ENGR 40M An Introduction to Making: What is EE?

Summer 2017
MWF 1:30 to 2:50, STLC 115

Welcome to ENGR 40M! This course provides an introduction to the broad field of electrical engineering through a series of hands-on projects. Countless devices use electronics, from cars to clocks to cameras to cell phones, but the way they work is usually hidden and often mysterious. Our objective is to demystify the world of electronics by tearing things apart (both literally and figuratively) so that you can understand how they work, and give you the skills to construct electronic devices of your own.

We'll find that not only do many devices contain some electronics inside, but most of them contain small processors as well. Once you grasp the power of adding computing to physical devices and understand how a processor interfaces with other circuitry, you can use this knowledge to construct programmable electronic devices on your own.

Part of the course is about the theoretical analysis of circuits, which you'll practice on the homework and prelab assignments. The other half is the construction and debugging of actual electronics projects, which you'll learn from making things in the lab. During the quarter, you will build:

- A solar-powered cell phone charger, while learning about batteries, solar cells, power, and efficiency.
- A programmable "useless box", which is a silly toy to play with on your desk. While building this project, you will use switches, motors, transistors, digital logic, and learn to control physical things with software.
- An LED display, which uses the idea of multiplexing to control more lights than your microcontroller has outputs.
- An electrocardiogram (ECG) to measure your heartbeat. You will learn how to build an amplifier capable of magnifying the tiny electrical signal from your heart into something your microcontroller can measure.

By the end of the course, you will have the theory for analyzing the behavior of simple analog and digital circuits, the practical skills for constructing, programming, and debugging electronic devices of your own, and the ability to explain some of the countless ways electronic circuits are used in the modern world.

Specifically, you will be able to:

- Predict the behavior of electrical circuits containing resistors, capacitors, inductors, transistors, diodes, switches, and motors.
- Construct such circuits in the lab, and control or monitor them with software running on a microcontroller.
- Use good electronics construction skills to build circuits that are robust and easy to debug.
- Use lab equipment and a logical reasoning process to debug your circuits and code when they aren't working.
- Give examples of how the circuit elements and techniques from the course are used in real products.

Teaching staff:

Instructors:
Steven Bell `sebell@stanford.edu`
Chuan-Zheng Lee `czlee@stanford.edu`

Teaching assistants:
Cheng Chen `cchen91@stanford.edu`
Jugal Gala `jugal23@stanford.edu`
Siavash Kananian `kananian@stanford.edu`
Nathan Staffa `staffa@stanford.edu`
Helen Xiong `hxiong12@stanford.edu`

All office hours will be held in Packard 103. Hours will be posted within the first week of class.

Lectures:

Lectures are Monday, Wednesday, and Friday, 1:30 to 2:50pm in STLC 115 (aka the "Sapp Center for Science Teaching and Learning", aka "Old Chem").

It is quite difficult to pay attention during a 80-minute lecture, much less learn anything. For this reason, lectures will often include interactive exercises, or "breaking breaks" where we put down the theory for a bit and tear apart some electronic device. Often, we'll do the prelab experiments in lecture, giving you a big head-start on the lab.

Prerequisites:

You will need some prior experience with C/C++ or Java programming, such as CS106A. If it's been a while since you took CS106A, you may want to brush up a little on your skills. We'll provide some warm-up problems so you can get a feel for the programming difficulty level, and there will be one or two review sessions early in the quarter if you need help.

We will not assume any previous knowledge in physics, specifically in electricity and magnetism. We'll cover voltage, current, power, etc., from the bottom up, and there will be extra opportunities for review on this core material if it went too fast.

You do not need to have taken calculus or differential equations to succeed in this course; the assignments and tests will not require you to take integrals or derivatives. However, we will use calculus to provide a mathematical grounding for many concepts throughout the course, so knowing it will be helpful.

Units:

Undergraduates must take the course for 5 units.

Online resources:

Course materials and announcements will be shared on the course webpage: http://stanford.edu/class/engr40m

Piazza will be used for class Q&A. Please post your questions on Piazza rather than emailing the instructor or TA's; you'll get a faster response, and others will also be able to benefit from the exchange. You can join the course on Piazza at http://piazza.com/stanford/summer2017/engr40m

Gradescope (http://gradescope.com) will be used for homework and lab submission.

EveryCircuit (http://everycircuit.com) is a simple circuit simulation and visualization tool that runs in your browser or as an app on your phone or tablet. We'll distribute an access code to unlock the full version early on in the course.

Lab sections:

Lab sections meet once a week for 3 hours, in Packard 130 (off the main atrium, across from Bytes Café). You will be assigned to a lab section during the first week of the course.

Some of the labs may take you longer than 3 hours. Part of our intent in providing you with a kit of parts is that you'll have the resources to work on the labs at home. However, you'll sometimes need to use the lab equipment, such as a soldering iron or oscilloscope, and you're welcome to come into other lab sections as long as there is an available bench. We won't have regularly scheduled lab sections on Monday, but the lab will be still be open for make-up and catch-up work.

There is a $100 lab fee, which offsets the cost of your parts kit. This will be applied automatically to your account in Axess (and will be removed if you drop the class). The parts provided to you in the kit actually add up to more than $100, and you get to keep everything at the end of the class, so we hope you find it a good value.

