Learning objectives of the subject

The aim of this course is to train students in methods of design, analysis and specification of analog circuits for RF (radiofrequency) communication systems, integrated in microelectronic CMOS technology. In the first part of the course, system-level analysis will link specifications of communication systems with the figures of merit of the electronic circuits that implement the receivers/transmitters in those systems. A comprehensive analysis of the different specs will be done, and a specification procedure of the circuits using software tools will be described. Next, the major circuits in a RF
communication receiver front-end will be described, for the particular target of integration in CMOS technology. Performance trade-offs will be analyzed and for each of the circuits, design procedures will be described and practiced in specific exercises using professional EDA tools for microelectronic design (Cadence). Basic knowledge of the microelectronic CMOS technology is assumed, although the possibilities, limitations and particularities of this technology for RF will be also discussed in the course.

<table>
<thead>
<tr>
<th>Study load</th>
<th>Total learning time: 125h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours large group:</td>
<td>26h</td>
</tr>
<tr>
<td>Hours medium group:</td>
<td>0h</td>
</tr>
<tr>
<td>Hours small group:</td>
<td>13h</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
</tr>
<tr>
<td>Self study:</td>
<td>86h</td>
</tr>
<tr>
<td>%</td>
<td>20.80%</td>
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<tr>
<td>%</td>
<td>0.00%</td>
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<tr>
<td>%</td>
<td>10.40%</td>
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<tr>
<td>%</td>
<td>0.00%</td>
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<tr>
<td>%</td>
<td>68.80%</td>
</tr>
</tbody>
</table>
# Content

## 1. System-level design

<table>
<thead>
<tr>
<th>Learning time: 38h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 10h</td>
</tr>
<tr>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>Guided activities: 14h</td>
</tr>
<tr>
<td>Self study: 12h</td>
</tr>
</tbody>
</table>

**Description:**
- Reminder front-end architectures, basic concepts on modulations.
- System-level parameters: error probability, SNR, tolerance to interferers, ACPR, sensitivity
- Circuit-level parameters: gain, linearity, noise figure, power
- From communication standard definitions to circuit specs. Case study: The Bluetooth receiver design.
- Lab, practical exercise.

**Related activities:**
- Exercises, to be delivered
- Pre-lab
- Lab

## 2. The CMOS technology for RF

<table>
<thead>
<tr>
<th>Learning time: 19h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>Guided activities: 7h</td>
</tr>
<tr>
<td>Self study: 6h</td>
</tr>
</tbody>
</table>

**Description:**
- MOS models for RF.
- Passive components integrated in CMOS technology
- Lab, characterization of a MOS transistor for RF

**Related activities:**
- Exercises, to be delivered
- Lab
### 3. Design of Low-Noise Amplifiers (LNA)

**Learning time:** 30h
- Theory classes: 7h
- Laboratory classes: 2h
- Guided activities: 11h
- Self study: 10h

**Description:**
- Tuned Low-Noise Amplifiers. Analysis and design procedure.
- Other LNA topologies.
- Specific analysis for RF using SpectreRF.
- Lab, design of a tuned LNA and performance analysis using SpectreRF

**Related activities:**
- Exercises, to be delivered
- Pre-lab
- Lab

### 4. Design of Voltage-Controlled Oscillators (VCO)

**Learning time:** 19h
- Theory classes: 4h
- Laboratory classes: 2h
- Guided activities: 7h
- Self study: 6h

**Description:**
- Resonant LC-CMOS VCO design. Analysis and design procedure.
- Other VCO topologies. QVCOS.
- Introduction to PLLs and frequency synthesizers.
- Lab, design of a VCO and performance analysis using SpectreRF

**Related activities:**
- Exercises, to be delivered
- Pre-lab
- Lab
### 5. Design of Mixers

**Learning time:** 19h  
- Theory classes: 4h  
- Laboratory classes: 2h  
- Guided activities: 7h  
- Self study: 6h

**Description:**  
- Active mixers. Analysis and design procedure.  
- Other mixers: passive, polyphase filters  
- Lab, design of a mixer based on a Gilbert cell, using SpectreRF

**Related activities:**  
- Exercises, to be delivered  
- Lab

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### Planning of activities

#### LABORATORY

**Hours:** 24h  
- Guided activities: 12h  
- Theory classes: 12h

**Description:**  
All lab practices will be partly done with the assistance of a professor during regular class sessions, and partly done individually by the students as part of their guided study.  
- System-level budget analysis  
- Characterization of a MOS transistor for RF  
- Design of a tuned LNA and performance analysis using SpectreRF  
- Design of a VCO and performance analysis using SpectreRF  
- Design of a mixer based on a Gilbert cell, using SpectreRF

#### EXERCISES

**Hours:** 13h  
- Self study: 13h

**Description:**  
Exercises using analytical methods, with the aim to strengthen the theoretical knowledge.

#### ORAL PRESENTATION

**Hours:** 8h  
- Self study: 4h  
- Theory classes: 4h

**Description:**  
Presentation of a RF circuit/system
**Qualification system**

The basic qualification system of the course is through continuous assessment, obtained from the following components:

- Exercises and problems, personal solving: 35%
- Individual presentation of a RF circuit/system: 10%
- Laboratory assessments: 35%
- Written test: 20%

In order to be qualified through continuous assessment, regular attendance to the classes/lab practices and regular delivery of exercises/laboratory reports is expected. In case a minimum of attendance and deliveries is not fulfilled, the student can be qualified through a single final written examination.

**Bibliography**

**Basic:**


**Others resources:**

Course slides, exercises, tutorials and labs available through the Atenea virtual campus.