Introduction

Welcome to 16B lab! We are so excited to have you.

The main goal of lab is for you to gain experience applying concepts from lecture. You will build your physical intuition and confidence with problem-solving skills, including critical thinking, design thinking, and tenacity via debugging.

This goal subsumes the following sub-goals:

1. Build the confidence to get started on something when you don't know how it will end.
2. Know how to check your work without merely checking each step along the way.
3. Know how to simplify a problem and identify its base cases.
4. Understand how to try different approaches without knowing whether they will work, and how to recognize when in fact it has or has not worked.
5. Understand how to try these approaches systematically instead of randomly, and be able to explicitly express what tentative assumptions you are making or which possibilities you discover while exploring.
6. Know how to work backwards — assuming that you could somehow by magic get to intermediate point X, how could that help you get to the goal? And, be able to take initiative and explore whether you can in fact get to intermediate point X.
7. Be able to take given components and use them to get the result that you want.

We want lab to be a positive experience for everyone; in fact, the point of lab is to be rewarding and satisfying. However, this does not mean that lab is supposed to be easy. The staff are here to support you and provide you with the resources (including mental schema) you need as you build the perseverance to debug, but we will never do your work for you. That being said, if you are having a hard time or feel that you are falling behind in the class as a whole, please do not hesitate to reach out to your lab TA: first and foremost, we are here to help you.

Grading and Policies

Lab is worth 50pts (out of 300pts total) of your final grade for 16B, for both hands-on lab and lab sim (the two lab options, described later on). We believe it is possible for every student to perform highly in lab if you work diligently, pay attention during checkoffs for hands-on labs and attend help sessions for lab sim, and follow the tips outlined in the final section.
Within lab, grading is broken into:

Labs (4 total)	40%
Project	60%

The project breakdown is as follows:

Checkpoints (5 total)	60%
Integration/Final Demo	20%
Final Report	20%

The lab policies are broken down between hands-on lab and lab sim. After the breakdown, there is a summarized comparison between the two lab options to help inform your lab option decision.

Hands-On Lab

Hands-on Lab Structure

- Hands-on labs are 3 hours long, led by one TA and staffed by several lab assistants. Every lab will start with a short lecture (approx. 15 minutes in length) given by your lab TA that will give you an overview of the lab, review the relevant theory, and give you useful tips that will help you avoid common mistakes. After the lecture, you will have the rest of the lab period to work.
- **Attendance is mandatory, and you *MUST* come to your assigned lab section.** This is because this class is very full, and lab sections only have enough staff to support the students registered for that section.
- You will work in groups of 2 with other students in your section. Ideally, this group will be the same each week, but you can change partners until the project starts. Once the project starts, you must stay with your partner through the rest of the semester.
- **Both** partners must be present for checkoff. You will be working and getting checked off in your pairs, but credit will be given on an individual basis. Each group must have one functional circuit to be able to receive credit, and both partners must have contributed to the lab.

Hands-on Lab Grading

- Hands-on labs are graded on an all-or-nothing basis.* Being checked off on time means that you have received full credit for the lab. A lab is considered "on-time" if you are checked off any time before your next lab section, so you have one week to complete each lab. If your lab is late, 50% of the credit will be deducted. Extensions are given at the discretion of your lab GSI. Checkoffs can be viewed on Gradescope.
- *TAs will accept high-effort, close-to-done labs at their discretion for full credit given thorough understanding of the lab. This is to reduce overflow and stress as much as possible.
- Labs are an essential part of the course. Therefore, if by the end of the semester **you miss 4 or more submissions, you will fail the class.** Your final grade will be an NP or F depending on your grading option.

Hands-On Lab Help

- If you need assistance during the lab period, you can submit a help form and a TA/lab assistant will join you. The process for checkoff is similar; you will fill out a checkoff request form and a TA/lab assistant will join you. **You MUST have your checkoff request submitted 10 minutes before the end of lab** to give you a bit of a time buffer in case the queue is long so that staff can get to you before the next section starts.
- Lab questions (beyond logistical questions) will not be answered on Piazza to encourage students to seek debugging help in-person, where staff is best equipped to help you. However, you are encouraged to collaborate with your peers on Piazza and other platforms!
- Every lab and project sub-part has been tested by lab staff and is fully completable in a nominal time of less than two and a half hours, including reading everything from scratch. However, because it is possible to experience unusual bugs or hardware failure modes (a part of real life whether one is working either with hardware or any real software system that is high performance), sometimes groups will find that their lab doesn't finish during your section.
- If you did not finish your lab in your section, find a section that works for both you and your partner. Fill out the Lab Make-up form that will be available on Piazza soon. You will receive a confirmation on whether you can attend if you fill out the form $>$24 hours in advance. If you attend a same-day lab or attend a section without prior explicit approval, you might not receive help.

