UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona

telecos BCN

230730 – DESIGN OF ANALOG MICROELECTRONIC CIRCUITS

Credits: 5 ECTS

LECTURER

Coordinating lecturer: Xavier Aragones Cervera

Others:

PRIOR SKILLS

The course assumes basic concepts on MOS transistor behavior and modeling, circuit implementation in microelectronic technologies, amplification and analog circuit analysis, as well as circuit simulation and layout edition in Cadence Virtuoso environment or similar, corresponding to the "Introduction to Microelectronic Design" bridge course or similar:

- MOSFET basic behavior: states, equations, curves.

- Characteristics of microelectronic technologies.

- Full-custom design methodology. Basics on layout of custom analog circuits.

- Analog circuit analysis: large signal and small-signal

- Basic 1-transistor amplifier stages. Basic concepts on noise and distortion.

- Circuit simulation at transistor level (.DC, .TRAN, .AC analysis)

- Basic concepts on active-RC filters.

- Basic concepts on DAC and ADC conversion.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

- Conceive and design electronic circuits for signal amplification, both low and high (radio) frequencies, according to the type of application and objectives of gain, consumption, noise, linearity, stability, impedances, bandwidth.

- Identify and apply solutions for analog signal filtering and conversion to/from the digital domain, analyze the limitations associated with its microelectronic implementation and select the optimal approach based on specifications, resolution, frequency.

- Apply methodologies for the analysis and design of analog circuits in CAD environments for microelectronic design.

Transversal:

TEAMWORK. Being able to work as a member of an interdisciplinary team, either as a member or carrying out management tasks, in order to contribute to developing projects with pragmatism and a sense of responsibility, assuming commitments taking into account the available resources.

EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

TEACHING METHODOLOGY

- Lectures

- Laboratory practical work

- Individual work (distance)

- Design exercises (analysis and simulation)

- Extended answer test (Final Exam)

LEARNING OBJECTIVES OF THE SUBJECT

Learning objectives of the subject:

The aim of this course is that the student knows different circuit solutions to implement analog signal acquisition and processing (amplification, filtering and conversion from/to digital domain) and the design of these circuits in CMOS microelectronic technologies. Special attention will be given to understand the non-idealities that limit the dynamic range, resolution, precision, frequency of operation, or power consumption of the circuits, the effects of manufacturing and time variability, and how different solutions can cope with these limitations. Specific design scenarios such as low-power, low voltage, or radio-frequency, will be reviewed in the course. The student will also acquire skills to design these circuits in a microelectronic technology, and know the analysis and verification processes for analog design using specific CAD tools for IC design. After this course, the student will be in position to follow specialized courses related to microelectronic design, focused on specific applications (eg. high-frequency communications, signal conditioning, power management...).

Learning results of the subject:

- Know and apply advanced design techniques in analog signal processing circuits in CMOS technology. Low power supply voltage, low consumption, high frequency scenarios.

- Know circuit and design solutions to respond to the limitations of analog circuits linked to their CMOS implementation, such as noise, distortion, manufacturing variability, variability over time.

- Know the methodologies of analysis and design of analog circuits in CAD environments of microelectronic design.

STUDY LOAD

Hours large group: 26

Hours small group: 13

Hours self study: 86

CONTENTS

1.- Fundamentals:
- MOS transistor models for analog microelectronic design
- Reminder basic analog circuits: common-source stage, common-drain, common-gate, current mirror. The cascode structure.

Time: 4 h.

2.- Biasing circuits
- Cascode current mirrors
- Implementation issues: matching, transistor sizing, layout techniques
- Voltage and current references. Bandgap.

Time: 4 h.

3.- Amplification at high-frequencies
- Limits in 1-stage amplifier.
- Narrowband amplification.
- Cascaded and distributed amplifiers

Time: 2 h.

4.- Feedback amplifiers
- Open-loop and closed-loop gain, bandwidth, linearity. Stability.
- Differential amplifiers. Common-mode feedback.
- Implementation issues: matching, transistor sizing, layout techniques
- 1-stage OTA solutions. Folded-cascode.
- 2-stage OTA.

Time: 6 h.

5.- Active filter approaches
- Continuous-time active-RC
- Gm-C
- Switched-capacitors.

Time: 6 h.

6.- Analog blocks in mixed-signal circuits
- Basic concepts on D/A and A/D converters
- Sample and hold circuits.
- Comparators. Latch comparators.

Time: 4 h.

7.- Practical design projects
The student will apply the concepts and skills learned in the course to the design of at least two circuits implemented in a CMOS microelectronic technology, using the Cadence Virtuoso IC design environment:
- An analog circuit with large-signal operation. Examples can be an image sensor, or a current-steering DAC.
- An OTA.

Time: 26 h.

GRADING SYSTEM

- Writing exam: 40 % - 60 %
- Assignments: 10 % - 20 %
- Lab work: 25 - 40%

BIBLIOGRAPHY

Basic:

- Sansen, W.M.C. Analog design essentials [on line]. Boston, MA: Springer US, 2006 [Consultation: 08/07/2019]. Available on: http://dx.doi.org/10.1007/b135984. ISBN 9780387257471.

- Razavi, B. Design of analog CMOS integrated circuits. 2nd ed. Boston: McGraw-Hill, 2017. ISBN 9781259255090.

- Carusone, T.C.; Johns, D.; Martin, K.W. Analog integrated circuit design. Int. stud. version. New York: John Wiley, 2013. ISBN 9781118092330.

- Allen, P.E.; Holberg, D.R. CMOS analog circuit design. 3rd ed., int. ed. New York: Oxford University Press, 2012. ISBN 9780199937424.

- Gray, P.R. ... [et al.]. Analysis and design of analog integrated circuits. 5th ed. New York: John Wiley, 2010. ISBN 9780470398777.

Complementary:

- Baker, R.J. CMOS circuit design, layout, and simulation. 4th ed. Hoboken, NJ: IEEE Press : Wiley, 2019. ISBN 9781119481515