

## ELEC4707: Analog Integrated Electronics

### Introduction

This course explores advanced analog signal processing techniques with a focus on monolithic integrated circuit (IC) technology. Students will learn about continuous active filter design, CMOS and MOS IC technology, operational amplifier design, and noise considerations in analog circuitry. Topics such as switched capacitor filters, Z-transform analysis, and RF IC design will also be covered, providing a comprehensive understanding of modern analog electronics and their applications in integrated circuit design. Designed for fourth-year electrical engineering students, this elective offers an in-depth and practical approach to analog and mixed-signal circuit design.

### Course Description and Requirements

**Course Description:** Emphasis on integration of analog signal processing techniques in monolithic IC technology. Continuous active filter design. MOS IC technology. OP amp design. Basic sampled data concepts; Z-transform analysis, switched capacitor filters. Noise aspects. Bipolar technology: radio frequency IC design.

**Includes:** Experiential learning activity

**Prerequisite(s):** ELEC 3509

**Lectures:** three hours per week

**Laboratory and problem analysis:** three hours alternate weeks

### Instructor

**Professor:** Dr. MacEachern

**Email:** [leonard.maceachern@carleton.ca](mailto:leonard.maceachern@carleton.ca)

**Course Webpage:** on Brightspace

### Textbook: Please include price of required books

Course notes are given in class during lectures. No textbook is required for purchase. On-line resources will be suggested in due course. Previous year's materials has already been posted on the course page.

### Lecture Outline

In person, Mondays and Wednesdays, 10:05am-11:25am, Jan 6-April 9, 2024. Room 3356ME.

The following topics will be covered during the course lectures with an approximate schedule:

**Week 1:** Manufacturing, CMOS Processing

**Week 2:** MOSFET Characteristics, Small Signal Modelling

**Week 3:** Small Signal Modelling, Biasing, First Building Block

**Week 4:** Current Mirrors, Common Source Amplifiers

**Week 5:** MOSFET Differential Pairs, Op-Amp Stages, Feedback

**Week 6:** Stability, Bode Plots, Stability Criteria, Polarity

**Week 7:** Analog Filters (High Pass, Low Pass, All Pass)

**Week 8:** Switched Capacitors, Switched Capacitor Filters

**Week 9:** Z-Transform and Discrete Integration

**Week 10:** Charge Balance Equations

**Week 11:** Strays-Insensitive Switched Capacitors and SC Building Blocks

**Week 12:** Noise

## Laboratory and Problem Analysis Sessions

3 hours (alternate weeks) as per schedule and location posted on Brightspace.

### Notes for Labs

- There are 5 labs as follows:
  - Lab 1: MOSFET Exploration
  - Lab 2: Common Source Amplifiers
  - Lab 3: MOSFET Differential Pairs
  - Lab 4: Operational Amplifier Design
  - Lab 5: Switched Capacitors
- Labs are 3 hours in duration and will be held in Room 6030MC. Labs and PA sessions usually “alternate” from week to week and will be held according to the schedule shown on the course page.
- If for some reason a Lab needs to be rescheduled OR a Lab falls on one of the University holidays, students must try to rearrange their schedule to make up the lab in another of the regularly scheduled lab sessions, as arranged by the instructor.
- Attend each lab punctually. Be prepared for the lab experiment by reading the lab instruction sheets before entering the lab. Some labs have a pre-lab exercise that must be completed before the start of your lab period. You are not permitted to do the lab unless the prelab is completed. The instructor will check that the pre-lab has been completed.
- Lab deliverables vary lab-to-lab and will be provided ahead of each lab. Generally a report prepared in LaTeX will be required from each student.

### Self-Declaration form and Deferred Term work

Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for submitting a self-declaration form no later than three (3) days after the date/deadline of term work including test/midterm, labs, assignments. Any alternate arrangements made with the instructor for submission of term work should be made as soon as possible but within 3 days of the missed due date. If this is not possible after discussion with the instructor, alternate arrangements must be made before the last day of classes in the term as published in the academic schedule.

Instructors can require (or not) the student to submit the self-declaration form. Include the following statement if you require the student to submit a completed self-declaration form:

**Consult with the instructor no later than 3 days after any missed course work or midterm examination.**

or

**Contact the instructor with the completed self-declaration form no later than 3 days after the date/deadline of term work including test/midterm, labs, assignments.**

## Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

Labs 1-5:	20 points (4 points each) [due one week after scheduled labs]
Assignments 1-2:	10 points (5 points each) [A1 due Feb 5/25, A2 due March 28/25]
Midterm:	20 points [week prior to Reading Week]
Final:	50 points [entire exam period; take home]

To pass the course you need: 50% term mark.

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a) Final Exam: **Final exams are for evaluation purpose and will not be returned to students.**

ii) Take-home final exam. The exam will cover all course material. This is not a “must-pass” exam. The examination will commence at the start of the official exam period and conclude at the end of the official exam period. Problems will be open-ended design problems. The marking rubric for each problem will be given in the exam.

iii) Final exam weight:

50%

iv) Deferred Final Examinations:

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

(<https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/examinations/>)

b) Additional requirement(s):

The format of all deliverables is given in the rubric and/or instructions for each.

## Learning Outcomes

1. Explain CMOS Technology processing steps: Explain CMOS processing and manufacturing techniques and their application to integrated circuit design.

2. Analyze and Design Analog Circuits: Analyze and design analog circuits, including current mirrors, differential amplifiers, and operational amplifier stages, with a focus on small-signal modelling and biasing.

3. Evaluate Stability and Frequency Response: Evaluate the stability and frequency response of analog circuits using tools such as Bode plots and stability criteria.
4. Implement Active Filters: Design and implement continuous active filters (high pass, low pass, and all pass) using operational amplifiers and other active components.
5. Utilize Switched Capacitor Technology: Develop and analyze circuits incorporating switched capacitors and switched capacitor filters for sampled data systems.
6. Apply Z-Transform Techniques: Apply Z-transform and discrete integration methods to analyze and design digital and mixed-signal systems.
7. Address Noise in Circuit Design: Identify, analyze, and mitigate noise sources in analog circuits to improve overall circuit performance.
8. Analyze SC Circuits: Apply charge balance equations to design and optimize strays-insensitive switched capacitor circuits and SC building blocks.
9. Integrate Design Concepts: Integrate multiple analog signal processing techniques to create functional monolithic IC designs.
10. Demonstrate Problem-Solving Skills: Apply engineering problem-solving approaches to complex analog circuit design scenarios, considering trade-offs in performance, cost, and manufacturability.

## Graduate Attributes

Not collected for this course.

## 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 acknowledgment;
- Submitting a computer program developed in whole or in part by someone else, with or without modifications, as one’s own;
- Failing to acknowledge sources of information through the use of proper citations when using another’s work and/or failing to use quotations marks; and

- Unless explicitly permitted by the instructor in a specific course, the use of generative AI and similar tools to produce assessed content (such as text, code, equations, images, summaries, videos, etc.).

## Academic Accommodations

You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:

**Pregnancy obligation:** Contact us 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 ([click here](#)).

**Religious obligation:** Contact us 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 more details [click here](#).

**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](mailto:pmc@carleton.ca) for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send us your 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, contact us, if needed, to ensure that accommodation arrangements are made.

You should request your academic accommodations in the [Ventus Student Portal](#), for each course at the beginning of every term. For in-term tests or midterms, please request accommodations at least two (2) weeks before the first test or midterm.

Please consult the [PMC website](#) for the deadline to request accommodations for formally-scheduled exams (if applicable).

**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>

**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 us 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>