Worcester Polytechnic Institute  
Department of Electrical and Computer Engineering  
EE523 --- Power Electronics, Fall 2008  
COURSE DESCRIPTION, GUIDELINES, AND SYLLABUS

Lecturer: Prof. Marc T. Thompson, office Atwater Kent Room 316, (marctt@thompsonrd.com).  
Office hour: Thursdays before class, 5-6 pm  
TA: Ms. Grazia Todeschini (grazia@wpi.edu), AK225, 508-831-6697.  
Office hour: By appointment  
Course level: Graduate level  
Course website: Found on myWPI  
Lecture: Thursdays, 6-8:45 pm  
Marc Thompson WPI website: http://www.ece.wpi.edu/People/mtt.html  
Marc Thompson business website: http://www.thompsonrd.com

PHILOSOPHY
This is a graduate-level power electronics course, covering power electronic systems, device physics, rectifiers, switching power converters (DC/DC and resonant), control issues, practical design issues such as snubbers, gate drives, and thermal design, and magnetic design. The focus is on real-world, approximate design techniques, case studies, and intuitive methods, with special emphasis on switching DC/DC converters. Circuit simulations will be used when necessary.

PREREQUISITES
Basic background in device physics, transistor amplifier and operational amplifier design. Control systems. Electromagnetism. Access to web searching, MATLAB and PSPICE simulation tools. It is also assumed that the students understand the basics of Bode plots, pole-zero analysis, and Laplace transforms.

COURSE LOAD

Lectures and In-class Interaction  
Attendance in lecture and class participation is required. It is expected that the lecture will be very interactive with a lively "give-and-take."

Problem Sets  
Problem sets will be given most weeks during lecture and will be due the following week. Material covered will be derived from lecture topics and reading assignments. Some homework assignments may contain a lab or simulation (PSIM, SPICE or MATLAB component).

All problem sets must be legible with clearly labeled axes on graphs. Circle your answers. Write the units for each numerical result. Note that the instructor will do a cursory grading of your homework set. It is the student’s responsibility to check his results vs. the homework solutions. **Late problem sets will not be accepted.**

Design Problems  
Several 2-week design problems will be given. The design problem assignments will be wider in scope than the homework assignments and will require significant design effort, simulations and/or lab work, and a written report.
Exams
There will be two or more exams covering material in lecture, problem sets, design problems, and reading assignments. During the exams the use of the course notes, textbook and of the calculator is allowed, but any communication device and laptop should be shut off.

GRADING
Grading will be done with the approximate percentage distribution (subject to change without notice):

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem sets</td>
<td>25%</td>
</tr>
<tr>
<td>Design problems</td>
<td>45%</td>
</tr>
<tr>
<td>Classroom participation</td>
<td>10%</td>
</tr>
<tr>
<td>Exams</td>
<td>20%</td>
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</table>

REQUIRED TEXT AND SOFTWARE

PSPICE AND PSIM SIMULATION TOOLS
Student (evaluation) version of PSPICE will be provided. We’ll be using the Microsim evaluation version 8.0. A tutorial on how to use this is found here:

http://www.coe.uncc.edu/mosaic/mosaic_help/pc_help/pspice/getting_started1.html

The demo version of PSIM is available here:
http://www.powersimtech.com/download.html

MAGNETIC SIMULATION TOOLS
I’ll be intermittently using magnetic finite-element analysis tools to illustrate magnetic fields, etc. The program that I use for 2-dimensional analysis is freeware, provided by Dr. David Meeker of Foster-Miller (Waltham, MA), and the software can be found here:
http://femm.foster-miller.net/wiki/HomePage

OTHER RECOMMENDED TEXTS:

**COLLABORATION AND ACADEMIC HONESTY**

All the rules of WPI's Academic Honesty Policy will be in effect (http://www.wpi.edu/Pubs/Policies/Judicial/sect5.html). You must review them and be familiar with them. They describe procedures that will be taken if dishonesty is suspected.

You may not copy from any source (person, book, old homework, web etc.). If you are not sure whether your or a classmate's behavior follows the Honesty Policies, be sure to ask. In general, collaboration on the homeworks and design problems is discouraged ..... make sure you do your own work.

