1   Introduction to 16B Lab

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

In 16B, labs are an integral part of the learning process. Many times, concepts introduced in lecture and discussion will be quite abstract. Labs have been designed to put the ideas and concepts discussed in lecture and discussion into perspective. Learning about these concepts and applying them are two very different things, and the goal of labs is to bridge the gap between the two.

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 up.

2. Know how to make educated guesses to check your work and identify potential issues and their solutions.

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 they have or have 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 up your debugging skills, but we won't do the 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. We are here to help and support you at each step along the way.

2   Lab Pro Tips

16B lab has an eventual goal: build a voice-controlled robot car. As daunting as it may sound as an overall project, we make it doable by making it step-by-step and leveraging previous learnings at every step along the way. We break down the project into multiple sub-parts to be done throughout the semester and achieve smaller goals incrementally. This enforces modularity as well as the design-before-build principles of engineering. The goal of 16B labs is ambitious and definitely a step-up from 16A labs. Therefore, it is ever more important to stay focused, dedicated, and curious about labs. Over the past semesters, course staff has done a careful analysis of students' performance in lab and the time it takes to finish. An overwhelming majority of students who follow the tips below have finished the lab in the allotted time.

1. Before the lab each week, set aside time to work on the pre-lab. The purpose of pre-labs is not to overwhelm you with more work; rather, we want you to have the conceptual understanding needed before you start each lab. This requires you to fully read and understand the lab resources we release for each lab beforehand, including the lab note and notebook. It is completely okay and expected to have some conceptual gaps after doing the pre-labs. Following the tips below will clear up these gaps even more. In fact, doing the pre-labs properly will save you from design and debugging errors resulting from lack of conceptual understanding.

2. If there is a lab problem on the homework, make sure you also complete it prior to your lab section. We put these problems on the homework to save you as much time as possible in lab, and even to help you finish early. These problems will enforce conceptual and analytical understanding of the lab in addition to the pre-labs.

3. Labs will be released well before your lab section. Think carefully about what possible bugs you may encounter or which parts of the lab will take the longest, and have a plan for avoiding those bugs and staying on-track time-wise.

4. Think about which concepts might be the hardest to understand. If you are shaky on the concepts used in lab, go back to the course notes and your lecture notes to get familiar with these concepts.

5. Pay attention during your lab TA's presentation at the start of each section. Do not start the lab during the presentation as you will miss crucial information and tips about the lab and will most likely not finish on time. Ask questions, be curious, and stay engaged at all times.

6. If any conceptual gaps still exist after the presentation, please make sure you ask any questions to clear up these gaps before you start the lab. We have found that students who understand the concepts complete the lab more efficiently and effectively instead of having to review them during the section itself and risk running out of time.

7. We include a suggested time breakdown of how much time each part of the lab should take in the lab presentation. Try your best to stick to that. We include buffer time to allow you the flexibility in completing the lab.

8. Get to know your lab partner well. This also extends to the other students in your section. Exchange contact information. You will be working with the same people for the entirety of the project and you will have a peer group too! It's much easier to work with friends! Friendships from 16B lab truly last forever (we are speaking from experience)!

9. 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?

10. During lab checkoffs for hands-on, pay close attention to the questions asked. If any of questions are confusing to you, ask questions to clear up the confusion. Many of these questions will appear again on the lab reports, which form a significant portion of your lab grade and will test your conceptual and analytical understanding of the 16B labs. Again, we stress here the importance of thinking about each lab in a conceptual way throughout the semester. Pay close attention to the connection between concepts covered in lecture and discussion and how they are applied in lab. When focused on debugging, it is easy to lose sight of big picture concepts, so be sure to understand all concepts in addition to developing debugging skills in lab.

3   How to debug a circuit

Circuit debugging is very similar to debugging a piece of code, with some additional nuances relating to hardware. However, the basic steps and principles of debugging still apply.

