Course Schedule:

Lectures: Mon/Wed 08:35-09:55, 3275ME
Labs: L1: Tue 14:35-17:25, 4195ME;
L2: Thu 11:35-14:25, 4195ME;
L3: Thu 14:35-17:25, 4195ME;
L4: Mon 11:35-14:25, 4195ME;

Instructor: Prof. Q.J. Zhang, email qijun.zhang@carleton.ca

Teaching Assistants: TBD

Objective: To study the principles, design and analysis of analog electronic circuits.

Course Description:

Calendar description: *Introduction to semiconductor devices and ICs. DC, AC and switching properties of BJTs. Linear amplifiers; bandwidth considerations; two-port analysis. Large signal amplifiers; power amplifiers; transformerless circuits. Feedback and operational amplifiers; gain, sensitivity, distortion and stability. Filter design. Oscillators.*

In this course, the student will learn both analysis and design of electronic circuits. Both discrete and integrated circuits will be discussed. This course builds on the concepts covering analysis of basic circuits and signals (covered in ELEC 2501) and also basic electronic devices and circuits, such as diodes, BJTS, MOSFETS and Amplifier/Rectifier/Regulator Circuits (covered in ELEC 2507). In this course, single transistor circuits will be extended to multiple transistor circuits made of Bipolar Junction Transistors. Designs of various one and two transistor amplifier circuits will be studied, followed by an exploration of the opamp. Finally some opamp application such as design of filters and oscillators will be seen.

Specific topics include:

- Review of Basic Electronic Devices and Circuits: p-n Junction, Diode Equation, Bipolar Junction Transistors (BJT): Concepts, Current Relations, Regions of Operation, Characteristics, Biasing, Small-Signal BJT model.
- Common Emitter Amplifier: AC analysis, Input and Output Resistance, Voltage/Current Gains, Frequency Response.
- Common Base Configuration and Cascode Amplifier, Common Collector Configuration, CC-CB Wideband Amplifier, Current Source/Sink Bias.
- Frequency Analysis of Transistor Amplifiers, Bode Plots.
- Differential Amplifier Stage, CMG, DMG, CMRR, Analysis of 741 IC Op-Amp.
- Power Amplifiers: Class A, Class B, Class AB, Class C.
- Thermal Analysis of Power Transistors and Design Considerations.

- Filters: RC Filters Theory, Second-order Transfer Functions.
- Filter Design Methodology: Types, Specifications, Approximations and Practical Circuit Topologies, Applications.
- Feedback Stability and Linear Oscillator Circuits, Applications.

Textbook and References:

Textbook (not compulsory):

A. Sedra, K. Smith, T.C. Carusone and V. Gaudet, *Microelectronic Circuits*, 8th Edition, Oxford, 2020.

Or:

A. Sedra and K. Smith, *Microelectronic Circuits*, 7th Edition, Oxford, 2015.

Supplementary book:

R. Schaumann and M.E. Van Valkenburg, *Design of Analog Filters*, Oxford, 2001.

Labs:

Goals: The laboratory portion of the course reinforces the theme of the course through analysis and design of electronic circuits. As well, through the lab experiments, students will extend their previous experience of circuit design using a few discrete transistors, and will begin to use ICs as the basis for designs.

Topics: The lab topics form a coherent sequence following the lectures, beginning with BJT characteristics, followed by BJT amplifiers, op-amp circuitry, and, finally, the op-amp's use in filters and oscillators.

Organization: The labs are an integrated mixture of 5 multi-week exercises and projects. In order to complete all of the work, students attend the lab once per week, every week; there are no problem analysis sessions in the course. For every lab, students work individually and provide a report.

Exercises: For the lab exercises, students are expected to have completed any required preparation before they come to the lab, and, in the lab, to take notes which ***must*** be initialed by a lab demonstrator before they leave. For most of the exercises, a formal report is written after all the parts of the lab have been completed, and must be submitted by 3:00 p.m. seven days after the period in which the lab's last exercise was performed. The report must include the initialed lab notes as an appendix. The last exercise has an in-lab quiz and no formal report. (See attached schedule.) The reports should be in PDF format and should be submitted by uploading the file to the ELEC 3509 Course website in Brightspace.

