

ECE562
Power Electronics
Schedule and Grading

Class Time: Tuesday and Thursday 5:30 – 6:45 PM in B105 (Engineering B wing)

Instructor: Professor George Collins, Email: gcollins@engr.colostate.edu

Text Book: Fundamentals of Power Electronic, by R. W. Erickson and D. Maksimovic

http://www.amazon.com/Fundamentals-Electronics-Second-Robert-Erickson/dp/0792372700/ref=ntt_at_ep_dpt_1

Class website: <http://www.engr.colostate.edu/ECE562/>

COURSE OBJECTIVES

This course will teach students how to understand, analyze, design and better employ new commercial IC power supplies on a chip or on a board in any electronic system requiring powered DC levels different from the general DC system bus. Typically this is 6-12 additional DC levels. One illustrative commercial example is a remarkable **Dialog Semiconductor** product which provides, on ONE IC chip: 18 LDO(low drop out regulators) for low noise voltages needed for cell phones , two Buck converters for cell phone processors and semiconductor memory power supplies and one Boost converter for driving LEDS for backlighting or for the flash camera. ALL on one IC chip and driven by the batteries!! Texas Instruments has similar products. This kind of chip allows for low cost cell phones employing various chips using various DC voltages all from one rail voltage.

This course will cover the two major approaches to high efficiency DC-DC conversion in detail: Pulse width modulation and resonant converters. Both employ ideal lossless “L-C” networks and ideal lossless switches. The former is primarily an IC solution to point of load DC power requirement and the latter is for high performance DC power applications at kW levels usually implemented on PC boards with discrete components. However, some attention will be given to linear power supplies like low drop out regulators and switched capacitor supplies for a comparison to our two circuit types.

GRADING

We will emphasize group efforts with teams of students handing in weekly HW sets and take home POP quizzes. PLEASE FORM a GROUP for HW, POP QUIZZES and for presentations, described below, ASAP in the first week of the semester.

In a nut shell the ECE562 grading is scored as follows in 6 parts:

1. Homework assignments will comprise **5 %** of the grade. Five assignments at 1 point each. See page 4 of this document for details of assignments and due dates. I will email each of you to remind you of HW problem changes and due date changes if any. Spice assignments are worth **10 %** of the final grade and are listed at the end.
2. Talk #1/Paper #1 given as a group effort will count for **20%**. **Email the PPT SLIDES and the Word Paper to me as attachments so I have a record of their receipt versus the due date.**
3. Talk #2/Paper #2 given as a group effort will count for **30%**. Again **email the PPT SLIDES and the Word Paper to me as attachments so I have a record of their receipt versus the due date.**
4. I count **30%** for weekly class pop quizzes, which are ALL of take –home variety and done as a group effort. Each student will receive an email from me each week detailing the Pop Quiz for the week. Again email the PPT SLIDES for the pop quizzes as electronic attachments on the due date of THURSDAY the week after the assignment so I have a record of their receipt from your group versus the official due date. Late assignments lose points.
5. Exams will count for **10-15%** are done INDIVIDUALLY.
6. Up to **10%** of the grade will be for in class participation—you cannot act like a potted plant and expect credit for this portion. Folks who interrupt or bring to lectures quality questions or important comments will earn these points. I love questions from the class. You are paying to be taught and I am being paid to teach so ask lots of questions. Do not act like a potted plant in class. There will be no final exam. Grading will be with both + and - letter grades. In addition I will give up to 10 extra points on the final grade for an approved special project to improve the course in future years (See me and we will write a contract together)

YES the total is **>100 %** and final grades will be curved as described below:

Our approach will be more traditional with both + and - letter grades to achieve a sliding curve and a distribution of grades. In an ideal statistical world we would seek in a class grade distribution as follows:

Grading will be curved with students above the median receiving an “A”, students below the median and above one standard deviation below the median receiving a “B”. 1 to 2 standard deviations below the median will receive a “C”, 2 to 3 standard deviations below will receive a “D”, and anything lower will receive an “F”.

