ECE 3113: Introduction to RF Circuit Design
A Term 2014
Syllabus

Department of Electrical and Computer Engineering
Worcester Polytechnic Institute

Professor: Reinhold Ludwig, AK228, ludwig@wpi.edu , 508-831-5315

Assistant: Mihir Hitendra Vaidya mhvaidya@wpi.edu

Office Hours/Help Sessions:

Dr. R. Ludwig	AK228	MTWRF 10:00 – 11:00 am
Mihir H. Vaidya	TBA	
	TBA	Lab project demos

Lectures: AK233 MTWRF 9:00 – 9:50 am

Homework: 6 assignments;

Exams: 3 exams; closed book, 1 sheet of notes; bring a calculator

Textbook: R. Ludwig, G. Bogdanov, RF Circuit Design: Theory and Practice, 2nd edition, Prentice Hall, 2009, ISBN-13: 9780131471375.
Book website: http://ece.wpi.edu/RF_Circuit_Design/

Related texts: G. Gonzales, *Microwave Transistor Amplifiers: Analysis and Design*, 2nd edition, Prentice Hall, 1996.

D.M. Pozar, *Microwave Engineering*, Addison-Wesley, Reading, MA, 3rd edition, 2005.

Course Website: http://ece.wpi.edu/courses/ece3113/

Grading:

	Each	Total
Exams 1 and 2	20%	40%
Final Exam		40%
6 homeworks	2.5%	15%
Design-effort		5%
		100%

Grade A (≥ 80%), B (60%-80%), C (50%-60%), NR (<50%)

Course Objectives:

This course is designed to provide students with the basic principles of radio frequency (RF) circuit design. It concentrates on such topics as fundamental concepts of transmission line theory, high frequency circuit behavior, designing tuning and matching networks and power flow considerations for analog systems as encountered in cell phones, base stations, transceivers (Bluetooth), and wireless LAN (WLAN) equipment.

After reviewing equivalent circuit representations for passive components, RF diodes, BJTs, FETs, and their respective input/output impedance behavior, the course examines the difference between lumped and distributed parameter systems. Key concepts such as characteristic impedance, standing waves, reflection coefficients, insertion loss, and the scattering or S-parameters will be explained and demonstrated.

Within the context of distributed circuit theory, the course will then focus on the graphical display of the reflection coefficient (Smith Chart) and its importance in designing matching circuits. Students will learn the difference between SPICE and Agilent's Advance Design System (ADS) circuit modeling. Biasing and matching networks for single and multi-stage amplifiers in the 900 to 2,000 MHz range are examined and optimized in terms of input/output impedance matching, inserting loss, and power flow. Depending on coverage, the course will finish with the design of a complete mixer or a low noise amplifier (LNA) circuit.

The assumed background is a basic analog design course such as ECE 3204 and/or the electromagnetics course ECE 2112. Exposure to MATLAB is helpful.

Lectures:

Lecture attendance is not mandatory, but strongly recommended. Some topics cannot be completely covered in lecture, so pay attention to the reading assignments. Short summaries of lecture notes will be available on the course website in advance. However, full lecture notes will not be distributed. The instructor will use the backboard extensively, and encourages students to keep their own lecture notes.

An approximate day-by-day schedule of ECE 3113 lecture topics follows.