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1 Excerpted from Prof. Fred Looft’s Academic Honesty webpage, http://ece.wpi.edu/~fjlooft/honesty.htm
<table>
<thead>
<tr>
<th>Date</th>
<th>Lecture material covered</th>
<th>Reading Assignment Due at Next Lecture</th>
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</thead>
<tbody>
<tr>
<td>9/4/08</td>
<td>---INTRODUCTION</td>
<td>Problem Set #1 handed out</td>
</tr>
<tr>
<td></td>
<td>• Course logistics, overview, requirements, prerequisites</td>
<td>Mohan: Chapters 1, 2, 3.1-3.2</td>
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<tr>
<td></td>
<td>• Academic honesty</td>
<td>Powerpoints: 00, 01, 02, 03A, 03C, 03D</td>
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<tr>
<td></td>
<td>• Introduction to power electronics</td>
<td>MTT notes:</td>
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<tr>
<td></td>
<td>• Background, motivation, etc.</td>
<td>---“Lecture note on switches.doc”</td>
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<tr>
<td></td>
<td>• Introduction to power switches</td>
<td>---“Note on RMS value of various waveforms.doc”</td>
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<td></td>
<td>• Circuit concepts</td>
<td>--- “Energy dissipated charging a capacitor.doc”</td>
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<td>• Sinusoidal steady state</td>
<td>--- “PSIM Hints 12-24-07.doc”</td>
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<td></td>
<td>• Power factor</td>
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<td>• Harmonics</td>
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<td></td>
<td>• Root-mean square (RMS)</td>
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<tr>
<td>9/11/08</td>
<td>---INTRODUCTION TO MAGNETIC DESIGN</td>
<td>Problem Set #1 due</td>
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<tr>
<td></td>
<td>• Basic magnetic concepts</td>
<td>Problem Set #2 handed out</td>
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<tr>
<td></td>
<td>• Ampere’s Law</td>
<td>Powerpoints: 03B, 03C, 04, 05</td>
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<td>• Gauss’ Law</td>
<td>MTT note:</td>
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<td></td>
<td>• Faraday’s Law</td>
<td>---“Note on power and the Poynting vector.doc”</td>
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<td>• Lorentz force law</td>
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<td>• Magnetic components</td>
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<td>• Inductors</td>
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<td>• Transformers</td>
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<td></td>
<td>---ISSUES IN COMPUTER SIMULATION</td>
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<td></td>
<td>---DIODE RECTIFIERS</td>
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<tr>
<td></td>
<td>• Single wave rectifier with resistive load</td>
<td></td>
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<td></td>
<td>• Single wave with LR load</td>
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<tr>
<td></td>
<td>• Current commutation</td>
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<tr>
<td>9/18/08</td>
<td>---DIODE RECTIFIERS</td>
<td>Problem Set #2 due</td>
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<tr>
<td></td>
<td>• Single wave with LR load</td>
<td>Problem Set #3 handed out</td>
</tr>
<tr>
<td></td>
<td>• Current commutation</td>
<td>Powerpoints: 05, 06</td>
</tr>
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<td></td>
<td>• 3 phase, full bridge</td>
<td>MTT notes:</td>
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<tr>
<td></td>
<td>--- PHASE CONTROLLED RECTIFIERS</td>
<td>--- “Note on 3 Phase Rectifier Analysis”</td>
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<td></td>
<td>• 3 phase rectifiers</td>
<td>---“Examples of power factor calculations.doc”</td>
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<td>---“Power factor with harmonics.doc”</td>
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<tr>
<td>Week</td>
<td>Date</td>
<td>Topics</td>
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</table>
| 4    | 9/25/08 | ---INTRODUCTION TO DC/DC CONVERTERS  
  • Buck converter  
  • Boost converter  
  • Buck-boost converter  
  • Cuk converter  
  • Output voltage ripple  
  • Interleaving | Problem Set #3 due  
Problem Set #4 out  
Powerpoints: 07A  
MTT notes:  
---“Basics of DC_DC converters DRAFT 4.doc”  
Manufacturers notes:  
Analogic --- “Output Capacitors”  
Microchip --- “Synchronous Buck Design”  
National Semiconductor --- “LM2852 Synchronous Buck Regulator” |
| 5    | 10/2/08 | ---REAL-WORLD DC/DC CONVERTER ISSUES  
---CONVERTERS WITH ELECTRICAL ISOLATION  
  • Flyback  
  • Forward converters | Problem Set #4 due  
Design Problem #1 handed out; due in 2 weeks (buck converter)  
