

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

Course Information:

Title: EE 608 Power Electronics Design (3+3)
Lecture Time: MWF (11:45AM-12:45PM) in Duckering 202
Lab Time: M (2:15-5:15PM) in Duckering 202, Duckering 330, and Duckering 216
Prerequisites: Graduate standing or permission of the instructor

Instructor: Dr. Richard Wies, Associate Professor, ECE Dept.
Office: Duckering 213
Office Hours: W 2-3:30PM, TR 10:30AM-12PM or by phone/e-mail
Phone: 474-7071
E-mail: rwwiesjr@alaska.edu

Required Text: Mohan, Undeland, and Robbins, Power Electronics: Converters, Applications, and Design, 3rd ed., Wiley, 2003.

References: Daniel W. Hart, Power Electronics, McGraw-Hill, 2011.
Other references provided as needed.

Course Description: Analysis and design of power electronic conversion, control and drive systems with emphasis on smart grid applications. Topics will include the theory and application of thyristors, rectifiers, DC-DC converters, inverters, resonant converters, AC and DC switches and regulators, power supplies, DC drives, and adjustable-speed drives. Includes laboratory exercises using power electronic converter boards and a complete power electronics design project.

Course Goals: Students will develop an understanding of power electronic conversion, control and drive systems with emphasis on analysis and design concepts. The course will develop the building blocks for power electronic devices including rectifiers and converters. Analysis will include the use of PSpice and the use of Fourier transforms for determining harmonic content. A major design experience will include a project to build an operational power electronic conversion device using knowledge and skills acquired in earlier course work that incorporates *“multiple realistic constraints and engineering standards”*. The *IEEE code of ethics* will also be addressed in the design process.

Instruction Methods: Application of fundamental circuit and electronic principles, including time domain and Fourier analysis, in the design, simulation and operation of power electronic devices.

Design Project/Labs: The design project entails working alone (graduate credit) to design, simulate, build, and test a power electronic conversion device using knowledge and skills acquired in previous course work and incorporating *“multiple realistic constraints and engineering standards”*. The *IEEE code of ethics* will also be addressed in the design process. The laboratory focuses on the design project with six labs during the first half of the semester addressing concepts and building each stage of a power electronic conversion device. A design project requirement and specification handout and a laboratory syllabus will be provided during the first laboratory session and posted on the Blackboard site for the course.

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

Evaluation/Grading: Plus/Minus grading will be used – see page 48 of the 2011-2012 UAF catalog for numerical values. Grades will be assigned based on absolute scores. The percentages in the following grading criteria are based on the total points possible (1250) in the course.

| | | |
|-------------------------------|-------------|-------------|
| Exam I | 75 | 6% |
| Exam II | 75 | 6% |
| Homework | 75 | 6% |
| Project Reports | | |
| Proposal | 50 | 4% |
| Bi-Weekly Progress (4) | 50 | 4% |
| Mid Term Progress | 50 | 4% |
| Draft Report | 150 | 12% |
| Final Report | 125 | 10% |
| Lab Reports (6) | 150 | 12% |
| Oral Presentations | | |
| Proposal | 50 | 4% |
| Mid Term Progress | 50 | 4% |
| Final | 100 | 8% |
| Project Performance | | |
| Design Criteria | 250 | 20% |
| Total Points | 1250 | 100% |

Graduate Credit Requirements: EE 608 Power Electronics Design is stacked with its undergraduate counterpart EE 408 which satisfies the undergraduate senior design elective and W and O intensive course requirement for a BSEE degree. **Students taking this course for graduate credit will be required to complete a more rigorous design project and more difficult problems on the exams and homework assignments with more points allotted than for EE 408.**

Writing: Written assignments include a proposal, three major project reports (midterm progress, draft & final), four bi-weekly progress reports, and six laboratory reports. **Journal quality writing in IEEE technical journal format is expected from graduate students for the project proposal, midterm progress, draft, and final reports.** The grade for written assignments will be based on the content, English usage, organization and format. Content refers to the effectiveness of the report in communicating the technical aspects of the assignment. English usage refers to punctuation, spelling, sentence structure, etc. Organization refers to how logically the sentences, paragraphs and body of the report are organized. Format refers to how well the report conforms to the required report formatting guidelines. Please proofread your written reports. Writing assistance is available at the Writing Center in Gruening 801, 474-5314.

Oral: Oral presentations include a proposal, midterm progress, and final presentation of 10, 15, and 20 minutes, respectively. Each presentation will be followed by a 5-minute question and answer period and instructor evaluation. All presentations are recorded in HD video format for use in evaluation, grading, and for students to identify areas of improvement. Oral presentations will be graded according to content, voice, use of visual aides and format.

