ECEN 5014 – Active Microwave Circuits, Spring 2024

Prof. Zoya Popovic and Prof. Laila Marzall

- ***Goals***: to learn various techniques used in circuit design at microwave frequencies. We will cover linear and nonlinear circuits required to build a super-heterodyne transceiver, and related topics that are relevant to microwave component and system design. The class consists of 7 projects and a final project which is a MMIC design.
- ***Projects:*** Most are 2 weeks long – make sure you start on time, since it will be difficult to complete any of them at the last minute. The project reports will vary from project to project. The reports and grading are designed to train you in the following: paper writing, technical presentations, technical evaluations, and research proposals.
- ***Level:*** MS and undergraduate students will be given less assignments within each project compared to PhD students.

Class: Tuesday/Thursday 3:30-4:45pm, ECEE 1B-32

Office hours: Monday 5-7pm and if needed on Fridays, ECEE 254 (RF lab)

CAD tools:
You can use one or both of the two main CAD tools used in industry: ADS (Agilent) and Microwave Office (AWR, now Cadence). We have licenses for both tools.

Microwave Office is generously provided to all of you from Cadence for up to a year following graduation. To obtain the software, follow this:

- Go to https://awrcorp.com/register/customer.aspx?univ
- Use my name for the professor information.
- If you have previously already registered on the AWR website, you will use the same account to get the software.
- If you have not previously registered, the license generation will send you an email with the account login information.
- You will then obtain a license file with a link to the software download area.

ADS is generously provided by Keysight:

- Get the latest version of ADS INSTRUCTIONS

Grading:

	Percentage	**Comment**
Projects	45%	Bi-weekly, N_p=7
Final exam	25%	Closed everything
Final project	20%	MMIC design and submission for tape-out

Textbook:

- There is no official textbook for the class. We recommend having a copy of Dave Pozar's microwave engineering book and will assign chapters from a few other texts throughout the course.
- We will post notes for every week, as well as some classic papers.

There are a number of reference books you can use in my office and check out for a few hours:

Topic	Title	Author/Publisher
Microstrip	Foundations for microstrip circuit design	T.C. Edwards, Wiley '91
Active devices	RF and microwave passive and active technologies, Vol. 2 of RF and Microwave Handbook	Mike Golio (editor); CRC Press 2008
	HEMTs and HBTs: Devices, Fabrication and Circuits	Fazal Ali, Aditya Gupta; Artech House '94
	Microwave MESFETs and HEMTs	Mike Golio; Artech House '91
	Modern microwave transistors	F. Schwierz, J.J. Liou, Wiley, 2003
Linear amplifiers	Microwave transistor amplifiers; Analysis and Design	G. Gonzalez, Prentice Hall, 1997
Nonlinear amplifiers	Power Amplifiers for Wireless Communications	S. Cripps, Artech House, 2006
	Fundamentals of Microwave Transistor Amplifiers	Inder Bahl, Wiley, 2009

Approximate class schedule / topics / projects (please read updates – the order and topics might change depending on class background and interests) :

Week	Topics	Comments
1 Jan 16 Jan 18	Review of relevant microwave techniques (vocabulary) Impedance matching (various kinds), couplers, bias tees **Project 1 assigned (matching network and coupler design)**	From Pozar, notes and classic paper
2 Jan 23 Jan 25	Equivalent circuit models for microwave FET devices Small-signal linear amplifiers Basic amplifier circuit, stability **Project 1 due** **Project 2 assigned (small-signal gain amplifier)**	From notes, Edwards, Golio, Schwierz and Ingvesson From Gonzales and notes
3 Jan 30 Feb 1	Broadband amplifiers (resistive feedback, balanced, distributed, travelling wave) **Project 2 due** **Project 3 assigned (broadband amplifiers)**	From Gonzales and notes
4 Feb 6 Feb 8	Thermal and quantum noise Noise figure and noise temperature	From classic paper by Oliver, as well as notes and Gonzales
5 Feb 13 Feb 15	Low-noise amplifiers PA Introduction: Nonlinearity mechanisms in PAs **Project 3 due** **Project 4 assigned (LNAs)**	
6 Feb 20	Power amplifiers (reduced conduction angle classes, harmonically-terminated classes, switched-mode classes)	From notes and Cripps and Bahl

Feb 22	Power amplifier efficiency and linearity Resonators	
7 Feb 27 Feb 29	MMIC circuit technology MMIC pdk **Project 4 due** **Project 5 assigned (PAs)**	From notes, some books and WIN manuals
8 Mar 5 Mar 7	Oscillators (two-terminal, transistor oscillators and VCOs) Phase noise in oscillators **Project 6 assigned (oscillators)**	
9 Mar 12 Mar 14	Detectors Mixers Rectifiers **Project 5 due**	Tony Kerr's classic paper (mixers)
10 Mar 19 Mar 21	Rectifiers Limiters **MMIC proposal due (1 page)**	
Spring break, No class last full week of March, 25th – 29th		
11 Apr 2 Apr 4	Switches Phase shifters **Project 6 due** **Project 7 assigned (mixer/detector or switch/phase shifter)**	Old HP product note (now Keysight)
12 Apr 9 Apr 11	Direct and Superheterodyne transceivers Modulation (radar and comms) **Preliminary MMIC design review (turn in slides)**	From notes and several specialized books
13 Apr 16 Apr 18	Phased array Antenna theorem **Project 7 due**	
14 Apr 23 Apr 25	Review MMIC design review in class	
15 Apr 30 May 2	Office hours during class **Final MMIC projects due on May 2nd, electronically**	
Final exam scheduled time: Monday, May 6th, 1:30-4pm		

OTHER GENERAL CLASS RULES AND GUIDELINES

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

Requirements for Infectious Diseases
Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all public health orders to reduce the risk of spreading infectious diseases.

The CU Boulder campus is currently mask optional. However, if masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct & Conflict Resolution. Students who require accommodation because a disability prevents them from fulfilling safety measures related to infectious disease will be asked to follow the steps in the "Accommodation for Disabilities" statement on this syllabus.
For those who feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the further guidance of the Public Health Office. For those who have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home.

Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation
Disability Services determines accommodations based on documented disabilities in the academic environment. If you qualify for accommodations because of a disability, submit your accommodation letter from Disability Services to your faculty member in a timely manner so your needs can be addressed. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance.

Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Honor Code
All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@~~colorado~~.edu); 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

Preferred Student Names and Pronouns
CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation
The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual

misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about OIEC, university policies, reporting options, and the campus resources can be found on the OIEC website. Please know that faculty and graduate instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options.

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. *In this class, the students, as well as the instructors, are encouraged to inform the class about the religious holiday they wish to observe at least three weeks in advance, and we will jointly decide on an accommodation that everyone feels is equitable and fair.*

See the campus policy regarding religious observances for full details.