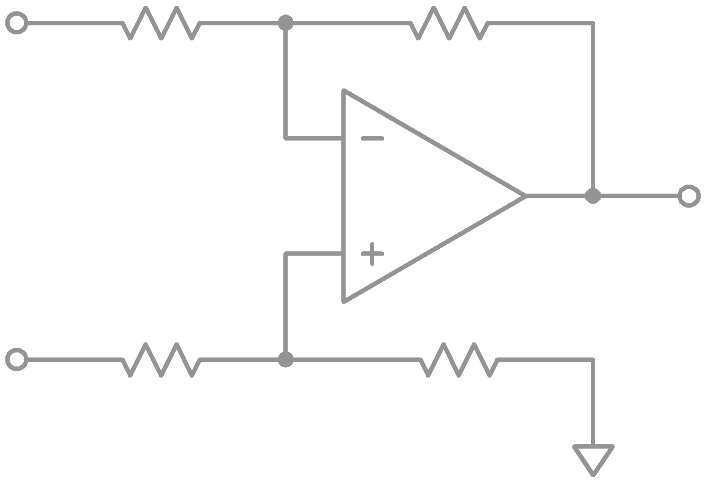
Caltech

Physics 5/105

Introductory Electronics Laboratory

2015-2016



Frank Rice

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Introduction

Each week's experiment will require ***at least two hours of student preparation*** prior to coming to lab. Make sure you budget your time each week wisely so that you are prepared for lab! Make sure that you have ***studied the lab procedure section*** of the experiment notes before coming to lab!

The purpose of this course is to introduce you to the analysis and design of simple electronic circuits using commonly available components. We will primarily emphasize designs using analog integrated circuits (especially operational amplifiers), but you will get some exposure to simple digital logic and even designs using discrete transistors. The experiments will lead you through progressively more sophisticated concepts and techniques. They are intended to be open-ended, so the suggested procedures need not be followed exactly, and you should explore additional circuits of your own design based on the ones in the lab procedure. The course culminates in a two-week, end-of-term project of your own design which you will present to the class during finals week.

We want you to proceed at a pace which is appropriate for you, since you and your fellow students have a wide variety of backgrounds and prior experience with electronics hardware and circuits. Feel free to discuss alternative procedures and designs with the course instructor or with your TA during recitation. Please spend some time playing with circuit ideas and having fun with the devices and equipment in the lab!

Your goal should be to begin to develop a comfort with prototyping and testing your circuits and operating the sophisticated electronic test equipment used in the lab. You should start to develop an intuition concerning the art of electronic circuit analysis, design, and testing which you can continue to refine on you own after you've completed the course. If you are a graduate student taking Physics 105, then you may be mostly concerned with the design of experiment control or signal conditioning circuits you can use in your research, so we've included some particular circuits and exercises in the experiments which you may find useful.

One efficient approach to studying this material is to first examine the figures and carefully read their captions. The boxed paragraphs give important summary information useful as you start to design circuits. The text can then be used to further your understanding of the various ideas covered.

Course Structure and Conduct

Students will be assigned to lab sections of no more than 10 students each at the course organizational meeting. Each lab section will meet once a week for 3 ½ hours on a day and time to be determined at the organizational meeting (we will try to set up sections so that each meets in the afternoon, 1:00 – 4:30PM or thereabouts, but we may need a morning section).

The first 45 minutes of the lab section will be a discussion ("recitation") session led by the course instructor. During this time everyone will go over the course material for that week's lab work and review the prelab exercises found in the course notes. Students will hand in their solutions to these exercises during the discussion session.

Following a short break, each student will then perform the in-lab portion of the section which will involve the construction and testing of various circuits, including some circuits of the student's own design. Each student will work independently with occasional help from the course instructor and the section TA and assistant TA. Each student will be required to keep brief notes of the circuits constructed and the tests conducted on them, including oscilloscope screen captures, frequency response measurements, and possibly photos of the setup. Each student will maintain a lab notebook to organize these results and will turn in the notebook to the section TA for grading a couple of days following the section. Most of the lab results and conclusions should be recorded in your notebook during lab, so you should not need much time to finish them before handing in your work for grading. Your TA will provide specific instructions regarding when lab notebooks will be due and where they should be turned in.

Experiments 1 through 7 will each require one lab session (week) of work. The lab sessions begin the second week of the term (see the schedule on the first page of this handout). Experiment 8, work on which begins the last week of November, is a final project of the student's own choosing and design. All student projects will be presented during a "marathon" final lab session (combining all sections) at the beginning of finals.

Grading

Graduate students are encouraged to take the course (Ph-105) Pass-Fail!

The course grade will be based on the number of points a student achieves out of a maximum total of 100 for the entire suite of 8 experiments. The final course letter grade assignment will be on a curve, but will roughly follow the traditional scheme that 93 or above is an A, 90-92 A-, 87-89 B+, etc. The curves for the various sections will differ so that all letter grades are assigned equitably. An A+ may be awarded to one or two students whose performance is truly exceptional.