The grading for 562 is in six parts as indicated above with opportunity for both group and individual efforts. Group efforts are encouraged in HW, Spice assignments and talks as well as papers. Groups of up to but not to exceed 6 students per group are acceptable to encourage team efforts and provide the opportunity to learn team dynamics. Upon leaving CSU you will work in a company in teams—the Word and PowerPoint skills you learn in presenting technical materials in 562 will be to YOUR benefit. The practice and experience of living with the “psychodrama of technical group efforts will also benefit you personally.

DETAILED SECOND GO THROUGH ON GRADING

1. Exams and Pop Quizzes (40-45 points total)

- a. In class WEEKLY pop quizzes on material from the recent weeks in class material will count for **30** points and **can be done as a group effort**. Pop Quizzes usually will be due **Thursdays** and sent out to you by email the prior week. Sometimes you will also have quantitative problems on the Pop quizzes based on HW and additional problems gone over in class in some detail. Other times you are expected to “drill deep” into a Power topic, by at minimum, distilling my notes and bringing in references from the literature and power components from manufacturers websites.
- b. **Sit down exams are an individual effort** The first in class exam will be in late Oct. or early Nov. and be worth **10-15** points (to be determined). It will include questions many people missed on POP quizzes, HW problems and items I ask you to know in class The qualitative exam problems may take the PARTIAL form of a TAKE HOME portion of the exam.

SAMPLE Qualitative Questions for EXAM # 1. This kind of information you are expected to know by exam # 1:

- Draw full circuit diagrams for Buck, Boost, synchronous Buck, and Buck Boost using MOS FET transistors and diodes as well as inductors and capacitors IN THEIR PROPER PLACES..
- Draw the current wave forms versus time (above each other with relative timing) for each of the circuits of Problem 1 for
- The active MOSFET Switch(s) $I_{DS}(time)$
- The passive Diode where applicable
- The inductor waveform versus time. In the case of the synchronous Buck compare inductor waveforms with the simple Buck and how synchronous Buck improves output characteristics—be quantitative.
- Sketch for Problem 1 the drive circuit for the active MOSFET switch with remarks whether or not this is a floating or grounded drive FET drive and be sure to label all three MOSFET terminals, as you know them with emphasis on where the gate drive is applied BETWEEN.
- For Problem 1 tell which circuits are providing electrical isolation from input to output and why or why not this is occurring.
- For Problem 1 comment on the EMC (conducted currents) noise characteristic of each circuit and the origins of EMC where it occurs.
- By means of inductor current waveforms describe the continuous versus discontinuous conduction mode (DCM). Be quantitative and describe why every circuit must operate DCM and for what load condition this DCM operation occurs.
- Describe by equations HOW the core losses for BOTH inductors and transformers vary with applied switch frequency. Plot loss versus f_{sw} .

- Explain the REAL $Z(f)$ curves for REAL inductors and REAL capacitors. Explain why higher switch frequency allows for smaller geometric component sizes BUT introduces more parasitic elements. Use equations and impedance versus frequency diagrams for capacitors, resistors and inductors to prove your points.
- Explain the effect of ESR of output capacitors on the output ripple voltage. Be specific with comments on the relative role of capacitive versus ESR voltages. Which capacitor types have lowest ESR and highest ESR.
- Explain with equations the DC versus AC losses for MOSFET semiconductor switches. In AC losses distinguish the separate contributions from switching losses from on to off and off to on and why they differ from each other. Comment on the trend toward higher operating frequency and how this affects types of losses.

