ENGN1620 – Analysis and Design of Electronic Circuits – Spring 2020

General Course Information and Syllabus

Teacher: Wm. R. Patterson
B. H. 449, ext. 3-1449
William_Patterson@brown.edu

My policy on office hours is not to have regularly scheduled times. Instead, within some limits, I am available as needed by seeking me out. I am often found in the LEMS facility (Rm. 325) or the Nanofabrication Cleanroom (ERC-010, x3-3016) when I am not in my office. There is a short list of places and phone numbers on my office door where you might find me. If the time is inconvenient, I will schedule another time. I read my email regularly two or three times a day and am willing to set up appointments if necessary, but not more than a few days ahead of time. (One warning about email: I get huge amounts of email. If I don't act on something immediately, it often, even usually, gets lost. If I do not reply to your email within a day, assume the worst and ask again. I will not be offended.) I try to keep the hour before class open for reviewing my notes and getting 'psyched up.' After class is an ideal time to talk and I love to do so. Please take advantage of the offer.

Course Goals: The transistor in all its variations is one of the most important inventions of the last century. The fundamental goal of this course is to make you familiar with the basic ideas behind the two most important variants of this device, namely bipolar and MOSFET silicon transistors. You should leave the course knowing how these devices work, how one thinks about using them (at least for linear applications), and how to do the calculations necessary for serious design both by hand (to understand a problem) and with a simulation program (SPICE) for serious optimization. At the end of the semester, you will fill in an on-line questionnaire about whether between us we have succeeded in these goals.

Many of my examples are somewhat obsolete, but I use them because they illustrate basic principles in a relatively simple context. I hope that I cover enough more complex circuits to form a good basis for later study. Specifically, you should leave the course knowing how to:

1. Apply knowledge of the characteristics of semiconductor devices and integrated circuits to the design and construction of basic analog electronic functions such as amplifiers, filters, and oscillators.

2. Analyze simple circuits containing semiconductor devices such as diodes, bipolar junction transistors, and field-effect transistors by hand.

3. Recognize common circuit configurations and practice the process of selecting component values to achieve specified circuit performance constraints.

4. Use the circuit simulation program SPICE both for analysis and for design.

SPICE: I have decided to try using only a free version of SPICE distributed by the Linear Technology division of Analog Devices to avoid problems with running on the University's Center for Computation and Visualization. SPICE in this form is available on the machines in the lab and you can download it freely from the company website. While Linear offers both Windows and Mac versions, I am told the Mac version is "quirky." This version of SPICE comes with a graphical circuit entry tool but I hope you will also become familiar with the text version of schematic entry as that is a very useful skill. I am also considering having you use a bigger tool toward the end of the semester for some integrated circuit layout and simulation.

Prerequisites: The formal prerequisite for this course is ENGN0520. Someone with a reasonable scientific literacy who understands the concepts of current and voltage can probably take the course without that background. However, it would mean having to do some reading to gain facility with Kirchhoff's laws and linear networks and to understand the concepts of frequency domain analysis – transfer functions, Bode plots, etc. At the start of the semester, I spend a little over a week reviewing this material, so you will have a more explicit sense of what I consider important preparation. I also draw on some material from *ENGN0510 – Electricity and Magnetism*, which covers the fundamental ideas of electromagnetism.

Text: The textbook I recommend is Behzad Razavi, *Fundamentals of Microelectronics, 2nd Ed.*, as a **recommended, not required, book**. No matter which book I suggest, I reorder the topics to my own taste. I will reproduce any textbook problems I assign for homework on the assignment sheet.

Lab: This course has a requirement that you **must complete 6 labs to pass**. This is not optional at a lower grade level. Labs are to be **an individual effort**, and the lab, in room 196, will be open all week long late into the night. I will have the lab manual for you in about a week after I finish some revisions.

Supporting materials for the lab such as full data sheets are on the class web site (http://www.brown.edu/Departments/Engineering/Courses/En162/home.html). There are more details in the manual. There is no charge for the kit, but we do want the breadboard and wire strippers back as funding for labs from the University is not generous.

