ELEC 4502: Microwave Circuits

Fall 2026 Academic Term

1 Introduction

Dive into the fascinating world of high-frequency electronics with ELEC 4502: Microwave Circuits, a hands-on course designed to equip you with the skills to design and analyze cutting-edge RF and microwave systems. Explore the fundamentals of microwave semiconductor devices, passive components, integrated circuit technology, and precision circuit measurements, building a solid foundation in the principles that power modern wireless technologies, radar systems, and satellite communications. Delve into essential network theory and scattering matrix methods to model and optimize circuit behavior at microwave frequencies. Through practical design projects, you'll master the creation of matching networks, filters, and amplifiers, using industry-leading tools like Ansys HFSS for advanced electromagnetic simulations and Keysight ADS for professional layout preparation. The course culminates in an exciting course project where you'll design, fabricate, and characterize a transistor RF amplifier, bridging theory and real-world application. Whether you're aiming for a career in telecommunications, aerospace, or RF engineering, this course offers a blend of theoretical depth and laboratory experience to sharpen your expertise. Join us to unlock the secrets of microwave engineering and emerge ready to tackle the challenges of tomorrow's high-speed technologies!

2 Course Description and Requirements

2.1 Course Description

Introduction to microwave semiconductor devices, microwave passive components, microwave integrated circuit technology, and microwave circuit measurements. Basic network theory and scattering matrix description of circuits. Design of matching networks, filters, amplifiers and oscillators at microwave frequencies.

Includes: Experiential learning activity
Lectures: Three hours a week
Laboratory: Course Labs three hours alternate weeks

2.2 Instructor

Professor: Shulabh Gupta
Email: Shulabh.Gupta@carleton.ca
TA: TBD
Course Webpage: On Brightspace

2.3 Textbook

1. David Pozar, "Microwave Engineering", 4th or latest edition. (recommended, estimate cost of about $275)
2. M. Sadiku, "Elements of Electromagnetics", 6th or latest edition. (optional)

Note: Contact the bookstore for current pricing of required textbooks.

3 Laboratory Sessions

Three hours every alternate week as per schedule and location posted on Brightspace.
Note 1: All sessions are mandatory, and attendance will be taken. Zero will be assigned for the corresponding lab reports in case of absence.
Note 2: All HFSS/lecture-related questions must be posted on the Brightspace forum only, to avoid repetitions and so that everyone benefits.

3.1 Notes for Labs/Project

- There are a total of 5 course labs and 1 lab dedicated for project work.

- All deadlines mentioned in the course outline are firm. No late submission allowed, and will be automatically marked as zero.
- All labs will be in ME4140 in the Mackenzie building, except the first lab in MC6030 (Minto), which may be revised based on available resources.
- All lab reports must be prepared using LaTeX only (individually or as a group, as needed), using the templates provided, and submitted as a PDF file, with suggested section headings and specified page limits. The LaTeX template will be provided in advance.
- No entry in the hardware labs after 10 mins of the allocated time.
- Any unsafe practice, irresponsible usage of the equipments inside the lab, and any careless damage to components and equipments, judged by the course instructor and the teaching assistant will lead to immediate suspension from the labs, and the students will be barred to enter the labs until re-instated.
- The prepared document must be electronically submitted on Brightspace within 10 days.
- Reports must be named according to the following format:
  `Lastname_Firstname_ELEC_4502_Fall_2026_Lab_ #.pdf`

4 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. **No make up labs will be possible, and for missing the labs with a valid reason upon approval from the instructor within 1 days of the missed lab, the lab weight may possibly be transferred to the final exam.**

Requirement: Contact the instructor with the completed self-declaration form no later than 3 days after the date/deadline of term work, including tests/midterms, labs, or assignments.

Note: In engineering courses, the grade from a deferred examination replaces the final examination grade in the published grading scheme and the grade from deferred term work replaces the grade for that term work in the published grading scheme. Students who defer either term work or the final examination are evaluated using the same grading scheme as all others in the course.

5 Evaluation and Grading Scheme

The cumulative course grade will be determined as follows:

- **Course Labs (Labs 1–5)**: 25% of the overall grade (25 marks total).
- **Course Project (Lab 6)**:
  1. A preliminary project report must be submitted with the final layouts and complete simulation design and results by November 13, 2026. This report, in addition to the measurement results, will become the final project report. Missing preliminary report will be marked as Zero for the entire project.
  2. A complete final report is due on December 4, 2026. The report must include all measurements conducted during Course Lab 6. 15% of the overall grade (15 marks total).
- **Mid-term exam:** 10% of the overall grade, October 22, 2026 during lecture hours (10 marks total)
- **Closed-book Final Exam (During normal exam period)**: 50% of the overall grade.

5.1 Final Exam

- Scheduled during the examination period at the end of the Fall term.
- Traditional 3-hour closed-book format, in-person on campus.
- For evaluation purposes only and will not be returned.
- Students who miss the final exam may be granted permission to write a deferred examination. See the Undergraduate Calendar for regulations on deferred examinations.

5.2 Midterm

- Occurs during the course lecture, in-person on **October 22, 2026.**
- Open-book format. Students may bring any textbook material.
- No discussions between students allowed. Evidence of cheating will have serious consequences.
- Missing the midterm without a valid medical certificate or reason results in a mark of zero. With justified explanation, the midterm weight will be moved to the final exam.