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

Personal Meetings: Each student will have a personal interview with the instructor following the proposal and midterm progress presentations to provide feedback for improvement of presentations and to discuss the proposal and progress. An interview with each student will also follow the submission of the draft final report to provide feedback for refinement of the final report.

Course Policies:

Exams: Midterm exams are open book and closed notes with *two* 8.5x11 (INCHES) formula sheets allowed. Formula sheets cannot have solved problems and must be attached to the exam. **Laptops, cell phones, and calculators with communication capability (Bluetooth, etc.) are not permitted to be used during the exams.** Absences from exams must be preceded by a valid excuse. In the event of a valid excused absence it is the student's responsibility to contact the instructor to arrange for a make-up exam.

Homework: Homework assignments will include computer-aided simulation and analysis of power electronic devices and systems. Homework is **due at the beginning of class** on the due date. No late homework will be accepted unless previously authorized by the instructor. I encourage discussion of solution techniques with your fellow students, but you must independently formulate your results. Homework solutions will be posted on Blackboard.

Laboratory: The laboratory is an integral part of this course and focuses on the design project with six labs during the first half of the semester addressing concepts and building each stage of a power electronic conversion device. Each student will be required to do a report for each lab. Lab reports are to be completed on an individual basis. **All labs must be attended and completed (including the lab report) to pass the course.** Instructions for each lab will be posted on Blackboard at least one day before the scheduled lab. A lab syllabus including format, grading, and policies will be handed out at the first lab.

Cheating/Plagiarism: Cheating and plagiarism will not be tolerated and will result in failure of the course.

Attendance: As directly quoted from the 2011-2012 UAF Course Catalog under Academics/Attendance (page 48): "You are expected to attend class regularly; unexcused absences may result in a failing grade. You are responsible for conferring with your instructor concerning absences and the possibility of arranging to make up missed work....However, your instructor is under no obligation to allow you to make up missed work for unexcused absences or if notification and arrangements are not made in advance of the absence."

Writing Assistance:

Writing assistance is available at the English Writing Center in Gruening 801, 474-5314.

Disabilities Services:

The Office of Disability Services implements the Americans with Disabilities Act (ADA), and insures that UAF students have equal access to the campus and course materials. The instructor and the administrative assistant will work with the Office of Disabilities Services to provide reasonable accommodation to students with disabilities. Disability Services is located at the in 208 Whitaker, 474-5655, fydso@uaf.edu.

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

EE 608 – Tentative Lecture/Lab Schedule – Spring 2012

All dates and topics are tentative. Exam dates are subject to change.

| MONDAY (LECTURE) | MONDAY (LAB) | WEDNESDAY | FRIDAY |
|--|---|---|---|
| | | | Jan. 20 – Lecture #1 Power Electronics vs. Linear Electronics; Classification of Power Processors; Convention – Sections 1.1-1.7 |
| Jan. 23 – Lecture #2 (ELIVE) Power Electronic Circuit Analysis Concepts: Displacement PF (DPF), Fourier Analysis of Voltage & Line Current Harmonics, THD, & True PF – Section 3.2.4 Inductor & Capacitor Response: Steady-State & Transient Responses – Section 3.2.5 | Jan. 23 – Lab (ELIVE: Wies) Introduction to Project: - Project Overview - Project Schedule - Report & Presentation Guidelines Introduction to: - PSPICE Power Electronics Tools (Eshwar) - Eagle CAD (Kibler) - TTEch Circuit Board Prototyping Machine and ISO Tool (Hawkins) | Jan. 25 – Lecture #3 (ELIVE) Semiconductor Switching Devices: Intro, Diodes, Thyristors – Sections 2.1-2.3 Controllable Switches: Desired Characteristics, Types (BJT, FET, Thyristor Based); Comparison, Drive & Snubber Circuits – Sections 2.4-2.11 Idealized Device Characteristics – Section 2.12 | Jan. 27 – Lecture #4 (ELIVE) Uncontrolled Diode Rectifiers: Concept using Simple R-L Circuit and Back EMF; Single-Phase Diode Bridge Rectifier Circuits with DC Side Current Source – Sections 5.1-5.3 |
| Jan. 30 – Lecture #5 Uncontrolled Diode Rectifiers: Single-Phase Diode Bridge Rectifier Circuits with: 1) AC side Inductance and DC Side Current Source 2) AC Side Inductance and DC Side Voltage – Section 5.3 | Jan. 30 – Lab Lab #1: Single-Phase Diode Rectifiers: Design, Simulation, Construction, & Testing – Sections 5.1-5.5 – Progress Report #1 Due: Project Schedule (Divided Tasks) | Feb. 1 – Lecture #6 Uncontrolled Diode Rectifiers: Single-Phase Diode Bridge Rectifier Line Current and Voltage Distortion; Voltage Doubler; Three-Phase, 4-Wire Neutral Current Effects – Sections 5.3-5.5 | Feb. 3 – Lecture #7 Uncontrolled Diode Rectifiers: Three-Phase, Full-Bridge Rectifier – Section 5.6 |
| Feb. 6 – Lecture #8 Uncontrolled Diode Rectifiers: Comparison of Single-Phase and Three-Phase; Inrush Current and Overvoltage at Turn-On; Improving Line Current Harmonics and PF – Sections 5.7-5.9 | Feb. 6 – Lab Oral Presentation I: Project Proposal Presentations – Project Proposal Due: Initial Design, Parts List, Budget, & Timeline | Feb. 8 – Lecture #9 DC-DC Switch Mode Converters: Types; PWM Control; Buck (Step-Down) with Continuous Conduction Mode (CCM) – Sections 7.1-7.3.2 | Feb. 10 – Lecture #10 DC-DC Switch Mode Converters: Buck with Discontinuous Conduction Mode (DCM); Output Voltage Ripple; Boost (Step-Up) with CCM & DCM – Sections 7.3.3-7.4 |

