Carleton University

Department of Electronics

Winter 2025

ELEC4506: *Computer-Aided Design of Circuits and Systems*

In this course students will learn the fundamentals of electronic design automation of analog circuits and systems with emphasis on their modeling and simulation. Laboratories will reinforce the concepts learnt in the class by implementing them and comparing with the state-of-the art circuit simulators.

Course Description and Requirements

Course Description: Basic principles of Computer-Aided Design tools used for analysis and design of communication circuits and systems. Device Stamps and Modified Nodal Analysis. Frequency and time-domain analysis. Noise and distortion analysis. Sensitivity analysis and circuit performance optimization.
Includes: Experiential learning activity
Prerequisite(s): Fourth-year status in Engineering
Lectures: Three hours a week, laboratory three hours alternate weeks
Laboratory: Three hours every alternate week

Electronic Design Automation tools, particularly the analog circuit simulators, form the backbone of the rapidly growing semiconductor industry. These tools enable the designers to design and validate large scale circuits prior to fabrication. If not designed and validated properly, the resulting fabricated chip may become inoperable, or they can distort an analog signal such that it fails to meet specifications. Since extra iterations in the VLSI (*Very Large-Scale Integrated Circuits*) design cycle are extremely costly, properly designed analog circuit simulators and their understanding become very important for both the developers of CAD (Computer-Aided Design) tools as well as to the designers of these circuits/systems. Particularly, the students will be able to learn the modules and fundamentals of Analog Circuit Simulators such as SPICE (or equivalent ones such as HSPICE from Synopsys, SPECTRE from Cadence, ELDO from Siemens EDA, Nexxim from Ansys etc.) and build a prototype circuit simulator.

Students taking this course can benefit from a career pathway as a developer of the emerging CAD software/tools for modern electronic circuits, as users of CAD tools, and as circuit/system designers.

Instructor:

Professor: Dr. Ram Achar
Email: achar@doe.carleton.ca
Office Hour: Wed, 4:15pm to 5:15pm
Course Webpage: on Brightspace

Lecture Notes and Optional Textbooks

1) Lecture Slides will be provided
2) Computer Methods for Circuit Analysis & Design
   J. Vlach and K. Singhal, Van Nostrand Reinhold 1983/1994 [Price - $277 USD on Amazon]
3) Electronic Circuit and Simulation Methods
   L. Pillage, R. Rohrer, C. Visweswariah, McGraw-Hill 1995 [Price - $133 USD on Amazon]
4) Circuit Simulation
   F. Najm, Wiley, 2010 [Price - $154 USD on Amazon]

Lecture Schedule and Outline

Date & Time: **MW 2:30pm to 4pm;** Room: **ME 4494;** **In person**
The following topics will be covered during the course lectures with an approximate schedule:

Frequency-Domain:

- *Weeks 1: Introduction to Circuit Simulation, Device Stamps, Nodal Analysis*
- *Week 2: Modified-Nodal Analysis*
- *Week 3: LU decomposition, Sparse Matrix techniques, Iterative Matrix solution Techniques,*

Linear Time-Domain:

- *Week 4: Laplace and Fourier Transforms with Applications to Circuits*
- *Week 5: Time-Domain Analysis methods: Forward Euler, Backward Euler and Trapezoidal Rule based techniques*
- *Week 6: Multi-Step Time-Domain Analysis methods*
- *Week 7: Numerical stability*

DC Solution of Nonlinear Circuits

- *Week 8: Newton's iterations, Convergence and accuracy issues*
- *Week 9: Jacobian matrix*

Nonlinear Time-Domain

- *Week 10: Charge-based formulation of the circuit equations*
- *Week 11: Iterative time-stepping solution*

Other Types of Analysis

- *Week 12: Sensitivity Analysis, Noise Analysis, Distortion analysis*

Laboratory Sessions

- 3 hours per every alternate week as per schedule and location posted on Brightspace. There are 6 labs that are conducted during the term, as follows:
  - Lab 1: Network equations and frequency responses
  - Lab 2: MNA based formulation and development of prototype circuit simulator – Part I
  - Lab 3: MNA based formulation and development of prototype circuit simulator – Part II
  - Lab 4: Time Domain Analysis of Linear Circuits
  - Lab 5: DC Analysis of Nonlinear Circuits
  - Lab 6: Sensitivity Analysis
- Labs are 3 hours in duration and will be held in Room 6030MC on alternate weeks according to the schedule shown on the course module in Brightspace. You must attend your lab in the session you are registered. Changing sessions is not allowed without the instructor's permission. A TA will take attendance at each lab session.
- If for some reason a Lab needs to be rescheduled OR a Lab falls on one of the University holidays, students in those sections 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. 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 TA will check that the the pre-lab has been completed.

- A lab report will be submitted online for each lab and by each student. A template for each lab report will be provided by the indicated respective deadline. One day late lab report will only be worth 50% of its original marks. Two days late, it is worth 0.

Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

Grading:

10% **In-Class Quizzes** *(Best of 70% of the quizzes is considered for this component).*

25% **Labs**

25% **Mid-Term Exam** *(*In person, proctored, closed book, calculator allowed.

Wed, Feb. 26th 2024, 10am -11:30am).

Note: Mid-Term Exam is optional. In case of a missed mid-term exam for any reason, its weight will be automatically shifted to the final exam.

40% **Final Exam** (In person, proctored, closed book, calculator allowed.

Final exams are for evaluation purpose only and will not be returned to students)

To pass the course, a minimum of 45% marks is required in the final exam and at least 4 labs (with an average of 60% or above marks) are required to be completed

Learning Outcomes

Upon successful completion of this course, students will be able to:
By the end of this course, students will be able to:

1. Explain, Analyze and Formulate the circuit equations of large circuits in an automated way using Modified Nodal Analysis
2. Explain and Perform frequency-domain analysis including sparse matrix techniques and LU Decomposition.
3. Explain and Perform DC Analysis of circuits including Jacobian and Newton iterations.
4. Explain and Perform Transient Analysis of circuits including Forward Euler, Backward Euler and Trapezoidal Rule based integrations and multi-step methods.
5. Explain and Perform Sensitivity Analysis of circuits in both frequency and time-domains.

Graduate Attributes

The Canadian Engineering Accreditation Board requires graduates of undergraduate engineering programs to possess 12 attributes: Graduate-Attributes.pdf (engineerscanada.ca) or GA's. Courses in all four years of our programs evaluate students' progress towards acquiring these attributes. Aggregate data (typically, the data collected in all sections of a course during an academic year) is used for accreditation purposes and to guide improvements to programs. Some of the assessments used to measure GAs may also contribute to final grades; however, the GA measurements for individual students are not used to determine the student's year-to-year progression through the program or eligibility to graduate. Accreditation metrics are based on courses common to all students in a program.

This following list provides the GAs that will be measured in this course, along with the indicators that are intended to develop and assess these attributes.

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.

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 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 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 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