Projects: As with the exercises, students are expected to have completed any required preparation before they come to a project lab. During one of the periods for each project, the student will be required to demonstrate a working circuit. If after the demonstration, the lab instructor or T.A. is satisfied that the circuit and the demonstration are acceptable, he will initial the student's de-sign schematic. This initialed schematic ***must*** be submitted as an appendix to a formal engineering report fully analyzing and documenting the designed circuit(s). Sufficient data should be recorded to show that all the requirements have been satisfied. The final report is due in Brightspace by 3:00 P.M. 7 days after the student's last scheduled lab period for the project.
For the second project, the final demonstration will require some time and so will be made at an appointed time during the lab period. Thus, it is expected that the student will have his or her circuit functioning to meet the specification ***before*** the final period of this project. It is emphasized that full advantage should be taken of the scheduled laboratories and the advice available from faculty members and teaching assistants, as well as from laboratory demonstrations, during these periods.

Lates: Late reports and demonstrations are each penalized 30% if received within one week of the listed deadline, while later ones will receive a grade of 0. However, in order to pass the course, you must complete all labs

Lab Outline

Lab 1: **BJT A.C. and D.C. Operation**
-BJT D.C. Characteristics and the current Mirror.
-BJT A.C. Characteristics

Lab 2: **Amplifier Project**
-Single Transistor and Two-Transistor Amplifiers
-Cascode Amplifier Design Review and Development
-Cascode Demonstration

Lab 3: **Bipolar Op-Amp Simulation**
-Design, Schematic
-To investigate the effect of various design parameters

Lab 4: **Active Band-Pass Filter Project**
-Introduction to Active Filters and Filter Simulations and Measurements
-Chebyshev Filter Design Review
-Chebyshev Filter Demonstration

Lab 5: **Oscillators**
-Wien Bridge and the Active-RC Phase Shift Quadratic Oscillators

Health and Safety:

Students should be familiar with the regulations and the University Health-And-Safety document. Respecting lab safety precautions and following directions of lab staff is essential to keep everyone safe. Important information on Health-And-Safety can be found at

https://carleton.ca/ehs/programs/working-lab/laboratory-health-and-safety/

Learning Outcomes:

On successful completion of the course, a student is expected to be able to:

1) Design DC bias circuits; selection of alternative bias schemes and understanding of their comparative advantages and disadvantages; determine the DC operating voltages and currents for a circuit containing up to ten transistors.
2) Design of small-signal amplifiers; determine the small signal-gain, input impedance, and output impedance of an amplifier consisting of two transistors; determine the operating bandwidth of a simple amplifier; selection of basic types of amplifiers and understanding of their comparative advantages and disadvantages.
3) Analyze simple op-amps at the transistor level to determine gain, common-mode range, and slew rate. Analyze basic power amplifiers to determine efficiency and maximum output power.
4) Design op-amp based filters from required specifications on frequency-domain responses; determine filter type, Q, gain, and corner frequency of 2nd order op-amp based filters; alternative choices of several basic types of 2^{nd} order active filters and understanding of their comparative advantages and disadvantages.
5) Apply the Barkhausen Criteria to circuits to test if they oscillate and if they do determine under what conditions this occurs.

Precluded Courses: None

Precludes additional credit for: ELEC 3509 may not be taken for credit by students in the Biomedical and Electrical Engineering or Biomedical and Mechanical Engineering programs.

Prerequisites: ELEC 2507

Evaluation:

Grading:	
Labs (5)	35%
Midterm Exam	15%
Final Exam	50%
Total	100%

Additional requirements: All labs must be completed with an average grade of 50% or better to pass the course. At least 50% on the final exam is required to pass the course.

Final Examination -The final exam is for evaluation purposes only and will not be returned to the student.

Students who are unable to write the final examination due to serious illness, emergency or other circumstances beyond their control may apply for accommodation by contact the Registrar's office. Consult Section 4.3 of the University Calendar.

Assignments – Assignment questions are provided on the course web page. Students are highly encouraged to solve them. Answers to the problems are provided in web.

Accreditation Units

Accreditation units (AU's) are used by the Canadian Engineering Accreditation Board (CEAB) to determine if an Engineering program meets a minimum number of class hours required for accreditation in each of 5 components: math, natural science, engineering science, engineering design, and complementary studies. Accreditation metrics are based on courses common to all students in a program. Forty percent of AU's of ELEC3509 is Engineering Science, and sixty percent is Engineering Design.

