COURSE INFORMATION

Instructor:

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Office Hours: M 2-3 p.m., Th 3-4 p.m., in 574 Cory

Teaching Assistants (TA's):

Mr. Travis Massey, 656B Sudardja-Dai Hall, Tel: (510)644-4114
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Office Hours: M 11-12 a.m., Tu 9:30-10:30 a.m., in the Moore Room, Cory Hall Courtyard

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Office Hours: Tu 2-3 p.m., F 2-3 p.m. in the Moore Room, Cory Hall Courtyard

Lecture: Tuesday, Thursday 12:30-2:00 p.m. in 213 Wheeler

Discussion Sections:

Section 101: Wednesday, 2-3 p.m. in 3108 Etcheverry
Section 103: Friday, 4-5 p.m. in 293 Cory

Laboratory Sections:

Section 10: Monday, 4-6 p.m. in 353 Cory, TA: Travis Massey
Section 11: Tuesday, 5-7 p.m. in 353 Cory, TA: Yang Lin
Section 12: Wednesday, 9-11 a.m. in 353 Cory, TA: Yang Lin

Office Hours:

Office hours are the primary mechanism for individual contact with Professor Nguyen and the TA's. All students are strongly encouraged to make use of office hours.

Course Description:

Integrated Circuits have seen tremendous growth over the past forty years and promise to continue that growth for many years to come. The year 2010 has already seen silicon CPU chips using more than 2 billion transistors, and Moore's Law promises even larger transistor counts in the coming years. Analog integrated circuits are becoming ever more sophisticated and important, since they provide the very important function of interfacing many data acquisition and signal processing systems with purely digital computers. In addition, as mixed-mode analog/digital systems become more important in many consumer products, such as cellular communications and wireless data acquisition systems, the design and analysis of analog integrated circuits has become a very important requirement for many designers of VLSI systems. One major component in many of today's analog electronic systems is the operational

amplifier. The op-amp is used as a circuit block in systems such as analog-to-digital and digital-to-analog converters, switched-capacitor functions, signal processing systems, integrated circuit filters, and virtually all systems where amplification of input signals is needed. Indeed, the op-amp is probably the most commonly used analog circuit block. As a result, it is important for students interested in electronic circuit design and analysis to have a thorough knowledge of the design and analysis of the operational amplifier. This course will examine the technology and circuit techniques associated with integrated monolithic amplifier circuits and the challenges that lie ahead in their development. The goal is to achieve a basic understanding and knowledge of the driving and limiting factors in circuit performance, of circuit design techniques, and of fabrication techniques and technology issues important to integrated amplifier circuits in general, and to op-amps in particular.

The first part of the course reviews the small-signal models of both Bipolar Junction Transistor (BJT) and Metal-Oxide-Semiconductor (MOS) transistors. The course assumes that students have had a significant amount of experience in the analysis and design of discrete BJT amplifiers, and some experience in the design and analysis of MOS amplifiers. Consequently, MOS amplifier stages will be emphasized initially and more lab experiments will be geared towards illustrating specifically the design of MOS amplifiers. BJT and MOS multi-transistor amplifiers are reviewed next with an emphasis on inspection analysis of multi-transistor circuits. After covering basic material on transistor amplifiers, we will review the application of transistors in the design of various basic analog circuit blocks that are utilized in the implementation of a complete integrated operational amplifier circuit. These circuit blocks include current sources and current mirrors, level shifters, active loads, and differential amplifier stages. These circuit blocks are needed in the design and analysis of many amplifier circuits, and are particularly required for the design and analysis of op-amps. Although much of the lecture coverage will be on MOS op amp design, you will assemble and design an operational amplifier in the laboratory using several different circuit blocks based on BJT devices, which are more robust for use in a laboratory setting. Since it is impractical to build an actual CMOS op-amp in the laboratory using off the shelf components, you will be given a design project that involves the design and simulation of a CMOS op-amp using available CAD tools. This laboratory will be a software lab assignment, and will focus on the design tradeoffs involved in the design of CMOS op-amps. There will be no hardware labs during this time. Note that the design project will be due before the end of the semester, unless circumstances dictate otherwise. An important topic in the design of any amplifier circuit is that of feedback and amplifier stability, and this course will spend sufficient time discussing feedback and the use of feedback techniques to stabilize the response and performance of amplifier circuits. The course concludes with coverage of some practical issues in analog circuit, such as stability against variations in power supply and temperature, for which supply and temperature independent bias references will be needed.

