

The University of  
New South Wales



School of Electrical  
Engineering  
and Telecommunications

# ELEC9702

## RF Integrated Circuits

### COURSE INTRODUCTION— Session 1, 2009

#### Course Staff

Course conveners: Prof. Chee Yee KWOK, room EE242;  
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**Consultations:** Consultation times through the week will be agreed upon with students in the first couple of weeks of lectures to arrive at times that suit most students. Email queries are discouraged unless it is of a very brief and trivial nature.

#### Course details

**Credits:** The course is a 6 UoC course; expected workload is about 10 hours per week throughout the 12 week session.

**Contact hours:** The course consist of 3 hours of lectures per week, and laboratory demonstrations will be given during lectures time when needed

**Lectures:** Tuesday, 6pm–9pm (MorvB G3)

**Computer Labs::** Room EEG19

## COURSE INFORMATION

#### Context and aims

An essential module in any mobile and wireless communication system is the transceiver. The receiver transforms incoming RF signals from the antenna in to

signals that can eventually be processed digitally. The transmitter transforms the analog version of the digital stream at baseband into a RF signal of sufficient power level to be delivered to the antenna.

Over the past 10 years, the market drive has been to integrate the complete transceiver on a single substrate as a multi-chip module in silicon technology with comparable performance to what's existing. This includes the integration of passive components like inductors, varactors, bondpads and electrostatic protection devices on chip. Today, the technology has achieved more than 50% reduction in discrete components and more than 60-70% reduction in PCB area, using state of the art IC technology in the technology nodes below 100nm.

The drive to reduce complexity and chip area requirements has led to the implementation of direct conversion techniques - the RF signal is down converted to baseband with a single local oscillator frequency (also known as zero-IF architecture). The building blocks include amplifiers (low noise), filters, mixers and oscillators and RF power amplifiers. A phase locked loop is used as a frequency synthesizer to generate the local oscillator frequency.

This course is meant to teach students the art of designing RF transceiver modules in Si integrated circuit technology as distinct from the traditional RF design with discrete components on PCB. The course will discuss each of the building blocks in some detail. This course complements the knowledge taught in ELEC4602 dealing with basic microelectronics design and ELEC9701 dealing with mix-signal IC design.

**Aims:** The course aims to make the student familiar with design issues in radio frequency integrated circuits as distinct from RF design using discrete transistors with microstrip lines. This will enable the student to do analysis and design of RF ICs implemented at these frequencies.

### **Relation to other courses**

This is a postgraduate course, following on from the fourth year L4 elective, ELEC4604, offered to students in the Master of Engineering Science at the University of New South Wales. The course gives an advanced treatment in RF design for integrated circuits.

**Pre-requisites:** The pre-requisites for the course are ELEC3106 Electronics, ELEC4602 Microelectronics design or equivalent. It is essential that the students are familiar with circuit theory and basic analogue electronics as well as basic communication principles, covered in any EE undergraduate program.

**Assumed knowledge:** It is further assumed that the students are familiar with SPICE-like circuit simulators, and have a good computer literacy. Familiarity with Cadence would be a great benefit.

**Following courses:** This postgraduate course ELEC9702 RF Integrated Circuits, which is a core course in the Microsystems and Microelectronics specialisation of the Master of Engineering Science post-graduate coursework program offered by the school. Together with ELEC9701, this is the most advanced level of electronics course offered for a student progressing from year 1 to the masters coursework program.

**Old courses:** The course replaces previous course ELEC9340 Electronics Communication Systems

## Learning outcomes

After the successful completion of the course, the student will be able to:

1. Analyse and design RF integrated circuits
2. Use modern CAD design tools like CADENCE to simulate RF circuits
3. Use modern instrumentation to measure RF circuit parameters
4. Understand the limitations of conventional low frequency integrated circuit analysis and RF circuit analysis techniques. For the frequencies under consideration, the size of IC components places it near the point where distributed circuit analysis may be treatment will be required, in some cases.

The course delivery methods and course content address a number of core UNSW *graduate attributes*; these include:

1. The capacity for analytical and critical thinking and for creative problem-solving, which is addressed by the design task and tutorial exercises.
2. The ability to engage in independent and reflective learning, which is addressed by the design task.
3. The skills of effective communication, which are addressed by the reports.
4. Information literacy, which is addressed by the homework.

Please refer to <http://www.ltu.unsw.edu.au/content/userDocs/GradAttrEng.pdf> for more information about graduate attributes. *[Note, graduate attributes are supposed to link to learning outcomes; I think linking them to the learning process is a lot more appropriate for us.]*

## Teaching strategies

The course consists of the following elements: lectures, tutorial work, and assignments.

### Lectures

The lectures, delivered in class, will cover a range of RF IC topics. Beginning with an overall view of RF communication systems, basic RF design issues like non-linearity and noise. Revision of transmission line fundamentals, Smith charts, and S-parameters. The essential building blocks of a typical RF communication system will be considered and analysed. These include an extensive treatment on low noise RF amplifier design and optimisation within power constraint requirements. A wide range of mixer types will be analysed and noise performance compared. RF oscillators and VCO phase noise will be studied. Various types of RF power amplifiers including class C, D, E and F will be discussed. Phase locked loop systems will be analysed as a major building block of any RF communication system.

