WASHINGTON STATE UNIVERSITY

EE 486 Power Electronics
School of Electrical Engineering and Computer Science
Spring 2014

1 Course Overview

Title	EE 486 Power Electronics
Credits	Three credit hours
Semester	Spring 2014
Instructor	Prof. Ali Mehrizi-Sani
Email	mehrizi@eecs.wsu.edu
Office	EME 35
Phone	(509) 335-6249
Fax	(509) 335-3818
Lecture Room	SLOA 46
Lecture Hours	Mondays, Wednesdays, Fridays from 9:10 AM 10:00 AM
Course Website	http://eecs.wsu.edu/~mehrizi/ee486/2014S
Office Hours	• Mondays from 10:00 AM to 11:00 PM; or • Email me for an appointment with "EE 486" in the subject line.
TA Name	Younes Sangsefidi
TA Email	younes.sangsefidi@email.wsu.edu
TA Office Hours	Fridays from 4:00 pm to 5:00 pm in EME 504
Catalog Description	High power semiconductor devices; analysis and design of linear and switching power supplies, high frequency magnetics, controller design.
Longer Description	This is a first course on power electronics. EE 486 discusses conversion of electrical energy using solid-state electronic switches. This courses discusses the four main converter types uses in power electronics: {dc|ac} to {dc|ac} converters. You will learn the principles of operation and modeling and analysis methods tailored for these converters. You will also see the application of power electronics for motor drives, power supplies (e.g., your cell phone), and power systems (e.g., grid integration of renewable energy resources such as wind and solar). Homework assignments include simulations and sometimes have a programming component.

2 Required Background by Topic

You need to have taken the following courses. For each course, the topics that will be used in this course are listed. A general knowledge of other topics typically covered in the respective course is preferred.

Electronics (EE 311 at WSU) Circuit representation of semiconductor devices (MOSFET/IGBT and diode)

Electrical Circuits II (EE 321 at WSU) Transient analysis of circuits, three-phase circuits, transfer functions, frequency response, Fourier series representation, and transformers.

PSCAD/EMTDC This is not an official prerequisite of the course, but you will need this software package to do some of the assignments of the course. A free version of PSCAD is available for download at https://mycentre.hvdc.ca (watch the video "How to get the Free version"). Several short tutorial videos are available on the same website. You can ask myself or your TA your PSCAD questions. You can also use the support request form from within PSCAD. A user forum is available at bb.pscad.com.

MATLAB/SIMULINK You also need to be familiar with MATLAB for the programming assignments. Students who wish to have MATLAB on their own personal computers can purchase MATLAB/SIMULINK Student Version from the Bookie or from http://www.mathworks.com/store. One great source is "MATLAB Programming Tips," from The MathWorks available for free at http://www.mathworks.com/help/pdf_doc/matlab/programming_tips.pdf.

3 Learning Outcomes

At the end of this course, you are expected to be able to

- Explain the purpose and principles of operation of power electronic converters;
- Analyze the voltage and current waveforms resulting from a power electronic converter;
- Compare and contrast different converter topologies;
- Analyze the steady-state operation of a power electronic converter;
- Design the parameters of a power electronic converter, e.g., a voltage-sourced converter (VSC); and
- Compare different converters (e.g., different DC-DC converters) based on the application.

4 Course Topics

The course topics include

- Power computations and review of circuit analysis [a, b, c]
- Inductor voltage-second balance (IVSB) and capacitor charge balance (CCB) [a, b, c, e]
- DC-DC converters (choppers) modeling and analysis [a, b, c, e]
- DC power supplies [a, b, c, e]
- DC-AC converters (inverters) modeling and analysis [a, b, c, e]
- AC-DC converters (rectifiers) modeling and analysis [a, b, c, e]
- AC-AC converters (cycloconverters) [a, b, c, e]
- Applications of power electronics in power systems [a, b, c, e, g, i, k]

Below is the approximate course schedule (the text in crimson and green are hyperlinked). Important dates are also marked. Because of the necessary travel, we will have a few make-up classes on Thursday evenings (marked below as EVE) at 5:15 PM, unless otherwise stated. The make-up classes will be held in the same classroom.

