



# Course Details

## 2023 Radio Frequency Integrated Circuit Design ELEC 5503 (ELG 6353)

RFIC Classes start January 9, 2023, 11:35-12:55, MC 6030. A map of campus can be found at <https://carleton.ca/campus/map/>

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### Course Outline

Last partially updated: Dec, 2022

#### Schedule:

Carleton University, Mon, Wed, 11:35-12:55, MC 6030

Mon January 9 – Wed April 5, 2023, (The term is Mon Jan 9- Wed Apr 5, Break Week is February 20-24)

Zoom Link: <https://carleton-ca.zoom.us/j/92628907153>

Discord Channel: <https://discord.gg/kuGJEjVMdK>

#### Outline:

This course is for IC designers who would like to become familiar with the design of integrated radio front-end circuits. The emphasis is on the detailed design of some radio front-end circuits, such as low-noise amplifiers, mixers, voltage-controlled oscillators and power amplifiers. There will also be discussion of general topics such as impedance matching, noise, linearity, stability, the use of simulators, and layout consideration.

#### Course Content

1. **General Discussion:** Overview of Radio Systems, then go ahead to detailed component design in the following sections. Discuss general concepts as needed, including: link budgets, filtering considerations, matching, use of Smith Charts, intermodulation, intercept points (IP3), compression, noise figure, sources of noise, stability, simulation issues, packaging, printed circuit boards; layout concerns such

as isolation, coupling, matching, parasitics, shielding; components such as transistors, capacitors, resistors, inductors, baluns, interconnect.

2. **LNA Design:** simple, cascode, tuned, balun coupled, noise, linearity, signal levels, gain, frequency response, biasing, power dissipation broadband design, UWB, distributed amplifiers. Layout considerations.
3. **Mixer Design:** Gilbert cell, use of inductors and baluns, balanced, doubly balanced, single-sideband, image-reject mixers, noise, linearity, signal levels, conversion gain, frequency response, feedthroughs, power dissipation, simulation issues, passive mixers, subsampling mixers. Layout considerations.
4. **VCO Design:** types, resonators, varactors, phase noise, signal levels, frequency, tuning methods and tuning range, startup time, frequency switching speed, isolation from other circuits, injection locking, power dissipation, simulation issues. Layout considerations.
5. **Power Amplifier Design:** different classes, efficiencies, output power, power control, packaging issues, simulation issues, linearization. Layout considerations.
6. **Examples: from research and literature**

### **Marks:**

Marks will be based on four assignments worth 70% and a final exam, worth 30% of the final mark.

### **Assignments:**

Assignments involve design and layout of an LNA, a mixer, a VCO, and a power amplifier, through simulation using a commercial process and SpectreRF from Cadence.

Assignments will be submitted online via cuLearn.

### **Access to tools, Licenses, NDA:**

Once registered, students from Carleton will already have access to the course on cuLearn and will have a [cmail.carleton.ca](mailto:email.carleton.ca) account. Students from U. Ottawa will need to go through an extra step to create a MyCarletonOne account. For all students, running software tools will require obtaining the appropriate doe account, have access to the licence to run simulation tools, and have signed an NDA to access the technology.

**Instructions for Virtuoso (Cadence):** Look under CAD support in the TOC.

**Instructions for remote access the DOE servers at:** <https://www.doe.carleton.ca/doe-linux-servers>

**SpectreRF tutorial and further information:** The process we are using is proprietary. We have permission to use it for the course, provided students sign a non-disclosure agreement. However, we are not allowed to post any information on public web sites, so

all information will be given in class and on private sites, e.g, cuLearn, and some information may be further password protected.

## Textbook

**John Rogers and Calvin Plett, *Radio Frequency Integrated Circuit Design, Second Edition***, Artech House, 2010, ISBN 978-1-60783-979-8 Available from the publishers at US\$175, and elsewhere, (sometimes at lower price). Likely your best price will be if you get it as part of the course from the course instructor at cost price - but still quite expensive due to the unfavourable exchange rate.

RFIC Second Edition Textbook Errata, Comments

## References

**Sorin Voinigescu, *High-Frequency Integrated Circuits***, Cambridge University Press, 2013, ISBN 9780521873024

**Behzad Razavi, *RF Microelectronics***", second ed., Prentice-Hall 2011, ISBN 0137134738,

**Thomas H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits***, "second edition, Cambridge University Press, 2004.

**Steve Cripps, *Rf Power Amplifiers For Wireless Communications***, second ed. Artech House 2006. ISBN 978-1596930186

**Gonzalez, *Microwave Transistor Amplifiers***, Second Edition, Prentice-Hall 1997.

**Registration for Special Students:** \*\*\* verified in a previous year - probably still very similar \*\*\*

1. Register as a special student by filling out the special student form and bringing it and supporting documents to the registrar's office in TB 300 - the form is available on line or at the registrar's office. If you have previously been a student at Carleton, your previous student number will be reactivated. If you have never been a student at Carleton you will be issued a new number. This might take a few days.
2. Then, you need to get permission from the instructor teaching the course - typically they will decide based on two factors:
  - o The first factor is your background, so please provide information to the instructor about your prior schooling and your approximate grades.
  - o The second factor is the current course enrollment, noting that full or part-time students will get priority. Since enrollment may not be known until the first class, it is possible that this permission will be delayed.

If approved, the instructor will send an email to one of the DOE administrators (Anna or Blazenka) and they will open a spot for the student.

3. After this, the student can register using Carleton Central