Carleton University
Department of Electronics

Engineering ELEC 4502 Microwave Circuits

Course Outline **September 2020**

Instructor

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Course web page: www.doe.carleton.ca/courses/ELEC4502

Course Objective

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.

Textbook

1) The textbook (recommended but not necessary to purchase) is " Microwave Engineering" (**4th edition,** Wiley) by D. Pozar. I have not oredered it for the bookstore due to Covid 19. It can be purchased on amazon.ca .There is a cheaper paperback version also. Note the shipping times.
2) Tutorial on ADS (**purchase**) " RF Design Software Learning Kit: Step-By-Step Examples on Using ADS Software for an Introductory RF/Microwave Course" by Keysight Technologies, paperback. Order on amazon.ca (Cdn$27.65). There will be weekly assignments from this book. Purchase and have it delivered before the first class.
3) Lecture notes and lab materials (pdf) will be available on the course website.

Course Delivery During Covid 19 Pandemic

This course will be offered in synchronous format, that is at the scheduled lecture and lab times, unless otherwise notified.

Lecture Outline (Tuesday and Thursday. 4:00-5:30, on Big Blue Button)
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 (Pathwave) ADS

Laboratory (Wednesday 8:30-11:30, odd weeks, online method tba)
There are 2 lab experiments. The labs will be done remotely with more details available later. 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.

You will have access to Keysight ADS online.

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.

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

2 lab reports	10%	
2 engineering reports	50%	(25% each)
Midterm examination	10%	(actually near end of term)
Final examination	30%	(1/3 may be oral component depending on class size and timing; oral exam will be based on general principles)

Each student must submit both lab reports and both engineering reports. A student must receive at least 50% for each of the lab report-, engineering report-, and final examination segments of the total grade in order to pass the course. The final examination is for evaluation purposes only and will NOT be returned to the student.

Students who miss the final exam may be granted permission to write a deferred examination (see the Undergraduate Calendar for regulations on deferred examinations).

Major Measurable 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.

Student Responsibilities in the Laboratory

1) Attend each lab punctually. Absence (without permission of the instructor) means NO MARK for that lab. If you have a valid reason for missing a scheduled lab, the lab must be completed as soon as possible after the scheduled lab period.
2) Be prepared for the lab experiment by reading the lab instruction sheets before entering the lab. You will be part of a lab group, but each student must submit his/her own lab report. The lab report is due one week following the scheduled lab period.
3) NO FOOD or DRINK is permitted in the lab or computer rooms.

Plagiarism

Plagiarism is a serious instructional offense that will not be tolerated. It involves passing off someone else's original work as your own. Most cases of plagiarism can be avoided by carefully citing sources

for any ideas, statements, results etc. that are not your own. Please refer to the section on instructional offenses in the Undergraduate Calendar for additional information.

Academic Accommodation

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

Pregnancy obligation**:** write to me 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 visit the Equity Services website: http://carleton.ca/equity/accommodation/student_guide.htm

Religious obligation**:** write to me 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 visit the Equity Services website: http://carleton.ca/equity/accommodation/student_guide.htm

Students with disabilities requiring academic accommodations**:** in this course must register with the Paul Menton Centre for Students with Disabilities (PMC) for a formal evaluation of disability-related needs. Documented disabilities could include but are not limited to mobility/physical impairments, specific Learning Disabilities (LD), psychiatric/psychological disabilities, sensory disabilities, Attention Deficit Hyperactivity Disorder (ADHD), and chronic medical conditions. Registered PMC students are required to contact the PMC, 613-520-6608, every term to ensure that I receive your *Letter of Accommodation*, no later than two weeks before the first assignment is due or the first in-class test/midterm requiring accommodations. If you only require accommodations for your formally scheduled exam(s) in this course, please submit your request for accommodations to PMC by the last official day to withdraw from classes in each term. For more details visit the PMC website: http://www.carleton.ca/pmc/students/acad_accom.html