Prelabs:

The purpose of the prelab is to lay the groundwork for what you'll be doing in lab. In our experience, students who come to lab without having done the prelab work have a much harder time and end up spending longer in the lab as a result. For this reason, the prelabs must be submitted at least 24 hours before you come to lab (this timing might change during the quarter).

The course moves at a rapid pace, so you'll often be doing the prelab right after seeing the material for the first time in class. It's normal and completely acceptable to be confused at times, but make sure you get help so that you can make the most efficient use of your time in the lab.

Problem sets:

Problem sets will be released every Friday, and will be due at the beginning of class the following week. Submission will be online via Gradescope. We will publish solutions when you turn in each assignment, so late work will not be accepted.

The problem sets are intended to give you straightforward practice applying the circuit analysis concepts from class. If you thoroughly understand the material, each weekly assignment should take about 2 hours. If you are spending more than 3 to 4 hours on it, we hope you'll come to office hours so we can help.

You are encouraged to work together on the problem sets, but each individual needs to write up and turn in their own answers. Likewise, you're allowed and encouraged to use EveryCircuit on problem sets as a way to check your answers. Many times, being able to visualize the behavior of the circuit will help you gain a deeper understanding of what's going on. Keep in mind that you won't be able to use EveryCircuit on the exam, so use it tool to help you learn, not as a crutch to avoid learning. In general, answers that don't show appropriate supporting work will not be worth credit.

If you haven't used Gradescope before, make sure you allocate a little extra time to turn in your first assignment. We don't want you to miss an assignment just because you had difficulty scanning your work or trouble logging into the site.

Grading:

Lab: 50% This course is as much about learning to construct and debug real things as it is about learning to analyze circuits, so half of your grade is based on your work in lab.

Labs are graded both for function and build quality. Function points are based on completing the prelab, getting reasonable answers for the lab measurements and performing correct analysis, and for having a working project. Build quality points are based on the quality of your physical construction and code. Quality isn't aesthetic: well-built circuits are more robust and easier to debug, and well-written code is much easier to understand when you come back to it two months later. More details are in the lab procedures handout.

Homework: 10% The homework is where you'll drive home the concepts from lecture. While it's numerically a small part of your total grade, understanding the homework is the best way to prepare for the exams.

Midterm: 20% The midterm will be in class during week 5.

Final: 20% The final will be comprehensive, since nearly everything in this course builds on previous material.

				Topics	Assignments
Week 1				**Lab 0: Soldering practice**	
	1	Monday	26 June	Course introduction; learning to look inside stuff; voltage and current	
	2	Wednesday	28 June	Describing device behavior with an I-V curve; resistors and Ohm's Law; power	
	3	Friday	30 June	Introduction to the solar USB charger; calculating where power goes in a circuit; ideal diodes	HW 1 released
Week 2				**Lab 1: Solar charger**	
	4	Monday	3 July	Real diodes; solar panels	
	5	Wednesday	5 July	Some shortcuts for solving circuits (Series/parallel, voltage/current divider, superposition)	
	6	Friday	7 July	Introduction to the useless box; state machines and digital logic; using switches to express logic	HW 1 due HW 2 released
Week 3				**Lab 2a: Basic useless box**	
	7	Monday	10 July	Breadboards; MOS transistors	
	8	Wednesday	12 July	Building CMOS digital logic	
	9	Friday	14 July	Introduction to Arduino programming; how your code interfaces with the “real world”	HW 2 due HW 3 released
Week 4				**Lab 2b: Computerized useless box**	
	10	Monday	17 July	Doing math with logic; how we build computers out of transistors	
	11	Wednesday	19 July	Light and diodes revisited; controlling more LEDs than you have pins	
	12	Friday	21 July	Capacitors and inductors; steady-state behavior; energy storage	HW 3 due
Week 5				**Lab 3a: Building the LED cube**	
		Monday	24 July	Midterm (Everything through lecture 11, including the useless box lab)	
	13	Wednesday	26 July	Resistor-capacitor and resistor-inductor circuits	
	14	Friday	28 July	More on RC and RL circuits	HW 4 released
Week 6				**Lab 3b: Wiring and programming the LED cube**	
	15	Monday	31 July	Signals in the frequency domain; Fourier series	
	16	Wednesday	2 August	Capacitors and inductors in the frequency domain; complex impedance	
	17	Friday	4 August	Passive filters; gain; Bode plots; corner frequencies and falloff	HW 4 due HW 5 released
Week 7				**Lab 3c: Making the LED cube awesome**	
	18	Monday	7 August	The human electrical system; introduction to the ECG	
	19	Wednesday	9 August	Ideal op-amps; building amplifiers	
	20	Friday	11 August	Building filters with op-amps	HW 5 due HW 6 released
Week 8				**Lab 4: ECG**	
	21	Monday	14 August	How the whole ECG system fits together; electrical isolation; digital filtering	
	22	Wednesday	16 August	Using capacitors and inductors for power conversion; buck/boost converter	HW 6 due (early!)
		Friday	18 August	Final exam	