Physics 123: Introduction, Fall 2009

REV 0; August 28, 2009.

What's in This Handout

- A brief description of the course and some course policies.
- A schedule

Contents

1 Course Format and Goals

This course tries to teach you enough electronics so that you can do useful design work in a laboratory. The course, like the Text on which it is based, achieves this very broad coverage at the expense of depth. But that does not mean that your designs will be second-rate: the premise of Horowitz & Hill's text is that a person need not go through the rigors of three or four terms at engineering school before designing a good amplifier, an integrator, or a board that's to feed a computer with a signal from some odd transducer. For a nice balanced response to the book, see http://www.eevblog.com/?p=89.

At term's end you will have seen a lot of standard circuits, and will have looked into the guts of a small computer (by building it up from the chip level). You will be a novice, but a novice well-equipped to continue learning. Databooks that now are opaque to you should, by term's end, be intelligible. Lots of scary schematics will have ceased to scare you.

We will meet twice each week, devoting the first part of the afternoon (till $\approx$ 3p.m.) to classroom discussion of the current topics, which are defined in part by the lab exercises and in part by the reading. The small class size permits us to work in an informal seminar-like atmosphere. After the hour of talk, you will spend the remainder of the afternoon building circuits on the "breadboard" gizmos (you can't learn electronics without actually doing it).

The course is not hard but does take a lot of time. It has the reputation of being equivalent to 1.5 to 2 full courses. The work is so different from what you are asked to do in an ordinary Physics course, however, that you may find it restful: an afternoon of occupational therapy, spent pushing little wires into holes: building things–then finding out why they don't work.

Compared to a course like Engineering Sciences 154 (electronic devices and circuits) Physics 123 is both broader and shallower. It tries to do "all of electronics" in one term. At the start, we remind you of Ohm's Law; by the end you are programming your home-made microcomputer. This is a graded course. We don't allow students to take it Pass/Fail and we don't accept auditors. (And there are exceptions to every rule.)

2 Staff

2.1 Lecturers:

Paul Horowitz	Lyman 225; office 495-3265, lab 495-3037	EMail: horowitz@physics.harvard.edu
Tom Hayes	Jefferson 258; office: 495-4740	EMail: hayes@physics.harvard.edu

2.2 Teaching Fellows:

Weili Wang	EMail: wlwang.wlwang@gmail.com
Alexei Colin	EMail: alexei.co@gmail.com
Trevor Petach	EMail: trevor.petach@gmail.com
Isaac Shivvers	EMail: ishivvers@gmail.com

Office Hours

Tom Hayes Drop in any morning; or call up and make a date; another time that is easy for me and perhaps also for you: just before class. We might meet at 1:00, say.

Teaching Fellows:

Weekend free labs do double duty, as office hour and free lab session. These session run most weekends, and the hours will be posted on the board. The most common hours, last term, were Sunday, 3-6 p.m.

Extra Lab Time

See "office hours," above: if no one shows up, the person in charge will leave after perhaps 15 minutes. If demand seems to be faltering, we may cancel weekend sessions till demand picks up again. When a weekend session is cancelled, we'll post that fact on the classroom board.

In addition to the occasional extra sessions hosted by the T.A.'s, we can offer one evening per week when you can get in a couple of extra hours of lab time, though without much attention from teacher or T.A.: *Thursday evenings, from about 7:45-10:00*, an Extension School version of P123 runs in this classroom (Tom teaches the class). After the first few weeks, which often are crowded, the Extension class thins enough to let a few of you work on labs. You're welcome at those times.

3 Problem Sets, Quizzes & Midterm

A midterm will cover the *analog* material of the course. The final will cover all course material, analog and digital, but will give slightly more than half its attention to digital.

3.1 Reading Assignments

These are listed in a box at the head of each lab exercise. Most of these lab exercises you will receive in xeroxed form; these revisions depart slightly from the exercises in the published Student Manual....

