ECE 488 / 588 – Microwave Engineering II – Active Circuit Design
Course Syllabus, Spring 2013

Lectures: T – Th 9:30am – 10:45am, ECE – 102

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Secretary: Ms. Caroll Mainvielle, Room 228, Phone: 621-2435
Office Hours: Tues: 3:30-5:00pm, Th: 3:30-5:00pm, or by appointment, ECE 356E
Teaching Assistant: ???
Text: *Microwave and RF Design – A System Approach*, Michael Steer, SciTech Publishing
Suggested Readings: *Microwave Transistor Amplifiers* 2nd Edition, Guillermo Gonzales, Prentice-Hall, 1997. *Nonlinear Microwave Circuits*, Stephan Maas, IEEE Press
Class Web-site: www.ece.arizona.edu/~ece488-588
Prerequisite: ECE 486/586 – Microwave Engineering I, basic knowledge in solid-state devices, basic operation of UNIX system

INTRODUCTON:

ECE 488/588 is used to:

- Understand various modulation schemes
- Understand basics of wireless transmitters and receivers
- Understand basics of Antennas and wireless link
- Understand fundamentals of RF systems
- Design various matching networks
- Design single-ended, balanced, and sub-harmonic microwave mixers
- Design single-stage microwave amplifiers for maximum gain performance
- Design microwave low-noise amplifiers
- Design broadband and high power microwave amplifiers
- Design multi-stage microwave amplifiers
- Design DC bias networks for microwave amplifiers
- Understand basics of microwave transistor oscillators
- Evaluate the performance of various active microwave circuits based on their characteristics

Microwave engineering is growing in importance with each passing year. It has application to the wireless industry and to high density electronic packaging for computer systems with fast clock speeds. Some common applications of passive microwave circuits include communication systems (e.g., satellite-to-ground link), mobile phones and wireless local-area-network, radar, navigation and guidance systems (e.g., GPS), antennas, radio astronomy, electronic warfare, remote sensing, and biomedical devices.

GENERAL PROCEDURES: This course will consist of lectures, reading assignments, practicing problems, (2) mid-term exams/quizzes, a midterm project and a final exam.

The dates for the mid-term exams are: Exam 1, Feb. 14th 2013 (in-class); Exam 2, April 28th 2013 (in-class), Final Exam date will be on May 7th 2013 (8 – 10AM). Homework consisting of practicing problems (and occasional opportunities for extra-credit) will be assigned each Thursday and collected the following Thursday in class. Only selected homework sets will be randomly graded. It is very important to work out all of the assigned problems. The assignments for ECE 488 and ECE 588 will be different. The workload is not intended to be overwhelming, yet it is distributed to encourage you to keep up with the course material and it accounts for **15%** of the final grade. The exams/quizzes will be a combination of fill in the blank and worked problems. I will draw on a combination of material discussed in class, in the books, and from your homework assignments. If you expect to miss a lecture, you are welcome to have a colleague record the lecture or take notes for you. Keep an eye on the web-page for a list of handouts that will be available for download. Not every class will have handouts. Homework assignments, solutions, test solutions will be available on the ECE 488/588 course web-page. Be sure to check the web-page at least twice a week for special announcements that come up during the semester.

ATTENDANCE: Roll will be taken in the lecture only for a few meetings. Students are expected to take part in general class discussions and any group activities. The exam dates are firm and not negotiable. Do not enroll in the course if you expect to be absent on any of these days. **There will be no make-up tests.** If a student has a legitimate reason for missing a midterm exam and he/she notifies me before the exam, he or she will be assigned a grade that is the average the remaining exams. The midterm project must be turned in and the final exam must be taken in order to receive a grade. Let me know if you require special accommodations to take the midterms and the final within the next week. I will need time to arrange for you to take your exam through the testing center.

HOMEWORK: Homework will be assigned every week on Thursday and will be due the following Thursday. Solutions for each assignment will be posted after the due date on the course website. Not all the homework will be graded. If you find a grading error, write a note on your paper explaining the problem and I will make the final decision on it. It may take some time to resolve the problem.

EXAMS: There will be two mid-term exams and one final examination. Participation in all the exams is **mandatory**. All exams will be open book and open notes. Any suspected grading errors must be reported no later than the next class meeting after the exam is returned to you. The exam will be designed to test if you know the basic concepts and if you know how to apply them.

