

**SABANCI UNIVERSITY**  
DEPARTMENT OF ENGINEERING AND NATURAL SCIENCES

*EE 303: ANALOG INTEGRATED CIRCUITS -FALL 2021*  
Course Information Sheet

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**Analog Integrated Circuits - 10564 - EE 303 - 0**  
***Scheduled Meeting Times***

Type	Time	Days	Where
In-Class	03:40 am - 05:30 pm	M	FENS G035
In-Class	10:40 am - 11:30 am	T	FENS L062 (FASS G022)

**Analog Integ. Circuits Rec. - 10565 - EE 303R - A1**  
***Scheduled Meeting Times***

Type	Time	Days	Where
In-Class	04:40 pm - 06:30 pm	R	FENS L030

**Analog Integ. Circuits Rec. - 10566 - EE 303R - A2**  
***Scheduled Meeting Times***

Type	Time	Days	Where
In-Class	04:40 pm - 06:30 pm	R	FENS L035

**Office Hour: Thursday, 09:40-10:30 (FENS 1044) (YG)**

**Office Hour: Thursday, 18:40-19:30 (FENS 1033) (CNK+KA)**

**It would be more convenient if you could send us email when coming at any time other than these hours.**

**Course Outcomes:**

A student who successfully fulfils the course requirements will have demonstrated:

- 1) To understand the concept of integrated circuits, in general
- 2) To understand the concept of analog integrated circuits and differences and challenges with respect to different applications of electronic circuits
- 3) To analyse basic CMOS basic analog circuit building components (integrated components): transistors, active and passive components
- 4) To design these analog circuit building blocks: current sources/mirrors, constant voltage, and current sources.
- 5) Analog Integrated Circuit Applications (Amplifiers): Single and multi-stage amplifiers, differential, cascode amplifiers, inverters and comparators
- 6) Design Methodology and Analysis of Integrated CMOS Amplifiers: Noise, frequency response, feedback, stability, compensation, PSRR, CMRR, Power Consumption, Gain.
- 7) To design / implement different/complex analog integrated circuits and their applications
- 8) To design, simulate and optimize analog circuits with the aid of Cadence tools
- 9) To practice layout techniques and more complex analog circuits in Cadence design environment

**Objectives:**

- 1) To understand the concept of analog integrated circuits
- 2) To analyse basic CMOS basic analog circuit building blocks (through lectures, homework, and recitations)
- 3) To design these analog circuit building blocks (through lectures, homework and recitations.).
- 4) To design, simulate and optimize analog circuits with the aid of Cadence tools (through recit).

- 5) To practice layout techniques and more complex analog circuits in Cadence design environment (through recit).
- 6) To understand complex/different applications of analog integrated circuits.

Summary of course content:

- Theoretical and computer-aided analysis,
- Simulation and design of analog CMOS integrated circuits,
- MOS device physics,
- Second-order effects,
- Single-Stage CMOS amplifiers,
- Differential CMOS Amplifiers,
- Current Mirrors,
- Frequency Response
- Feedback in CMOS Amplifiers,
- Noise Effects,
- CMOS op-amps,
- Introduction to Comparators, ADC/DAC and Switched-Capacitor circuits (if time permits).

### **Prerequisites:**

Prerequisite courses are ENS 203 and EE 202. Before attending this course, students are expected to understand the principles of,

- 1) Basic operation of electronic devices, such as diodes, BJTs, MOS transistors (EE 202).
- 2) Linear systems, Laplace transform, frequency response, Bode diagram (ENS 203, EE 202).
- 3) KCL, KVL, nodal equations, large/small signal response and analysis (ENS 203).

### **Textbook:**

Design of Analog CMOS Integrated Circuits Jan 20, 2016 by Behzad Razavi, Publisher: McGraw-Hill Education; 2 edition ISBN-10: 0072524936, ISBN-13: 978-0072524932

You can obtain the course text book by ordering from <https://www.homerbooks.com/urun/design-of-analog-cmos-integrated-circuits> website.

### **Reference Books:**

*Microelectronic Circuits (The Oxford Series in Electrical and Computer Engineering)* 7th edition, Nov 14, 2014, by Adel S. Sedra and Kenneth C. Smith (**Circuit 2 textbook**)

CMOS Analog Circuit Design. Phillip E. Allen, Douglas R. Holberg by P E Allen (2012-07-01)

P. Gray, P. Hurst, S. Lewis, and R.G. Meyer, "Analysis and Design of Analog Integrated Circuits", 5th Edition, John Wiley and Sons, 2010, ISBN 978-0-470-39877-7.

