# ECE 746
## Analysis and Design of RF ICs for Communications

COURSE OUTLINE

Please refer to the course website for updated information.

## CALENDAR DESCRIPTION

This course provides fundamental and in-depth knowledge of the analysis and design of radiofrequency (RF) integrated circuits (IC) in CMOS technology for wireless communications. The topics include the modeling of active and passive components for AC and noise analysis and design examples of amplifiers, filters, oscillators, PLL and frequency synthesizers. Circuit performance will be evaluated by both hand calculations and computer simulations. A good understanding of circuit analysis and CAD tools (e.g., HSPICE or SpectreRF) is required.

## SCHEDULE And MODE OF DELIVERY

The material for this course will be delivered through a mixture of online videos, textbook readings, live online lectures and tutorials (which are also recorded), and virtualized laboratories and projects. The platform for each component is noted at the end of each line.

Lecture: Thursdays 11:30 a.m. – 2:20 p.m.

## INSTRUCTOR

Dr. Chih-Hung (James) Chen
Email: chench@mcmaster.ca
Office: ITB-A321
Phone: 905-525-9140 ext. 27084
Office Hours**:** By appointment on Microsoft Teams

## COURSE WEBSITE/S

http://avenue.mcmaster.ca

## COURSE OBJECTIVES

By the end of this course, students should be able to demonstrate their competency and be knowledgeable on the operating principles, design methodologies, and analysis techniques of radio frequency (RF) integrated circuits (IC) and their applications. They will be measured using three metrics:

- Knowledge Base for Engineering - Competence in Specialized Engineering Knowledge Related to Electronic Devices and Circuits.
- Problem Analysis - Obtain substantiated conclusions as a result of a problem solution, including recognizing the limitations of the solutions.
- Investigation - Capable of selecting appropriate models and methods and identifying assumptions and constraints.

## ASSUMED KNOWLEDGE

Good knowledge of circuit theory, microelectronics, and microwave engineering. Special emphasis is on the semiconductor devices, small-signal models, scattering parameters, linear two-port network theory, circuit design (e.g., single-stage and differential amplifiers, passive and active filters, and negative feedback circuits), and circuit analysis (in both time and frequency domains).

## COURSE MATERIALS

Textbooks:
Bosco Leung, *VLSI for Wireless Communications*, Prentice-Hall, TK7874.75.L48, 2002

Reference Texts:
1. B. Razavi, RF Microelectronics, Prentice-Hall Inc., 1998.
2. T.H. Lee, The Design of CMOS Radio-Frequency Integrated Circuits, Cambridge University Press, 1998.
3. G. Gonzalez, Microwave Transistor Amplifiers: Analysis and Design, 2nd ed., Prentice-Hall Inc., 1997.
4. Lawrence P. Huelsman, Active and Passive Analog Filter Design: An Introduction, McGraw-Hill, 1993.
5. D.A. Johns and K. Martin, Analog Integrated Circuit Design, John Wiley & Sons, Inc., New York, 1997.
6. P.E. Allan and D.R. Holberg, CMOS Analog Circuit Design, 2nd ed.,Oxford Press, 2002.
7. B. Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill, 2001.
8. Clarke and Hess, Communication Circuits: Analysis and Design, Krieger, Reprint, 1994.
9. H.L. Krauss, C.W. Bostian, F.H. Raab, Solid State Radio Engineering, Wiley, 1980.

## COURSE OVERVIEW

| Week | Topic |
|---|---|
| 1 | Passive and Active Components at RF |
| 2 - 3 | Noise Theory |
| 4 - 5 | Design of Low-noise Amplifiers |
| 6 - 7 | Nonideality |

| | |
|---|---|
| **8** | Design of Active Mixers |
| **9 - 10** | Volterra Series |
| **11** | Voltage-controlled Oscillators (VCO) and Phase Noise |
| **12 - 13** | Design of Phase-locked Loop (PLL) |

At certain points in the course, it may make good sense to modify the schedule. The instructor may modify elements of the course and will notify students accordingly (in class, on the course website).

## ASSESSMENT

| Component | Weight | Note |
|---|---|---|
| Assignments | 60% | Three assignments (LNA, Mixer, and VCO) |
| Term Project | 40% | |
| Total | 100% | |

Late submissions of assignments or project reports are subject to a 20% penalty per day (less than one day is counted as one day).

## CONDUCT EXPECTATIONS

As a McMaster graduate student, you have the right to experience and the responsibility to demonstrate respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the *Code of Student Rights & Responsibilities* (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery) will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

## COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright-protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors.

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution or by a student for the purpose of personal study. Students should be aware that their voices and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

## ACADEMIC ACCOMMODATIONS OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make arrangements with a Program Coordinator. For further information, consult McMaster University's *Academic Accommodation of Students with Disabilities* policy.

## ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within ten (10) working days*** of the beginning of the term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

## EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.

## RESEARCH ETHICS

The two principles underlying integrity in research in a university setting are these: a researcher must be honest in proposing, seeking support for, conducting, and reporting research; a researcher must respect the rights of others in these activities. Any departure from these principles will diminish the integrity of the research enterprise. This policy applies to all those conducting research at or under the aegis of McMaster University. It is incumbent upon all members of the university community to practice and promote ethical behaviour. To see the Policy on Research Ethics at McMaster University, please go to http://www.mcmaster.ca/policy/faculty/Conduct/ResearchEthicsPolicy.pdf.