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

| MONDAY (LECTURE) | MONDAY (LAB) | WEDNESDAY | FRIDAY |
|---|--|---|---|
| Feb. 13 – Lecture #11 DC-DC Switch Mode Converters: Buck-Boost with CCM & DCM – Section 7.5 | Feb. 13 – Lab Lab #2: DC-DC Converters: Buck, Boost, and Buck-Boost – Sections 7.1-7.5 – Lab #1 Report Due | Feb. 15 – Lecture #12 DC-DC Switch Mode Converters: Cuk – Section 7.6 | Feb. 17 – Lecture #13 DC-DC Switch Mode Converters: Full-Bridge (4-quadrant); Bipolar and Unipolar Switching; Voltage Ripple – Section 7.7 |
| Feb. 20 – Lecture #14 DC-DC Switch Mode Converters: Comparison using Switch Utilization Factor; Equivalent Circuits; Reversing Power Flow – Section 7.8 | Feb. 20 – Lab Snubber Circuits: Diodes, Transistors, & Thyristors – Sections 27.1-27.9 Lab #3: Switching Characteristics of MOSFETs & Diodes in DC-DC Converters – Lab #2 Report Due – Progress Report #2 Due: + IEEE Code of Ethics | Feb. 22 – Lecture #15 Switching DC Power Supplies: Intro; Overview – Sections 10.1-10.3 DC-DC Converters with Electrical Isolation: Isolation Transformer Excitation & PWM Control – Sections 10.4.1-10.4.1.4 | Feb. 24 – Lecture #16 Switching DC Power Supplies: Flyback Converters – Section 10.4.2 |
| Feb. 27 – Lecture #17 Switching DC Power Supplies: Forward Converters – Section 10.4.3 | Feb. 27 – Lab Lab #4: DC-DC Converters: Flyback and Forward Converters – Sections 10.4.2-10.4.3 – Lab #3 Report Due | Feb. 29 – Lecture #18 Switching DC Power Supplies: Push-Pull, Half- Bridge, Full-Bridge, & Current Source – Sections 10.4.4-10.4.7 | Mar. 2 – EXAM #1 Cps. 1-3, 5, 7, & 27 OPEN BOOK 2 Formulas Sheets |
| Mar. 5 – Lecture #19 Switching DC Power Supplies: HF Transformer Design (Core Selection and Design) – Sections 10.4.8, 30.6- 30.9 | Mar. 5 – Lab Lab #5: Magnetic Component Design: HF Transformers & Inductors – Sections 10.4.8, 30.1- 30.10 – Lab #4 Report Due – Progress Report #3 Due: + Engineering Standards | Mar. 7 – Lecture #20 Switching DC Power Supplies: Control Systems (PWM) – Section 10.5 | Mar. 9 – Lecture #21 Switching DC Power Supplies: Protection, Feedback Isolation, & Design Specifications – Sections 10.6-10.8 |
| Mar. 12 – NO CLASS Spring Break | Mar. 12 – NO LAB Spring Break | Mar. 14 – NO CLASS Spring Break | Mar. 16 – NO CLASS Spring Break |