Analog Integrated Circuit Design (Wiley) Tony Chan Carusone, David A. Johns, Kenneth W. Martin, Publication Date: December 13, 2011 | ISBN-10: 0470770104 | ISBN-13: 978-0470770108 | Edition: 2

Hastings, The Art of Analog Layout, Prentice Hall, 2001.

**Tentative schedule:** (The schedule may not be strictly followed.)  
(Page numbers will be upgraded!)

**Week 1** (Sept 27 – Oct 1)

Common Source Amplifiers

Please read Chapter 1 and Chapter 2.1 (pp. 1 - 12 1<sup>st</sup> edition, pp. 1 – 10 2<sup>nd</sup> edition of your book Analog Integrated Circuit Design) to review your knowledge regarding semiconductor device and to have an idea of CMOS processing.

**Week 2** (Oct 4 – Oct 8)

HW 1

*Lab 1* IV characteristics

Common Gate Amplifiers

Source Follower (Common Drain)

Please read **Chapter 2** (pp. 12 - 39 1<sup>st</sup> edition, pp. 10 – 38 2<sup>nd</sup> edition) from your course book until recitation hour.

**Week 3** (Oct 11 – Oct 15)

HW 2

*Lab 2* Three single stage amplifier

Common Source Amplifiers with Source Resistance / Degeneration

Cascode and Folded Cascode Structures

Suggested reading: **Chapter 3.3, 3.6** (pp. 48-67, 83-93 in 1<sup>st</sup> edition, pp. 47 – 67, 82-92 in 2<sup>nd</sup> edition)

**Week 4** (Oct 18 – Oct 22)

HW3

Simple Current Mirrors/Sources

Suggested reading: **Chapter 5.1** (pp. 135-139 in 1<sup>st</sup> edition, pp. 134-139 in 2<sup>nd</sup> edition)

**Week 5** (Oct 25 – Oct 29)

HW 4

*Lab 3* Cascode Amplifier

Cascode Current Mirrors/Sources

Suggested reading: **Chapter 5.2** (pp. 139-145 in 1<sup>st</sup> edition, pp. 139-146 in 2<sup>nd</sup> edition)

**Week 6** (Nov 1 – Nov 5)

Active Loads

\*\*\*\*\* Midterm I (November 4<sup>th</sup>, 2021 (Thursday) -- Recitation hours) \*\*\*\*\*

**Week 7** (Nov 8 – Nov 12)

HW 5

*Lab 4* Differential Amplifier

Differential Pair Amplifier

Common Mode Response, Effects of Mismatches,

Suggested reading: **Chapter 4.1, 4.2 and 4.3** (pp. in 100-124 1<sup>st</sup> edition, pp. 100-123 in 2<sup>nd</sup> edition)

**Week 8** (Nov 15 –Nov 19)

*Opamp Design*

Differential Pair with Current Mirror Load

Frequency Response, Feedback, and Stability

Suggested reading: **Chapter 4.4** (pp. in 100-124 1<sup>st</sup> edition, pp. 100-123 in 2<sup>nd</sup> edition)

*Lab 5: Opamp Design Project*

**Week 9** (Nov 22 – Nov 26)

Introduction to Noise

Suggested reading: **Chapter 7.1-7.4** (pp. in 201-233 1<sup>st</sup> edition, pp. 219-254 in 2<sup>nd</sup> edition)

**Week 10** (Nov 29 – Dec 3)

*Folded Cascode*

Operational Amplifiers (Opamps)

Suggested reading: **Chapter 9.2 1<sup>st</sup> edition Chapter 9.2.4-9.2.6 2<sup>nd</sup> edition** (pp. in 296-307 1<sup>st</sup> edition, pp. 355-361 in 2<sup>nd</sup> edition)

**Week 11** (Dec 6 – Dec 10)

Comparator, switched capacitor-based applications, ADC, DAC, etc.

Reading materials will be supplied.

**Week 12** (Dec 13 – Dec 17)

Comparator, switched capacitor-based applications, ADC, DAC, etc.

Reading materials will be supplied.

**Week 13** (Dec 20 – Dec 24)

Review of the materials...

\*\*\*\*\* Midterm II (Dec. 23, 2021 Thursday, Recitation hours) \*\*\*\*\*

**Week 14** (Dec 27 – Dec 30)

Comparator, switched capacitor-based applications, ADC, DAC, etc.

