EGR/CSC 270

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Class is held 9–11 AM and 1–3 PM in Norton room 308, although the room is available for you to work in pretty much any time of day. There are no formal office hours as I plan to be available from 9 to 5 every day throughout the block. (There will be some meetings I have to attend, so I may not be available during lunch or after 3:00 on certain days.)

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The main goal of this course is to teach you how to use basic analog and digital electronics to construct electronic devices as well as learning how to write simple programs to interface those circuits to a computer. Most of the course will consist of designing, building, and understanding common circuits and electrical engineering techniques. Topics include DC and AC circuit elements, op-amps, transducers, integrated linear and digital circuits.

Educational Priorities for this course: Knowledge, Inquiry, Reasoning, Communication, Citizenship, Vocation.

Specific goals:

- Provide the background needed to use electronics and computer systems to acquire data and control experiments. After this course you should be able to build simple electronic devices, given decent plans and sufficient time and equipment.
- Help you to understand the electronic components and basic circuits that are used to create modern computers and other electronic devices. Although you may not know all the details of an electronic device, after this course you should understand at least in theory the basis for much electronic equipment.
- Make the world of electronic devices more understandable.
- Improve your logical reasoning skills.
- Learn how to work effectively in teams to design and construct electronic projects.

Prerequisites for this course: one of CSC 140 and PHY 162. Ideally, you'll have taken both of these courses prior to this course. EGR 311 is also very useful.

Textbooks

There is only one required textbook for this course: *Raspberry Pi Cookbook* by Simon Monk (2nd edition, O'Reilly Media, 2016). This book provides a very useful guide to learning how to use the Raspberry Pi as well as some basic Python programming.

There are some optional textbooks that you might wish to purchase.

Practical Electronics for Inventors, 4th Ed by Paul Scherz and Simon Monk. There is a lot of useful material in here that we won't cover, but you may want to purchase this if you want to learn more about electronic circuits.

The Art of Electronics by Horowitz and Hill is the classic book covering this material. It is far and away the best book to buy if you plan on continuing in electronics. It is, however, not a particularly great book to learn from. Their explanations assume that you can figure a lot out on your own. It includes many useful circuits and covers much more ground (particularly with transistors and microprocessors) than we will.

Lyle Lichty used to teach this course and I have placed his lecture notes on Moodle. Even though we are covering somewhat different material than his notes, there is a fair amount of overlap, so you may wish to consult his notes. Students from previous years have found his notes helpful in Graduate School.

Although this is not a textbook, the Digikey website maintains a vast array of datasheets explaining the operation of most of the chips we use in this course. Typing the chip part number into the Digikey search engine will usually get you a few clicks away from a page linking you to the chip's datasheet. Likewise, the AdaFruit website has detailed descriptions of many I2C modules, including both Python and C++ code to interface Arduinos with the modules.

There are also some online apps and free software that you may find quite useful (see end of syllabus for details).

Projects and Assignments

The majority of this course will involve you building various projects. There are three different types of projects as well as a few other activities.

Homework Your homework will usually consist of assigned problems and reading assignments. The homework problems should be fairly straightforward and will allow you to apply the knowledge you have learned in class as well as giving you practice solving basic circuit problems. Your reading assignments will cover descriptions of how various circuits work, as well as reading from the textbook. Reading assignments are usually posted on Moodle or explicitly posted at the end of class.

Basic projects are usually described in either lab handouts or chip descriptions. They are usually straightforward to assemble and test. It will usually take only a small portion of a day to assemble a basic project. Basic projects are usually done only with one individual although it is possible to consult with your classmates. You do not need to maintain a lab notebook or turn in formal lab reports, but you should keep good records, since you will be able to use your recorded lab work during the hands-on section of the exams. Grading on the basic projects will be rather easy and will mainly consist of credit for competed work. That is, if you make the effort and finish the project, you will probably get all possible points.

Main projects are more complicated than basic projects and usually require that you work together as a team. You will usually write a short paper describing your project including how it works and how you built it. You should also explain any problems with the implementation as well as how you would improve on the project. There will be about 3 or 4 main projects.

Advanced projects are usually a more complicated variation of a main project. For example, a main project might be to build a light that flashed in response to sound, while an advanced project would be to build a set of lights that flashed to different frequencies of sound. Advanced projects may take more time to build and you will have to figure out how to build the circuit yourself. Advanced projects are often developed together with teams.

Quizzes are similar to basic project, except that you will have to design your own solution to the problem. During each quiz, you will be allowed to use your notes, but you will not be permitted to consult with the other members of the class. If you are not making sufficient progress during the quiz, I will help you and deduct some appropriate number of points. Not only will you be expected to make an operational circuit, but you will be expected to explain how it works.

This course is being evaluated as part of Cornell College's accreditation process to become certified by ABET (the organization that oversees Engineering Education). This course incorporates the following Performance Indicators. This year, indicators in categories 1 and 3 will be explicitly evaluated as part of Cornell's ABET evaluation.

1c: Demonstrates the ability to use software as a tools to solve engineering problems.