PROJECT: The design project and the associated laboratories are a fundamental part of this class. Students will be required to go through a complete design iteration of an active circuit that includes devices survey, selection, and ordering, initial design according to specifications, simulation and circuit optimization, fabrication, and measurements. For this purpose, Agilent ADS software tool will be extensively used. Participation in the laboratory for circuit fabrication and measurement is **mandatory** (absence will result in loss on the final grade). At the end of the iteration cycle student

will submit a detailed report on the work they performed. Completing and submitting the project report is also **mandatory**, since the laboratory is an essential component of this class. Failure to submit the required report will result in the loss of all the credit for the project.

WITHDRAWALS: You may withdraw without instructor permission up to and including Feb. 5th, 2013. After Feb. 5th 2013, you may withdraw with the permission of the instructor. This permission will be given in all cases, but you must obtain the instructor's signature on a DROP-ADD form. Simply ceasing to attend does not drop you from the course and you will receive a grade of E. There will be **NO** withdrawals after March 5th, 2013. Incompletes will only be given if the student is doing passing work and is prevented from completing a small portion of the course work by illness or other legitimate emergency. Please note that if you are on the class roll at the end of the semester, you will receive a grade of zero for any work not completed and will be graded accordingly. It is up to the student to keep track of the enrollment/withdrawal deadlines and paperwork.

GRADING:

Your grade in the course will be computed as follows:
- Midterm 1: 15%
- Midterm 2: 15%
- Homework: 15%
- Design Project: 30%
- Final Exam: 25%

Be sure to check the ECE 488/588 web-page periodically for course and information updates: www.ece.arizona.edu/~ece488-588

Grading Criteria of 488 and 588

ECE 488 and ECE 588 will be tracked and graded accordingly with separate grade books and class performance statistics. ECE 488 will be geared toward the undergraduate students who have successfully completed ECE 486. The homework assignments will consist of 4-5 worked problems and will be assigned on a weekly basis. Many homework assignments will also involve computer simulations using Agilent Advanced Design Systems. The students should be familiar with ADS through ECE 486. The in-class midterm exams will consist of 4-5 worked problems and 1-2 essays and fill in the blank questions.

ECE 588 will be geared toward the graduate student who has successfully completed ECE 586 and has additional technical electives in electromagnetic courses. The mathematics background and computer programming skills of the ECE 588 students is expected to be more in-depth than the ECE 488 students. The homework assignments will consist of 6-7 worked and will be assigned on a weekly basis. The homework assignments will also consist of 1 or 2 "research study" related problems that involve a

comparative study between some of the different equations and concepts discussed in-class. The in-class midterm exams will consist of 6-7 worked problems and 1-2 essays and fill in the blank questions. The ECE 588 students are expected to have a strong electromagnetic background, and thus they are expected to be able to solve more problems than the ECE 488 students in the same time allotted for an in-class midterm exam. The ECE 588 midterm questions will involve additional mathematical derivations than the questions assigned to the ECE 488 students. The ECE 588 students are expected to consult additional resources, such as journal articles and other microwave books, to help supplement the material we discuss in class and to solve some of the take home problems.

Tentative Lecture and Exam Schedule

Lecture	Day	Date	Topic Reading	Reading
1.	Th	1/10	Introduction and Review	Notes
2.	Tue	1/15	Introduction of Modulation Techniques	Ch. 1.1 – 1.3
3.	Th	1/17	Digital Modulation I	Ch. 1.4
4.	Tue	1/22	Digital Modulation II	Ch. 1.4 - 1.6
5.	Th	1/24	Receivers, Modulators and Demodulators	Ch. 1.7 - 1.9
6.	Tue	1/29	Antennas	Ch. 2.1 – 2.5
7.	Th	1/31	Radio Link	Ch. 2.6 – 2.8
8.	Tue	2/5	Radio Systems	Ch. 3.1 – 3.9
9.	Th	2/7	Cellular Radio: 1G – 3G	Ch. 3.10 - 3.14
10.	Tue	2/12	Beyond 3G and Radar	Ch. 3.11 - 3.13
11.	Th	2/14	**EXAM 1**	
12.	Tue	2/19	Matching Networks	G. Ch. 2.1 - 2.4
13.	Th	2/21	Microstrip Matching Networks	G. Ch. 2.5
14.	Tue	2/26	Microwave Transistors	G. Ch. 1.11
15.	Th	2/28	Scattering Parameters and Signal Flow Graphs	G. Ch. 1.9, 1.10, 2.6
16.	Tue	3/5	Power Gain Expressions and VSWR Calculations	G. Ch. 2.7, 2.8
17.	Th	3/7	Stability Considerations	G. Ch. 3.1 - 3.3
		SPRING	BREAK – 3/9 – 3/17/2013	
18.	Tue	3/19	Constant Gain Circles	G. Ch. 3.4 – 3.5
19.	Th	3/21	Simultaneous Conjugate Match	G. Ch. 3.6
20.	Tue	3/26	Operating Power Gain Circles	G. Ch. 3.7
21.	Th	3/28	Available Power Gain Circles	G. Ch. 3.7
22.	Tue	4/2	VSWR Circles and DC Bias Networks	G. Ch. 3.8 – 3.9
23.	Th	4/4	Noise in Microwave Systems	G. Ch. 4.1 – 4.2
24.	Tue	4/9	Constant Noise Figure Circles	G. Ch. 4.3
25.	Th	4/11	Design of Low-Noise Amplifier	G. Ch. 4.3
26.	Tue	4/16	Broad-Band Amplifier Design	G. Ch. 4.4 – 4.5