Reading materials will be supplied.

## **Labs / Recitations:**

(*Tentative, subject to change*)

- Introduction to Cadence, design rules and layout
- MOS device characterization
- Simple CMOS single-stage amplifier design
- Current mirrors and differential pairs
- Opamp Design Project
- *Filter or ADC/DAC*

## **RECITATION 1:**

(Location and schedule may subject to change, check SuCourse (or your inbox) for latest information)

**Requirements:** A portable computer with networking capability. It is better to have ethernet cable.

## **Subjects Covered:**

Installation and configuration of x2go

Establishing remote connection to workstations in SUNET with x2go

Creation of work folder and IHP13S

Basic schematic and symbol editing with Cadence Virtuoso

Basic simulation setup and run with Cadence Spectre

## **Grading:**

- 10 % Homework + Quiz
- 25 % Labs:
  - Lab1: IV characteristics (2%)*
  - Lab2: Three single stage amplifier (3%)*
  - Lab3: Cascode Amplifier (6%)*
  - Lab4: Differential Amplifier (6%)*
  - Lab5: Opamp Design Project (8%)*
  - Bonus Lab: ADC Design Project (2%)*
- 40 % Midterm Exams (2 in total)
- 25 % Final Exam

Instructor has right to change grading policy after announcing in the class.

Quizzes are given randomly every one to two weeks without announcement in advance.

Missed quizzes will not be made up and will count as zero grade.

Make-up for final and midterm exams will only be offered to students who produce officially accepted valid excuses. Otherwise, students cannot have make-up option.

The due date of the homework/project is one week later from the assignment date, unless otherwise stated.

Late homework/project submissions will be penalized 25% for first 6 hours and 50% for the first 24 hours. Late project/homework submissions more than 24 hours will not be accepted.

Discussion on homework/project assignments is encouraged. Turning in identical homework/project solutions is considered cheating.

Cheating in exams and project will not be tolerated and will be subject to disciplinary actions.

Attendance will be taken randomly, according to YOK regulations.

## **Last Words of the first Lecture 😊**

**I hope that you find the course enjoyable and rewarding in terms of the learning experience.**

**Keys to success in the course are:**

- 1) Good time management - designate fixed time slots in your schedule for reviewing the lectures and doing the guided cadence-software assignments.**
- 2) Keep yourself "in sync" with the rest of the class - don't allow material to accumulate.**
- 3) Work independently on the homework projects - this hands-on experience is crucial for fully understanding the theory.**
- 4) Keep open channels of communication with the course instructor (and TAs) - e-mail, call on the phone or visit during office hours.**

- 5) Never allow yourself to "get stuck" on a homework problem - seek help. You may do it by e-mailing the professor and make sure to include your problem statement clearly.
- 6) Whenever you feel "stuck" reading the theory or doing the hands-on assignments, try to articulate in words what exactly it is that you don't understand. Then e-mail your questions. You may also write your questions on a "post-it" notes, tacked to the appropriate written notes locations. When you come to an office hour visit, we may go through your specific questions one-by-one.
- 7) Make Recitations/Office Hours more productive, if you take the effort, ahead of the meeting, to do some preliminary work, and have some specific questions.
- 8) Allow at least an hour or two a week to go over recommended practice exercises from the book.
- 9) Always keep a "cool head" during exams. Exam questions will never be tricky. They are designed only to assess your knowledge in a straightforward manner, and reward you if you did all the homework and went through the practice exercises.
- 10) When preparing for an exam, don't skip topics. Announcements will be very explicit regarding test topics. Typically, exams attempt to cover ALL topics. Every one of the problems may feature a mix of several topics.
- 11) We provide formula paper in advance of the exam. But you will not have enough time to find right formula or understand the formula "in real-time" during exams. Come well organized - know exactly where / what each given formulas are.



- 12) Always bring your calculator to exams. All problems will feature real circuits with real-life component values. Therefore you should not expect the numerical answers to always be "nice numbers".**
- 13) Keep in mind that in the field of Electronics, most formulas are rarely "global". Circuit modifications (i.e. adding a load, adding source resistance etc.) may cause some of the formulas to slightly change appearance. Try always to grasp the ideas behind each formula. Then apply the ideas to modify the formulas to fit a new circuit. Don't blindly substitute numbers into any formula that catches your eye.**