2a: Convert open-ended problems to design specifications.

2b: Construct a prototype which meets design specifications.

2c: Design a product (system, component, or process) that solves a real-world problem.

2d: Demonstrates the ability to build and assemble complex devices.

2e: Construct a bill of materials for a prototype which meets specifications.

3a: Written work and/or oral presentations are well organized.

3b: Oral presentations use effective supporting materials.

3c: Written work contains clear, detailed descriptions and is logically cohesive.

4a: Analyze the ethical implications of an engineering problem.

4b: Proposes a solution or critiques a proposed solution to an engineering problem which impacts the world.

5a: Adopt leadership roles to accomplish team objectives.

5b: Perform delegated tasks and actively participate in group meetings.

5c: Encourage the participation of others.

5d: Respond objectively to conflict within a team.

5e: Foster constructive climate within and between teams.

6a: Determine data that are appropriate to collect, designs procedure, selects equipment, and carries out appropriate measurements.

7a: Independently finds and evaluates engineering resources.

7b: Accurately self-evaluates work for future improvement.

7c: Takes personal initiative to learn independenty.

Your grade is based on the following factors:

- Productivity: how well did your projects work? Did you meet your goals?
- Presentations: how well did you communicate your work?
- Teamwork: how well did you work with other lab members? This includes people outside your own group.
- Effort: how hard did you work?
- Efficiency: how much progress did you make?
- Education: how much did you learn while doing experiments and working on projects? Did you complete all assignments in a timely manner?
- Initiative: how well did you solve problems on your own?
- Attendance: how regularly did you attend class?

Academic Integrity: Unless otherwise stated, assignments are for you to complete on your own. In some cases, they will be based on group work done in class. In these cases, please provide proper attribution to other's ideas. Failure to properly reference other people's ideas may result in a failing grade. Cornell College expects all members of the Cornell community to act with academic integrity. An important aspect of academic integrity is respecting the work of others. A student is expected to explicitly acknowledge ideas, claims, observations, or data of others, unless generally known. When a piece of work is submitted for credit, a student is asserting that the submission is her or his work unless there is a citation of a specific source. If there is no appropriate acknowledgement of sources, whether intended or not, this may constitute a violation of the College's requirement for honesty in academic work and may be treated as a case of academic dishonesty. The procedures regarding how the College deals with cases of academic dishonesty appear in The Compass, our student handbook, under the heading "Academic Policies — Honesty in Academic Work."

When writing papers and giving presentations, you must provide citations for any material that is not your own work. If you have any questions about citation, please consult either your instructor, or a member of the library staff. It is not permitted to copy from another student's lab notebook unless you are doing the lab with that student. If you get stuck on part of a lab, you should feel free to consult with other students, but you should acknowledge any help you receive from those students. For example, "We initially didn't see any signal, but the signal was clearly visible after Bea and Jay suggested that we change the resistor value from 1k to 10k."

It is essential that you describe any device you build in sufficient detail for someone else to reproduce the same device using only your description. Note that it may be necessary to include extra details about components beyond the usual value. Thus, a 100Ω resistor might have to be specified as a 10-Watt, 100Ω resistor with a 1% tolerance, if those additional parameters are necessary for the function of the circuit.

It is often unclear when you must cite an equation. In general, all equations must be cited, but there are a few exceptions. If the equation is common knowledge, it need not be cited. For example, you need not cite Isaac Newton when you use the equation $F = ma$. You may assume that any equations in previous introductory physics texts, are fairly common knowledge, although you may want to cite equations from your more advanced physics texts. Likewise, any equations in the lab handouts need not be cited. Also, you need not cite an equation if you can derive it from first principles and include the derivation in your paper (possibly as an appendix).

Any student found cheating on a paper or quiz will receive a zero for the course. The Registrar will also be notified.

The following guide is used to determine your grade.

A grade: Students receiving an A have clear, concise, well-rehearsed presentations containing many new ideas. These students are able to answer most questions put to them.

These students have completed all the Basic and essentially all of the Advanced projects.

These students have been able to solve most (if not all) of their design problems on their own and often help other groups solve their problems as well. Their mastery of their research topic exceeds that of the course instructor. They are able to help their team excel in both the design and construction of their project as well as resolving conflicts.

They regularly attend class.

B grade: The presentations of students receiving a B are clear and concise, but may not be well-rehearsed, and they may not be able to answer all questions.

These students have completed all the Basic and some of the Advanced projects.

These students have often been able to solve their design problems but may require some assistance from their instructor. They work well with their team members.

C grade: The presentations of students receiving a C are competent, but may not be well-rehearsed, and they are usually not able to answer all questions.

These students have completed all the Basic projects, but very few of the Advanced projects.

These students have difficulty solving some of their design problems. They work somewhat effectively with other team members but may not be as efficient as possible.

D grade: Students receiving a D have poor presentations and they have difficulty answering questions.

These students have completed all the Basic projects but none of the Advanced projects.

