University of Southern California

Ming Hsieh Department of Electrical Engineering

Course Number & Title: EE 479, Analog Integrated Circuit Design

Units: 4

Semester: Fall Semester

Schedule: Mondays & Wednesdays, 11am-12:20pm
Fridays, 12-12:50pm

Location: OHE 132

Instructor: Dina El-Damak

Office: PHE 620

Office Hours: Wednesday, 9:45 am – 10:45 am

Contact Information: eldamak@usc.edu

Teaching Assistant: Haolin Cong (haolinco@usc.edu)
Office Hours: Thursday 10 am to 11 am (PHE 320)

Catalogue Description:

MOSFET and BJT operation and models; elementary amplifier configurations; biasing and references; frequency response; feedback; operational amplifiers

Course Description:

EE 479 is a second level electronic circuits course that is focused on the analysis and design of analog integrated circuits. EE 479 serves three fundamental purposes. First, it offers undergraduate students a complete coverage of the salient aspects of the theories, concepts, and analysis and design strategies that pervade the analog circuits and systems arena. Second, EE 479 attempts to ensure that electrical engineering students who are interested in pursuing a leadership engineering career in the circuits and systems discipline are well prepared for EE 536a, an advanced course that addresses mixed signal integrated circuits. As such, EE 479 bridges the cavernous gap that often separates a basic undergraduate course on electronic circuits (EE 348L at USC) and EE 536a. Finally, EE 479 provides graduate students with interest in other specialties, such as digital VLSI, devices, and processing technology adequate education about the fundamentals of analog integrated circuit analysis, design, and applications.

Learning Objectives:

As with other USC courses in the electronics circuits venue, EE 479 emphasizes design-oriented circuit analysis. In particular, EE 479 teaches that deducing the correct answer to an analytical exercise or achieving the target specifications of a design venture is not the end of the problem; in many respects it is only the beginning of the engineering undertaking. Engineering entails the ability to ask and intellectually resolve numerous questions before finalizing a design undertaking. For example, does the work identify the dominant attributes, as well as the shortfalls, of the circuit undergoing investigation? For example, does the biasing evoke adequate power supply rejection, excessive sensitivity to ill-controlled or ill-defined device and circuit parameters, and/or excessive sensitivity to operating temperature? Is there a long settling time or significant overshoot/undershoot to transient excitation? Does a potential stability problem lurk in the background? These and a myriad of other questions are difficult to answer when the focus of analysis and design is largely directed to assimilating elegant and presumably accurate mathematical expressions for circuit responses. EE 479 teaches that tractable, approximate results premised on meaningful, realistic, and well-understood approximations are perfectly acceptable. Indeed, they are even preferred for at least three reasons. First, simplified analyses generally require minimal algebraic annoyances, thereby enabling a shift of emphasis toward understanding how the various dynamics that are implicit to a circuit interact to produce the observed response. Second, the ability to make reasonable approximations in advance of a first order estimate of circuit responses mandates an insightful understanding of active device operation and characteristics, the attributes and shortcomings of the frequency responses of the circuit cells embedded in the considered network, and the electrical implications of both lossy and energy storage parasitics implicit to the architectural layout of the circuit. Third, it is possible and even likely that these foregoing insights, when conflated with the simplified mathematical forms of approximated analytical or design results, breed a reinvigorated methodology that nurtures innovative and creative design solutions. To these ends, EE 479 teaches students computationally efficient manual and computer-aided methods for analyzing the electrical dynamics of both linear and nonlinear models of active networks destined for monolithic realization in Complementary Metal-Oxide-Semiconductor (CMOS) and Bipolar Junction (BJT) Transistor technologies.

Students should be aware that the computer tools addressed in the lectures and required in several homework assignments, include SPICE. Virtually any form of SPICE, such as HSPICE, LTSPICE, PSPICE, TOPSPICE or SPICE versions embedded within CADENCE, TANNER, or other design suites are acceptable. Students may also benefit from using MATLAB and EXCEL in this course.

Prerequisite: EE 348L or an equivalent junior-/senior- level course focused on the analysis and design of analog integrated circuits.

Main Text Book: P. Grey, P. Hurst, S. Lewis, and R. Meyer, *Analysis and Design of Analog Integrated Circuits*, John Wiley and Sons, 5th Edition, 2009.