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

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| Mar. 19 – Lecture #22 FET Gate & BJT Base Drive Circuits – Sections 28.1-28.7 | Mar. 19 – Lab Oral Presentation II: Midterm Progress Report Presentations – Midterm Progress Report Due: Design, Schematic, Standards, Final Parts, Budget, Revised Timeline, IEEE Code of Ethics, Concerns | Mar. 21 – Lecture #23 Thermal Considerations for Semiconductor Devices: Heat Transfer and Heat Sink Selection – Sections 29.1-29.4 | Mar. 23 – Lecture #24 Phase-Controlled Rectifiers: Thyristor Circuits – Sections 6.1-6.2 |
| Mar. 26 – Lecture #24 Phase-Controlled Rectifiers: Ideal Single-Phase Converters – Section 6.3.1 | Mar. 26 – Lab Lab #6: PWM Control & Driver Circuits in Switching DC Power Supplies: Design, Simulation, Construction, & Testing – Lab #5 Report Due – Progress Report #4 Due: + Engineering Constraints | Mar. 28 – Lecture #25 Phase-Controlled Rectifiers: Single-Phase Converters with Source Inductance – Section 6.3.2 | Mar. 30 – Lecture #26 Phase-Controlled Rectifiers: Practical Single-Phase Converters and Inverter Mode of Operation – Sections 6.3.3-6.3.4 |
| Apr. 2 – Lecture #27 Phase-Controlled Rectifiers: Ideal Three-Phase Converters – Section 6.4.1 | Apr. 2 – Lab Design Project Time – Lab #6 Report Due | Apr. 4 – Lecture #28 Phase-Controlled Rectifiers: Three-Phase Converters with Source Inductance – Section 6.4.2 | Apr. 6 – Lecture #29 Phase-Controlled Rectifiers: Practical Three-Phase Converters and Inverter Mode of Operation – Sections 6.4.3-6.4.4 |
| Apr. 9 – Lecture #30 Switch-Mode Inverters: Basic Concept, PWM, & Square-Wave Switching – Section 8.2 | Apr. 9 – Lab Design Project Time Draft Project Report Due: Intro, Design, Standards, Constraints, Schematic, PSPICE, Final Parts, Budget, Lab Testing, Revised Timeline, IEEE Code of Ethics, Conclusions (Summary of Current Results, Problems & Possible Solutions) | Apr. 11 – Lecture #31 Switch-Mode Inverters: Single-Phase Half-Bridge; Full-Bridge with Bipolar Switching – Sections 8.3.1-8.3.2.1 | Apr. 13 – Lecture #32 Switch-Mode Inverters: Single-Phase Full-Bridge with Unipolar Switching & Square Wave Operation – Sections 8.3.2.2-8.3.2.3 |

University of Alaska Fairbanks
Electrical and Computer Engineering Department
EE 608 - Power Electronics Design
Spring 2013

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|--|---|---|--|
| Apr. 16 – Lecture #33 Switch-Mode Inverters: Single-Phase Full-Bridge with Voltage Cancellation; Switch Utilization; Voltage Output Ripple – Sections 8.3.2.4-8.3.2.6 | Apr. 16 – Lab Design Project Time | Apr. 18 – Lecture #34 Switch-Mode Inverters: Push-Pull Inverters; Switch Utilization – Sections 8.3.3-8.3.4 | Apr. 20 – EXAM #2 Cps. 6, 10, & 28-30 OPEN BOOK 2 Formulas Sheets |
| Apr. 23 – Lecture #35 Switch-Mode Inverters: Three-Phase Inverters and Voltage Source PWM – Section 8.4.1 | Apr. 23 – Lab Design Project Time | Apr. 25 – Lecture #36 Switch-Mode Inverters: Three-Phase Inverters with Square-Wave Operation; Switch Utilization; Voltage Output Ripple – Sections 8.4.2-8.4.4 | Apr. 27 – NO CLASS Nanook SpringFest |
| Apr. 30 – Lecture #37 Switch-Mode Inverters: Three-Phase Inverters with DC side Current; Switch Conduction – Sections 8.4.5-8.4.6 | Apr. 30 – Lab Project Evaluations (Demonstrations) | May 2 – Lecture #38 Switch-Mode Inverters: Effect of Blanking Time on Voltage in PWM Inverters – Section 8.5 | May 4 – Lecture #39 Switch-Mode Inverters: Other Switching Schemes; Rectifier Mode of Operation – Sections 8.6-8.7 |
| | | May 9 – FINAL EXAM 10:15 AM – 12:15 PM Oral Presentation III: Final Project Presentations – Final Project Report Due: Intro, Design, Standards, Constraints, Schematic, PSPICE, Final Parts, Final Budget, Lab Testing, Timeline, IEEE Code of Ethics, Conclusions (Summary of Final Results, Problems & Possible Solutions) | |