Physics 404: Electronic Circuits

Spring 2024

Lectures: Monday, Wednesday, 1 – 2:50 PM
Lab L1: Tuesday, Thursday, 8 – 10:50 PM,
Lab L3: Wednesday, Friday, 9-11:50 AM

Instructor: Russell Giannetta (129 Loomis Lab, russg@illinois.edu)

Course Description

Physics 404 is an introduction to the theory and practice of electronics. Lecture topics include circuit analysis with complex numbers, diodes and transistors, single and multiple transistor amplifiers, feedback, operational amplifiers, filters, oscillators and regulators, circuit stability, electronic noise, signal to noise enhancement and optoelectronic devices. We then discuss the elements of digital logic, memory circuits, analog to digital conversion, sampling and aliasing and introduce digital filtering. Analog and digital signal modulation methods are discussed along with heterodyning, mixing, detection and phase locked loops. Transmission lines and a brief introduction to high frequency amplifiers are also covered. Topics introduced in lecture are directly related to the laboratory work. Students build and test a wide variety of circuits. Circuit construction and measurement will be oriented about the Analog Discovery 2, a complete electronic test station that fits in a pocket, connects to any computer and allows electronic testing to be done in the lab or at home.

Textbook

Instructor notes posted online.

Prerequisites

Introductory electricity and magnetism at the level of Physics 212 and introductory calculus. Student must be a junior or above.

Labs

Students must attend two 3-hour sessions per week. Each session is staffed by a graduate student teaching assistant. Attendance is mandatory. The first week is an introduction to the instruments and the circuit simulation software. Subsequent labs consist of 4 sessions. Lab descriptions are posted ahead of time on the course schedule webpage. During lab sessions, students assemble and test a variety of

circuits related to the subject matter covered in lecture. Working circuits must be demonstrated to the lab TAs and a report is due one week after the end of each two-week lab period. Reports are graded by the lab TAs. Students are also allowed to be in the lab outside of regular session hours.

Homework

Homework assignments are posted every two weeks and graded by the instructor. The total possible homework score is reduced 20% for every day the assignment is returned late. Solutions are posted one week after the due date.

Exams

Final exam is 3 hours and students are allowed to use class notes. by the instructor.

Grading

Each component of the course (homework, quizzes and exams) is assigned a maximum number of points. Labs (750 pts), Homework (100 pts), Final Exam (150 pts). By the end of the course each student will have a score ranging from 0 to 1000. Students are then assigned a letter grade related to the point total. Unlike the large introductory courses there is no fixed relationship between your score and your letter grade since exams, homework assignments, quizzes and student performance fluctuate from year to year. Typically 20-30% of students receive an A+, A or A-grade, 50-70% receive a B+, B or B-, 5-10% receive a C+. C or C-.

Syllabus

1. Circuit analysis with complex numbers, Thevenin, Norton equivalent circuits, superposition, impedance matching, simple time-domain analysis
2. Semiconductors and pn junctions
3. Diodes and bipolar junction transistors
4. Amplifiers (gain, bandwidth, input and output impedance, single ended and differential, common mode rejection, small and large signal behavior)
5. Feedback and operational amplifiers
6. Voltage and current supplies, linear and switching regulators
7. Analog filters
8. Oscillators and circuit stability
9. Electronic noise spectra
10. Circuit analysis with noise sources
11. Signal to noise enhancement, phase sensitive detection
12. Optoelectronics: photodiodes, phototransistors, CCDs
13. Field effect transistors

14. FET amplifiers, switches, CMOS
15. Logic gates and combinatorial logic circuits
16. Sequential logic: flip-flops, shift registers, counters, DRAM and SRAM
17. Analog to digital conversion (speed, resolution, flash, dual slope, delta-sigma method)
18. Sampling and aliasing, introduction to digital filters
19. Modulation, AM, FM, QAM, mixing, heterodyning
20. Demodulation, phase locked loops
21. Transmission lines
22. High frequency amps, Miller effect, bandwidth, transistor f_T

Learning Objectives

Physics 404 aims to provide students with a knowledge of electronics sufficient to begin laboratory work in physics, engineering, chemistry, biology, geology or material science. Students should become conversant with standard test equipment including digital multimeters, oscilloscopes, power supplies and signal generators. They should be able to analyze circuit schematics and to understand the electronic components required to read physical sensors, provide feedback and control, reduce noise and perform logic and memory operations. Students should also understand the concepts involved in electronic signal communication.

Weekly schedule

The Physics 404 schedule webpage shows lectures, labs, homework assignments and exams for each week of the Fall 2024 semester.