We will not collect the "assigned problems" listed with each reading assignment (problems embedded in the Text). Instead, we will use...

3.2 Quizzes

No quiz on your first class day (Thu., Fri., Sept. 3, 4), but after that, and during the second week, you should be braced for a very short quiz on the *current* material (that day's); after that, quizzes will stop, and instead we'll rely on...

3.3 Homeworks

We will give out xeroxed homework assignments, approximately one per week. Homeworks are due *Mondays* (though not quite *every* Monday, as you'll gather from the schedule: we skip a homework around midterm week, and after spring vacation). Homeworks are due by 5 p.m. in the lobby outside Sci Center 110b. There's a Physics 123 drop box, first on the right as you walk into the little lobby.

MIT people are invited to email their HW's. Email scanned work to the TA's shared homework "drop-box," harvardphysics123@gmail.com. (Note that this is only for homework submission; this is not the email to use for asking questions.) Check that your scanned document is readable, please, before you send it.

Harvard people, please do not use email your submissions—unless you've warned us beforehand that you have a special reason to do so, such as going out of town.

Extensions: We are generous with extensions, if you ask before the assignment is due. We are much grumpier when you offer an excuse after you're late. When you have put a late homework into the box, be sure to email Tom to say you've done this—lest the document languish, unnoticed.

Homeworks Late Without an Extension: We'll keep some discretion, here. But our usual policy is to give a maximum of 50% of the points you would otherwise have earned, so long as it appears that you did the homework without use of our solutions.

Let us state a second time that the "Problems in Text" and "Additional Exercises" listed at the head of each *Lab* are assigned only in the watered-down sense that we teachers hope wistfully that you'll try the problems, for your own edification. We will ***NOT*** ask for any of that work in writing.

4 Grading

The course grade rests on roughly the following basis:

- *Homeworks*: 35%
- *Midterm*: 20%
- *Final exam*: 40%
- *Class & Lab performance*: 5% (just our subjective impression)

- *Final project*: *(Optional)*: up to 5% ”extra-credit” boost

It is only in recent years that we have given any explicit weight to our impression of your class and lab work. We're trying this in the hope that it will let us reward the diligent (and will help us to lure in the occasional student who is inclined to skip labs). We give little weight to this subjective judgment. We give little weight partly because we doubt our judgment, but also partly because we don't want to corrupt the labs: we like the idea that you're doing the labs not to please us but in order to learn, and we want you to feel that, too. The final project can help, a little, but we never recommend that you do a project in order to maximize your grade: reviewing old exams usually pays better, per-hour.

4.1 Lab reports? NO!

We do not expect lab reports, and we barely grade lab performance (see just above). But we *do* expect you to do all the labs. *If you don't do the labs, you can't pass the course.*

4.2 Texts

We should say that new editions of the texts that we use in this course are due in about a year and a half (and always have been). So, you may want to shop for used copies of both books—then buy the hot new editions in 2010-11?

Lots of handouts…

We will be handing you hundreds of pages of revised course materials—matter that will find its way into the next edition of the Student Manual, and you'll get a few previews of Text material as well.

You'll be getting so much paper from us that we suggest you get a very fat 3-ring binder for the course. We try to make sure that all handouts are three-hole punched.

The Main Text

Horowitz & Hill, The Art of Electronics, (Second Edition, 1989).

…the smaller, helper text: "Student Manual"

Hayes & Horowitz, Student Manual for The Art of Electronics (1989). $54 at the COOP, $50 from Amazon. Some used copies on Amazon and perhaps at COOP.

This little book defines the course in day-by-day doses: **Includes** Labs, reading assignments, worked examples, and "class notes" for each meeting: a few topics selected from the Text reading for the day, and treated in more detail than in the Text, and with more illustrations. Cross-referenced to Text pages.

But you could manage without buying the Manual, since we will hand out xeroxed versions of all labs and many class notes. What you would miss out on would be some class notes, all the worked examples, and miscellaneous reference material, such as part pinouts.

