EEE572 - Advanced Power Electronics
Fall 2020

Instructor	:	Raja Ayyanar	Class hours	:	M W 3:05 – 4:20 PM
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Scope and objective: Power electronics is a critical enabling technology that covers a wide spectrum of applications including power supplies for all electronic equipment, motion control, interface of renewable energy resources such as solar and wind, electric vehicles and efficient lighting. The major focus of this course is on design-oriented analysis of topologies and control methods for various power electronic converters used for dc-dc, dc-ac and ac-dc power conversions in important applications. This course is intended as a second course in power electronics, building on EEE472. However, several lectures initially will be devoted to the fundamentals of switch-mode power conversion and analysis of basic converters to help students without a formal first course on power electronics. PLECS simulations will be used extensively to reinforce the basic concepts, and as a design tool. Students will have an opportunity to specialize in a specific area of power electronics such as dc-dc converters, motor drives or power systems applications through suitable choice of the required course project.

Reference books: (Optional only; there is no required textbook for this course)

N. Mohan, T.M. Undeland, W.P. Robbins, “*Power Electronics: Converters, Applications and Design*,” John Wiley and sons, 3rd edition.

R.W. Erickson, D. Maksimovic, “*Fundamentals of Power Electronics*” Kluwer Academic Publishers, second edition.

Main topics:

- **Review of basic principles of switch-mode power conversion**
  Concept of steady state in switching converters, volt-second, ampere-second and power balance, concept of power pole and average models
- **DC-DC converters**
  - Analysis and detailed design of buck, boost, buck-boost, Cuk and SEPIC converters
  - Analysis and detailed design of isolated dc-dc converters including forward, flyback, full bridge and dual-active bridge and other soft switching topologies
  - Discontinuous current mode (DCM) operation of dc-dc converters
  - Small-signal average models of dc-dc converters
  - Voltage mode and current mode control: modeling and design methods
  - Design of high frequency magnetics for dc-dc converters
  - Power management: Switching regulators for modern processors – multi-phase voltage regulators, design for high dynamic performance, features of power management integrated circuits
- **AC-DC PWM rectifiers**
  - Power quality issues
  - Boost and flyback converter based power factor correction circuits (PFC)
  - Models, design and control of PFC
  - Full bridge bi-directional PWM rectifiers, applications in EV chargers and motor drives
- **DC-AC PWM inverters**

- Voltage source inverters - topology and waveform analysis
- Models of single phase and three phase inverters and control methods
- Single-phase and three-phase PWM techniques
- Major applications including electric vehicle traction drives

- **Wide bandgap (WBG) devices**
  - Power device characteristics and basics of WBG devices
  - Applications of SiC and GaN devices in high performance power converters
  - Designing with SiC and GaN devices

- **Digital control of power electronic converters**
  - Digital control techniques for power converters; modeling and simulation
  - Design examples of dc-dc, and PWM dc-ac converter

- **Grid interface of renewable energy resources**
  - Power converters and control for interfacing solar PV
  - Solid state transformers and other power systems applications of power converters

- **Soft switching and resonant converters**
  - Concepts of ZVS and ZCS
  - Zero voltage transition converters
  - Resonant converters and applications in lighting

- **Practical issues in power electronic converters**
  - Selection criteria for diodes, MOSFETs and IGBTs; gate drive circuits
  - Thermal management, EMI and layout issues

PLECS simulation tool: The Power Electronics simulation software called PLECS from Plexim Inc. is the supported simulation tool for the course. Each student will be given a code in the second week of classes using which a license for PLECS valid for one year can be obtained.

Homework: Eight (8) homework assignments will be given. Students are expected to typically spend about eight hours on each homework. The answers should be submitted online in Canvas by the due date. Late homework submission will not be accepted. Many assignments will involve PLECS simulations.

Course project: A significant part of the grade is based on a required course project. Students will choose a fairly complex power electronics application in their preferred area, complete the analysis and detailed design of power converter and control for this application, and finally validate the design through extensive PLECS simulation. A formal technical report is required on the last day of class.

Grading:
Homework 20%, Project 20%, Midterm exam 25%, Final exam 30%, Participation in class and online forum 5%.

Exam dates:

Midterm exam – Monday 10/12/2020

Final exam – Friday 12/11/2020

Absence & Make-Up Policies
Completed homework assignments are due (submitted through Canvas) at midnight on the due date. Late homework submission will NOT be accepted. Two homework scores will be dropped and the best six of eight homework grades will be included in the final grade.

Classroom Behavior
Cell phones and pagers must be turned off during class to avoid causing distractions. The use of recording devices is not permitted during class. Any violent or threatening conduct by an ASU student in this class will be reported to the ASU Police Department and the Office of the Dean of Students.

Academic Integrity
All students in this class are subject to ASU's Academic Integrity Policy (available at http://provost.asu.edu/academicintegrity) and should acquaint themselves with its content and requirements, including a strict prohibition against plagiarism. All violations will be reported to the Dean's office, who maintain records of all offenses. Students are expected to abide by the FSE Honor Code (http://engineering.asu.edu/integrity/).

Disability Accommodations
Suitable accommodations will be made for students having disabilities and students should notify the instructor as early as possible if they will require same. Such students must be registered with the Disability Resource Center and provide documentation to that effect.

Sexual Discrimination
Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at https://sexualviolenceprevention.asu.edu/faqs.

As a mandated reporter, I am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services, https://eoss.asu.edu/counseling is available if you wish discuss any concerns confidentially and privately.

Tentative Schedule of Lectures, Assignments, Project and Exams

8/24 M	Introduction to power electronics, applications and basic concepts	
8/26 W	Basic principles of switch mode power conversion	
8/31 M	Analysis and design of buck converter; PLECS simulations, demo	
9/2 W	Analysis and design of boost and buck-boost converters	Homework 1
9/7 M	*Labor Day - No classes*	
9/9 W	Cuk and SEPIC converters	
9/14 M	Multiphase dc-dc converters; Analysis of converters in DCM mode	
9/16 W	Average models of converters; basic linear control system concepts	Homework 2
9/21 M	Small signal model of dc-dc converters	
9/23 W	Controller design for dc-dc converters	
9/28 M	Controller design (continued); Current mode control	Homework 3
9/30 W	Magnetics review and converters with magnetic isolation	
10/5 M	Forward converter and Flyback converter	
10/7 W	Full bridge converters; Dual active bridge converters; Active reset topologies	Homework 4
10/12 M	**Midterm Exam**	
10/14 W	Design of transformers and inductors	
10/19 M	Power semiconductor devices: characteristics and selection; loss analysis	
10/21 W	Soft switching in dc-dc converters	Homework 5
10/26 M	Powering the information technology; power management IC characteristics	
10/28 W	AC-DC rectifiers: Power quality standards, Boost PFC analysis, design	
11/2 M	DC-AC inverters; sinusoidal PWM; phasor analysis	Homework 6
11/4 W	Inverter harmonic analysis; single phase inverter design	
11/9 M	Inverter and rectifier controller design; digital control principles	Project selection
11/11 W	*Veterans Day – No classes*	
11/16 M	Digital control of power converters	Homework 7
11/18 W	Three phase converters – analysis and design; multilevel converters	
11/23 M	Characteristics and applications of wide bandgap devices	
11/25 W	Topologies, design and control for solar PV power converters	Homework 8
11/30 M	Electric vehicles, lighting and power systems applications	
12/2 W	EMI, filters, and thermal management; course review and future directions	Project final report
12/11 F	**Final Exam**	