5.3 Passing Requirements

To pass the course, you need:

1. Minimum term course grade of 50% **AND**
2. Minimum grade of 50% in the final exam.

6 Additional Requirements

- Students must review assignment and quiz grades as soon as they are returned. Any marking concerns must first be addressed to the TA. If clarifications are insufficient, bring the issue to the instructor's attention before December 10, 2026, for an informal appeal and re-marking.
- Course materials (including the course outline, slides, notes, videos, labs, projects, assignments, quizzes, exams, and solutions) are for personal use and may not be reproduced or redistributed without prior written permission from the instructor.
- Consult Section 5 of the undergraduate regulations: `https://calendar.carleton.ca/undergrad/regulations/academicregulationsoftheuniversity/grading/`

6.1 Generative Artificial Intelligence (AI)

Students may use AI tools for sharing ideas, clarifying challenging concepts, or getting started on projects. Some acceptable uses include:

1. Students may use AI tools for basic word processing and formatting functions, including grammar and spell checking, basic formatting and design suggestions.
2. Creating outlines (e.g., using AI to structure an essay or presentation flow).
3. Providing definitions or explanations of complex concepts (e.g., using AI to explain a difficult theory).
4. It is required to document your use of AI in this course, using the following guidelines:
    - Clearly identify and cite AI-generated text (e.g., 'The following paragraph was generated by ChatGPT/Microsoft Word's Researcher tool'). Please consult resources on the Library website.
    - Review, edit, and ensure the accuracy and originality of final submissions.
    - AI-generated content should not exceed 30% of the total work deliverable length.

This policy supports the use of AI as a supplementary tool, helping students develop ideas and structure their work while emphasizing the importance of transparency and personal engagement with the content. AI can be used for inspiration and foundational support, and can encourage students to critically assess and refine AI-generated material.

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.

Note: Students can also access resources related to citing Generative AI on the MacOdrum Library website. Additional resources are also available on https://carleton.ca/ai/.

Important: While the AI tools maybe used following these guidelines, the ownership of the work must belong to the students only, and they should be able to describe their work deliverables satisfactorily. In case, it is demonstrated that any submitted work was generated by AI and the student is unable to explain the work, in-person if and whenever deemed necessary, a grade penalty may be enforced following academic misconduct policy set by the university.

6.2 Exam Format and E-Proctoring

Engineering courses shall have on-campus and proctored final examinations.

7 Learning Outcomes

Upon successful completion of this course, students will be achieve the following outcomes:

1. **Master Microwave Component Fundamentals:** Develop a comprehensive understanding of microwave semiconductor devices, passive components (e.g., transmission lines, resonators), and their electromagnetic behavior, enabling effective design and analysis of RF circuits.
2. **Apply Network Theory and Scattering Matrix Analysis:** Gain proficiency in using network theory and scattering matrix techniques to model and optimize the performance of microwave circuits at high frequencies.
3. **Perform Advanced Electromagnetic Simulations:** Acquire expertise in using Ansys HFSS as the primary solver to simulate microwave components, mastering project setup, boundary conditions, mesh generation, and analysis of S-parameters and field distributions.
4. **Design and Prepare Microwave Layouts:** Develop advanced skills in using Keysight ADS for layout preparation, including creating precise layouts, performing design rule checks (DRC), and exporting designs to industry-standard formats like GDSII for fabrication.
5. **Conduct Precision RF Measurements:** Master the operation and calibration of RF measurement equipment (e.g., Vector Network Analyzer, Spectrum Analyzer, Frequency Generator) to measure S-parameters, insertion loss, return loss, and resonant frequencies with high accuracy.
6. **Analyze and Optimize Amplifier Performance:** Understand RF amplifier characteristics (e.g., gain, linearity, 1-dB compression point, IMD) and gain expertise in measuring and optimizing these metrics for practical applications using simulation and experimental data.
7. **Evaluate Resonator Performance and Tuning:** Gain proficiency in computing Q-factors for various resonators (e.g., ring, stub, open-ended) and studying resonance tuning in varactor-loaded ring resonators with DC biasing, assessing their impact on circuit design.
8. **ntegrate Simulation and Fabrication Processes:** Build skills to integrate Ansys HFSS simulation results with Keysight ADS layout designs, ensuring production-ready microwave circuits that meet performance specifications and fabrication constraints.
9. **Develop Project Management and Documentation Skills:** Enhance project management abilities by independently designing, fabricating, and characterizing an RF amplifier, and acquire professional skills in documenting results with detailed reports and appendices.
10. **Solve Practical RF Design Challenges:** Develop problem-solving and analytical capabilities to troubleshoot measurement setups, correlate experimental and simulation data, and propose design improvements for microwave circuits based on real-world performance insights.

These learning outcomes encompass the theoretical foundations, practical skills, and project-based experience outlined in the course and lab descriptions, preparing students for advanced work in microwave engineering and related fields.

8 Academic Integrity and Plagiarism

1. 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.
2. 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.).

9 Academic Accommodations

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

1. **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 here.
2. **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.
3. **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).
4. **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 here.

5. **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. See here.