Lab Sim

Lab Sim Structure

- We will host three-hour lab sections where you can come work together on labs and get help from course staff. You will have the flexibility to attend any of our offered lab sections.
- We expect that you can complete each lab in less than 3 hours. The labs have been tested by course staff to be completed in a nominal time of less than two and half hours.
- With each lab sim assignment, you can finish the lab asynchronously and submit the Gradescope checkoffs until the Wednesday deadline. You need to submit the checkoffs individually, but the labs are meant to be completed collaboratively and with guidance from course staff, especially to ensure you have a strong conceptual understanding of lab.

Lab Sim Grading

- Labs are submitted on Gradescope and are graded on correctness by an autograder that will be run after the lab deadline. You will have one week to complete each lab, and they will be due on Wednesdays. Late lab submissions will be scaled by 50% credit and accepted until one week after the deadline. This means total points received will be halved for late submissions. We will not accept any submissions afterwards.
- Labs will have an effort policy. Any lab sim submission with a score of 80% or higher will receive full credit, and scores below 80% will be scaled accordingly. In other words, your final score on a lab sim assignment will be min(100%, 1.25 * score %).
- Labs are an essential part of the course. Therefore, if by the end of the semester **you miss 3 or more submissions, you will fail the class.** Your final grade will be an NP or F depending on your grading option. A submission without displayed effort is also a missed submission, which will be defined below a 50% **raw** score.
- Every lab sim student must make an individual submission for each lab. However, you are welcome to work in pairs or in groups to share ideas, as long as the work you submit is your own.

Lab Sim Help

- We highly recommend that you set aside time each week to complete the lab and attend one of our scheduled lab sim sections each week to answer any questions you may have. If you need assistance from lab staff, you can join the queue and a TA/lab assistant will join you.
- Lab sim questions (beyond logistical questions) will not be answered on Piazza by staff to encourage students to seek live help. However, you are encouraged to collaborate with your peers on Piazza and other platforms (as long as you don't post pictures of your work)!

LPTs: Lab Pro Tips

Following these tips will ensure you succeed in and get the most out of lab.

1. Read through the lab note and lab notebook before coming to lab. Think carefully about what possible bugs you may encounter, or which parts of the lab will take longest, and have a plan for avoiding those bugs and staying on-track time-wise.
2. If there is a lab problem on the homework, make sure you do it prior to your lab section. We put these problems on the homework to save you as much time as possible in lab and perhaps even help you finish early. This and tip number 1 are the top tips for making sure that you finish on time and get the most out of lab — if you follow these tips, you won't be scrambling to finish and will have the time to develop a deep understanding of the lab.
3. Talk to the other students in lab, not just your partner(s). Utilize Piazza and other electronic platforms to ask others if they have encountered similar bugs or problems and what they have tried to fix it. Or, if you've already fixed that bug, offer them some pointers.

4. As you're working through the lab, formulate sanity-check questions that allow you to quickly check if there is something wrong with your circuit. Ex: *What should VDD and VSS be? What voltage do I expect at this node? What do I expect the signal at this node to look like?*

5. Get to know your lab partner(s). This also extends to the other students in your section. For hands-on, you will be working with the same people for the entirety of the project! For lab sim, form groups to work on labs together each week. It's much easier to work with friends!

Here is quick list of important things to consider for a successful hardware assembly (or virtual hardware assembly):

1. Be neat and organized. All breadboard wiring should be planar - avoid spaghetti wiring.

2. Measure the voltage at circuit nodes as you are building your circuit up and compare with your expectations. This will help you identify problems early.

3. Often check for loose contacts or breaks in wires that should be connected. These are the main reason for circuits not working - or working unreliably.

Deciding Between Hands-On Lab and Lab Sim

You will be completing either **hands-on lab** or **lab sim**, as described below. In any given week, both labs will emphasize the same lecture concepts and design goals.

