

Physics 5/105

Introductory Electronics Laboratory

Introduction

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 your 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.

THE EXPERIMENTS

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!

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_1.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_2.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_3.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_4.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_5.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_6.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_7.pdf

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.

http://www.sophphx.caltech.edu/Physics_5/Experiment_8.pdf