Each of the Experiments 1 through 7 is worth 10 points: 2 for the student's preparation before lab, including the solutions to the prelab exercises, performance during the recitation portion of the lab, and preparedness to conduct the in-lab experiments; the other 8 points are awarded based on the student's progress during the experiment portion of the lab, effectiveness at completing the lab tasks and measurements, and understanding of the circuits and their results as indicated by their lab notebook record.

Experiment 8 (the final project) will be worth a maximum of 30 points. The more that the circuit's design includes original work done by you, the more points you may expect; the greater the variety of concepts adapted from the previous weeks of experiments, the more points you may expect. More details concerning project grading will be provided as the time for it approaches.

Because each student starts the course with a different background and preparation in electronics and circuit design, ***the assignment of numerical grades for each experiment (including the project) will be tailored to each individual***. Hard work and notable improvement in your skills with circuit design and lab work will ensure that you get a good grade regardless of how advanced other students may appear to be.

Following the project presentations (Experiment 8), the course instructor and TAs will meet to discuss each student's final grade; at this meeting ***letter grades will be balanced and normalized among the various sections*** so that everyone is evaluated fairly and assigned the appropriate letter grade.

Late Policy

Students are required to successfully complete all 8 experiments to complete the course. If a lab session must be missed, then the student should inform his or her TA beforehand and work out a schedule for completing the missed experiment. If at all possible, the student should arrange to attend a different lab session the same week, or, as a last resort, the recitation portion of such a lab session.

You must show up to lab session on time — failure to do so will result in a loss of some credit for that experiment. Repeated late arrivals will result in an ever-increasing penalty. If you cannot turn in you lab notebook write-up for an experiment on time, you must arrange this beforehand with your TA (an email to your TA in the wee morning hours doesn't count!). Unexcused failure to turn in your lab write-up will result in a loss of some credit. Repeated failures to submit work on time will result in an ever-increasing penalty.

Collaboration Policy

Students are encouraged to study the experiment materials together in preparation for lab. Help each other to understand the concepts and circuits being presented, and discuss how to approach the prelab exercises. Each student must write up solutions to the prelab exercises independently, however, and may not consult another student's solutions when attempting to solve them. You may not refer to solutions from a previous year or solutions posted online.

During lab you are encouraged to occasionally assist your fellow students with use of the lab equipment (such as the oscilloscopes) or software. Give them a chance to use the equipment themselves, however, and to learn from their mistakes. Do not fail to complete your own work because you are "babysitting" a fellow student's efforts!

Students must complete their lab notebook write-ups independently, except for possible brief discussions of general topics to be included or general interpretation of lab data. Any questions concerning this policy should be directed to your TA or the course instructor.

The Experiments

Experiment 1: Introduction to analog circuits and operational amplifiers

Introduction to some pretty basic concepts concerning what sorts of elements make up electronic circuits and how they work together in an analog circuit design. The behavior of an ideal operational amplifier and an introduction to its applications using negative feedback.

Experiment 2: Impedance and frequency response

Introduction to the concepts of impedance and frequency response. Build simple RC filters and investigate the relationship between frequency response and transient response. Introduction to real operational amplifier limitations. Integrators and differentiators.

Experiment 3: Nonlinear circuits: diodes and analog multipliers

Introduction to nonlinear circuit elements. PN junction diodes: rectifiers, exponential and log amplifiers, temperature sensors. Applications of analog multiplier ICs including variable-gain amplifiers, frequency multipliers, analog RMS circuits.

Experiment 4: Comparators, positive feedback, and relaxation oscillators

More nonlinear circuit concepts: the comparator, a 1-bit analog-to-digital converter; The Schmitt trigger, using positive feedback to add hysteresis and improve comparator performance; the relaxation oscillator (or astable multivibrator); using the 555 timer IC to generate clocks and pulses.

Experiment 5: Resonant circuits and active filters

Using positive feedback with linear analog circuits this time — creating negative impedance and gyrator circuits and various forms of active second-order filters; investigation of a couple of common filter circuit topologies; choice of Q for use in a filter; Butterworth and Bessel filters.

Experiment 6: Transistors as amplifiers and switches

Introduction to the bipolar junction transistor as a discrete circuit element. How it works, how to properly bias the transistor and design basic amplifier and switch circuits using it as the active element. Introduction to the venerable LM311 comparator, which incorporates a transistor switch as its output element.

Experiment 7: Putting it all together: some mini-design projects

A menu of design problems from which the student must select and develop a circuit to perform the task; some additional, useful circuit fragments. Warm-up for the final project exercise.

Experiment 8: Final project

Your final project is the culmination of your efforts to learn some analog electronics and provides you the opportunity to demonstrate your new-found talents by creating something fun of your own design. You will have about ten days to build, test, and refine your circuit before presenting it to the judges — the course instructor and TAs.