1. **Identify**: The most important thing about debugging is to identify the bug and where it is originating in your circuit. Ask yourself: what should be the voltages at the key nodes for this lab? Are they as expected? Is the unexpected behavior introduced in the current part of the circuit you're investigating, or is caused by the propagation of unexpected behavior from an earlier stage?

2. **Investigate**: Investigate whether the bug is a one-time bug or a recurring one. Then, try disconnecting different components connected to the buggy component and see if it behaves differently as you do this.

3. **Solve**: After following steps 1 and 2, you should have identified the source of the bug. Solving it could be a quick fix like swapping out a component, or it may be a bigger fix such as changing your breadboard layout to ensure your components don't touch. It is important that you don't ignore bugs due to your breadboard design. Fix them as you identify them, as these will always come back and bite you. Don't put temporary solutions in place for these design problems.

4. **Collaborate**: In order to fight against a bug, your first line of defense after trying to figure it out yourself is asking your neighbors or your assigned peer group. Ask them if they have already encountered a similar bug. If they haven't encountered it, even though course staff will not offer Piazza support, you can utilize Piazza and other electronic platforms to ask other students if they have encountered similar bugs or problems and what they have tried to fix. Also, don't be afraid to ask course staff for help. Pay very close attention to how course staff debugs it and solves the issue. Document it. If you already fixed a certain bug, offer other students some pointers on Piazza. This one small step of yours can help many other students avoid this problem in the future, as well as being a learning experience for yourself too.

Just like the golden rules of op-amps, in 16B Lab, we have the following 3 golden rules relating to successful hardware assembly:

1. Be neat and organized. All breadboard wiring should be planar (flat against the breadboard) - avoid spaghetti wiring. It takes infinitely longer to debug spaghetti circuits than planar circuits, as it takes a long time to understand spaghetti designs before we can even help you debug it. So, planar circuits are the move.

2. Measure the voltages at various circuit nodes while you are building your circuit and compare it with your expectations. This will help you identify problems early.

3. Check often for loose contacts or breaks in wires that should be connected. These are common reasons for circuits not working - or working unreliably.

4   Parting Thoughts

Traditionally, 16B labs are the heart of this class at an emotional level. They are difficult and time-consuming, but they teach you practical skills you can obtain nowhere else in college. How do you work with others? How do you overcome challenges? How do you respect deadlines? How do you follow a methodology? How do you work systematically? These are the skills we intend to help you achieve. Labs are very fun and very fulfilling, and are the place where students see 16B in action. Historically, lab has been the favorite part of the course for students.

Do not hesitate to reach out for help. You can reach out to anyone who you feel comfortable with - be it the Head Lab TAs, your lab section TA, or the lab assistants. Course staff is always here to help and is constantly on the lookout, so please help them help you by reaching out. Course staff are students too and sympathize with you; we understand that life is unpredictable and things happen. Nothing should stop you from getting the best of what the course has to offer. Everyone on staff works very hard to make each student's experience as worthwhile as possible. We have people on course staff who have taught this class for more than 5 semesters; that's more than 63% of an undergraduate's entire time at college. We love teaching labs. We love inspiring students to take up this challenge and to help them reach the finish line.

Never give up. Sometimes, things might not be in your favor or you are facing a lot of difficulty. It's perfectly normal. Everyone who has done 16B labs will say this, including the course staff. However, brace the challenge and don't give up. If you need help standing up, seek help and ask us for help. Just don't give up. We assure you that staying up and motivated will definitely be worth it, especially when you see your final project in action! It is the most fulfilling part of this course.

Try to review as much material as you can for labs. Labs provide a great add-on to the material covered in the rest of class. It offers great, practical perspectives for the densely, theoretical materials in the course. Reviewing and understanding as much lab material as you can will expedite your success in labs.

We have one final message for all of you - **have fun**! Labs are one of the best things 16B has to offer. Make the most of it.

All the very best. See you all in lab!!

Go S1XT33N!