University of California, Berkeley Extension

Integrated-Circuit Design and Techniques Program

X138: Semiconductor Devices for Integrated-Circuit Design

A. Course Description

The ever-increasing-bandwidth state-of-the-art IC design requires a comprehensive in-depth understanding of not only basic characteristics of semiconductor devices but also their second-order effects and device modeling. This course is intended for working professionals who have no experience on IC design yet are interested in building an in-depth understanding of semiconductor devices and their modeling for advancing career development in the integrated-circuit design. A broad range of topics in BJT and MOS is covered, with an emphasis on delivering an inspiring and practical perspective involving physical concepts, operation principles, second-order effects, and modeling and simulation. The project options cover nanoelectronics—transistor scaling & future trends, recent breakthrough and real world issues in CMOS nanotechnology ranging from 90nm down to 22nm, CMOS device design and performance parameters, and future trends in the statistical IC design in nanoelectronics.

B. Prerequisite

- *"X32: Intro to Physics of Semiconductor Devices"*

or working-level knowledge on basic solid-state electronics, such as

- *Intrinsic & Extrinsic Semiconductors—Intrinsic Carrier Concentration, Donors, and Acceptors*
- *Carrier Transport Phenomena—Drift & Diffusion*
- *Depletion Layer of PN Junction—Concepts & Electrostatics*
- *Minority Carrier Concentration Distribution of PN junction—Forward & Reverse Bias*
- *Junction Capacitances of PN Junction—Depletion & Diffusion Capacitance*

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 knowledge of semiconductor devices for integrated-circuit design.
- Thoroughly understand the operation principle of BJT and MOSFET.
- Have a comprehensive in-depth understanding of the second-order effects and device modeling through which you can cope with an ever-increasing-speed state-of-the-art design.

H. Short Session-By-Session Summary

Session 1. BJT Device Physics

Learn the BJT device physics consisting of the transistor effect, minority-carrier distribution, current-voltage characteristics, and base-width modulation. Also, students will be impressed by the proposed intuitive mechanical model related to the real daily life which is analogous to the microelectronic world.

- *Key Concepts of BJT Device Physics*
- *Designing the Current Gain of Bipolar Transistors*
- *Minority Carrier Concentrations Under Forward-Active Bias*
- *Advanced Derivation of Forward-Active Current Gains*
- *Current-Voltage Characteristics of Bipolar Transistors*
- *Secondary Effects of the Actual Bipolar Transistor*

Session 2. BJT Device Modeling

This session provide students an opportunity to establish a solid foundation for future analog circuit analysis. Students will learn an impressive concept of device modeling. Also, they will have a whole picture in this topic and realize its importance related to analog or digital field. Topics include the physical meaning, formula derivation, and SPCIE modeling associated with each resistor and capacitor.

- *Low-Frequency Modeling of Bipolar Transistors*
- *Key Concepts of Small-Signal Input Resistances*
- *Key Concepts of Small-Signal Output Resistance*
- *High Frequency Modeling of Bipolar Transistors*

Session 3. MOS Device Physics

The student will learn the operation principles of a MOSFET, understand how the current-voltage characteristics are developed by going deeper into the device physics. In addition, it's always been critical for a circuit designer to have a through understanding of second-order effects of MOSFET before he or she can conduct a high-speed state-of-the-art design.

- *Key Concepts of MOS Device Physics*
- *Current-Voltage Characteristics of MOSFET*
- *P-Channel Enhancement MOSFET*
- *Secondary Effects of the Actual MOS Transistor*
- *Adjusting Threshold Voltage vs. Depletion MOSFET*
- *SPICE Simulation Examples*

Session 4. MOS Device Modeling & Simulation

Concentrate on the physical meaning and formula derivation associated with resistors, dependent current courses, and five internal capacitors in the device modeling. Plus, students will be able to prioritize the importance of each capacitor on the circuit performance in the high-frequency model.

- *Low-Frequency Modeling of MOS Transistors*
- *Key Concepts of MOS Body Transconductance*
- *High Frequency Modeling of MOS Transistors*
- *Advanced MOS SPICE Modeling Parameters--Part I*
- *Advanced MOS SPICE Modeling Parameters--Part II*

I. Methods of Instruction

- Online bilingual presentation—English and Mandarin
- Progress update & 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/.