You will sign up for your lab option in the first week of classes. Note that you cannot change your lab option later in the semester, so please make your decision carefully.

	Hands-On Lab	**Lab Sim**
Overview	Hands-on lab involves physical circuit building and debugging. It occurs in assigned 3-hour lab sections each week, led by a TA you will meet each week. You will gain hands-on experience with circuit building and debugging.	Lab sim builds an understanding of circuit building concepts in a software format, through simulation and analysis. There will be no physical circuit building required, although we have limited availability of kits if you'd like to play with a real circuit board.
Materials	You will receive a lab kit during your lab section, which you will need to bring to lab section each week.	There are limited lab kits available for pick-up if you'd like to play with one, but it is not required to complete the lab.
Support	Each lab section will be supported by the same TA and ASEs each week, so you can build relationships with course staff. You must attend your scheduled lab section each week. We will not be answering any questions on Piazza or other course office hours.	We will offer a few scheduled lab sim sections in a hybrid format, and it's encouraged (but not required) that you join the same section each week to build relationships with lab staff. We will not be answering any questions on Piazza or other course office hours.
Grading	Checkoffs will be graded on an all-or-nothing basis. TAs will accept high-effort, close-to-done labs, at their discretion. If you miss 4 or more lab checkoffs, you will automatically fail the class.	The autograder will be run after the deadline. By nature of using an autograder, your score will be based on correctness. If you miss 3 or more lab submissions, you will automatically fail the class.
Collaboration	Every student must participate in the group checkoff. Everyone is expected to work on their own hardware during the lab, but only one student in each group needs working hardware for the group to check off. Each lab group will be 2 students.	Every student must submit their own checkoff via a Gradescope assignment by a given deadline, but you may work with others so long as you submit your own work.

Schedule

Lab sim and hands-on labs will both follow the same schedule and teach similar concepts each week. Lab sim students will not complete hardware components of the lab described below. The "Date" column indicates when the lab will first be introduced.

Date	Lab	Overview	Goals
8/25	Syllabus Week	No Lab	
8/30	Lab 1: Tinkercad Intro	Build a circuit virtually on Tinkercad.	Practice simulating and translating circuit schematic onto a breadboard.
9/7	Lab 2: Debugging	Build and debug an inverting amplifier.	Review digital logic, practice good circuit-building and debugging techniques, and re-familiarize yourself with lab equipment.
9/14	Lab 3: DAC/ADC	Build a 4-bit DAC using the MSP430 and a resistor net. Modify the DAC to build a 4-bit SAR ADC by adding a comparator and implementing binary search.	Review superposition and continue familiarizing yourself with the MSP430.
9/21	Buffer Week	Buffer Lab	Finish DAC/ADC.
9/27	Lab 4: Color Organ Part 1	Use the mic board and filters to illuminate different LEDs depending on sound frequency.	Explore low-pass and high-pass filters.
10/4	Lab 4: Color Organ Part 2	Use the mic board and filters to illuminate different LEDs depending on sound frequency.	Explore band-pass filters and see how a physical circuit can do classification of sounds.
10/11	Project Part 1: Front End Circuits	Build car and test motor behavior.	Build the front-end circuitry for the car (neatly, to minimize chances of wires coming loose later)
10/18	Buffer Week	Buffer Lab	Finish Front End Circuits.
10/25	Project Part 2: System ID	Profile motor behavior and determine operating point.	Explore modeling and linearization using least-squares as a precursor to controls.
11/1	Project Part 3: Closed-Loop Control	Implement and fine-tune closed-loop model to make car go straight.	Explore discrete state-space control via eigenvalue placement.
11/8	Project Part 4: SVD/PCA	Record voice samples, find PCA vectors, and implement cluster classification algorithm for samples projected onto PCA subspace.	Explore SVD and PCA as they relate to data science in order to distinguish different commands.
11/15	Project Part 5: Advanced Controls	Make car turn and implement classification on MSP430.	Use SVD/PCA in order to make your car correctly respond to live voice commands.
11/22	Buffer Days	Buffer Lab	Finish Advanced Controls.
THANKSGIVING BREAK 11/24 - 11/28			
11/29	Project Part 6: Integration	Make the car respond to voice commands.	Bring everything together and achieve understanding of the complete system.
12/6	Buffer Week	RRR Week	Finish Integration.
SCHEDULE IS SUBJECT TO CHANGE.			