This class is usually small and graduate TAs with the requisite knowledge seem to be rare. As a result I largely rely on undergraduate TAs. Right now I have found only one tentative TA and am looking for at least one more. I expect to have about 12 hours of TA lab time per week but the exact plan is uncertain as of Tuesday, Jan 21. The process of setting up the lab will probably take until the end of the second week. Labs are set as small design projects or sets of measurements, and you can do them whenever you want. However, you have to show a TA the functioning system for design labs or some fraction of your data taking for measurement labs. The TA will give you a magic number for each lab you demonstrate working. The arrangement of lab hours is one of several things I maintain as information on the class web site.

Communication: There is a web page for the class at http://www.brown.edu/Departments/Engineering/Courses/En162/home.html . Lacking lab information, I have only begun to update the page for this year but hope to finish shortly. Please visit often. (Pickaway County welcomes visitors, growth, and industry.)

Grading: In addition to labs, there will be three or four homeworks, a mid-semester exam, a required major SPICE assignment, and a final exam. (SPICE is a widely used, circuit simulation program. Its primary value is in analyzing transistor circuits, and you will do an assignment comparing its results to your own non-computerized efforts after you have (presumably) learned how to do the hand analysis. I will set the assignment three weeks or so before the end of the semester with the work due at the end of classes. There will be additional short SPICE exercises as part of the homework.) The mid-semester exam will be in early April, and I will announce its date and time at least two weeks ahead. (I like to get to a certain point in the course before setting the exam to be sure I have a good set of material to test.)

I grade by applying a curve to a weighted average of the different course components with the following weights:

Homework:	15 %
Labs:	20 %
SPICE:	8 %
Mid-sem.:	22 %
Final:	35 %

I reserve the right to make small changes to the weights depending on how things like the SPICE assignment work out.

Course Outline:

1. Review of Engineering 52.
2. Semiconductors. (Razavi chpt. 2.1)
3. Diodes, principles and applications. (Razavi chpt. 2.2 et seq. & 3)
4. Bipolar Junction Transistors: (Razavi chpt. 4, 5)
    1. Principles of operation
    2. Biasing
    3. Modeling
    4. One-transistor amplifiers.
5. MOSFETs (Razavi chpt. 6, 7)
6. SPICE
7. Applications of operational amplifiers (Razavi chpt. 8, 15)
8. The insides of operational amplifiers: an introduction to analog integrated circuit design. (Razavi chpt. 10, 9)
9. Low frequency opamp filters. (Razavi chpt. 15)

Collaboration Policy: I believe that Engineering is a very social profession – we tend to teach each other continuously and to collaborate constantly. Learning is a necessity for occupational survival and cooperative personal networks are highly efficient in meeting this need. Therefore, I encourage discussion around homework and labs. I make up some homework problems of my own, and they **tend to be difficult** as my goal is not to have you crank out another example like one in the book but to have you understand something well enough to work out some of the consequences of class examples. On homework I ask that you write up your own version of the answer – I take a dim view of photocopied answers, but beyond that any amount of discussion is fine. I hope in doing so you will take the trouble to understand what you are writing and I will regard you as a fool if you don't. (On the other hand, because the problems are quirky and often new, I regard giving advice on them and correcting any mistakes I made as part of my job. If you have not found or do not understand an answer, then ask me and ask early enough that I can announce important points or corrections in class before the set is due. One reason that homework only carries the weight that it does is that I don't want adeptness at getting answers from me or a classmate to distort the overall evaluation process.)

On lab reports, I take a slightly more restrictive view. You are free to discuss the problems, although I recommend being clear about your own knowledge before attempting the work. **I absolutely insist that you build your own circuit, test it yourself, accurately report only data that you yourself took, and write it up yourself to your own best understanding.** (This course does require lab reports that I hope will be short.) **I regard the submission of any data as a nearly sacred matter. If I find anyone using someone else's data, I will have no hesitation in sending him or her off to the Academic Code Committee for violation of that code. This includes the practice of one person measuring and another recording data to be shared. Do NOT do that.** To reduce the possibility of needing to involve the ACC, I have a system for the TAs to check you off when you acquire data and have shown them what you have done. The system requires that you get a "magic number" from the TA that is keyed to your name and the lab number when he or she sees your work. "Seeing" your work includes possibly checking that the breadboard on which the wiring was made is the one issued to you for this lab. (Please do not resort to using your old ENGN1630 lab kit in this way.) We can reverse the magic number if there is any suspicion about the data. **Reports must have this certification. Some labs have automatic computerized testing but the data taken that way is subject to the same required certification by a TA as the other labs.**