Description: Introduction to switching devices: volt-ampere characteristics of BJTs, thyristors, GTOs, IGBT and MOSFETS, switching losses. Average, rms and peak current and voltage ratings of power electronic devices. Commutation of power electronic devices; analyses of uncontrolled and controlled converter circuits, single-phase and three-phase AC-DC converters, DC drives. Principle of DC to DC conversion: analyses of boost and buck choppers. Principle of DC to AC conversion, application of inverters, analysis of inverter circuits, voltage control in inverter circuits, reduction of output harmonics in inverters. Snubber circuits. Emphasis will be placed, throughout the course, on the utilization of software application packages. (Official Description from the Course and Program Catalogue)

Prerequisites: EE 221
Pre /Co-requisites: EE 341
Instructor: Nurul Chowdhury
Associate Professor, Department of Electrical and Computer Engineering
Office: 3B44
Phone: (306) 966-5396
Email: nurul.chowdhury@usask.ca

Lectures: Online: Q&A Sessions - Monday, Wednesday, Friday, 11:30 am – 12:20 pm
Tutorials: None
Laboratory: Online: 3 hrs every two weeks

Website: Lectures, assignments, solutions, lab schedules, general course information, and announcements will be posted on the course website. Students are responsible for keeping up-to-date with the information on the course website.

http://www.engr.usask.ca/classes/EE/xxx/

Course Reference Numbers (CRNs): 85447 (lecture), 85448 (lab), 85449 (lab)


Office Hours: Send emails to contact the instructor

Reading List:
- “Power Semiconductor Circuits” by S. B. Dewan and A. Straughen, Wiley-Interscience
- “Power Electronics” by Marvin J. Fisher, PWS-KENT Publishing Company
**Assessment:**

The methods of assessment and their respective weightings are given below:

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assignments</td>
<td>10%</td>
</tr>
<tr>
<td>Design Project</td>
<td>10%</td>
</tr>
<tr>
<td>Laboratory</td>
<td>15%</td>
</tr>
<tr>
<td>Midterm Exam</td>
<td>15%</td>
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<tr>
<td>Final Exam</td>
<td>50%</td>
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</tbody>
</table>

- Assignments: 10% ; up to 8 assignments
- Design Project: 10%
- Laboratory: 15% ; 6 online labs, 3 hrs. every two weeks
- Midterm Exam: 15% ; 1 hr. 30 min. exam, Oct 21, open book, online
- Final Exam: 50%; 3 hr. exam, open book, online plus 5-15 min oral assessment

A student must complete all labs, submit the design project, write the midterm, the final examination and complete the oral assessment to be eligible to earn a credit. Due to COVID-19, one or more of the assessment methods and their corresponding weightings may be changed with the approval of the Department/College.

**Final Grades:**

The final grades will be consistent with the “literal descriptors” specified in the university’s grading system.


The distribution of final grades in the class may be adjusted to conform with Departmental grading standards.

For information regarding appeals of final grades or other academic matters, please consult the University Council document on academic appeals.

[http://students.usask.ca/academics/grading/appeals.php#Undergraduate](http://students.usask.ca/academics/grading/appeals.php#Undergraduate)


**Course Content:**

<table>
<thead>
<tr>
<th>Week</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transient and steady state voltages and currents in resistive, inductive, RL and RC circuits, voltage and currents in an inductive load circuit with a free-wheeling diode, half-wave rectifier (diode) circuit with a resistive load, average and rms output voltage and current, half-wave diode rectifier circuit with a RC load circuit</td>
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<td>2</td>
<td>Half-wave diode rectifier circuit with a RL load; average and rms output voltage and current, conduction angle; numerical example on output voltage and current calculations in a half-wave diode rectifier circuit with a RL load, half-wave rectifier circuit with a RL load and a free-wheeling diode, evaluation of output voltage and current in a half-wave rectifier circuit with a RL load and a free-wheeling diode</td>
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<tr>
<td>3</td>
<td>Power semiconductor switches, diodes, thyristors, BJT, MOSFET, GTO, RE recovery time, turn-off time, losses in semiconductor switches, half-wave thyristor rectifier circuit with resistive, RL and inductive load circuits, effect of delaying thyristor gate current, time dependent expression for</td>
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</table>
output current, evaluation of the conduction angle from the current expression, average and rms values of output voltage and current

4 Numerical examples on output voltage and current in a thyristor controlled half-wave rectifier circuit with a RL load, thyristor controlled half-wave rectifier circuit with RL load and EMF source, commutation, line commutation, load commutation and forced commutation, Single-phase full-wave rectifiers; transformer between the source and the converter, single-phase full-wave controlled rectifiers

