School of Electrical Engineering & Telecommunications
University of New South Wales

ELEC4614 - POWER ELECTRONICS

Course Outline

Aims of this course

Power electronic circuits are now-a-days essential for a whole array of consumer and industrial electronics products. At the low power end, these may include switched-mode regulated power supplies for hand-held devices, TVs, light fittings, computers and other entertainment systems. At the high power end, there are diverse industrial applications in power electronic converters for variable-speed drives, in automotive and railway traction and accessories, in steel rolling, textile, paper rolling mills, machine tools, robotic, disk and other automation drives, ship propulsion and positioning, aircraft actuators and navigation; High voltage DC transmission, grid connections for wind generators and PV systems; Power supplies for telecommunication equipment, welding, furnaces, and smelting; to name a few. Electronic processing of electrical power for these applications also provides the means to control these processes to obtain certain desirable goals such as energy efficiency, better product quality and accurate control of the processes.

The subject is primarily concerned with the wide range of power electronic converter circuits for AC-DC, DC-DC and DC-AC power conversion. The operating principles, design, characteristics, protection and application of these electronic power converter circuits are treated in detail, with the goal of equipping the students with capability to design, select and maintain such power supplies. The reliable, efficient, cost effective and appropriate converter for a particular application is usually foremost in the mind of a power electronics engineer.

Student learning outcomes and graduate attributes

At the conclusion of the course, the student is expected to:

1. have a basic understanding of modern power semiconductor devices, their strengths, and their switching and protection techniques. These include power diodes, bipolar and MOSFET power transistors, other gate controlled devices such as thyristors, insulated-gate bipolar transistors (IGBT) and gate turn-off thyristors (GTO).

2. understand the operation and develop analysis skills of several important topologies of power converter circuits for specific types of applications. These include controlled and uncontrolled rectifiers, DC-DC converters and inverters.

3. understand and analyze the qualities of waveforms at input and output ends of these converters. The quality of these waveforms is of major concern to users of modern power converter circuits and the utility authorities alike.

Course Details

This is a 6 UoC course and the expected workload is 10 – 12 hours of work per week throughout the 13 seek session. It comprises of 3 hours of lectures/week 0.5 hours of tutorial/week and 4 – 5 laboratory experiments of 3 hours duration each over the duration 12 weeks of the session.

Pre-requisites and assumed knowledge

Pre-requisite courses are ELEC2134 (Circuits and System) or equivalent and ELEC2133 (a first course in Electronics) or equivalent. A good understanding of linear circuit theory and electronics is assumed. It will be assumed that the student will have the skills of analyzing RLC circuits with DC and AC inputs; skills of analysis of circuit dynamics with the help of Laplace operator, operation of some basic electronic circuits like diodes, transistors, basic gates and comparators will also be assumed.

Brief syllabus:

The subject starts with coverage of the full spectrum of modern power semiconductor devices, their characteristics, both static and switching. Modern power semiconductor devices eg, diodes, thyristors, MOSFETS, and other insulated gate devices such as the IGBT, MCT and the FCT; Static and switching characteristics, gate drive and protection techniques; their drive circuit design and protection techniques including the snubber. Various topologies of power converter circuits are then treated, together with analysis of their operation, control characteristics, efficiency and other operational features. These include major areas of applications in AC-DC, DC-DC, and DC-AC power converter circuits. Analyses of input and output waveforms of these circuits so as to obtain their harmonic performance are also undertaken. A basic understanding of devices, circuit principles and implications in input/output waveform quality is stressed throughout the subject. Application considerations for remote and un-interruptible power supplies, and for computer systems, telecommunications, automobiles, traction and other industrial processes; Utility interaction, harmonic distortion, and power factor will also be included.

Course Webpage:

All lecture notes, assignments, tutorial and laboratory sheets for this subject can be found on the school webpage, via *http://subjects.ee.unsw.edu.au*. You may have to enter your *zID* and *zPass* to access the webpage for this course. Students will be expected to bring the printed lecture notes, tutorial or laboratory sheets into the lecture/tutorial room or laboratory, as appropriate. They are also expected to visit the site regularly to keep up-to-date on Lecture Notes, Tutorial and Laboratory sheets, announcements of mid-session test/ assignment, and other information related to this course.

