Carleton University
Department of Electronics

ELEC 4502A: Microwave Circuits **Fall 2024**

Course Schedule:

Lecture Wed/Fri 2:35 pm-3:55 pm ME 4342
Lab A1O Wed 8:35 am-11:25 am, ME 4140

Instructor: Prof. Barry Syrett , Room ME 4150, BarrySyrett@cunet.carleton.ca

Teaching Assistant: Shakeeb Abdullah, ShakeebAbdullah@cmail.carleton.ca

Calendar Description:

ELEC 4502 [0.5 credit]
Microwave Circuits
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.
Prerequisite(s): ELEC 4503; may be taken concurrently.

Includes: Experiential Learning Activity
Lectures three hours a week, laboratory three hours alternate weeks.

Course Description

The design of circuits to operate at RF/microwave frequencies is a specialized art, requiring both a good knowledge of conventional circuit design concepts and a very good understanding of wave propagation effects (transmission line behaviour). In this course you will learn the fundamentals of microwave circuit design theory, use state-of-the-art CAD tools (ADS), fabricate hybrid microwave integrated circuits, and test these circuits to become familiar with basic microwave measurements. This will involve two formal laboratories and two design projects. The course is strongly design orientated to development of practical design skills through the two design projects, and use of ADS.

Lecture Outline:

This course is offered in the same term as the co-requisite course ELEC4503.
There will be some necessary overlap in material during the first few weeks, but this should strengthen the student's understanding of transmission line theory and Smith Chart usage.

3 weeks	TEM waves on transmission lines; transmission line theory; Smith Chart usage; Scattering parameters; microstrip transmission line.
1 week	Microwave circuit theory
2 weeks	Impedance matching
1 week	Microwave resonators
1 week	Basic theory and operating characteristics of microwave semiconductor devices(bipolar transistors, GaAs FETs, varactor diodes, PIN diodes)
4 weeks	Microwave transistor amplifier and oscillator design.
1/2 week	Wilkinson splitter, hybrid couplers
All weeks	CAD design using Keysight ADS

Labs:

There are 2 lab experiments. The lab instruments involved are the network analyzer, spectrum analyzer, power meter, and noise figure meter.

Lab 1 --- Operating Characteristics of a Microwave Amplifier
(Spectrum Analyzer, AM/AM and AM/PM Conversion, Harmonic Distortion)
Lab 2 --- Noise Figure Measurements

A lab report will be submitted for each lab. This report should include the measurement set-up, a clear description of the measurement performed, data, sample calculations, discussion of results and conclusions. It is NOT a formal lab report with Purpose, Apparatus, Observations etc.

Design Projects:

In order to give the student some experience in all the steps of microwave circuit design, (device characterization, computer-aided circuit analysis and optimization, circuit board layout, and testing), each student will individually design, construct and test two hybrid microwave integrated circuits. These projects should be considered as extended problem analysis/lab sessions ---- the student will be guided through the complete design process. The student will also become familiar with operation of the Vector Network Analyzer for microwave device characterization.
The two projects are:
Project 1 --- Microstrip Edge-Coupled Bandpass Filter
Project 2 --- Bipolar Transistor Amplifier

An engineering report must be submitted for each design by the due dates (to be announced).
The engineering reports will be graded on the basis of report organization, presentation (clarity of writing, grammar, and neatness), technical design content (accuracy and originality), measured circuit performance, and discussion of results.

Problems:

Several problems will be assigned each week to help the student understand the lecture material and prepare for the final exam. The weekly homework exercises will develop your problem-solving skills and also in some cases require you to research new information. The student's solutions will not be submitted or graded. Solutions will be available from the TA or be posted on the website.

Health and Safety:

Respecting lab safety precautions and following directions of lab staff is essential to keep everyone safe.

It is important to remember that COVID is still present in Ottawa. The situation can change at any time and the risks of new variants and outbreaks are very real. There are a number of actions you can take to lower your risk and the risk you pose to those around you including being vaccinated, wearing a mask, staying home when you're sick, washing your hands and maintaining proper respiratory and cough etiquette. Should you have questions, please contact covidinfo@carleton.ca.