# Electrical and Computer Engineering Lab Safety

## Information for Laboratory Safety and Important Contacts

This document is for users of ECE instructional laboratories in the Information Technology Building.

This document provides important information for the healthy and safe operation of ECE instructional laboratories. This document is required reading for all laboratory supervisors, instructors, researchers, staff, and students working in or managing instructional laboratories in ECE. It is expected that revisions and updates to this document will be done continually. A McMaster University lab manual is also available to read in every laboratory.

## General Health and Safety Principles

Good laboratory practice requires that every laboratory worker and supervisor observe the following:

1. Food and beverages are not permitted in the instructional laboratories.
2. A Laboratory Information Sheet on each lab door identifying potential hazards and emergency contact names should be known.
3. Laboratory equipment should only be used for its designed purpose.
4. Proper and safe use of lab equipment should be known before using it.
5. The course TA leading the lab should be informed of any unsafe conditions.
6. The location and correct use of all available safety equipment should be known.
7. Potential hazards and appropriate safety precautions should be determined, and the sufficiency of existing safety equipment should be confirmed before beginning new operations.
8. Proper waste disposal procedures should be followed.

## Location of Safety Equipment

**Fire Extinguisher**
On walls in halls outside of labs

**First Aid Kit**
ITB A111, or dial “88” after 4:30 p.m.

**Telephone**
On the wall of every lab near the door

**Fire Alarm Pulls**
Near all building exit doors on all floors

## Who to Contact

**Emergency Medical / Security:** On McMaster University campus, call Security at extension **88** or **905-522-4135** from a cell phone.
**Non-Emergency Accident or Incident**: Immediately inform the TA on duty or Course Instructor.
**University Security (Enquiries / Non-Emergency)**: Dial 24281 on a McMaster phone or dial 905-525-9140 ext. 24281 from a cell phone.
**See TA or Instructor**: For problems with heat, ventilation, fire extinguishers, or immediate repairs
**Environmental & Occupational Health Support Services (EOHSS):** For health and safety questions dial 24352 on a McMaster phone or dial 905-525-9140 ext. 24352 from a cell phone.
**ECE Specific Instructional Laboratory Concerns:** For non-emergency questions specific to the ECE laboratories, please contact 24103.

## In Case of a Fire (Dial 88)

When calling to report a fire, give your name, exact location, and building.

1. Immediately vacate the building via the nearest Exit Route. Do not use elevators!
2. Everyone is responsible for knowing the location of the nearest fire extinguisher, the fire alarm, and the nearest fire escape.
3. The safety of all people in the vicinity of a fire is of foremost importance. But do not endanger yourself!
4. In the event of a fire in your work area, shout "*Fire!*" and pull the nearest fire alarm.
5. Do not attempt to extinguish a fire unless you are confident it can be done in a prompt and safe manner utilizing a hand-held fire extinguisher. Use the appropriate fire extinguisher for the specific type of fire. Most labs are equipped with Class A, B, and C extinguishers. Do not attempt to extinguish Class D fires which involve combustible metals such as magnesium, titanium, sodium, potassium, zirconium, lithium, and any other finely divided metals which are oxidizable. Use a fire sand bucket for Class D fires.
6. Do not attempt to fight a major fire on your own.
7. If possible, make sure the room is evacuated; close but do not lock the door and safely exit the building.

## Clothing on Fire

Do not use a fire extinguisher on people

1. Douse with water from the safety shower immediately or
2. Roll on the floor and scream for help or
3. Wrap with a fire blanket to smother flame (a coat or other nonflammable fiber may be used if the blanket is unavailable). Do not wrap a standing person; rather, lay the victim down to extinguish the fire. The blanket should be removed once the fire is out to

disperse the heat.

## Equipment Failure or Hazard

Failure of equipment may be indicative of a safety hazard - You must report all incidents.

Should you observe excessive heat, excessive noise, damage, and/or abnormal behaviour of the lab equipment:

1. Immediately discontinue the use of the equipment.
2. In Power Lab, press the wall-mounted emergency shut-off button.
3. Inform your TA of the problem.
4. Wait for further instructions from your TA.
5. TA must file an incident report.

## Protocol for Safe Laboratory Practice

Leave equipment in a safe state for the next person - if you're not sure, ask!

In general, leave equipment in a safe state when you finish with it. When in doubt, consult the course TA.

## Defined Roles

| | | |
|---|---|---|
| TA | The first point of contact for lab supervision | |
| ECE Lab Supervisor | Steve Spencer - ITB 147 | steve@mail.ece.mcmaster.ca |
| ECE Course Instructor | Please contact your specific course instructor directly | |
| ECE Administrator | Shelby Gaudrault - ITB A111 | gaudraus@mcmaster.ca |
| ECE Chair | Mohamed Bakr - ITB A111 | mbakr@mcmaster.ca |