To download PSCAD simulation cases, click on the green link and then press Ctrl-S (Save) in your browser. Make sure the file is saved with an extension of .pscx, and not .pscx.txt.

Week	Topic	Reading and Notes
W1 Jan. 13	M Overview of the course and policies W Review of circuit concepts F Review of Fourier series and component models	M Slides. W LaTeX resources (Gettig something out of LaTeX; LaTeX Wikibook; The Art of LaTeX; A (not so) Short Introduction to LaTeX; TeX StackExchange; TikZ graphics in LaTeX)
W2 Jan. 19	M No class—WSU Holiday W **Diagnostic Test** F Test review, IVSB, CCB, and SRA	M W Solution of Diagnostic Test
W3 Jan. 26	M Buck converter analysis W Ripple in buck F PSCAD/EMTDC	M W F BuckConverter

W4 Feb. 2	M	Boost converter	M Homework 1
	W	Boost ripple	W
	F	Inverting buck-boost converter	F
W5 Feb. 9	M	Buck-boost ripple	M Homework 2
	W	Cuk converter	W **Homework 1 due** Homework 1 Solution
	F	Cuk converter	F Test 1 Coverage
W6 Feb. 16	M	No class—Presidents' Day	M
	W	**Midterm Test 1**	W Solution of Midterm Test 1
	F	Nonideal converters	F **Homework 2 due** Homework 2 Solution
W7 Feb. 23	M	Discontinuous conduction mode	M Homework 3
	W	DCM in Buck	W **Homework 2 due** Homework 2 Solution
	F	DCM in Boost	
W8 Mar. 2	M	DCM in boost; DC power supplies	M Homework 4
	W	Flyback converter	W **Homework 3 due** Homework 3 Solution
	F	Flyback; forward converter	
W9 Mar. 9	M	Forward converter	M Homework 5
	W	Example; control and modeling of converters in transient state	W **Homework 4 due** Homework 4 Solution
	F	Simulation of forward and flyback converters	F PSCAD FlybackConverter PSCAD ForwardConverter
Mar. 16	Spring break		
W10 Mar. 23	M	DC-AC conversion	M
	W	Square-wave operation	W **Homework 5 due** Homework 5 Solution
	F	Amplitude and harmonic control	
W11 Mar. 30	M	Half-bridge converter; selective harmonic elimination	M Homework 6
	W	Multilevel converters; PSCAD	W PSCAD FullAndHalfBridge
	F	Pulse-width modulation (PWM)	
W12 Apr. 6	M	PSCAD simulation of bi- and unipolar PWM for half- and full-bridge	M Homework 7 PSCAD PWMinverter
	W	Inverter harmonics; 3Φ inverters	W **Homework 6 due** Homework 6 Solution
	F	3Φ square-wave	Inverter Harmonics
W13 Apr. 13	M	Half-wave rectifiers	M Homework 8
	W	Full-wave rectifiers	W **Homework 7 due** Homework 7 Solution
	F	Test 2 Coverage	F Test 2 Coverage
W14 Apr. 20	M	**Midterm Test 2**	M Solution of Midterm Test 2
	W	Rectifier with RL load	W Homework 9
	F	Rectifier with RLE load	F **Homework 8 due** Homework 8 Solution

W15 Apr. 27	M Three-phase rectifiers, AC-AC converters W AC voltage converters F Review	M Homework 10 (due May 7) W **Homework 9 due** Homework 9 Solution F Final Exam Coverage PSCAD Cycloconverter PSCAD RectifierFullWaveControlled PSCAD RectifierHalfWaveUncontrolled
Final	**Final Exam,[1] Thursday, May 8, 2014 8:00 AM to 10:00 AM**	M W Extra Class and Review (3–4pm) Homework 10 Solution F Solution of Final Exam

[1] http://www.registrar.wsu.edu/Registrar/Content/FinalExams20141.pdf

5 Textbook

The required textbook is

1. D. W. Hart, *Power Electronics*. New York: McGraw-Hill, 2011, 512 pp.

(Please see the errata on McGraw-Hill's website at http://highered.mcgraw-hill.com/sites/0073380679/information_center_viewo/errata.html; I have also put one together at http://eecs.wsu.edu/~mehrizi/ee486/2014S/201209_HartErrata.pdf.)