Date	Day	Lecture	Topic	Reading	Homework
8/28	Th	01	Introduction and logistics	pp. 1 - 6	
8/29	F	02	RF Behavior of Passive Components	6 - 32	
9/02	T	03	Transmission Line Analysis (Review)	41 - 51	
9/03	W	04	General Transmission Line Equation	62 - 67	
9/04	Th	05	Lossless Transmission Line Model	67 - 78	**HW1 due @ 9am**
9/05	F	06	Special Termination Conditions	78 - 87	
9/08	M		Sourced and Loaded Transmission Lines	78 -87	
9/09	T	08	From Reflection Coefficient to Load Impedance (Smith Chart)	103 - 111	
9/10	W	09	Impedance Transformation	112 - 116	
9/11	Th	Review	Review of Part I	1 - 116	**HW2 due @ 9am**
9/12	F	**Exam 1**	RF behavior of passive components, transmission lines		
9/15	M	10	Admittance and Combined Smith Chart	123 - 127	
9/16	T	11	Parallel and Series Connections	127 - 137	
9/17	W	12	Single- and Multi-Port Networks	145 - 162	
9/18	Th	13	Network Properties	163 - 169	**HW3 due @ 9am**
9/19	F	14	Scattering Parameters	169 - 172	
9/22	M	15	Measurements of Scattering Parameters	172 - 175	
9/23	T	16	Scattering Parameters and Mismatched Source/Load	175 - 188	
9/24	W	17	Semiconductor basics, RF diodes	277 - 298	
9/25	Th	Review	Review of Part II (lectures 08-14)	103 - 172	**HW4 due @ 9am**
9/26	F	**Exam 2**	Smith Chart, network analysis		
9/29	M	18	RF diodes	298 - 306, 361 - 367	
9/30	T	19	Nonlinear and linear RF field effect transistor (FET) models	367 - 415	
10/01	W	20	Matching Networks	421 - 427	
10/02	Th	21	Matching Networks (continued)	428 - 439	
10/03	F	22	Matching Networks and Classes of Operation	446 - 452, 458 - 463	
10/06	M	23	Biasing and Setting Operating Points	463 - 479	
10/07	T	24	Power Flow of RF Active and Passive Devices	485 - 492	**HW5 due @ 9am**
10/08	W	25	Stability/Constant Gain	492 - 510	
10/09	Th	26	One-Stage RF Amplifier Design Example	Handouts	
10/10	F	27	Amplifier design example	Handouts	
10/13	M	28	Mixer/Osc. design examples	Handouts	
10/14	T	Review	Review of Course		**HW6 due @ 9am**
10/15	W	**Final Exam**	Cumulative Exam		
10/16	Th	-	Celebration - Boyton		

Homework:

The 6 weekly homework assignments are 15% of your grade. Homework is designed to help you learn the material as well as prepare for the exams. Homework solutions will be distributed in class on the due dates. Homework submissions after the solutions are available will not receive credit. Homework must be legible and must show all solution steps to receive full credit.

From time to time, the TA and I will hold help sessions each week to assist you with the course material, homework, as well as preparation for exams. See course website for an updated help session schedule. The instructor is also available to answer your questions for one hour after every lecture.

The TA grades the homework. He will attempt to return it within a few days of submission. An ECE mailbox is required for homework return. Be aware that the ECE department retains a sample of the homework submissions.

Lab project demonstrations:

The TA will schedule several lab project demonstrations where RF measurement equipment, such as network analyzers, will be used on real RF circuits. Attendance and participation in these demonstrations is strongly encouraged. These demonstrations will be scheduled on a per-student group, per-project basis and have no pre-determined dates at this time.

Exams:

The 3 exams are 80% of your grade, 20% each for the first and second exams, and 40% for the final. All exams are **closed book, closed notes**. You are allowed one 8.5"×11" sheet (both sides) of your own hand-written notes that you must attach to the exam when done. These notes must not be photocopies or printouts, otherwise points will be deducted (also if no notes where attached). You will need a calculator. You will be given 55 minutes to complete an exam.

The exams are graded on a partial credit basis. The final answer carries less weight than the solution approach. Be sure to clearly show all the steps in your solution, or you will not receive full credit even if the answer is correct.

A review session will be held during the normally scheduled lecture preceding each exam. Bring your homework and exam questions.

The first two exams are on Fridays. The instructor will try to grade your exams and distribute solutions (through email) by the following Monday. An ECE mailbox is required for exam return. Be aware that the ECE department retains a sample of the exams.

Generally, make-up exams will not be offered. The instructor can make exceptions for documented medical reasons, documented emergencies, and to honor religious observances. In cases of illness or emergency, the student must notify the instructor as soon as possible. In case of religious obligation, notify the instructor at least 2 weeks before the planned absence. Be aware that any make-up exam will likely be after the end of term.

Academic Honesty:

Please read the WPI academic honesty policy:
http://www.wpi.edu/Pubs/Policies/Honesty/.

Briefly, some collaboration among students is allowed during the preparation of homework, but you are not permitted to copy someone else's work. All the work you hand in is expected to represent your understanding of the material. Identical homework problem solutions will be considered cheating. Acts of academic dishonesty will be reported to the department head. The minimum penalty is an assignment score of 0 for all individuals involved. Stricter penalties may also be sought.