University of California, Berkeley Extension

Professional Sequence in Semiconductor Technology Fundamentals
Certificate Program in Semiconductor IC Design

EL ENG X488: Semiconductor Devices for IC Design
(2 semester units in EL ENG, Online Format)

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.

Side-note: Student Testimony

I find materials covered in X488 class very helpful and related to my work. One interesting experience I'd like to share is I took a similar course during my sophomore year in college as an entry level analog IC design class. It was hard for me to appreciate the importance of having a good understanding of the device level knowledge. After working in RFIC design industry for a few years it is apparent to me good circuit designers have solid understanding from device level physics to top level architectures. Taking this course it really allows me to improve my circuit design skills to the next level.—Tianming Chen (2014)

B. Prerequisite

- *Intro to Semiconductor Devices, EL ENG X481.1 (1 semester unit)*

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

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**	100% of lectures done
Day 90	Final exam setup	

Day 120	**Midterm Exam**	
Day 120	Final exam date confirmed	
Day 150	Optional final project	Extra bonus
Day 165	**Proctored final exam**	
Day 180	Course end	Lecture access expires

- 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.
- The course registration date (Day 1) is the date you receive the login information and welcome email.
- *You final exam request/setup process normally takes up to a couple of months to finalize. Therefore, it is strongly suggested you reserve the last two weeks (Day 165-180) for contingency.*

D. Required Readings

PDF Slides (Downloadable in the Classroom).

E. 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.

F. Intended Audience

Many types of working professionals find this course interesting and challenging. This course is intended for technical professionals who want to enter the semiconductor market and are looking to build a solid foundation on device physics and modeling *for future transistor-level circuit analysis and design courses*.

G. Course Content Outline

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.

- *Course Overview*
- *Key Concepts of BJT Device Physics*
- *BJT Current Gain_Circuit Perspectives*
- *[Challenging] Minority Carrier Distribution*
- *[Challenging] BJT Current Gain_Device Perspectives*
- *Current-Voltage Characteristics of BJTs*
- *Secondary Effects of BJTs*

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.

- *BJT Low Frequency Modeling_Transconductance*
- *BJT Low Frequency Modeling_Input Resistances*
- *BJT Low Frequency Modeling_Output Resistances*
- *BJT High Frequency Modeling*

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*

Optional

- *BJT Current Gain_Problem Solving*
- *Advanced MOS SPICE Modeling Parameters--Part I*
- *Advanced MOS SPICE Modeling Parameters--Part II*

H. Course Length

- The 30-hour course length covers not only the audio runtime but also the time to catch up by rewinding and replaying video. It also includes the time to take notes and to communicate/discuss with the instructor.
- 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.

- Most students watch the lecture video or read PDF slides two or three times before they can fully grasp the concepts, cultivate problem-solving skills, and have a good grade on the final exam.

I. Course Grade Weighting (Grading)

The student's cumulative grade in the course will be based on the following criteria:

- Discussion Participation: 10 points
- Progress Updates: 10 points
- Written Homework Assignments: 30 points
- Midterm Exam (Take-home exam): 20 points
- Final Exam: 30 points
- Optional Final Project (Extra bonus up to 10 points): 0 to 10 points

You must pass the final exam with a grade of at least 70 percent to pass the course.