University of Southern California

Ming Hsieh Department of Electrical Engineering

Course Number & Title: EE 536a, Mixed Signal Integrated Circuit Design

Units: 4

Semester: Fall 2023

Schedule: Mondays & Wednesdays 10:00 am – 11:50 am
Fridays: 10:00 am – 10:50 am

Location: OHE 100B

Instructor: Hossein Hashemi

Office: PHE 616

Office Hours: Mondays & Wednesdays 8:45 am – 9:45 am

Contact Information: hosseinh@usc.edu, 213-740-3596

Teaching Assistant: TBD
Office Hours: Tuesdays & Thursdays 4 pm – 6 pm

Catalogue Description:

MOSFET operation and models; elementary amplifier configurations; biasing and references; frequency response; noise; feedback; operational amplifiers; frequency compensation; nonlinearity and mismatch; passive and active filters

Course Description:

EE 536a covers theory, analysis, and design of analog integrated circuits at the transistor level. The course includes a few design projects as homework assignments and a comprehensive final design project using state-of-the-art semiconductor technologies and computer aided design environments. The principles covered in this course enables designing low noise, high frequency, low power, analog integrated circuits such as operational amplifier and active filters.

Learning Objectives:

EE 536a is designed as the first graduate course covering theory, analysis, and design of analog integrated circuits. At the completion of the subject students will be able to analyze and design

analog integrated circuits for wide range of applications such as wireless and wired communications, biomedical implants, controls, computation, sensing, imaging, etc. The course serves as the pre-requisite for EE 536b covering basics and advanced mixed-signal integrated circuits.

Prerequisite: EE 348L

Main Text Book: B. Razavi, *Design of Analog CMOS Integrated Circuits*, McGraw Hill, 2nd Edition, 2019.

Supplementary Texts:

- P. Grey, P. Hurst, S. Lewis, and R. Meyer, *Analysis and Design of Integrated Circuits*, John Wiley and Sons, 5th Edition, 2009.
- A. Sedra and K. Smith, *Microelectronic Circuits*, Oxford University Press, 6th Edition, 2009.
- D. Johns and K. Martin, *Analog Integrated Circuit Design*, John Wiley and Sons, 1st Edition, 1997.

Readings: All lectures will be available on Blackboard.

Grading:

Homework (9)	10%
Midterm Exam	30%
Final Exam	40%
Design Project	20%

Tentative Weekly Schedule

Week	Date	Subject	Readings	HW
1	Mon 08/21/2023	Review of nonlinear resistors and linearized model	Chapters 1, 2, 16, 17	HW 1 Assign
	Wed 08/23/2023	Review of MOSFET large-signal equations		
	Fri 08/25/2023	Review of MOSFET small-signal model		
2	Mon 08/28/2023	Review of MOSFET device physics & capacitances	Chapter 3	HW 2 Assign
	Wed 08/30/2023	Common source		HW 1 Due
	Fri 09/01/2023	Common source (active load)		
3	Mon 09/04/2023	Labor Day Holiday	Chapter 4	HW 3 Assign
	Wed 09/06/2023	Cascode, Cascade, Common gate		
	Fri 09/08/2023	Common gate, Source follower, Folded cascode		HW 2 Due
4	Mon 09/11/2023	Differential amplifiers	Chapter 5	HW 4 Assign
	Wed 09/13/2023	Differential amplifiers		HW 3 Due
	Fri 09/15/2023	Differential amplifiers		
5	Mon 09/17/2023	Amplifier design example	Chapters 5, 6	
	Wed 09/20/2023	Current mirrors, current amplification		
	Fri 09/22/2023	Current mirrors, current amplification		HW 4 Due
6	Mon 09/25/2023	Differential pair with current mirror load	Chapter 6	HW 5 Assign
	Wed 09/27/2023	Review of time- and frequency-domain analysis		
	Fri 09/29/2023	Review of frequency response and Bode plots		
7	Mon 10/02/2023	Frequency response	Chapter 6	
	Wed 10/04/2023	Frequency response		
	Fri 10/06/2023	Frequency response		HW 5 Due
8	Mon 10/09/2023	Frequency Response		HW 6 Assign
	Wed 10/11/2023	Frequency response		
	Fri 10/13/2023	Fall Recess		
9	Mon 10/16/2023	Midterm Exam	Chapter 8, Lecture Notes	
	Wed 10/18/2023	Feedback		
	Fri 10/20/2023	Feedback: stability and Routh Hurwitz		HW 6 Due
10	Mon 10/23/2023	Feedback: stability	Chapter 8, Lecture Notes	
	Wed 10/25/2023	Feedback: phase margin and circuit models		
	Fri 10/27/2023	Feedback: circuit models		
11	Mon 10/30/2023	Feedback: circuit models	Chapter 10	
	Wed 11/01/2023	Feedback: circuit models		HW 7 Assign
	Fri 11/03/2023	Feedback: circuit models		
12	Mon 11/06/2023	Feedback: frequency compensation	Chapter 9	
	Wed 11/08/2023	Common-mode feedback		
	Fri 11/10/2023	Common-mode feedback		HW 7 Due
13	Mon 11/13/2023	Noise	Chapters 9 & 10	HW 8 Assign
	Wed 11/15/2023	Noise		
	Fri 11/17/2023	Noise		
14	Mon 11/20/2023	Operational Amplifiers	Chapter 7	HW 9 Assign
	Wed 11/22/2023	Thanksgiving Holiday		
	Fri 11/24/2023	Thanksgiving Holiday		
15	Mon 11/27/2023	Operational Amplifiers	Chapter 7	HW 8 Due
	Wed 11/29/2023	Operational Amplifiers		
	Fri 12/01/2023	Operational Amplifiers		HW 9 Due

	Mon 12/11/2023	Final Exam (8 am – 10 am)		

Homework

Unless otherwise stated, homework assignments are due at the beginning of the class (before the lecture starts). Solutions will be posted on the class website on the same day.

Late homework will not be accepted. No exceptions except institution-established emergency reasons; credit for such late homework is with the discretion of the professor.

Limited collaboration in solving homework problems is allowed. This includes reviewing and discussing the problems with current EE 536a students and TA prior to writing down your solution. Everybody has to write his/her own solution independently and make sure to fully understand it. Exchanging solutions, consulting with people other than class members, finding solutions on the web or elsewhere, etc. are not allowed. Violations result in losing the credit for the entire homework set in addition to a significant percentage of the overall course grade, all with the discretion of the professor.

All answers should be clearly and fully justified. If we can't figure out your steps from is turned in, points will be deducted, even if your final answer is correct.

One or more of the homework assignments include design problems as well as the typical analysis problems. Simulation and performance verification of the design problems will be in the Cadence environment.

Final Design Project

The final project will consist of a transistor-level design, analysis, and simulation of a complete integrated circuit such as a high-performance Operational Trans-conductance Amplifier (OTA) in the Cadence environment using a state-of-the-art semiconductor foundry process design kit. Design project must be completed individually. Final project grading will be based on design creativity, achieved specifications, completeness of the written report including comparison between analysis and simulation results, and the quality of the oral presentation including answering to the questions posed by the instructor and other classmates. The approximate timeline for the project is as follows:

Late October:	Announcement of the final project description
Last Monday of the class:	Due date for electronic submission of the project schematic
Last Week of the class:	Oral presentations, and due date for submission of the report

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards*
https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions/.
Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct:
http://policy.usc.edu/scientific-misconduct/.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu/ or to the *Department of Public Safety* http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage sarc@usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs*
http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html
provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* *http://emergency.usc.edu/*will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.