Lectures are intended to discuss and supplement the material in the text and the laboratory experiments. A number of suggested reference books are listed below that should supplement the material not covered in the textbook. Problem sets will attempt to emphasize important points. Students will analyze and simulate circuits using SPICE, and analyze problems related to fabrication of analog ICs. Both hardware and software labs will be assigned to familiarize students with the design aspects of amplifier circuits in general, and op-amps in particular.

Lectures and discussion, 4 units.

Prerequisites:

The prerequisites for this course are EE 105 and some aspects of EE 20N. It is assumed that you are familiar with the following topics:

- Basic network theory
- Basic linear systems theory (Fourier and Laplace transforms, Bode plots)

- The use of small-signal models in the analysis and design of BJT and MOS amplifier circuits
- Analysis of single- and multi-transistor amplifiers with BJTs and MOS (including common-emitter (source), common-collector (drain), common-base (gate), cascode, cascade, darlington, etc.)
- Elementary semiconductor physics and device operation for pn junctions, bipolar junction transistors (BJTs), and MOS field-effect transistors (MOSFETs)

Familiarity with integrated circuit fabrication techniques is helpful, but not necessary. We will review IC fabrication techniques whenever needed.

Texts:

Required: Gray, Hurst, Lewis, Meyer, *Analysis and Design of Analog Integrated Circuits*, 5th Edition, John Wiley & Sons, 2009.

Various material to be distributed throughout the course.

Recommended: B. Razavi, *Design of Analog CMOS Integrated Circuits*, 1st Edition, McGraw Hill, 2001.

Note that this text was used for previous renditions of this course, so is still very relevant as supplemental reading, especially for MOS circuit design.

Suggested References: (on reserve in the Engineering Library)

1 P.E. Allen, D.R. Holberg, *CMOS Analog Circuit Design,* Holt, Reinhart, and Winston, Inc., 1987. This is one of very few books dedicated entirely to MOS analog circuits. We will use some of the material in chapter 8 on the topic of CMOS op-amp design.

2 D.A. Johns, K. Martin, Analog Integrated Circuit Design, J. Wiley & Sons, 1997. This is also a very good book that covers a wide range of topics dealing with CMOS analog integrated circuits.

3 K.R. Laker, and W.M.C. Sansen, *Design of Analog Integrated Circuits and Systems,* McGraw-Hill, 1994. This book is a very good book and provides a very detailed treatment of many topics that we will cover in our course. I strongly recommend that you buy this book if you can afford it. Otherwise, try to use it as a reference for additional reading material.

4 M. Ismail and T. Fiez, *Analog VLSI Signal and Information Processing,* McGraw-Hill, 1994. This book is a VLSI-oriented analog text book that emphasize the design of larger systems using standard building blocks. It has discussions on op-amps and the use of various types of op-amps in different circuits. A good book for the VLSI analog designer.

5 R. Gregorian, G.C. Temes, *Analog MOS Integrated Circuits for Signal Processing,* John Wiley & Sons, Inc., 1986. NMOS and CMOS analog circuits with emphasis on switched-capacitor circuits.

6 A.B. Grebene, *Bipolar and MOS Analog Integrated Circuit Design,* New York: John Wiley & Sons, Inc., 1984. An excellent reference on a variety of MOS and bipolar analog circuits and their implementation.

7 A.S. Sedra, K.G. Smith, *Microelectronics Circuits,* New York: Holt, Rinehart, and Winston, Inc. 1987. An introductory text covering a variety of analog circuits, including CE, CB, CC transistor amplifiers.

8 R.L. Geiger, P.E. Allen, N.R. Strader, *VLSI Design Techniques for Analog and Digital Circuits,* New York: McGraw-Hill, Inc., 1990. A good reference book covering both fabrication technology and basic circuit principles for analog and digital circuits. No real circuit details.