

West Virginia University
College of Engineering and Mineral Resources
Lane Department of Computer Science and Electrical Engineering

EE 551 – Linear Integrated Circuits
Spring 2019

Class Info

Meeting Time: 6:00-8:30 M
Location: AER 135
Prerequisites: EE 355, EE 356, and EE 450
Credit Hours: 3 (Lecture)

Instructor

Dr. David W. Graham
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AER 355
304-293-9692

Office Hours

Mondays 4:00-5:00 in either AER 355 or ERB 216

Text

Analysis and Design of Analog Integrated Circuits, 5th Edition
By Paul R. Gray, Paul J. Hurst, Stephen H. Lewis, Robert G. Meyer
John Wiley & Sons, Inc., New York, 2009
ISBN: 9780470245996

Webpage

community.wvu.edu/~dwgraham/classes/ee551
Contains a detailed schedule of course coverage, reading assignments, homework, and projects.

Course Description

Design and analysis of analog integrated circuits. Both linear and nonlinear transistor models are covered. Applications focus on linear analog circuits including simple amplifiers, operational amplifiers, and reference circuits. This course focuses on CMOS technology.

Course Objectives

The purpose of this course is to equip the student with the fundamental concepts of analog circuit design specifically geared towards integrated-circuit technology. Analog circuit design will focus primarily on CMOS technology, covering the topics of transistor modeling, simple amplifiers, operational amplifiers, and reference circuits. At the completion of the course, you should be able to analyze and design linear analog integrated circuits. Specifically, you should be able to use theory along with SPICE and layout tools to completely design complex amplifiers and their supporting circuitry.

Expected Learning Outcomes

1. Ability to understand the origins and uses of different transistor models, as well as their differences and limitations.
2. Ability to analyze and design analog circuits in CMOS technology.
3. Ability to design the physical layout of analog integrated circuits.
4. Ability to use standard analog circuit computer-aided design (CAD) tools to design analog integrated circuits. Examples include SPICE and layout editors.

Attendance

Students are responsible for all material covered in class and any announcements made during class time (including changes to test dates, etc.). Please arrive at class on time.

Class Policies

The use of portable phones in the classroom is not permitted (i.e. no calls, no texting, no ringers, etc.). Please remember to turn off your ringers before class. If there are extenuating circumstances that warrant the need of a cell phone in class, let me know *beforehand*.

Assessment

Tests (2)	40%
Projects	35%
Final Project	25%
Extra Credit	5%

Grading	A ≥ 90%	90 > B ≥ 80%	80 > C ≥ 70%	70 > D ≥ 60%	F < 60%
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Homework

Regular homework assignments will be given to help provide understanding of the material and also practice solving problems. Solutions for the homework problems will typically be provided at the time the problems are assigned. These problems should be completed, but they do not need to be turned in.

Tests

Two 75-minute tests will be given in class. For each test, you will be permitted to bring a calculator and an equations sheet consisting of one 8.5x11 inch piece of paper with handwritten notes, front and back. You will be able to bring in previous equations sheets to subsequent tests. Please take special care of these equations sheets since you will not be permitted to remake them *for any reason*. The limitations on these equations sheets are that they must be handwritten, and they cannot contain completely worked out problems (equations and formulas only). Additionally, you may not add to them once the test is over. If there are infractions on any of these restrictions, I reserve the right to deduct points from your test, accordingly.

Projects

Projects will be assigned on an approximately weekly or biweekly basis. These projects will primarily cover data analysis and circuit design. They will, accordingly, make use of software packages such as MATLAB, SPICE, and circuit layout tools (e.g. Cadence). Not all projects will be of equal value.

Project reports are due at the BEGINNING of class. Late project reports will be deducted by 10 points each twenty-four-hour period after the time in which it is due. Projects turned in after an associated project presentation will be subject to an *additional* 20 point deduction. Additionally, your reports must be turned in electronically via e-mail as well as in paper form. Paper reports *must* be stapled. I reserve the right to deduct points if you fail to staple your report. Detailed directions about the project reports will be provided on the class website.

You may be required to work with a partner on these projects. If so, you will turn in a combined report with your partner (you will both receive the same grade). You are *not* permitted to communicate with other groups as you work on these projects.

Final Project

The Final Project will encompass a large design of a specific integrated circuit. Exact details on the Final Project will be released towards the end of the semester. Presentations for the Final Project will occur during the regularly scheduled Final Exam period.