27.	Th	4/18	**EXAM II**	
28.	Tue	4/21	High-Power Amplifier Design	G. Ch. 4.7
29.	Th	4/23	Two-Stage Amplifier Design	G. Ch. 4.8
30.	Tue	4/28	Oscillation Conditions	G. Ch. 5.1 – 5.2
31.	Th	4/30	Review	

Final Exam – 8AM – 10AM, May 7th 2013,
ECE-102

Expected Microwave Engineering II Outcomes

By the end of the course, the students are expected to be able to:

1. Understand various modulation schemes
2. Understand basics of wireless transmitters and receivers
3. Understand basics of Antennas and wireless link
4. Understand fundamentals of RF systems
5. Design lumped element matching networks
6. Design single and double stub matching networks for various loads
7. Apply single / double stub matching network designs for circuits in microstrip form
8. Create all active circuit designs in microstrip form
9. Identify the diode equation and the small signal model and equivalent circuit
10. Explain the role and operation of the depletion and diffusion capacitance
11. Describe the operation of a Schottky barrier diode
12. Explain how diodes can be used for RF/microwave signal detection and mixing
13. Identify the various types of microwave mixers, as well as parameters used for the evaluation of their performance
14. Design a single diode microwave mixer
15. Design a balanced microwave mixer
16. Design a sub-harmonic microwave mixer
17. Design a microstrip mixer
18. Determine which type of diode needs to be used for a specific microwave mixer design
19. Describe the characteristics of Bipolar and FET microwave transistors
20. Identify the small-signal electric models of microwave transistors
21. Apply the transistor model to evaluate its S-parameters
22. Explain how the S-parameters of a transistor can be measured
23. Apply signal flow graphs to evaluate scattering and other parameters of microwave circuits
24. Identify the different power gain expressions of microwave amplifier circuits
25. Calculate power gain expressions of a microwave amplifier from S-parameters
26. Calculate the input and output VSWR of a microwave amplifier
27. Determine the stability of an amplifier from the transistor, matching networks, and terminations

28. Explain when a two-part network is unilateral
29. Outline the procedure for drawing the constant G circles for the unconditionally stable and potentially unstable cases.
30. Identify and evaluate the unilateral figure of merit
31. Design a microwave amplifier with maximum transducer power gain
32. Design a microwave amplifier for a specific operating power gain both for an unconditionally stable and potentially unstable cases
33. Plot power gain circles for a two-port network
34. Design a microwave amplifier for a specific available power gain
35. Design a microwave amplifier with a specific gain and input/output VSWR
36. Design a DC bias network for a microwave amplifier
37. Calculate noise parameters in microwave circuits and systems
38. Design a low-noise microwave amplifier using constant noise figure circles
39. Design a microwave amplifier with good ac performance (noise figure, available power gain, power output and input/output VSWR)
40. Design a broadband microwave amplifier
41. Design a feedback microwave amplifier
42. Distinguish between class A, B, and C microwave amplifiers
43. Design a microwave power amplifier
44. Identify intermodulation distortion
45. Evaluate the dynamic range of a microwave amplifier
46. Design a two-stage microwave amplifier
47. List and describe oscillation conditions
48. Describe the operation of one-port negative resistance oscillators
49. Apply the Nyquist test to determine conditions for unstable operations of a given circuit
50. Design a two-port negative resistor microwave oscillator
51. Identify different commonly used oscillator configurations
52. Explain the operation of varactor frequency multiplier
53. Design a balanced microwave multiplier
54. Determine which active microwave circuit to use depending on the application
55. Identify potential limitations in the circuit fabrication process
56. Explain how different fabrication steps can affect circuit performance
57. Perform microwave measurements for the active circuit of the design project
58. Explain differences between simulated and measured data of active microwave circuit
59. Propose solutions to meet specific design goals if those were not achieved at first design iteration