### Laboratory work

There is no formal laboratory work in this course. Some lecture time will be devoted, where appropriate, to demonstrate the use of measurement equipment(NWA) in RF work.

### **Home work**

The lectures can only cover the course material to a certain depth; students must read the textbook and reflect on its content as preparation for the lectures to fully appreciate the course material. Students are encouraged to read the text book and reference materials. Home preparation before attending lectures will give students the maximum benefit.

### **Self-guided tutorials**

There is no set tutorial times for this course. From time to time, as deemed necessary, some lecture times will be devoted to discuss solutions to tutorial questions.

### **Assignments:**

Two assignments will be set for this course. Assignments will allow the student to explore the subject in great depth and need to use advanced CAD tools to assist in the assignment. Deadlines for the submission of assignments are in the course schedule.

### **Assessment**

There are 2 components of the assessment in this course:

Assignment: 30% overall weight

Final examination: 70% overall weight

Assessment task due dates are given in the course schedule.

**Final examination:** The exam in this course is a standard closed-book 3 hours written examination. University approved calculators are allowed. The examination tests analytical and critical thinking

and

general understanding of the course material in a controlled fashion. Assessment is a graded mark according the correct fraction of the answers to the exam questions.

## COURSE SCHEDULE --- ELEC9702 RF integrated circuits design

WEEK	TOPIC	LECTURER		Notes
0 (2/3)				
1(9/3)	RF communication systems; Non-linearity , cascaded stages.	CYK		
2(16/3)	Noise models, device noise, Noise figure calculations, Friis eqn.; Dynamic range; RF passive IC components	CYK		
3(23/3)	Revision of transmission line principles; Smith chart; S-parameter; matching networks	CYK		
4(30/3)	LNA: intrinsic 2 port MOSFET noise parameters, power match vs noise match, power constrained optimisation	CYK		
5(6/4)	LNA: design examples, power gain, stability	CYK		
	BREAK			
6(20/4)	Mixers: fundamentals, nonlinear system based , multiplier based,	CYK	Ass 1 due	
7(27/4)	Mixers: potentiometric mixers, diode mixers, noise analysis of mixers	CYK		
8(4/5)	Oscillators: voltage controlled, phase noise	CYK		
9(11/5)	RF power amplifiers: Class C	CYK		
10(18/5)	RF power amplifiers: Class D, E, F	CYK		
11(25/5)	PLL: phase locked loop analysis	CYK		
12(1/6)	PLL:charge pump PLL, noise considerations	CYK	Ass 2 due	

# RESOURCES FOR STUDENTS

## **Textbooks: Prescribed textbook**

The following textbook is prescribed for the course:

Lee: Design of CMOS RF integrated circuits, Cambridge, 2004.

## **Reference books**

The following books are good additional resources for topics on RF Electronics and Circuits:

D. Leenaerts, et.al. : Circuits design for RF transceivers, Kluwer 2001

Pozar: Microwave and RF design of Wireless Systems, Wiley 2001

Razavi: RF Microelectronics, Prentice Hall, 1998

Everhard: Fundamentals of RF Circuit Design with low noise oscillators, Wiley, 2001

Ludwig & Bretchko: RF Electronics – Theory and Applications, Prentice Hall 2000

Technical papers from the IEEE Journal of Solid State Circuits.

## **Books covering assumed knowledge**

The following books cover material which is assumed knowledge for the course:

A.S. Sedra and K. C. Smith, *Microelectronic Circuits*. Oxford University Press, 4th ed., 1998.

## **On-line resources**

Some additional on-line resources relevant to the course:

Resource: course webct <http://vista.elearning.unsw.edu.au>  
library resources <http://info.library.unsw.edu.au/web/services/teaching.html>

## **CAD resources**

Students will use the PCs in the CAD Laboratory (room G19 or 16) for all assignments. The CAD tools used in this course is the industry standard Cadence design suite which run under the Linux system on the dual boot PCs. For specific details on how to log on, see the course web page. Students can access the CAD tools after hours on the dual boot PCs in the School computer laboratory located in room EEG19.

# OTHER MATTERS

## **Academic Honesty and Plagiarism**

Plagiarism is the unacknowledged use of other peoples work, including the copying of assignment works and laboratory results from other students. Plagiarism is considered a serious offence by the University and severe penalties may apply. For more information about plagiarism, please refer to <http://www.lc.unsw.edu.au/plagiarism>

### **Continual Course Improvement**

Students are advised that the course is under constant revision in order to improve the learning outcomes of its students. Please forward any feedback (positive or negative) on the course to the course convener or via the Course and Teaching Evaluation and Improvement Process.

### **Administrative Matters**

On issues and procedures regarding such matters as special needs, equity and diversity, occupational health and safety, enrolment, rights, and general expectations of students, please refer to the School policies, see <http://scoff.ee.unsw.edu.au/>.