2. Homework Assignments and SPICE Homework Simulations (15 points total)

- a. Five sets of homework problems (5 points total) + 4 Spice Labs.(10 points total) which will lead you through Spice waveforms of the major commercial DC to DC converter circuits.
Note that there is EXTRA CREDIT FOR THOSE who do Spice analysis for either or both Cuk and Sepic converters as well as for L-C-C or C-L-L.
- b. **Be sure to note that I will change both the number of problems and which problems so pay attention to email announcements.**
- c. Five Homework Assignments: 5 Points. Work in teams of 4-6 students. Undergrads (UG) do only indicated problems. Graduate students **do all of the problems assigned**. Detailed assignments are list at the end of this memo. Homework assignments in Chapters 2,3,4,5,6, and 19 will be worth 1/2 point each and are due as indicated in class.
Roughly speaking, HW due dates for the HW assignments are as follows:
 - HW1: Ch 2 of Erickson Pbms. 1(UG), 2(UG),3,4,6,: DUE week 3 day 2
 - HW2: Chapter 3 of Erickson Pbms. 8(UG),9,10 (UG).: Due Week 5 day 2
 - HW3: Chapter 4 of Erickson Pbms. 2(UG),4,5,7(UG): Due week 6 day 2
 - HW4: Chapter 5 of Erickson Pbms. 1(UG),4, 5(UG),14: Due Week 8 day 2
 - HW5: Chapter 19 of Erickson Pbms 1(UG) and 3: Due Week 12 day 2
- d. **4 SPICE Spice Assignments (10 Points).**
 - Spice Lab1: Spice analysis of Buck: Due week 2 day2
 - Spice Lab2:Spice Analysis of Boost: Due week 3 day2
 - Spice Lab3:Spice Analysis of Buck-Boost: Due week 4 day2
 - Spice Lab4:Spice analysis of parallel and series resonant converters: Due week 13 day2.
 - For extra credit do the L-C-C converter Spice lab

3. Two Required Group Talks and Papers

For group efforts Microsoft has versions of Word and Power Point that reside on servers at [Microsoft OfficeLive](#) —moreover this allows MULTIPLE users to log on and work on the SAME document together.

Sign up early for your group talk date, as time slots are limited.

a. Talk#1/Paper #1: 20 points

- i. Talk/Paper #1 for all groups is on **Commercial Multi-Phase PWM converter** chips and circuits. **15** points for oral talk using PPT and **5** for associated paper in Word. Your group's efforts should document ONLY your group's exploration and presentation of commercial multi-phase buck or multi-phase boost PWM converter chips and hybrid circuits. Use the websites of manufacturers, available spec sheets and on-line design tools provided by manufacturers. National Semiconductor has the best site but TI, Maxim, International Rectifier, and Linear Technology all have excellent websites.
The ENTIRE GROUP has only **40 minutes** in class via power point presentation of 20-25 slides and paper in Word of **20 pages** is submitted separately. Both the PPT and the Word documents are due in **week # 7** of the semester.
- ii. Your technical presentations will be GROUP efforts to simulate your next environment—industry or graduate school. This group effort is purposeful to get students familiar with the team efforts that they will SOON encounter in industry.
- iii. Talk/Paper #1 MUST FOCUS on detailing commercially available MULTI-PHASE PWM converter chips and associated components. Be quantitative and comparative with several commercial designs. EACH group MUST include the comparison in the introduction to their talk's alternative complementary solutions to the approach they have chosen to do in detail. For example before you launch into your choice extensively briefly compare the chosen multi-phase PWM chip solutions. List advantages and disadvantages to each approach for your chosen application and then at the end of your talk/paper BRIEFLY tell how better solutions maybe found in tandem to achieve better power supply solutions. For example PWM DC-DC conversion followed by linear LDO to reduce noise compared to a simple PWM solution.

b. Talk #2/Paper # 2: 30 points

- i. Power Electronics topic of student group interest is encouraged: **30** points total with **25** points for the PPT presentation and **5** for the paper in word. Here is a chance to go into greater detail on a power electronics topic of keen interest to your group—drill deep in the talk-even expand on talk # 1 with written permission from me based on the quality of your efforts in talk #1.
- ii. Talk # 2 and associated paper will cover a power electronics topic of interest to your group (lots of freedom here) and will entail a 45-minute talk in class using PowerPoint of 35-40 slides and a **30-page** Word paper. **Both are due in weeks 12-14 of semester.** Unless you have sent me a written request this must be completed in the second week before finals to meet CSU requirements. That is talks and associated papers in the last week of the semester are by special permission only. **Do not be late or lose points accordingly.**

iii. If you have no particular interests, read suggestions below.