Extra Credit

There will be several extra-credit opportunities throughout the course of the semester. These may consist of pop quizzes, project presentations, out of class assignments, etc. These extra credit opportunities are designed to make sure you are keeping up with the material and are closely paying attention in class. Since quizzes will normally be unannounced, please make sure you bring in extra paper (please no spiral-bound notebook paper) and a calculator on a regular basis. Expect at least one pop quiz per class.

Extra credit assignments will be on a “points” basis (i.e. not all extra credit assignments will be of equal value). Extra credit can only help you (with no possibility of hurting you) by potentially bumping you over a letter grade boundary. All the extra credit assignments will equate to a specific percentage added to final grade. This will be at least 5%, and I reserve the right to make it higher (to further benefit the class). Since this is extra credit, you will not be permitted to make up a missed extra credit opportunity for *any* reason.

$$\text{Your extra credit (EC) grade} = (5\%) \times (\text{Your EC Points}) / (\text{Total EC Points Offered})$$

Make-Up Policy

You are expected to attend all tests, quizzes, etc. at the scheduled time and location. If you will not be able to attend a test for a legitimate reason (e.g. religious observance, attending a conference, etc.), let me know within the first week of the semester. Otherwise, you will not be permitted to make them up, unless there is documented proof of urgent medical care or an emergency. Any make up tests or projects that are granted may be given as oral examinations, at my discretion.

Honor Code and Academic Honesty Statement

All work you turn in must be completely your own unaided work. I will not tolerate cheating, copying, helping others, or harming others; these are strictly forbidden and are in violation of the university's academic honesty policy, as listed in the undergraduate/graduate catalogs. Plagiarism and any other forms of cheating will be severely penalized and may result in an F grade for the course or receive no credit for the specific test or exam or component of the course. Students are expected to exhibit the same level of professionalism and integrity that will distinguish them in their professional careers. Both the person who reproduced in whole or in any part from the work of others and the person who allowed the work to be copied will be penalized (including partners who turn in joint reports).

(Official University Statement) The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, I will enforce rigorous standards of academic integrity in all aspects and assignments of this course. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the Student Conduct Code at <http://studentlife.wvu.edu/studentconductcode.html>. Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see me *before* the assignment is due to discuss the matter.

Social Justice and Disability Statement

West Virginia University is committed to social justice. I concur with that commitment and expect to foster a nurturing learning environment, based upon open communication, mutual respect, and non-discrimination. Our University does not discriminate on the basis of race, sex, age, disability, veteran status, religion, sexual orientation, color or national origin. Any suggestions as to how to further such a positive and open environment in this class will be appreciated and given serious consideration. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with Disability Services (293-6700).

Statler College Policies for Enforcing Academic Integrity

- Grades assigned during the semester on exams, quizzes, reports, or homework assignments are considered final and are not subject to negotiation for any reason other than an indisputable mistake in grading.
- Use of cell phones, smart wearable devices, or possession of other external communication devices are strictly prohibited during exams, tests, or quizzes administered inside the classroom. Departments may specify acceptable calculators and additional restrictions.
- Common standards of academic integrity prohibit not only cheating or plagiarizing, but also the unethical conduct of trying to obtain grades that the student has not earned. Violations of academic integrity are described in the WVU Catalog: <http://bit.ly/2hDAeUa>.
- Incidents of student misconduct or academic dishonesty will be handled promptly and appropriately in accordance with the WVU Student Conduct Code and Discipline Procedure. The case will be referred to the Office of Student Conduct. Violations may lead to dismissal from the Statler College and expulsion from the University.

Disclaimer

The professor reserves the right to make changes in the syllabus. Any changes that are made will be in, what the professor deems, the best interests of the class.

Tentative Schedule

The following is a tentative schedule. The exact schedule, with associated reading assignments, will be kept up to date on the class website. Please complete all reading assignments BEFORE coming to class.

- Unit 1 – MOS Transistor Modeling
 - Device Physics Review
 - MOSFET Models (Sub and Above V_T)
 - Secondary Effects of MOSFETs
- Unit 2 – Single-Stage Amplifiers
 - Current Mirrors
 - Small-Signal Modeling
 - Single-Transistor Amplifiers
 - Single-Stage Amplifiers with Active Loads
 - Cascoded Amplifiers
 - Differential Pairs
- Unit 3 – Introduction to Opamps
 - Operational Transconductance Amplifiers
 - One-Stage Opamps
 - High-Gain Opamps
 - Frequency Response and Compensation
- Unit 4 – Physical Layout Design
 - CMOS Fabrication Cycle
 - Physical Layout
 - Parasitics, Matching, Latchup
- Unit 5 – Voltage/Current References (If Time)
 - Bandgap References
 - Temperature-Independent References