



# Course guide

## 2301207 - AICD - Analog Ic Design

Last modified: 20/03/2024

**Unit in charge:** Barcelona School of Telecommunications Engineering  
**Teaching unit:** 1022 - UAB - (ANG) pendent.

**Degree:** MASTER'S DEGREE IN SEMICONDUCTOR ENGINEERING AND MICROELECTRONIC DESIGN (Syllabus 2024).  
(Optional subject).

**Academic year:** 2024    **ECTS Credits:** 6.0    **Languages:** English

### LECTURER

**Coordinating lecturer:** Consultar aquí / See here:  
<https://telecos.upc.edu/ca/curs-actual/coordinadors-i-professorat>

**Others:** Consultar aquí / See here:  
<https://telecos.upc.edu/ca/curs-actual/coordinadors-i-professorat>

### TEACHING METHODOLOGY

Teaching methodology is based on classroom lectures and exercises (32h) and lab sessions (16h). The lab work includes the full-custom design of a two-stage Miller Opamp from functional specifications to full-custom layout in CMOS technology with industrial electronic design automation (EDA) tools and process design kit (PDK).

### LEARNING OBJECTIVES OF THE SUBJECT

This course is an introduction to the specific full-custom design techniques of analog integrated circuits in CMOS technologies. Besides the required knowledge at process, device and circuit levels, it provides hands on practice of the full-custom schematic and physical design methodologies to develop analog application-specific integrated circuits (ASICs) projects from specifications to tapeout.

Specific objectives:

1. Acquire knowledge on specific full-custom analog design techniques for integrated circuits at research and industrial levels with emphasis on low-power and low-noise scenarios.
2. Be able to select the most suitable CMOS technology given a set of specifications for an application-specific integrated circuit (ASIC) design project.
3. Learn to assess the different steps involved in the full-custom analog design methodology of integrated circuits both at schematic and layout levels.
4. Acquire hands on practice of industrial full-custom electronic design automatic (EDA) tools and CMOS process design kits (PDKs).

### STUDY LOAD

Type	Hours	Percentage
Self study	102,0	68.00
Hours large group	32,0	21.33
Hours small group	16,0	10.67

**Total learning time:** 150 h



## CONTENTS

### Introduction to Full-Custom Analog ICs

**Description:**

More than Moore versus More Moore. IC design flavors: from full-custom application-specific integrated circuits (ASICs) to third-party IP libraries. Mixed-signal CMOS technology modules. ASIC prototyping strategies (MPW, MLM, stitching). Impact of CMOS technology size and supply voltage downscaling in analog circuits. Trending topics and challenges in analog IC design.

**Full-or-part-time:** 2h

Theory classes: 2h

### Device Modeling for Analog CMOS Design

**Description:**

Transistor modeling suitable for analog hand design. MOSFET EKV model ( $I/V$ , transconductance, capacitance, noise). Subthreshold operation and circuit design driven by inversion coefficient (IC). BJTs and passive devices (planar resistors, MiM and MoM capacitors). Device process corners and technology mismatching.

**Full-or-part-time:** 4h

Theory classes: 4h

### CMOS Operational Amplifiers

**Description:**

Black-box figures of merit (gain, GBW, settling time, SR, offset, equivalent input noise, CMR, CMRR, PSRR). OpAmp building blocks at transistor level (common-S/G and back-gate stages, current mirrors, buffers, level shifters). Differential OpAmps and common-mode feedback (CMFB). Cascoding and gain boosting techniques. Folded and telescopic topologies. Stability and frequency compensation in multi-stage OpAmps.

**Full-or-part-time:** 6h

Theory classes: 6h

### Full-Custom Analog IC Design Methodology

**Description:**

Schematic and physical design flows. Full-custom electronic design automation (EDA) tools and CMOS process design kit (PDK). Guidelines for analog device sizing. Simulation analysis of analog circuits: large-signal DC, small-signal AC, transient, noise, sensitivity, periodic steady-state (PSS). The art of analog layout for signal decoupling and device matching. Parametrized cells (PCells). Physical verification (DRC, LVS, PEX) and post-layout simulation. Design for manufacturing (DFM).

**Full-or-part-time:** 4h

Theory classes: 4h

### Low-Power Operational Amplifiers

**Description:**

Low-power IC scenarios (battery supply, remote power, energy harvesting). Low-current versus low-voltage OpAmps. Subthreshold operation. Dynamic biasing. Class-AB output stages. Rail-to-rail topologies. Inverter-based pseudo-differential amplifiers.

**Full-or-part-time:** 4h

Theory classes: 4h



### Low-Noise Circuit Techniques

**Description:**

OpAmp noise optimization in low-frequency sensing applications. Chopping circuit topologies. Correlated double sampling (CDS) techniques.

**Full-or-part-time:** 4h

Theory classes: 4h

### Specific Building Blocks

**Description:**

Analog voltage references and bias current generators (PTAT, bandgap). Comparators. Current-mode circuits (conveyors, splitters, WTA). Linear transconductors and GmC filters. Switched-capacitor circuits (S/H, T/H, amplifiers, filters). Oscillators.

**Full-or-part-time:** 8h

Theory classes: 8h

## GRADING SYSTEM

Evaluation according to the following weighted rule: proposed exercises (10%), lab report (40%) and exam (50%). If exam mark is under 4/10, a remedial exam needs to be passed and its mark is downscaled to 80%.

## BIBLIOGRAPHY

**Basic:**

- Allen, P.E.; Holberg, D.R. CMOS analog circuit design. New York: Oxford University Press, 2012. ISBN 9780199937424.
- Razavi, B. Design of analog CMOS integrated circuits. 2nd ed. Boston: McGraw Hill, 2017. ISBN 9781259255090.
- Gray, P.R.; Hurst, P.J.; Lewis, S.H. Analysis and design of analog integrated circuits. 6th ed. Hoboken, New Jersey: Wiley, 2024. ISBN 9781394220069.
- Sansen, W.M. Analog design essentials [on line]. New York, NY: Springer US, 2006 [Consultation: 27/06/2024]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/b135984>. ISBN 9780387257471.
- Hastings, A. The art of analog layout. 2nd ed. Upper Saddle River: Prentice Hall, 2006. ISBN 9780131464100.