp.] Madrid [etc.] : Pearson Educación, D.L. 2012