Supplementary Texts:

- B. Razavi, *Design of Analog CMOS Integrated Circuits*, McGraw Hill, 1st Edition, 2000.
- P. E. Allen and D. R. Holberg, *CMOS Analog Circuit Design*, New York: Oxford University Press, 2002.
- M. Burns and G. Roberts, *An Introduction to Mixed-Signal IC Test and Measurement*, Oxford University Press, 2001.
- W-K. Chen, L. O. Chua, J. Choma, Jr., and L. P. Huelsman (editors), *The Circuits and Filters Handbook*, CRC/IEEE Press, 1995.
- J. Choma, Jr., *Electrical Networks*, Wiley–Interscience, 1985.
- J. Choma and W-K. Chen, *Feedback Networks: Theory and Circuit Applications*, World Scientific Press, 2007.
- K. K. Clarke and D. T. Hess, *Communication Circuits: Analysis and Design*, Addison-Wesley Pub. Co., 1978.
- D. Clein, *CMOS IC Layout: Concepts, Methodologies, and Tools*, Butterworth-Heinemann (Newnes), 2000.
- D. T. Comer, *Introduction to Mixed Signal VLSI*, Array Publishing Co., 1994.
- J. A. Connelly and P. Choi, *Macromodeling with SPICE*, Prentice-Hall, Inc., 1992.
- R. C. Dorf (editor), *The Electrical Engineering Handbook*, CRC Press, 1993.
- D. P. Foty, *MOSFET Modeling With SPICE: Principles and Practice*, Prentice Hall PTR, 1997.
- R. L. Geiger, P. E. Allen, and N. R. Strader, *VLSI Design Techniques For Analog And Digital Circuits*, McGraw-Hill Publishing Company, 1990.
- A. B. Grebene, *Bipolar and MOS Analog and Integrated Circuit Design*, Wiley–Interscience, 1984.
- R. Gregorian and G. C. Temes, *Analog MOS Integrated Circuits for Signal Processing*, Wiley– Interscience, 1986.
- R. J. Higgins, *Electronics With Digital and Analog Electronics*, Prentice Hall, Inc., 1983.
- R. T. Howe and C. G. Sodini, *Microelectronics: An Integrated Approach. Upper Saddle River*, Prentice Hall, Inc., 1997.
- J. H. Huijsing, R. J. van der Plassche, and W. Sansen (editors), *Analog Circuit Design*, Kluwer Academic Publishers, 1993.
- R. C. Jaeger, *Microelectronic Circuit Design*, McGraw-Hill, 1997.
- D. Johns and K. Martin, *Analog Integrated Circuit Design*, John Wiley and Sons, Inc., 1997.
- K. R. Laker and W. M. C. Sansen, *Design of Analog Integrated Circuits and Systems*, McGraw-Hill, Inc., 1994.
- T. H. Lee, *The Design Of CMOS Radio–Frequency Integrated Circuits*, Cambridge University Press, 2004.
- W. Liu, *MOSFET Models for SPICE Simulation*, John Wiley and Sons, Inc., 2001.

- G. Palumbo and A. Pennisi, *Feedback Amplifiers: Theory and Design*, Kluwer Academic Publishers, 2002.
- D. O. Pederson and K. Mayaram, *Analog Integrated Circuits for Communication*, Kluwer Academic Publishers, 1991.
- E. Sánchez-Sinencio and A. G. Andreou (editors), *Low-Voltage/Low-Power Integrated Circuits and Systems*, IEEE Press, 1999.
- T. F. Schubert, Jr. and E. M. Kim, *Active and Non–Linear Electronics*, John Wiley & Sons, Inc., 1996.
- M. H. Rashid, *Microelectronic Circuits: Analysis and Design*, Boston: PWS Publishing Company, 1999.
- B. Razavi, *Fundamentals of Microelectronics*, 2nd Edition, John Wiley & Sons, Inc., 2014.

Grading: Homework	15%
Midterm Exam (October 10th 11 am to 12:20 pm)	25%
Final Exam (December 5th 11 am to 1 pm)	35%
Design Projects	25%

Weekly Schedule

Week	Subject	Readings	
1	Review of Electrical Circuits, Time- & Frequency-Domain Analyses	Lecture Notes	
2	MOSFET Device Physics, Models, and Fabrication Technology	Chapters 1 & 2	
3	BJT Device Physics, Models, and Fabrication Technology	Chapter 1 & 2	
4	Single- and Multi-Transistor Amplifiers (MOSFET)	Chapter 3	
5	Single- and Multi- Transistor Amplifiers (BJT)	Chapter 3	
6	Current Mirrors & Active Loads (MOSFET & BJT)	Chapter 4	
7	Bias Circuits (MOSFET & BJT)	Chapter 4	
8	Output Stages (MOSFET & BJT)	Chapter 5	
9	Operational Amplifiers	Chapter 6	
10	Midterm, Operational Amplifiers	Chapter 6	
11	Frequency Response	Chapter 7	
12	Frequency Response	Chapter 7	
13	Feedback	Chapter 8	
14	Feedback	Chapter 8	
15	Applications	Notes	

Assignment:

- Homework (15%) → assign whenever each topic is finished. Work independently.

- Design Project (25%) → A few design projects throughout the semester. Design transistor level circuits with certain specification in given spice model.
  The score is evaluated based on report presentation clarity (20%), novelty (10%), circuit analysis (20%), schematic/simulation completeness (20%), specification (30%).

- Midterm (25%), Final Exam (35%) → Test the student's analytical capability of the circuits

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.