General lab safety precautions are still important and can be found at https://carleton.ca/ehs/programs/working-lab/laboratory-health-and-safety/

Learning Outcomes:

On completion of this course you will be able to:
1) appreciate the limits of conventional circuit design using lumped elements and understand the principles of distributed circuit design at high frequencies;
2) demonstrate proficiency in distributed-circuit design of microwave matching networks, filters, couplers, power dividers and amplifiers using analytical (theory), graphical (Smith Chart) and CAD methods;
3) design, simulate, layout, fabricate and test microwave hybrid integrated circuit (microstrip technology) components;
4) use Agilent ADS software for microwave circuit design and optimization;
5) perform scattering parameter measurements (by vector network analyzer) to determine load impedance, return loss, transducer loss, and perform error correction using the one-port or two-port SOLT calibration procedure;
6) understand noise sources and the theory for low noise amplifier design, and perform noise figure and associated gain measurements;
7) understand and measure gain compression, harmonic distortion, intermodulation distortion in microwave amplifiers;
8) understand the principle of oscillation and perform microwave transistor oscillator design;

9) perform special project design with defined specs on microwave transistor amplifier;
10) organize and write technical reports.

Precluded courses: none

Prerequisites (and recommended knowledge):

Prerequisite(s): ELEC 4503; may be taken concurrently.
The course assumes 3rd year-level knowledge of electromagnetic fields and eaves normally covered in ELEC 3105 and ELEC 3909

Accreditation Units:

Accreditation units (AU's) are used by the Canadian Engineering Accreditation Board (CEAB) to determine if an Engineering program meets a minimum number of class hours required for accreditation in each of 5 components: math, natural science, engineering science, engineering design, and complementary studies. Accreditation metrics are based on courses common to all students in a program. ELEC 4502 is an elective course and is not included in AU counts.

Graduate Attributes:

The Canadian Engineering Accreditation Board (CEAB) requires graduates of undergraduate engineering programs to possess 12 attributes: Graduate-Attributes.pdf (engineerscanada.ca) or GA's. Accreditation metrics are based on courses common to all students in a program. ELEC 4502 is an elective course so it does not include GA assessments.

Textbooks:

Lecture notes and lab materials (pdf) will be available on the course website in Brightspace.

The textbook (recommended but not necessary to purchase) is "*Microwave Engineering*" (4th edition, Wiley) by D. Pozar. It was not ordered it for the bookstore but it can be purchased on amazon.ca. There is a cheaper paperback version also. Note the shipping times.

Keysight Technologies Application Note *"RF Design Software Learning Kit: Step-By-Step Examples on Using ADS Software for an Introductory RF/Microwave Course"* available at
www.keysight.com/us/en/assets/7018-05596/application-notes/5992-2079.pdf

Weekly reading and exercises will be assigned from this application note.

Evaluation and Marking Scheme:

Considerable emphasis is given to hands-on design experience during the course as reflected in the following grade breakdown.

2 lab reports	6% (4% for Lab 1 and 2% for Lab 2)
2 engineering reports	44% (22% each)
Part 1 of Final examination	10% in class near end of term (open book, class notes only)
Scheduled Final examination	40% (open book, class notes only)

Each student must submit both lab reports and both engineering reports. A student must receive at least 50% for the lab reports and engineering reports segment of the total grade in order to pass the course. Also, the final exam must be completed with a minimum grade of 40% to pass the course.

The final examination is for evaluation purposes only and will NOT be returned to the student.

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

Deferred Final Examination:

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/)

Missed 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 making alternate arrangements with the instructor. In all cases this must occur no later than three (3) days after the term work was due. The alternate arrangement must be made before the last day of classes in the term as published in the academic schedule. Consult Section 4.4 of the University Calendar.

Copyright:

The materials (including the course outline and any slides, posted notes, videos, labs, project, assignments , quizzes, exams and solutions) created for this course and posted on the web site are intended for personal class use and may not be reproduced or redistributed or posted on any web site without prior written permission from the author(s).

Generative Artificial Intelligence (AI):

Use of generative AI tools (such as ChatGPT) in course work is prohibited unless explicitly authorized by the course instructor for specific elements of the course. Submission of AI generated work without authorization may lead to an academic integrity investigation.

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 acknowledgement;
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own; and
- failing to acknowledge sources of information through the use of proper citations when using another's work and/or failing to use quotation marks.

Advising and Counselling services

(a) Engineering Academic Advising

The Engineering Academic Support Service : https://carleton.ca/engineering-design/current-students/undergrad-academic-support/ assists undergraduate engineering students with course selection, registration, and learning support from first-year through to graduation.
Academic advisors contact information: https://carleton.ca/engineering-design/current-students/undergrad-academic-support/undergraduate-advisors/

(b) Student Mental Health Service

As a University student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. Carleton's Wellness Services Navigator https://wellness.carleton.ca/navigator/ is designed to help students connect with mental health and wellness resources. If you need to talk to someone, please reach out for assistance: https://carleton.ca/health/emergencies-and-crisis/.

Learning and Working Environment:

The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca

We strive to create an environment of mutual respect for all through equity, diversity, and inclusion within this course. The space which we work in will be safe for everyone. Please be considerate of everyone's personal beliefs, choices, and opinions.

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).