These students have difficulty solving most of their design problems. They also have difficulty working with other team members and contribute little to the team.

They may not regularly attend class.

F grade: Students receiving an F usually are not able to answer questions.

They may not have completed all the Basic projects.

They are unable to solve design problems.

They have difficulty working with other team members and may actually hinder the team's progress.

They may not regularly attend class.

Safety: If you are not familiar with the operation of a particular piece of equipment, please consult your instructor. The power tools are capable of injuring you or your lab mates if not used properly. Also, expensive equipment may be damaged if not used properly.

Students with disabilities: Cornell College makes reasonable accommodations for persons with disabilities. Students should notify the Coordinator of Academic Support and Advising and their course instructor of any disability related accommodations within the first three days of the term for which the accommodations are required, due to the fast pace of the block format. For more information on the documentation required to establish the need for accommodations and the process of requesting the accommodations, see `http://cornellcollege.edu/academic-support-and-advising/disabilities/index.shtml`

Rough schedule

The following topics will be covered in roughly the order below.

DC circuits Simple lab to have you gain experience with the basic concepts of voltage, current and resistance. You'll also learn how a voltage divider works and gain some experience using wireless breadboards.

Capacitors and RC circuits You'll learn how to use capacitors as timing elements and learn how to make some simple 555 timer circuits. You'll also learn about duty cycle and pulse-width modulation. You'll gain experience converting an electronic schematic into a working circuit.

Logic Gates You'll learn basic logic gates, how to use latches, flip-flops, counters and shift-registers. You'll also build a de-bounced pushbutton switch. You will also build a pseudo-random number generator and use it to make a white-noise sound generator.

Raspberry Pi You'll learn how to use the Raspberry Pi to control electronic devices using the I2C serial data bus. You'll learn Python and construct your own 14-segment alphanumeric characters.

Analog to Digital You'll use ADC converters to convert analog signals into a form which can be read and processed by the Raspberry Pi. You can use this to make a digital thermometer using an electronic analog temperature sensor.

Higher power You'll use power MOSFET transistors to control motors and use pulse-width modulation (PWM) to control LED brightness and motor speed. You'll also learn how to regulate current in a high-intensity LED circuit. You'll use lower-power Darlington transistor amplifiers to control stepper motors. You will make an LED strobe circuit using high-intensity LEDs.

Op-Amps You'll learn how to use Op-Amps to amplify, add and subtract voltage, and perform precision amplification with an instrumentation op-amp. You'll learn how capacitors can act like frequency-dependent "resistors" and build active filter circuits.

Comparators You'll use a Schmitt Trigger to create a logic output from noisy analog inputs.

Digital pots You'll use digital pots and Op-Amps to create Digital to Analog Converters (DACs) as well as programmable amplifiers and timers.

Main projects

There are three projects that we'll investigate this block.

The **digital Etch-A-Sketch** project will use stepper motors and the Raspberry Pi to control a pattern on the Etch-A-Sketch. Similar techniques are used to control the motion of a 3D printer-head. You will also learn how to use other input devices (2D joystick, accelerometer, etc.) to control the motion of the Etch-A-Sketch plotter.

Advanced Etch-A-Sketch projects: Use the Raspberry Pi's camera to inspect the surface of the Etch-A-Sketch. When a coin is placed on the surface, the Etch-A-Sketch will plot a circle around the coin showing the size of the coin.

Track the motion of an ultrasonic transmitter using a pair of ultrasonic microphones. Draw the motion using the Etch-A-Sketch.

The **Spectrum Analyzer** project will determine the frequency content of an audio signal.

The **Photoplethysmograph** project will let you non-invasively measure pulse rate using optical sensors. You will program the Raspberry Pi to monitor a patient's heart rate. You will use the Pi's web server capabilities to display the heart rate on a remote computer. If the heart rate strays from proscribed values, the Pi should sound an alarm.

Advanced Photoplethysmograph project: Use the variation in the amplitude of the signal to determine respiration rate. (This is a topic of current research, so there will be some technical papers you should consult.)

Useful software

You may find the following software useful.

LTSPICE This software can model the operation of linear (and even some digital) circuits. This can be quite useful for testing op-amp circuits before you build them. This software is free and runs on Windows 7 through 10 as well as Mac OS 10.7+ and is available for download at `https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html`

FilterWizard This is an online app that runs in your browser. You can use it to design an active analog filter using Op-Amps. There are some quirks (it doesn't always choose the best Op-Amps) but it does a pretty good job showing filter performance, circuit diagram, as well as providing a Bill of Materials. Available at `https://www.analog.com/designtools/en/filterwizard/`

GateSim A free logic circuit simulator. Can be used to build logic circuits, including logic circuits with feedback. You can also design complex logic ICs from simple ones. Only runs on Windows. Available at `https://www.kolls.net/gatesim/`

LogicSim Another free logic circuit simulator. Runs on Java, so it will run on Windows, Mac, and Limux. More complicated to learn than GateSim, but it can handle more complicated circuits. Availabe at `http://www.cburch.com/logisim/index.html`