University of California, Berkeley Extension

Integrated-Circuit Design and Techniques Program

X141: Advanced Design Techniques for Analog Integrated-Circuits

A. Course Description

Advances in signal processing, analog/digital conversion, power management, and continuingly scaling down of CMOS nanotechnology have ushered in the era of analog IC design with multi-standard challenges in the 21st century. This state-of-the-art course includes stability of feedback, frequency compensation, multistage OPAMPs, and CMOS OPAMP designs with HSPICE. You are required to work on a research project which scope covers the design of an advanced CMOS OPAMP, a compact low-voltage low-power OPAMP, and high-performance CMOS comparators for flash ADC applications.

B. Prerequisite

- *"X139: Advanced Analog Microelectronics"*
- *"X140: Fundamentals of Analog Integrated-Circuit Design Techniques"*

or possess working-level knowledge on fundamental analog ICs, such as

- *Feedback*
- *Current mirrors*
- *Differential amplifiers*
- *Single-stage amplifiers*
- *Frequency response*
- *Class AB output stages*

C. Timeline

Pacing yourself well is one of the key factors to succeed in this course. *Mark your calendar* for the timeline and course events. *Make a pla*n for studying lectures and then follow through. If you do that, the odds that you perform with excellence and succeed in this course are very high.

Timeline	Course events	Lecture pace
Day 30	Homework 1	30% of lectures done
Day 60	Homework 2	60% of lectures done
Day 90	Homework 3	90% of lectures done
Day 90	Final exam request	
Day 120	Midterm exam	100% of lectures done
Day 120	Final exam date confirmed	Review
Day 150	Proctored final exam	
Day 180	Project/Course end	Lecture access expires

The course registration date (Day 1) is the date you receive the login information and welcome email. Remember, the final exam request process could take up to a month to complete.

D. Course Length

30 hours.

- The course length covers not only the audio runtime but also the time you need to catch up with the lecture presentation, including the time to re-listen the soundtrack (rewind and play), the time to watch the slides (pause), and the time to take notes.
- The students are expected to *take notes*. Remember, the shortest pencil is longer than the longest memory. You haven't really studied unless you write things down, including primary circuit diagrams, analysis, and key concepts, etc.
- Other than the 30-hour course length, you are expected to spend additional 60 hours studying the lectures, digesting the materials, working on the assignments, and preparing for the exams. This is based on the level of effort that a "*UC Berkeley qualified*" student must spend to be successful in the course.
- Most students listen/watch the lectures two or three times before they can fully grasp the concepts, cultivate problem-solving skills, and have a good grade on the final exam.

E. Credit

- *Type of Credit: Academic credit at UC Berkeley campus level*
- *Campus Department: Electrical Engineering & Computer Science (EECS)*
- *Level: Upper Division (Junior/Senior)*
- *Number of Units: 2*

F. Instructors

- *Lead Instructor: Dr. Vincent Chang*
- *Program Instructor: Dr. Han-Bin Lin*
- *Instructor's bio: Please visit* http://www.ucberkeleyext.com/.

G. Learning Objectives

Upon successful completion of the course, students will be able to

- Grasp fundamental concepts of stability and frequency compensation and important characteristics of an OPAMP.
- Analyze, simulate, and design a multistage OPAMP and single-stage CMOS OPAMP.
- Possess the intuitive analysis skill to forecast/illustrate the circuit simulation results.
- Work on a hands-on design project with the scope including design of advanced CMOS OPAMP, a compact low-voltage low-power OPAMP, and high-performance CMOS comparator for the flash ADC application.

H. Short Session-By-Session Summary

Session 1. Stability

It's indispensable for analog designers to have the concept of stability of feedback, skills of evaluating stability, and knowledge of root locus. Those knowledge and skills will cultivate the students to be able to identify the stability of a feedback system.

- *Stability of Feedback: Basic Concepts*
- *Stability Study of an OPAMP-Based Noninverting Amplifier*
- *Root Locus: Effect of Pole Locations on Stability*

Session 2. Frequency Compensation

It's important for you to understand that the primary goal of frequency compensation and the several compensation techniques including Miller compensation, one of the most commonly used compensation techniques in the design of integrated operational amplifiers. You will learn a comprehensive lesson through session by session, from the theory, graphical illustration, to the concept of pole-splitting.

- *Frequency Compensation: Basic Concepts*
- *Frequency Compensation: Implementation Techniques*
- *Miller Compensation & Pole-Splitting*

Session 3. Bipolar Multistage OPAMP

The dc/ac characteristics, frequency response and the slew-rate of the multistage OPAMP will be demonstrated through both hand analysis and SPICE, respectively. This way of instruction will give students a hands-on experience about employing the simulation tools and comparing its results with intuitive concepts or sound methods.

- *The Multistage OPAMP: Identification of Parts and Functions*
- *DC Analysis of Bias Circuitry*
- *DC Analysis of Input and Gain Stages*
- *DC Analysis of Class AB Output Stage*
- *Frequency Response: Hand Analysis vs. Simulation*
- *Slew-Rate: Hand Analysis vs. Simulation*

Session 4. CMOS OPAMP

You will be inspired by some of the lectures, such as design of compensation network using HSPICE, design of two-Stage CMOS OPAMP using HSPICE, and folded-cascode CMOS OPAMP. Starting from an analog designer's perspective, this session will arm you with practical knowledge and hand-on skill on the CMOS OPAMP design.

- *Two-Stage CMOS OPAMP: Part I*
- *Two-Stage CMOS OPAMP: Part II*
- *Cascode CMOS OPAMP*
- *Folded-Cascode CMOS OPAMP*
- *(Optional) Design of Two-Stage CMOS OPAMP Using HSPICE*
- *(Optional) Design of Cascode CMOS OPAMP Using HSPICE*
- *(Optional) Design of Folded-Cascode CMOS OPAMP Using HSPICE*

I. Methods of Instruction

- Online bilingual presentation—English and Mandarin
- Interactive discussion with the instructor via email
- *Three* homework assignments
- Practices via not only hand analysis but also SPICE simulation

Discussion Policy

To create a positive sharing & learning environment where all students can be benefited by learning from each other, the instructor may select your questions along with the instructor's answers and *anonymously* put them into Discussion Q&A.

If you have a concern the question you ask the instructor might be *anonymously* posted in the Discussion Q&A or you *don't* want to *anonymously* share your question with other fellow classmates, you should notify the instructor via email within 30 days from the course registration date.

J. Grade Structure

- Progress update & discussion: 20%
- Homework assignments: 10%
- Mid-term (Take-home exam): 20%
- Proctored final exam: 25%
- Project: 25%

K. Additional Classroom Info

Additional information will be posted and updated on a regularly basis. Please visit your Classrooms at http://www.ucberkeleyext.com/.