Staff Contact Details

Course	Name	Email	Location	Phone
Lecturer	F. Rahman (convenor)	f.rahman@unsw.edu.au	EE133	93854893
Tutor	F. Rahman	f.rahman@unsw.edu.au	EE133	93854893

Lab in-charge	G. Liyadipitiya /D. Xiao	gamini@unsw.edu.au	EE119	NA

Topics Covered:

Sectio n	Topic	Approx. Hours
1	Introduction; Overview of power semiconductor devices, characteristics.	4
2	Diode (Uncontrolled) rectifiers.	5
3	Controlled AC-DC rectifiers.	4
4	Non-Isolated and isolated DC - DC converters, Control issues.	6
5	DC - AC Converters (Inverters)	5
6	Gate drive and Snubber circuits.	3
7	Device losses and thermal design.	3
	Total hours	30

Textbook:

1. N. Mohan, T. M. Undeland & W. P. Robins, “Power Electronics; Converters, Applications and Design”, John Wiley, Second Edition, 1995, New York.

References:

2. R. W. Erickson, "Fundamentals of Power Electronics”, Kluwer Academic Publications, 1997.

3. D. W. Hart, “Introduction to Power Electronics”, Prentice Hall International, 1997.

Assignments:

Students, both under- and postgraduate, may be given hand-in questions and assignments worth 20 marks. Marks scored in these assignments should be indicative of the level of understanding of and proficiency in the topics covered. Assignments will appear on the school webpage about ten days before their due dates.

Laboratory:

Undergraduate and postgraduate students in ELEC4614 will be required to perform five laboratory experiments, each laboratory session being allocated 3 hours. These will be conducted in room 119. Each experiment set will accommodate up to two students. Please consult the School Office about your laboratory group. The laboratory schedule will be available on the school webpage on or before the end of week. Laboratory will start from **week 2**.

Note that laboratory is a compulsory part of ELEC4614 and students must attend the laboratory during their allotted times and commence their experiments well in time. ***Late arrivals in the laboratory will not be allowed to proceed with the experiments.***

All five experiments must be completed in order to qualify for further assessment.
The list of laboratory experiments for this course is given below.

Laboratory Experiments:

E1 - Buck DC-DC Converter

This experiment introduces the step-down DC-DC PWM converter. Its steady-state characteristic in both continuous and discontinuous modes of operation is studied. The effects between the PWM duty cycle, switching frequency and buck inductor and capacitor values on the input/out characteristics are brought out. The dynamic characteristics of the converter are obtained through frequency response tests. The control loop design for voltage and current control is also studied.

E2 - Boost DC-DC Converter

This experiment introduces the step-down DC-DC PWM converter. Its steady-state characteristic in both continuous and discontinuous modes of operation is studied. The effects between the PWM duty cycle, switching frequency and buck inductor and capacitor values on the input/out characteristics are brought out. The dynamic characteristics of the converter are obtained through frequency response tests. The control loop design for voltage and current control is also studied.

E3 - Single-phase Inverter

Single and three phase pulse-width modulated inverter circuits, Transistor and diode turn-on and -off transients, Modulation schemes, effect of dead times and modulation frequency on output waveform quality.

E4 - Three-phase inverter

This experiment introduces you to the three-phase inverter circuit. Switching schemes for producing three-phase balanced six-step (quasi-square wave) and sine modulated AC output voltages will be studied. Effects of modulation frequency and third-harmonic injection into the modulating waveform will be studied.

E5 - PWM Rectifiers with Unity Power Factor

Input harmonics and power factor of simple diode rectifiers. Input distortion. Power factor correction technique using a single power semiconductor switch.

Laboratory sheets must be downloaded from the school Lecture Notes webpage for this course.

All experiments are interfaced with high-speed digital storage oscilloscopes and digital signal processors, when appropriate, with multi-channel data acquisition, waveform generation, control and data analysis, so that complex controls and data analyses are performed quickly and easily.

Laboratory Reports:

At the end of each laboratory session, each student will be required to produce their laboratory report to the lab demonstrator for marking. Students are expected to prepare their log books with data, graphs and waveforms generated during their experiments. The lab demonstrator will mark their reports in their log books and keep a record for forwarding to the lecturer. The reports are expected to include statements about their main observations of performance and characteristics the circuit studied and their conclusions. Answers to questions set in last section of the laboratory sheets for each experiment must also be included.

