I. BASIC INFORMATION

Course Title: ECE 533 H1F - Power Electronics: Switched Mode Power Supplies

Course Description:

The course covers the analysis, design and implementation of high-efficiency switched-mode power supplies (SMPS) used in modern electronic equipment. Topics to be covered include: isolated and non-isolated SMPS topologies; steady-state analysis; component datasheets; small-signal modeling and control of non-ideal converters; compensator design; thermal and magnetic circuits; power semiconductor devices; protection and practical implementation issues. The course includes an experimental design project, where teams design, solder and test a closed-loop dc-dc converter.

Prerequisites: ECE314/ECE359 or equivalent (exemptions may be granted based on individual requests)

Lectures: Mondays (12:00 to 13:00), BA 1210
         Wednesdays (12:00 to 13:00), BA1210
         Fridays (14:00 to 15:00), BA1210

Tutorials: TUT 01: Tuesdays (12:00 to 14:00), BA2155 (Alternates starting Jan. 20)
          TUT 02: Mondays (9:00 to 11:00), BA2165 (Alternates, Starting Jan. 12)

Labs (Design Project): PRA01: Thursdays (16:00 to 18:00), GB40 (Alternates, starting Jan. 22)
PRA02: Thursdays (16:00 to 18:00), GB40 (Alternates, starting Jan. 15)
PRA03: Fridays (12:00 to 14:00), GB40 (Alternates, starting Jan. 23)
PRA04: Fridays (12:00 to 14:00), GB40 (Alternates, starting Jan. 16)

Course Material: All course material and official announcements are posted on Blackboard
     An informal discussion forum is provided by on coursepeer. All Students should sign-up using the link (leave the tokens blank): http://crspr.com/?scid=1&rid=50836

II. COURSE STAFF

Instructor: Prof. Olivier Trescases
Office: SF1020A
Email: olivier.trescases@utoronto.ca

Office hours: Mondays (13:00 to 14:00) or by appointment
Teaching Assistants:

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III. TEXT BOOK AND COURSE MATERIAL

- R.W. Erickson and D. Maksimovic, *Fundamentals of Power Electronics*
- Lecture Notes
- Online references (datasheets, application notes, etc.)

IV. HOMEWORK ASIGNMENTS

Homework assignments will be regularly assigned. You are allowed to consult with the course staff, however you must work independently and show your own work to receive full marks. In some cases, homework assignments will have a simulation component.

V. TEST

There will be one 90-minute mid-term. The schedule for the test will be posted on the course web site.

VI. CAD Simulations

The software package PLECs from PLEXIM, in conjunction with Matlab/Simulink, will be used to simulate power converters in this course. Please refer to the online documentation for more information:

http://www.plexim.com/download/documentation

VII. PROJECT/LAB

The final project will involve the design, analysis, simulation and implementation of a practical switched-mode power supply using real-time control hardware from National Instruments (NI) and LabVIEW software.

VIII. MARK COMPOSITION

- Homework 10%
- Test 25%
- Project 15%
- Final Exam 50%
IX. COURSE TOPICS

1. Introduction
   - Course motivation and introduction to SMPS
   - Main specifications for high-performance SMPS

2. Non-ideal switching converters in steady-state (review)
   - Steady-state equivalent modes of non-ideal converters

3. Losses and efficiency – realistic converter models (review)
   - Sources of loss in SMPS (conduction/switching/gate-drive/magnetics losses)

4. Power semiconductor devices
   - Power MOSFETs, IGBTs, Diodes
   - Component datasheets
   - Reverse recovery
   - Gate-charge (non-linear gate capacitance)
   - Packaging
   - Thermal impedance, thermal circuits
   - Robustness testing (UIS test)
   - New devices: GaN & SiC

5. Small-signal dynamic modeling of SMPS
   - Basic AC modeling
   - State-space averaging
   - Averaged switch modeling
   - PWM model

6. Converter transfer functions
   - Extracting important transfer functions from the AC equivalent model
   - Significance of RHP zero in boost-derived topologies

7. Controller Design and Practical Issues
   - Basic SMPS control loop
   - Loop-gain, phase margin and stability analysis
   - Voltage loop compensator types (lead-lag – complex vs. real zeroes)
   - Integrated controllers (on-chip implementation of compensators, protection features)
   - Sensing in isolated converters
- Current sensing schemes

8. Basic Digital Control
   - Quantization issues in digitally controlled SMPS
   - Digital pulse-width modulator implementation

9. Current-Mode Control in SMPS
   - CPM architecture, trade-offs of voltage-mode vs. current-mode control
   - Oscillations for D > 50%
   - Slope compensation implementation
   - First-order model of CPM

10. Efficiency optimization techniques
    - Variable frequency techniques for high-efficiency at light-load (Burst-mode, Pulse Frequency Modulation)
    - Fixed-frequency techniques (adaptive gate-swing, segmented power-stage, dead-time optimization)

11. PWM Rectifiers: AC-DC Converters with Power Factor Correction
    - Concept of emulated resistance
    - CCM vs. DCM operation
    - Current control modes (CPM / ACMC / HCMC / BCMC)
    - PFC control ICs and practical implementation issues