Department of Electronics

ELEC5508 / ELG6358 / EGEN5399

Fall Term – 2026

Professor, Schedule:

Dr. Ram Achar **URL:** http://www.doe.carleton.ca/~achar/
Email: ram.achar@carleton.ca

Lectures: In person, three hours a week, **Wed 2:30pm to 5:30pm**, Lecture Room: **TC 210**
Course Webpage: Elec5508 Fall Term 2026 link in Carleton Brightspace Portal
Office Consultation Hour: Wed, 5:30pm to 6:30pm, Office Room: ME-5150

ELEC5508 / ELG6358: *Advanced Methods for Simulation of Large-Scale Circuits and Systems*
EGEN5399: *Special Topics in Electrical Engineering*

In this course students will learn the fundamentals of electronic design automation of analog circuits and systems with emphasis on their modeling and simulation. Analog circuit simulators form the backbone of the rapidly growing semiconductor industry, enabling the designers to design and validate large scale circuits prior to fabrication. If not designed and validated properly, the resulting fabricated circuits may become inoperable, or they can distort an analog signal such that it fails to meet specifications. Since extra iterations in the VLSI design cycle are extremely costly, properly designed analog circuit simulators and their understanding become very important for both the developers of CAD tools and the designers of these circuits/systems.

This course is intended for both the developers and users of CAD tools and circuit/chip/package/system designers. In particular, students will 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 career pathways as developers of emerging CAD software/tools, as users of CAD tools, and as circuit/system designers. The application of the course material spans a wide spectrum of engineering fields.

Includes: Experiential learning activity

Prerequisites: Familiarity with the basic concepts in circuit theory, analysis and design, algebra and calculus.

Course Objectives, Description and Requirements

Course Objectives

1) To understand the modules and fundamentals of Analog Circuit Simulators such as SPICE (or equivalent ones such as HSPICE, SPECTRE, ELDO, etc.).
2) To become conversant with various numerical analysis methods for frequency- and time-domain analysis, as applicable to linear and nonlinear circuits.
3) To understand the issues and limitations that designers face while using analog circuit simulators.
4) To design, build and test prototype analog circuit simulators.
5) To understand model-order reduction techniques to facilitate efficient simulation of large-scale analog VLSI circuits
6) To become familiar with the emerging trends in Artificial Intelligence and Machine Learning for applications in circuit simulation and optimization.

Course Content

The first part of the course covers the basic principles of circuit simulation. The second part focuses on advanced analysis techniques. Following is a broad outline and schedule of the material proposed to be covered in this course:

Frequency-Domain (weeks 1-3):

- *Modified-Nodal Analysis*
- *LU decomposition, Sparse techniques*
- *Stability and Passivity*

Linear Time-Domain (weeks 4-7):

- *Solution of Large-Scale Differential Equations*
- *Multistep methods - Fundamentals, FE, BE and TR Methods*
- *Numerical stability*
- *Sensitivity Analysis*

Nonlinear Time-Domain (weeks 8-9):

- *Jacobian matrix*
- *Newton's iterations*

Model-Order Reduction, AI (weeks 10-12):

- *Moment matching*
- *Padé approximation*
- *Asymptotic Waveform Evaluation*
- *Projection Techniques*
- *QR decomposition*
- *Krylov subspace*
- *Arnoldi algorithm*
- *Passivity preservation*
- *Macromodelling*
- *AI and its applications in Circuit Simulation*

Lecture Notes and **Optional** Textbooks

1) Computer Methods for Circuit Analysis & Design
   J. Vlach and K. Singhal, Van Nostrand Reinhold 1983/1994 [Price - $277 USD on Amazon]
2) Electronic Circuit and Simulation Methods
   L. Pillage, R. Rohrer, C. Visweswariah, McGraw-Hill 1995 [Price - $133 USD on Amazon]
3) Circuit Simulation
   F. Najm, Wiley, 2010 [Price - $154 USD on Amazon]
4) Asymptotic Waveform Evaluation and Moment Matching for Interconnect Analysis
   E. Chiprout and M. Nakhla, Kluwer Academic Publishers, 1994 [Price - $109.99 USD on Amazon]
5) IC Interconnect Analysis
   M. Celik, L. Pileggi and A. Odabasioglu, Kluwer Academic Publishers, 2004 [Price - $169.99 USD on Amazon]
6) R. Achar and M. Nakhla, Simulation of High-Speed Interconnects, *Proceedings of the IEEE*, May 2001
7) Lecture Slides, Handouts as relevant and feasible.

Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

Grading: **60%** **Assignments**

20% **Mid-Term Exam** *(*In Person, proctored, closed book, calculator allowed.

Wed, Oct. 28th 2026, 2:30pm -4pm).

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.

20% **Final Exam** (In Person, proctored, closed book, calculator allowed.

Note: Final exams are for evaluation purposes only and will not be returned to students)

To pass the course, a minimum average of 45% across the midterm and final exams is required.

Learning Outcomes

Upon successful completion of this course, students are expected to be able to:

1. Explain, Analyze and Formulate linear and nonlinear circuit equations 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.
6. Explain and Perform Model Order Reduction of large circuits and be familiar with related issues such as stability and passivity.

AI use in this Course

Students are expected to do the assignments, derive any formulations/solutions, any related programming and prepare the report, on their own without the use of AI tools. They may use the AI tools only for checking spelling/grammar of the prepared reports (e.g. Grammarly, Microsoft Word Editor, Copilot). As our understanding of the uses of AI and its relationship to student work and academic integrity continue to evolve, students are required to discuss their use of AI in any circumstance not described here with the course instructor to ensure it supports the learning goals for the course.

Academic Accommodations

Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes, including information about the Academic Consideration Policy for Students in Medical and Other Extenuating Circumstances, are outlined on the Academic Accommodations website (students.carleton.ca/course-outline).

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.

a) 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 quotation 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.).