5 continuous current and discontinuous current in single-phase rectifiers, average output voltage and output current, harmonic analysis of the output with Fourier transform, average and rms current ratings of thyristors (transistors) in a single-phase full-wave rectifier circuit, numerical example of a single-phase full-wave rectifier

6 transfer (commutation) of current from one thyristor to another in a single-phase rectifier, numerical example of a single phase full-wave rectifier; uncontrolled three-phase half-wave rectifiers, output voltage and current; controlled Three-phase half wave rectifiers, average and rms output voltage and currents; three-phase full-wave rectifiers, controlled and uncontrolled, average and rms output voltage and currents, input line current of a three-phase full-wave rectifier, harmonics in the output, average and rms thyristor currents

7 numerical example of a three-phase full-wave rectifier, effect of ac side inductance on the performance of a three-phase full-wave rectifier; Midterm Examination

8 dc motor drive with a separately excited field, steady-state model of a separately excited dc motor, relationship of armature circuit variables, dual converters, regenerative breaking. Block diagram of a closed-loop position/speed dc servo drive, constant torque and constant power operation, DC to DC converter, choppers, type B chopper with regeneration,

9 analysis of a type A chopper, Load current of a Type A chopper, conditions for continuous and discontinuous load current, output voltage under continuous and discontinuous load currents of a chopper, numerical examples on output current, voltage and peak current of a chopper, Fourier analysis of the output voltage of a chopper

10 Analysis of a boost chopper, output current of a boost chopper, conditions for discontinuous current in a boost chopper, output voltage and the maximum and the minimum currents through the
main switch and the diode in the boost chopper, numerical example

11 DC to AC converters, application of dc to ac converters, output voltage and current of a Single-phase half bridge inverter, harmonic contents at the output of an inverter, current through the switches and the antiparallel diodes in a half-bridge inverter, full-bridge inverter, 3-phase inverters,

12 Voltage control in inverters, multiple pulsed-width modulation, sinusoidal pulsed-width modulation; reduction of harmonics from the output voltage of an inverter, pulsed-width modulation technique of harmonic reduction

13 Snubber Circuits, turn-on, turn-off and overvoltage snubber circuits, di/dt and dv/dt protection of thyristors.

Assignments: Up to 8 assignments

Tutorials: Details

Quizzes: Details

Exams: Midterm Exam: 1hr & 30 min outside of the class time; Final Exam: 3 hrs, during the exam period plus an oral assessment.

Important Dates:

Date Details
Date Details
Date Midterm Exam Period

Student Conduct: Ethical behaviour is an important part of engineering practice. Each professional engineering association has a Code of Ethics, which its members are expected to follow. Since students are in the process of becoming Professional Engineers, it is expected that students will conduct themselves in an ethical manner.

The APEGs (Association of Professional Engineers and Geoscientists of Saskatchewan) Code of Ethics states that engineers shall “conduct themselves with fairness, courtesy and good faith towards clients, colleagues, employees and others; give credit where it is due and accept, as well as give, honest and fair professional criticism” (Section 20(e), The Engineering and Geoscience Professions Regulatory Bylaws, 1997).

The first part of this statement discusses an engineer’s relationships with his or her colleagues. One of the ways in which engineering students can demonstrate courtesy to their colleagues is by helping to maintain an atmosphere that is conducive to learning, and minimizing disruptions in class. This includes arriving on time for lectures, turning cell phones and other electronic devices off during lectures, not leaving or entering the class at inopportune times, and refraining from talking to others while the instructor is talking. However, if you have questions at any time during lectures, please feel free to ask (chances are very good that someone else may have the same question as you do).

For more information, please consult the University Council Guidelines for Academic Conduct.
Academic Honesty: The latter part of the above statement from the APEGs Code of Ethics discusses giving credit where it is due. At the University, this is addressed by university policies on academic integrity and academic misconduct. In this class, students are expected to submit their own individual work for academic credit, properly cite the work of others, and to follow the rules for examinations. Academic misconduct, plagiarism, and cheating will not be tolerated. Copying of assignments and lab reports is considered academic misconduct. Students are responsible for understanding the university’s policies on academic integrity and academic misconduct. For more information, please consult the University Council Regulations on Student Academic Misconduct and the university’s examination regulations.

http://www.usask.ca/university_secretary/honesty/StudentAcademicMisconduct.pdf
http://www.usask.ca/university_secretary/council/academiccourses.php

Safety: The APEGs Code of Ethics also states that Professional Engineers shall “hold paramount the safety, health and welfare of the public and the protection of the environment and promote health and safety within the workplace” (Section 20(a), The Engineering and Geoscience Professions Regulatory Bylaws, 1997).

