ECE 4660/6660 Syllabus Analog Integrated Circuits

ECE 4660/6660, Fall 2018, MSE 171, TuTh, 3:30 - 4:45

Catalog Description:

ECE 4660/6660 Analog Integrated Circuits Prerequisite: FUN 3 (Electronics I and Signals and Systems I). (NOTE: Microelectronics (ECE 3660) is no longer a prereq!)

Instructor:

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What are Analog ICs useful for?

The dominant market for ICs in the 20th century was for digital processing and storage, as the personal computer dominated the market by pushing digital bits around. ICs in the 21st century are increasingly complex, interacting with the real analog world in more and more meaningful ways that require interfacing with analog circuits. Even within a processor, things like neuromorphic computing that power the latest generation of AI chips require understanding of the concepts from analog circuits as computation is increasingly being done in non-binary domains. Analog circuits are used for everything from IoT sensors (personal health monitoring), to communication receivers and transceivers (5G cell phone circuits), to smart homes and devices (lighting control), signal manipulation (audio amplifiers and distortion or mixing up or down frequencies). All of these applications rely on the immense complexity that can be achieved by circuits that are all integrated onto a single chip. In the FUN classes, you have used discrete transistors to create designs, and even used some pre-made analog integrated circuits, such as op-amps in your designs, but this class will teach you how to actually go about designing and preparing an analog IC for fabrication, culminating in a final project where you design a low dropout (LDO) voltage regulator for low power mobile applications.

What are the objectives?

By the end of this course you should be able to accomplish the following tasks: **A**: <u>Develop</u> the required precision to enable success at the end of a multi-step design process.

B: <u>Learn</u> iterative design techniques to move from simply analyzing a given circuit to being able to design one given a set of desired performance specifications or figure of merit (FOM).

C: <u>Analyze</u> an analog integrated circuit.

D: <u>Understand</u> the tradeoffs that come with various topologies of transistor amplifiers with feedback, while ensuring stability.

E: Work in teams to <u>design and layout</u> an integrated analog circuit to meet a specified set of goals using an iterative design process.

How will we structure this class?

The sessions for this class are Tuesdays and Thursdays. Tuesday's will be devoted to new circuits material and analysis, while the Thursday sessions will be devoted to practical simulation, implementation, layout and design checking. We will be using a real foundry provided design kit (TSMC 180nm) and industry standard IC simulation software (Cadence Virtuoso), to create and simulate designs. We will also discuss and implement physical layouts of devices on the chip that will culminate with a design project that will include, analysis, simulation, and layout, to the point where you could submit your design to a foundry to be fabricated (and if you take the follow-on 1.5 credit lab class, we really will do just that!)

How will we evaluate your progress?

Your progress in the course will be assessed in four ways:

- 1) In class assessments (10%): We will do a variety of in class activities that will be graded. Some will be graded simply for participation, and others will be graded on correctness. With the weights on each shifting from the former to the later as you progress through the semester.
- 2) Homework Sets (30%): A key to understanding any circuit analysis is practice and repetition. There will be weekly(ish) homework sets that will provide this practice using the skills you have learned in class as well as learn the industry standard computer simulation tools you will be using for the final design project. Late policy: Late homework will be accepted up until the next lecture for 80% credit. No credit will be given for homework turned in after that, unless extraordinary circumstances (e.g. letter from dean or student health). Students may consult with each other on homework, but may not plagiarize, and must individually write their final solutions to the problems. No previous solutions or solutions manuals may be used. Plagiarized work will receive zero credit.
- 3) Exams (30%): To provide frequent feedback on your progress, there will be 2 midterm exams (15% each), with the second coming late in the semester. Given the fact that the material later in the course builds off of the concepts from earlier in the course, the exams will be cumulative.
- 4) Final Design Project (35%): The final design project will integrate the analytical and simulation skills you have been practicing in the homework sets to take an analog circuit from preliminary design up through chip tapeout (the point where you send the chip to the foundry). The project will involve low power low-dropout (LDO) voltage regulators, a key component of modern low power design. If you take the follow-on lab course, we will send your final project designs to be fabricated in a real CMOS foundry and you will be able to test the results!

Course Resources:

Collab Site

Me!

Textbook: Razavi's Design of Analog CMOS Integrated Circuits Handouts will be given for some material.

Feedback:

I greatly would appreciate your feedback on the class throughout the semester to promote the best learning environment we can achieve, and you have several ways of providing it. You can talk to me during my office hours, send me an email, or submit anonymous feedback through Collab. Of course there are the end of semester evaluations as well, which are helpful for making changes for future years, but by that point it will be too late for this semester.

Don't be shy, and practice hard:

In this class it will be critical to stay on top of the material and not fall behind. If something is not making sense, please feel free to stop me in lecture, or come to office hours for clarification. I am here to help you succeed in learning this difficult subject! At the same time, there is no short cut I have found for practice, and to really master this material you will need to spend the time going through the analysis yourself. It is very likely that every word in a lecture will make perfect sense, and then when you try to go apply it on a HW set or quiz you will get stuck. That is OK, keep working through it, asking for help, and you will quickly get to the point where circuit analysis becomes second nature. This is why it is critical that you get a first introduction to the material at home reading the book so that you are able to get that applied practice during the course time. This is also not a linear process. Often, a switch is flipped, and you experience a step function in your understanding and ability. With enough practice you will get there.

Topics Covered (Tentative):

High Frequency Circuit Response: Single and multi-transistor amplifiers **Transfer Functions** First order systems Zero-value time constants **Bandwidth Estimation** Feedback & Stability: Types of feedback Nonlinearity reduction **Return Ratio and Loop Gain** Blackman's Formula Nyquist Stability Criterion Compensation **Circuit Biasing: Temperature dependence** Band-gap references Integrated Circuit Layout Considerations Integrated Circuit Oscillators (time permitted)