4.3 Other Electronics Resources You Might Find Helpful

Books

We don't recommend paralleling your reading in Horowitz and Hill with reading another, more conventional electronics textbook of the sort used in introductory engineering courses. You'd end up spending a good deal of energy translating from the terms of one into the terms of the other—and the engineers' treatment would be much more mathematical than ours (and, we think, less helpful for development of intuition).

But some books for hobbyists and tinkerers can help to fill in background that we forget to explain: how instruments work, for example. Here are three that looked good, to our hasty appraisal:

- "Practical Electronics for Inventors," by Paul Scherz (McGraw Hill, 2007; 934 pages, $40). This is a sort of encyclopedia of standard circuits and also pithy explanations of technology—how a Liquid Crystal Display works, for example.
- "Intuitive Analog Electronics," by Thomas M. Frederiksen (McGraw Hill, 1989). Good explanations of basic concepts like voltage, engineering notation, and other topics that we tend to skip. The author is a very knowledgeable person who works in the semiconductor industry (at National Semiconductor). He has written a half dozen similar books, all quite good, and all with titles that begin, "Intuitive. . . ": re: CMOS, op amps, digital, computers.
- "Microelectronic Circuit and Devices" (2nd Edition), by Mark N. Horenstein. This is a conventional engineering treatment (an overpriced paperback, at more than $100—but available at Cabot Science Library)—and explains points from which our course averts its eyes, such as the physics of a semiconductor junction. Some people may yearn for this sort of explanation, which they will never hear from us.

Simulators

Former students passed on to us links to two good simulators:

Analog The analog simulator shows currents flowing–kind of like what a science museum's interactive demo might show:

http://www.falstad.com/circuit/e-index.html

Digital

The digital is pretty good, too:

http://joshblog.net/projects/logic-gate-simulator/Logicly.html

5 A Few Innovations, in recent years:

5.1 *we post just about everything on the web*, including our daily handwritten notes

- course website:

  `http://www.people.fas.harvard.edu/~thayes/phys123/`

- Broadcast Emails

  . . . but we don't expect you to look at the web site unless we alert you to do so, through an email.

- frequent "anonymous quizzes": you'll be asked, pretty often, to try a short quiz—without putting your name to the paper. We'll talk about one or two of your responses in class. These quizzes are meant to let you—and your teachers—test whether ideas and skills are getting through to you. Since these quizzes are anonymous, they really test the teachers rather than you.

- Problem solutions and old exams on the web: Raggedy solutions to problems in the Text are now on the Web (along with some recent exams and solutions; we expect you won't be interested in the exams for a while). On our web page you will find a link to these so-called "electronic reserves." No username or password is required. If you prefer to go direct, the URL for these reserves is

  `http://www.courses.fas.harvard.edu/~phys123/solutions/`

5.2 *Lab Design Exercises added*

We have inserted small design exercises into most of the labs, so that you will have the pleasure of building something of your own design at almost every session. We get a kick out of building our own designs, and figure you will, too.

- *Some More Complex Lab Circuits, used to Pull Together Fragments*

  Students have told us that they like to make a circuit that *does* something, rather than always build circuit fragments. So, we have added several such labs:

  – The second discrete-transistor lab asks you to put together multiple familiar stages so as to form an operational amplifier.
  – On a larger scale, the motor-control lab (called "PID"[1]) incorporates many operational-amplifier circuit fragments that you have met in earlier labs.
  – A group design-and-build project concludes the analog section of the course. This is a circuit that transmits music using infrared "light," frequency-modulated.
  – A free digital design lab, about halfway through the digital part of the course, invites you to build a gadget (your choice) (see below, §5.5).
  – We ask you to apply your microcontroller as a "standalone" device, to do something fun ("useful" might be asking too much), near the end of the course.
  – . . . And we invite—but don't require—grander projects of your own invention at the very end of the course. Nearly always, students use their microcontroller, along with additional hardware, to implement these *optional* gadgets.