Powerpoints: 07B, 07C, 10A, 10B  
MTT note:  
--- “Buck converter with parasitics”  
Manufacturers notes:  
Analogic note --- “Output Capacitors”  
Microchip --- “Synchronous Buck Design: National Semiconductor --- LM2852” |
| 6    | 10/9/08 | ---EFFICIENCY OF CONVERTERS  
---INVERTERS  
---EXAM#1 | Powerpoints: 07B, 08  
MTT notes:  
---“Switching loss in buck converters”  
---“Boost converter with inductor losses.pdf”  
---“Boost converter efficiency including inductor losses.doc”  
Manufacturers notes:  
Linear Tech note --- “50 A Synchronous Buck”  
Maxim --- “Buck Converter Noise” |
| 7    | 10/16/08 | ---RESONANT CONVERTERS  
  • PSIM study: noncontact resonant converter  
---INTRO TO MOTOR DRIVES | • Design problem #1 due (buck converter)  
• PS5 handed out  
• Powerpoints: 09, 12A |
| 8    | 10/23/08 | ---MORE ON MOTOR DRIVES | PS5 due  
PS6 handed out  
Powerpoints: 13, 14, 15 |
| 9    | 10/30/08 | ---POWER QUALITY AND UPS | PS6 due  
PS7 handed out  
Powerpoints: 11A, 16, 17, 18 |
| 10   | 11/6/08 | ---POWER DEVICES  
  • Basic semiconductor physics (Ch. 19) | PS7 due  
Design Problem #2 handed out (boost converter with losses) |
<table>
<thead>
<tr>
<th>Date</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 10/22/08   | - Power diodes (Ch. 20)  
             - Power BJTs (Ch. 21)  
             - Power MOSFETs (Ch. 22)  
             - Thyristors (Ch. 23)  
             - IGBTs (Ch. 25)  
             Mohan: Skim chapters 19, 20, 21, 23-26  
             Powerpoints: 19, 20, 21, 22, 23, 24, 25, 26  
             MTT notes:  
             ---“Power semiconductor devices.pdf” |
| 11/13/08   | **MORE ON POWER DEVICES**  
             - MOSFET switching speed analysis  
             - Use of gate charge data  
             - Gate drive design  
             Powerpoints: 28A, 28B  
             MTT notes  
             ---“Reading a MOSFET datasheet,”  
             ---“Note on Using MOSFET Gate Charge Test Data”  
             ---“Lecture Note on Switches”  
             ---“Mosfet switching speed example”  
             ---“Effect of source inductance on MOSFET switching speed.pdf”,  
             ---“MOSFET selection and figures of merit.pdf”  
             Manufacturers notes:  
             ---International Rectifier: AN936, 937, 944, “Power Mosfet Basics”, IRF150 datasheet  
             ---On-Semiconductor: AN1090 |
| 11/20/08   | **BASIC THERMAL DESIGN**  
             - Conductive, convective and radiative heat transfer  
             - Heat sink selection  
             ---INTRODUCTION TO BASIC MAGNETICS  
             - Maxwell’s equations  
             - Magnetic circuits  
             Design problem #2 due  
             Design problem #3 handed out (inductor design)  
             Powerpoints: 29A, 29B, 30A  
             MTT notes:  
             ---“Magnetic brake thermal model.pdf”  
             Paper:  
             Aavid --- “How to select a heat sink”  
             Manufacturers notes:  
             IRF --- “AN-997 Heat Sinking” and “AN-1057 Heatsink characteristics”  
             (No class next week …Thanksgiving !) |
<p>| 11/27/08   | <strong>NO CLASS …THANKSGIVING</strong> |</p>
<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 13       | **INDUCTOR AND TRANSFORMER DESIGN**  | - Demonstrations:  
- AC magnetic levitation  
- Eddy current braking  
- Magnetic field from power cables  
- Wire charts  
- Transformer design  
- High frequency losses in magnetics  
- Core losses  
- Skin and proximity losses  
- Dowell method  
- Litz wire  
- Powerpoints: 30A,B,C,D,E,F,G,H  
- MTT notes:  
  - “Note on AC winding resistance.doc”  
  - “Inductance Calculation Techniques --- Part 1.doc”  
  - “Inductance Calculation Techniques --- Part 2.doc”  
  - “Note on losses in ferrite cores.doc”  
  - “Note on wire packing factor kp.doc”  
- Papers:  
  - “Thompson --- Electrodynamic Magnetic Suspension.pdf”  
  - Witulski --- “Introduction to modeling of transformers and coupled inductors”  
  - Beattie --- “Inductance 101.pdf”  
  - P. L. Dowell, "Effects of eddy currents in transformer windings.pdf"  
  - Dixon--- “Eddy current losses in transformer windings.pdf”  
- Manufacturers notes:  
  - Texas Instruments --- “Windings.pdf”  
  - Texas Instruments --- “Magnetic core characteristics.pdf”  
  - Ferroxcube --- “3f3 ferrite datasheet.pdf”  
  - Ferroxcube --- “Ferrite selection guide.pdf” |
| 14       | **EXAM #2**  
**PRACTICAL DESIGN ISSUES**  | - Snubbers  
- Other  
- Design problem #3 due  
  - Mohan: Chapters 27, 29  
- MTT notes:  
  - “Snubbers”  
  - “Snubbers again”  
  - “Power Factor Corrected Offline Supplies”,  
  - “High Power Laser Driver”  
- Manufacturers notes:  
  - Texas Instruments --- Snubber circuits.pdf  
  - Fairchild AN-4147 Snubber design for flyback converters |
| 12/18/08 | **SNOW DATE** |

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