Note: *All figures/tables must be properly captioned. All graphs/CRO traces must be properly labeled. Axes of all graphs and traces must be properly labeled and scaled. Operating conditions under which data were gathered must also be included.*

Tutorials:

Lectures will be supplemented with problem solving sessions. Five to six tutorial sheets may be expected, each including about ten problems. These problem-solving sessions will be on most recently covered topics. Students will be expected to participate vigorously during these sessions, in the form of questions, suggested solutions and methods. Participation by students and the tutor should be viewed as desirable aspects of these sessions.

Tutorial sheets are available on the webpage. Solutions of problems set in tutorial sheets will be posted on the school webpage progressively, soon after problems set in each tutorial sheet are covered in tutorial classes.

Course Assessment:

Students will be assessed according to the following scheme:

Final Examination	60% of total
Mid-session Test	10% of total
Hand-in Assignment	10%
Laboratory work and reports	20% of total

A Mid-session Test will take place in week seven and cover materials covered up to the end of week 5. This submission is worth 10% of the final marks. The mid-session examination tests your general understanding of the course material, and is designed to give you feedback on your progress through the analytical components of the course. Questions may be drawn from any course material up to the end of week 6. It may contain questions requiring some numerical and analytical techniques. Marks will be assigned according to the correctness of the responses.

A Hand-in Assignment worth 10% of the final mark and based on PSIM analysis of one power electronic converter (to be specified) will be due in week 13. This exercise will enable you to present the detail simulation results for various operating and control conditions that may not be achievable during laboratory.

Laboratory assessment marks will be awarded according to your preparation (completing set preparation exercises and correctness of these or readiness for the lab in terms of pre-reading), how much of the lab you were able to complete, your understanding of the experiments conducted during the lab, the quality of the notes you write during your lab work (according to the guidelines given in lectures/demonstrators), and your understanding of the topic covered by the lab.

The final examination will be worth 60 marks. Copies of examination papers (without solution) for the past few years are posted on the webpage.

The final exam in this course is a standard closed-book 3-hour written examination, comprising five – six questions of which four must be answered. University approved calculators are allowed. The examination tests analytical and critical thinking and general understanding of the course material in a controlled fashion. Questions may be drawn from any aspect of the course (including laboratory), unless specifically indicated otherwise by the lecturer. Marks will be assigned according to the correctness of the responses. *Please note that you must pass the final exam in order to pass the course.*

Other matters

Attendance

Regular and punctual attendance at all classes is expected. UNSW regulations state that if students attend less than 80% of scheduled classes they may be refused final assessment. Students may be asked to sign an attendance list for each lecture and tutorial class. Note again that all lab experiments must be completed in order to be eligible for final assessment.

Relationship of Assessment Methods to Learning Outcomes

	Learning outcomes						
Assessment	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Laboratory practical assessments	✓	✓	✓	✓	✓	✓	✓
Mid-semester exam	✓	✓	✓	✓	✓	✓	✓
Assignment	✓	✓	✓	✓	✓	✓	✓
Lab examination							
Final exam	✓	✓	✓	✓	✓	✓	✓

Special Consideration and Supplementary Examinations

You must submit all assignments and attend all examinations scheduled for your course. You should seek assistance early if you suffer illness or misadventure which affects your course progress. All applications for special consideration must be **lodged online through myUNSW within 3 working days of the assessment**, not to course or school staff.

Academic Honesty and Plagiarism

Your laboratory report and assignment submissions must be your own work, not copied from other’s work and not including any material that is not fully acknowledged.,

Plagiarism is the unacknowledged use of other people’s work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a form of academic misconduct, and the University has very strict rules that include some severe penalties. For UNSW policies, penalties and information to help you avoid plagiarism see http://www.lc.unsw.edu.au/plagiarism. To find out if you understand plagiarism correctly, try this short quiz: https://student.unsw.edu.au/plagiarism-quiz.

Appendix C: Engineers Australia (EA) Professional Engineer Competency Standard

	Program Intended Learning Outcomes	
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing	✓
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓
	PE1.4 Discernment of knowledge development and research directions	
	PE1.5 Knowledge of engineering design practice	✓
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice	✓
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	
	PE2.2 Fluent application of engineering techniques, tools and resources	✓
	PE2.3 Application of systematic engineering synthesis and design processes	
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects	
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability	
	PE3.2 Effective oral and written communication (professional and lay domains)	✓
	PE3.3 Creative, innovative and pro-active demeanour	✓
	PE3.4 Professional use and management of information	✓
	PE3.5 Orderly management of self, and professional conduct	
	PE3.6 Effective team membership and team leadership	✓