The following are useful references for power electronics:

1. R. W. Erickson and D. Maksimonić, *Fundamentals of Power Electronics*, 2nd ed. New York, NY: Springer, 2001, 912 pp.
2. M. H. Rashid, Ed., *Power Electronics Handbook: Devices, Circuits, and Applications*, 3rd ed. Burlington, MA: Elsevier, 2011, 1417 pp.
3. N. Mohan, T. M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications, and Design*, 3rd ed. Hoboken, NJ: John Wiley & Sons, 2003, 824 pp.

6 Evaluation

Your performance in this course will be assessed based on the components shown below. Failure to complete assigned work or to take a test results in a zero for that portion of your grade, unless you have a compelling reason because of an emergency.

Diagnostic Test (2%) Given on **Wednesday, Jan. 22, 2014**, in class.

Assignments (28%) About 8 assignments. Each assignment is usually assigned on a Monday and is due at the beginning of the Wednesday of the week after. Extra credit may be given for an extraordinary assignment, e.g., solving bonus problems, an elegant solution, a comprehensive discussion, or an especially neat and tidy submission. You can discuss assignments with your fellow students, but the assignment you hand in must be your own work. No late assignments are accepted since I usually post solutions on the due date. Assignments will significantly help you in preparing for tests and final exam. Extra credit may be given for an extraordinary assignment at the discretion of the instructor, e.g., solving bonus problems, an elegant solution, a comprehensive discussion, or an especially neat and tidy submission.

Letter	Range
A	$[90, 100]$
A−	$[85, 90)$
B+	$[80, 85)$
B	$[75, 80)$
B−	$[70, 75)$
C+	$[65, 70)$
C	$[60, 65)$
C−	$[55, 60)$
D	$[50, 55)$
F	$[0, 50)$

Two Midterm Tests (40%) Two one-hour tests during lecture. The first midterm is on **Wednesday, Feb. 19, 2014**. The second midterm is on **Monday, Apr. 21, 2014**.

Final Exam (30%) Two-hour comprehensive exam on **Thursday, May 8, 2014**.

Class Participation (0%) But class attendance is required and no more than three absences will be allowed, unless with prior permission. Class participation can help you when in the boundary of letter grades.

7 Academic Integrity

I encourage you to work with classmates on assignments. However, each student must turn in original work. No copying will be accepted. Students who violate WSU's Standards of Conduct for Students will receive an F as a final grade in this course, will not have the option to withdraw from the course and will be reported to the Office Student Standards and Accountability. Cheating is defined in the Standards for Student Conduct WAC 504-26-010 (3). It is strongly suggested that you read and understand these definitions. Please also see http://academicintegrity.wsu.edu.

8 Students with Disabilities

Reasonable accommodations are available for students with a documented disability. If you have a disability and need accommodations to fully participate in this class, please either visit or call the Access Center (Washington Building 217; (509) 335-3417; Access.Center@wsu.edu) to schedule an appointment with an Access Advisor. All accommodations MUST be approved through the Access Center. For more information, see http://accesscenter.wsu.edu.

9 Safety and Emergency Notification

Washington State University is committed to enhancing the safety of the students, faculty, staff, and visitors. It is highly recommended that you review the Campus Safety Plan (http://safetyplan.wsu.edu) and visit the Office of Emergency Management web site (http://oem.wsu.edu) for a comprehensive listing of university policies, procedures, statistics, and information related to campus safety, emergency management, and the health and welfare of the campus community.

10 Disclaimer

Information contained in this document may and will change as required during the semester. Such changes will be communicated to you via email, in class, and/or on the website. Please make sure you

attend all lectures to stay up-to-date. Most course material, e.g., assignments, grades, and extra readings, will be communicated through the website. I encourage you to discuss any difficulties you may have in this course with me or with your TA.