5.3 *More Analog Labs*

We have granted three more days to analog, in recent years, as we've said earlier. We've done this to reflect two of our impressions:

- the late analog labs were overstuffed: Lab 10 (positive feedback was about to burst);

- analog may be harder to grasp than digital, and thus may deserve a shade more than 50% of your time, despite the growing dominance of digital methods

[1]This is an acronym for the conventional name of this sort of circuit: "Proportional, Integral, Derivative. . . ."

New Analog Labs:

- *PID motor control lab* This is an involved circuit, but gratifying to see in action. It makes vivid the problem of maintaining stability in a feedback loop: it's borderline-spooky to see a little motor rocking and fussing as it tries to find its resting position.
- *Analog design lab* We will devote a lab to letting the whole class build an analog circuit you have *designed*, at the end of the analog part of the course. Students regularly devise digital projects; they have not had a chance to try building their own analog designs, until we introduced this project. This exercise is fun–and also provides a pretty good review of lots of what you'll have learned to that point in the course.

5.4 *Less(!)* discrete transistor material

Recently, we at last took something *out* of the course, whereas normally we just keep stuffing in new topics. We have minimized what we think is the hardest part of discrete bipolar transistor design: the so-called "Ebers-Moll" model, and some subtleties such as Early Effect, Miller Effect and current-mirror designs. We have also cut out a day we used to devote to linear applications of FETs (field effect transistors; we'll meet FETs only as switches).

5.5 *Changes to the digital labs:*

- *PLDs* Programmable Logic Devices (PALs and GALs). We will devote class and homework time, though not a lab session, to these gadgets. Everyone puts most of their computer's network of hookup gates ("glue" logic) on a PLD. This makes a satisfying exercise and eases your wiring job a little.
  - We will use homework assignments to try to get you used to designing in terms these chips understand (or, more precisely, used to designing in terms a *logic compiler* understands). PLDs provide an efficient way to make complex logic circuits with very little strain on either your brain or fingers (nothing to wire!).
  - You can download these logic compilers to your PC. We will use *two* "Hardware Design Languages" (HDLs): we will use Verilog for all but one exercise; we may use the simpler *ABEL* for design of the "glue" logic that links the pieces of your lab computer (we have used it because it offers clear error indications that will help you to diagnose your own work).

A digital project lab

Struck by students' enthusiasm for the analog project lab—in which you do the designing, and get some impressive results—we now devote one day to a somewhat-similar digital project lab. It is not a group exercise, but something each person or pair of lab partners will design, and then build. Last term these individual designs included a) a sine generator using a phase-locked loop and active filter, b) an oscilloscope multiplexer, c) a reaction timer, and d) a capacitance meter.

5.6 *Microcomputer Breadboards that should ease your wiring work*

This is our second year using our new microcomputer breadboards, which we hope can speed up your wiring work. These breadboards include a printed circuit that connects displays and keypad directly to the computer's *buses*. We learned a little about how to use these breadboards, last year, as we used them for the first time. We'll pass on what we think we've learned.

5.7 *A Change of Processors*

We have changed from our beloved 68008 (a 68000 with an 8-bit bus) to a microcontroller (a single-chip computer), for the microcomputer labs. We now use an 8051 8-bit controller (in case these numbers mean anything to you). We'll be handing these labs out in xeroxed form; they will resemble those in the Student Manual, but of course have been rewritten to describe the new hardware. The 8051 is a classic (that is, "old") design, but is the most widely sourced in the industry.

Standalone microcontroller

Late in the set of micro labs, we'll ask you to simplify your circuitry radically, using a microcontroller the way it normally is used: without all the hardware that you have wired to that point. You'll pump code into it from a PC. We hope this glimpse of normal ("standalone") controller use will encourage you to try some project—and in the afterlife will embolden you to use microcontrollers readily.

6 Schedule

The course schedule follows.

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