Safety is taken very seriously by the Department of Electrical and Computer Engineering. Students are expected to work in a safe manner, follow all safety instructions, and use any personal protective equipment provided. Students failing to observe the safety rules in any laboratory will be asked to leave.
Laboratory Learning

Outcomes:

Lab 1: Half-wave rectifiers
Upon completion of this Lab the students should be able to:
  Verify the relationship between delay angle and the input and output voltages and currents in half-wave ac to dc converters.

Lab 2: Full-wave single-phase rectifiers
Upon completion of this Lab the students should be able to:
  Verify the relationship between delay angle and the input and output voltages and currents in single-phase full-wave ac to dc converters.

Lab 3: Full-wave three-phase rectifiers
Upon completion of this Lab the students should be able to:
  Verify the relationship between delay angle and the input and output voltages and currents in three-phase full-wave ac to dc converters.

Lab 4: Buck and boost choppers
Upon completion of this Lab the students should be able to:
  Verify the operation and relationship between duty cycle, operating frequency and the input and output voltages and currents in dc to dc converters.

Lab 5: Single-phase half-bridge and full-bridge inverters
Upon completion of this Lab the students should be able to:
  Verify the operating principles of half-bridge and full-bridge dc to ac converters and also to verify their output voltage wave shape and harmonics.

Lab 6: Three-phase full-bridge inverters
Upon completion of this Lab the students should be able to:
  Verify the operating principles of three-phase full-bridge dc to ac converters and also to verify their output voltage wave shape and harmonics.
Course Learning Outcomes: Upon completing this course students will be able to:

1. Derive equations for voltage, current and power in circuits with semiconductor devices.
2. Analyze ac to dc single-phase half-wave, single-phase full-wave and three-phase half-wave and full-wave converters; determine average output voltage and average and rms output current and currents through the semiconductor devices; determine the voltage and current ratings required to design the converter circuits.
3. Analyze dc to dc buck and boost converters; determine average output voltage and average and rms output currents and currents through the semiconductor devices; determine the voltage and current ratings required to design the converters.
4. Name, illustrate and relate the main components of DC drives.
5. Analyze dc to ac single-phase and three-phase converters (inverters); determine rms output voltage and current and currents through the semiconductor devices; determine the voltage and current ratings required to design the converters.

Attribute Mapping:

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>A5</th>
<th>A6</th>
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</table>

**Attributes:
A1 Knowledge base for engineering
A2 Problem analysis
A3 Investigation
A4 Design
A5 Use of engineering tools
A6 Individual and team work
A7 Communication skills
A8 Professionalism
A9 Impact of engineering on society and the environment
A10 Ethics and equity
A11 Economics and project management
A12 Life-long learning

*Levels of Performance:
1 - Knowledge of the skills/concepts/tools but not using them to solve problems.
2 - Using the skills/concepts/tools to solve directed problems. ("Directed" indicates that students are told what tools to use.)
3 - Selecting and using the skills/concepts/tools to solve non-directed, non-open-ended problems. (Students have a number of S/C/T to choose from and need to decide which to employ. Problems will have a definite solution.)
4 - Applying the appropriate skills/concepts/tools to solve open-ended problems. (Students have a number of S/C/T to choose from and need to decide which to employ. Problems will have multiple solution paths leading to possibly more than one acceptable solution.)

Accreditation Unit (AU) Mapping: (% of total class AU)

<table>
<thead>
<tr>
<th>Math</th>
<th>Natural Science</th>
<th>Complementary Studies</th>
<th>Engineering Science</th>
<th>Engineering Design</th>
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<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>80</td>
<td>20</td>
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</table>

Assessment Mapping:
<table>
<thead>
<tr>
<th>Component</th>
<th>Weighting</th>
<th>Methods of Feedback***</th>
<th>Learning Outcomes Evaluated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assignment</td>
<td>10%</td>
<td>S</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Design</td>
<td>10%</td>
<td>S</td>
<td>6</td>
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<tr>
<td>Laboratory</td>
<td>15%</td>
<td>S</td>
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</tr>
<tr>
<td>Midterm Examination</td>
<td>15%</td>
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<td>1, 3, 4</td>
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<tr>
<td>Final Examination</td>
<td>50%</td>
<td>S</td>
<td>1, 2, 3, 4, 5, 6</td>
</tr>
</tbody>
</table>

***Methods of Feedback:
F – *formative* (written comments and/or oral discussions)
S – *summative* (number grades)