- Your team should choose a topic of mutual interest. But just in case this is too challenging some very suitable topics include: pulsed capacitive power supplies, LDO power supplies in all their details, Power Electronics Systems for Fuel Cells, Solar Cells, as well as power electronics for electrical vehicles and microprocessors. Suitable power electronic solid state device talks include: IGBT's, Power FETS, thyristors, IGCT'S, newly discovered micro-mechanical switches, harmonics analysis in power electronics etc. There will also be allowed special topics, bordering power electronics, approved by the instructor AHEAD OF TIME, which the student group itself chooses. Final talks and papers are due weeks 13-15. Each Student must give a portion of the group talk using PowerPoint for an individual grade. The group total time CANNOT exceed 40 minutes for the ENTIRE talk. Rehearse and divide the presentation time so each person has equal time AS THEY WILL RECEIVE AN INDIVIDUAL GRADE FOR THEIR PART.

iv. Students detail his or her portion of a thirty-page paper in the header or footer of their pages or on the front cover.

v. TENTATIVE Talk # 2 schedule:

- Weeks # 12 and 13 Days 1 & 2: Two groups present each day BUT I ONLY allow talks in Week 14 and 15 by special permission, which I give if you request in writing.

4. Class participation: 10 points

- a. This portion of the grade is to encourage "multiple conversations and questions in the classroom" and limit boring "monologues" by the instructor. I will be delighted by in class questions, interruptions and individual additions.

1-5 add up to greater than 100 points –but I give you one more opportunity to raise your ECE562 grade.

5. Extra credit

- a. For extraordinary efforts up to 10 points such as Spice simulations of Cuk or sepic converters of comparing design issues and Spice simulations of L-C-C and L-L-C resonant converters.

TENTATIVE SCHEDULE OF HW, SPICE AND EXAMS

(WEEKLY Pop Quizzes are due Thursdays) organized below by week and day of the semester

Week#	Chapter	Web Lectures	Assignment due dates
1	Read Chapter 1	Web Lectures 1-2	
2	Read Chapter 2	Web Lectures 3-4	Spice Lab1: Due Week #2 day 2 in class
3	Read Chapter 3	Web Lectures 5&6	HW1: Due week 3 day 2 in class Spice Lab2: Due week 3 day2 in class
4	Read Chapter 4	Web Lectures 7&8	Spice Lab3: Due week 4 day2 in class
5	Read Chapter 4	Web Lectures 9&10	HW2: Due Week 5 day 2
6	Read Chapter 5	Web lectures 11& 12	HW3: Due week 6 day 2
7	Read chapter 6	Web lecture 13	HW4: Due Week 8 day 2
8		Web Lecture 14	
9		Web lecture 15	
10-11		Resonant converter Lectures	HW5: Due Week 12 day 2 WEEK # 11 day 2 is EXAM # 2 covering Chapters 4,5,6 and 19
13	Read Chapter 19		Spice Lab4: Due week 13 day2

Disclaimer Notice:

All items in this memo are subject to change by Prof. Collins in LATER class announcements and items are considered only a preliminary guide to the student. For example, the ECE562 classes can cover high frequency magnetics/transformers/inductors rather than more details of PWM circuits or basics of resonant converters, if strong class interest exists—each semester is unique in its class preferences in this diverse field. In week # 9 we will have a mid class review of past and future topics in which you are encouraged to input your desires for the remainder of the class lectures. See in class participation grade issues section.

Thank you again for reading though this missive. If you have further questions ask me in class so everybody benefits.