Engineering: ELEC 3509 Electronics II

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

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

Description: 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. 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.

Grading:
Labs (5) 30%
In-class Participation 5%
Midterm Exam 15%
Final Exam 50%
Total 100%

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.

You are expected to attend and participate in all lectures in the course **especially** if you are repeating the course. During the lectures, work will be collected five times during the term. Such work will contribute to the 5% weight in the overall grading.

Assignments are on the web. Students are highly encouraged to solve them. Answers to many problems are found at the back of the book. Others will be provided.

Academic accommodation for any reason must be sought as soon as possible, preferably early in the term. Verification will be required.

References:

1. A. Sedra and K. Smith, *Microelectronic Circuits*, 7th Edition, Oxford, 2015.
2. C.L. Alley and K.W. Atwood, *Microelectronics*, 1986, TK7874.A429.
3. P.R. Belanger et al, *Introduction to Circuits with Electronics*, 1985, TK7867.B37.
4. R. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory*, TK7867.B66.
5. P. Gray, *Analysis and Design of Analog Integrated Circuits*, TK7874.G688
6. H. Lam, *Analog and Digital Filter Design*, TK7872.F5L26.
7. J. Millman, *Microelectronics*, TK7874.M527.
8. C.J. Savant et al, *Electronic Circuit Design*, TK7876.S277.

9. R.J. Smith, *Circuits, Devices and Systems*, TK45.S616.
10. M.H. Rashid, *Microelectronic Circuits: Analysis and Design*, 1999.
11. M.N. Horenstein, *Microelectronic Circuits and Devices*, 1996.
12. R. Schaumann and M.E. Van Valkenburg, *Design of Analog Filters*, Oxford, 2001.

Learning Outcomes:

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.

Lecture Outline

Week 1-2: 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.

Week 3-4: Common Base Configuration and Cascode Amplifier, Common Collector Configuration, CC-CB Wideband Amplifier, Current Source/Sink Bias.

Week 5-6: Frequency Analysis of Transistor Amplifiers, Bode plots, Differential Amplifier Stage, CMG, DMG, CMRR, Analysis of 741 IC Op-Amp.

Week 7, 9: Power Amplifiers: Class A, Class B, Class AB, Class C, Filters: RC filters theory, Second-order transfer functions.

Week 10-11: Filter Design Methodology: Types, Specifications, Approximations and Practical Circuit Topologies, Applications.

Week 12-13: Feedback Stability and Linear Oscillator Circuits, Applications, Review.

Notes on Lab Projects and Exercises

Goals: The laboratory portion of the course reinforces this theme 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 10 multi-week exercises and projects. In order to complete all of the work, students attend the lab 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 cuLearn.

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 cuLearn 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 Equipment, Components and Tools: For the Fall 2020 term, all the labs for ELEC 3509 will be performed by a combination of computer-simulations and remotely controlled hardware measurement. Students are expected to remotely access the computers in the DOE labs (for example, the computers and server in the lab managed by Nagui) for both Multisim simulation and for controlling measurement equipment. You will use the NI Multisim software available on these computers to do all the labs (BJT, amplifiers, op-amp, filters, oscillators). You will also use these computers to remotely control the measurement equipment to perform necessary measurements for the labs.

Health and Safety: students should be familiar with the regulations and the University Health-And-Safety document. More information is provided on the course web page.

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

Accommodation:

Please see https://students.carleton.ca/course-outline/ for details on these university policies.

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.