TSEK03: Radio Frequency Integrated Circuits (RFIC)

Lecture 1a: Introduction

Ted Johansson, EKS, ISY

ted.johansson@liu.se
RFIC – Main Objectives

• Advanced continuation of TSEK02 Radio Electronics
• Main focus is on CMOS digital transceivers
• Main building blocks of digital transmitters and receivers
• Often the RX is more demanding => focus on downconversion, noise calculations/considerations
• Different architectures for each block are presented
• Design trade-offs for these building blocks are discussed
• Tutorials: dedicated to calculation of different metrics associated to these blocks (a lot of circuit analysis!)
• Lab sessions: main focus is on practical design issues, both measurements and simulations.
RFIC – Course Organization

- Lectures: 11 x 2h
- Tutorials: 6 x 2h
- Labs: 3 x 4 h – Sign-up is required for Lab 1 (ES lab) (if more than six students)

- Examination: Written exam at the end of the course
  To pass: Attend the labs (1.5 HP)
  Pass the written exam (4.5 HP)

- Examinations: 2018-10-22, 08-12
  2019-01-07, 14-18
  Aug 2019
Schedule

• Link to TimeEdit: https://cloud.timeedit.net/liu/web/schema/ri1X50gQ3560YvQQ06Z9175Y0Zy4507550Y58Q771.html

• Location ”Nollstället” for all lectures and tutorials.

• Lab 1: LNA circuit design in Cadence, computer lab (Sep 26)

• Lab2: LNA measurements, EKS-lab, 3D:542, 6 students/group, sign up (Doodle?) (Oct 3 + 10)

• Lab 3: Mixer circuit design in Cadence, computer lab (Oct 17)
Labs

- All labs include have preparatory material that you should read carefully and assignments in the lab manual that you should complete prior to performing the lab work.
- Lab 1 & 3 are Cadence spectre simulation labs of LNA and mixer performance.
- Lab 2 is about measurements of performance parameters of a low-noise amplifier (LNA) operating in the FM broadcast band: linearity, compression point, SFDR, noise figure. Sign-up is required, 6 students each time.
- Lab manuals will be downloadable from the course homepage.
Course material

B. Razavi,
*RF Microelectronics*,

T. H. Lee,
*The design of CMOS radio-frequency integrated circuits*,
Course homepage

- [www.isy.liu.se/en/edu/kurs/TSEK03/](http://www.isy.liu.se/en/edu/kurs/TSEK03/)

Or just google "TSEK03"!

Lecture notes, tutorials + solutions, home work, lab manuals + reading, old exams.
RFIC - Staff

• Ted Johansson
• Docent, Adjunct Professor
• Integrated Circuits and Systems (EKS), Dept. of Electrical Engineering (ISY)
• ted.johansson@liu.se, people.isy.liu.se/eks/ted/

• Lectures, examiner.
Ted Johansson: CV in short

• 1985: M.Sc. (Y, LiU + RWTH, Germany)
• 1985-1989: Institute of Microelectronics, Kista
• 1989-2002: Ericsson Microelectronics, Kista
• 1992-1998: Industrial PhD (LiU)
• 2002-2007: Infineon Technologies, Kista
• 2008-2011: Huawei R&D Center, Kista
• Own company/consulting 2008-
• Adjunct professor (external, part-time): 2009-
  Docent 2015
  Research on PA design in CMOS
  PhD supervision
  2015-/HT2: undergraduate course TSEK02
  2015-/VT1: undergraduate course TSEK03
  2017-/HT1: undergraduate course TSEK38
RFIC - Staff

• Oscar Morales
• Research Assistant
• Integrated Circuits and Systems (EKS), Dept. of Electrical Engineering (ISY)
• oscar.morales@liu.se

• Tutorials, labs.
RFIC – Course Content

• RF Transceivers

• RF section consists of mostly analog circuits.
• Baseband is mostly digital and it processes data, which should be sent to or received from the RF part.
• In this course, we will focus on building blocks in the RF part.
RFIC – Course Content

• Digital RF Transmitter

![](image)

- Baseband signal is compressed and coded and modulated in the first step.
- In the RF part, upconversion is performed and the signal is amplified in order to be transmitted.
RFIC – Course Content

• Digital RF Receiver

- In the RF part, received signal is filtered and amplified by a low-noise amplifier (LNA). Then image rejection and down conversion is performed.

- Decoding and demodulation is performed in baseband section.
RFIC – Course Content

• "Real" Superheterodyne "sampling-IF" (TDD)
Analog vs. digital – the radio
RFIC – Course Content

• RF building blocks which are used in RF digital transceivers are discussed in this course:
  • Low-noise amplifiers (LNAs)
  • Mixers
  • Oscillators
  • Frequency synthesizers (PLLs)
  • Power amplifiers (PAs)

• Different design perspectives and with different architectures are discussed

• Performance metrics are introduced

• Practical design challenges are presented
RFIC – Course Content

LECTURES OVERVIEW

Tu1: noise
L1: Course introduction. Noise, Ch 2.3.
L2: continued
L3: Linearity, impedance transformation, s-parameters, Ch. 2.2, 2.5, 2.6. LNA, Ch. 5.1-5.3.
L4: continued
L5: Mixers, Ch 6.1-6.3.
L6: continued
L7: Passive devices, Ch 7.
L8: Oscillators, Ch. 8.1-8.7
L9: continued
L10: PLL, Ch.9.1-9.3 + highlights from Ch. 10 and 11.
L11: PA, Ch. 12.1-12.4.

Tu2: LNA
L1:

Tu3: mixers
L5:

Tu4: oscillators
L8:

Tu5: PLL + PA
L10:

Tu6: repetition
L11:
Background material/knowledge

- Analog CMOS design (circuit analysis, oscillators, PLL; Razavi’s Analog book).
- System understanding: TSEK02 Radio Electronics (Razavi RF book ch 2 (parts), 3, 4).
- Transfer functions, Laplace transforms.

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Concept</th>
<th>Architecture</th>
<th>Circuit analysis</th>
<th>Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>+</td>
<td>-</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>LNA</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Mixer</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Oscillator</td>
<td>++</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>PLL</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>PA</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Background material/knowledge

- Razavi’s Analog book, used in TSEK37 Analog CMOS.
- Circuit analysis, oscillators, PLL.