Graduate Attributes:

An institution must demonstrate that graduates of its programs possess the attributes described below. In addition, the institution must implement and employ processes to demonstrate that program outcomes are being assessed in the context of these attributes, and that the results of such assessments will be applied to the further development of programs. The graduate attributes are:

1. A knowledge base for engineering: Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.

2. Problem analysis: An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.

3. Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

4. Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with

appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

5. Use of engineering tools: An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.

6. Individual and team work: An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.

7. Communication skills: An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.

8. Professionalism: An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.

9. Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

10. Ethics and equity: An ability to apply professional ethics, accountability, and equity.

11. Economics and project management: An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.

12. Life-long learning: An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.

This course (ELEC 3509) will score attributes 1.5E, 2.1, 2.2, 2.3, 2.4, 3.1, 3.2, 3.3, 3.4, 3.5, 4.1, 4.2, 4.4, 4.5, 4.6, and 4.7. They are scored through the responses provided in assignments, quizzes, pre-lab and lab reports, presentations, final exams. The graduate attribute scores may in some cases be derived from graded material, however the graduate attribute scores are not used in determination of the final grade for the course.

Copyright:

The materials (including the course outline and any slides, posted notes, videos, labs, project, assignments, quizzes, exams and solutions) created for this course and posted on the web site are intended for personal class use and may not be reproduced or redistributed or posted on any web site without prior written permission from the author(s).

Generative Artificial Intelligence (AI):

Use of generative AI tools (such as ChatGPT) in course work is prohibited unless explicitly authorized by the course instructor for specific elements of the course. Submission of AI generated work without authorization may lead to an academic integrity investigation.

Academic Integrity and Plagiarism

a) Please consult the Faculty of Engineering and Design information page about the Academic Integrity policy and our procedures: https://carleton.ca/engineering-design/current-students/fed-academic-integrity

Violations of the Academic Integrity Policy will result in the assignment of a penalty such as reduced grades, the assignment of an F in a course, a suspension or, expulsion.

b) One of the main objectives of the Academic Integrity Policy is to ensure that the work you submit is your own. As a result, it is important to write your own solutions when studying and preparing with other students and to avoid plagiarism in your submissions. The University Academic Integrity Policy defines plagiarism as "presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one's own." This includes reproducing or paraphrasing portions of someone else's published or unpublished material, regardless of the source, and presenting these as one's own without proper citation or reference to the original source.

Examples of violations of the policy include, but are not limited to:

- any submission prepared in whole or in part, by someone else;
- using another's data or research findings without appropriate acknowledgement;
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own; and
- failing to acknowledge sources of information through the use of proper citations when using another's work and/or failing to use quotation marks.

Advising and Counselling Services

a) Engineering Academic Advising

The Engineering Academic Support Service : https://carleton.ca/engineering-design/current-students/undergrad-academic-support/ assists undergraduate engineering students with course selection, registration, and learning support from first-year through to graduation.

Academic advisors contact information: https://carleton.ca/engineering-design/current-students/undergrad-academic-support/undergraduate-advisors/

b) Student Mental Health Service

As a University student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. Carleton's Wellness Services Navigator https://wellness.carleton.ca/navigator/ is designed to help students connect with mental health and wellness resources. If you need to talk to someone, please reach out for assistance: https://carleton.ca/health/emergencies-and-crisis/.

Learning and Working Environment

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca

We will strive to create an environment of mutual respect for all through equity, diversity, and inclusion within this course. The space which we work in will be safe for everyone. Please be considerate of everyone's personal beliefs, choices, and opinions.

Academic Accommodation

Academic accommodation refers to educational practices, systems and support mechanisms designed to accommodate diversity and difference. At no time should academic accommodation undermine or compromise the learning objectives that are established by the academic authorities of the University.

a) Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a

disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation.

If you are already registered with the PMC, contact your PMC coordinator to initiate a Letter of Accommodation at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (if applicable). After requesting accommodation from PMC, meet with the instructor to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

b) **Accommodation for Student Activities:** Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Contact the instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf

c) **Pregnancy Obligation**: contact the instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form.

d) **Religious Obligation**: contact the instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist.

e) **Survivors of Sexual Violence:** As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services