Introduction

The midterm lab report tests your understanding of EECS 16B Labs 1-5, with an emphasis on conceptual and analytical understanding. It also allows you to look at these labs from a bigger picture and reflect on your design process and choices. You may use your homeworks, pre-labs, labs, lab notes, presentation slides, and any other resources we provided throughout the semester to help you. Many of these questions have also been asked in lab checkoffs. **However, all of your answers and explanations must be in your own words; you are not allowed to directly copy from those resources.**

The report is to be done with your lab group using LaTeX or Google Docs/Microsoft Word. **At the top of the report, please include the names and emails of all your group members, as well as the group ID you use for checkoffs.** Make sure to complete the following for each section header (Sections 1-5):

- First, give a summary in your own words of what you have done in the lab this semester.
- Then, answer all of the questions listed under the section header. Remember to fully and clearly explain your answers. Some questions also require you to upload your work.

Under Section 7, please detail each group member's contributions to the lab report. **If we find a highly disproportionate amount of work distribution among the group, we will adjust grades accordingly to penalize non-contributors.** Also, cite any sources you used that were not provided with the course materials.

The midterm lab report is due on Tuesday, March 8 at 11:59 PM. Only one group member submits the lab report to Gradescope and you must add all of your group members into the same submission.

1 Introduction to Simulation

1. Name one piece of lab equipment you can use to gain more information about what your circuit is doing. What do you use it for?
2. What is the ideal gain of the buffer in Lab 1? What is the ideal gain of the inverting amplifier in Lab 1? What were your simulated/measured values? What are some possible explanations for the discrepancies between the ideal and calculated gain values?
3. We have an inverting amplifier with no reference voltage (non-inverting terminal is connected to GND) as shown in Figure 1. Please upload all of your work for this problem.

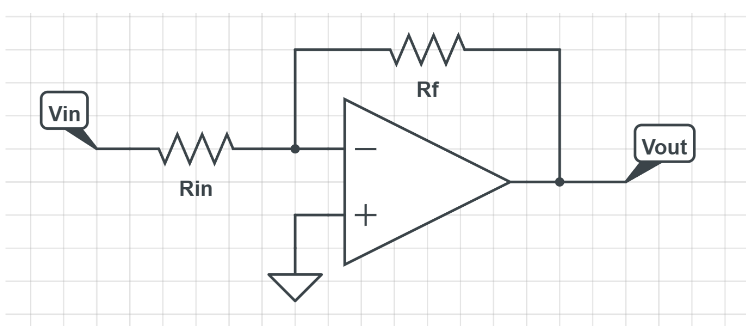

Figure 1: Inverting amplifier

   a) Derive the gain $\frac{V_{out}}{V_{in}}$, first assuming that the op-amp gain A is finite. (**Hint**: Superposition and voltage dividers will be useful here.)
   b) Simplify the expression for the gain you derived in part (a) if A is infinite. Explain why this makes sense intuitively.

2 Analog and Digital Interfaces

1. Why are Digital-to-Analog Converters (DACs) and Analog-to-Digital Converters (ADCs) important circuits in the world today?
2. What is the SAR ADC algorithm? What are the steps it goes through in order to find the digital representation of its input analog voltage?
3. Should we always strive for higher resolutions? Is increasing the resolution of our DACs and ADCs always beneficial? Why or why not?

3 Motion

1. What is a PWM wave/signal? What does duty cycle mean for a PWM signal?
2. What is the relationship between the duty cycle of a PWM signal and the rotation speed of the motor?
3. Why do we use the motor controller circuit we built instead of just directly plugging the Launchpad pins into the motors and applying the PWM directly to the motor?
4. The NPN Bipolar Junction Transistor (BJT) serves a very important purpose in our motor controller circuits.
   a) Describe the function of the BJT.
   b) In your own words, explain the model of the NPN BJT in the ON mode from the lab note.
   c) In your own words, explain the model of the NPN BJT in the OFF mode from the lab note.
5. What is the relationship between the resistance of the resistor connected to the Base pin of the BJT and the rotation speed of the motor?
6. Describe the purpose of the diode in parallel with our motor in our motor circuits.
7. How do the encoders work? (**Hint**: They're also called photo-interrupters.)

4 Sensing Part 1

For questions 3-6 in this section, refer to the mic board schematic below in Figure 2.

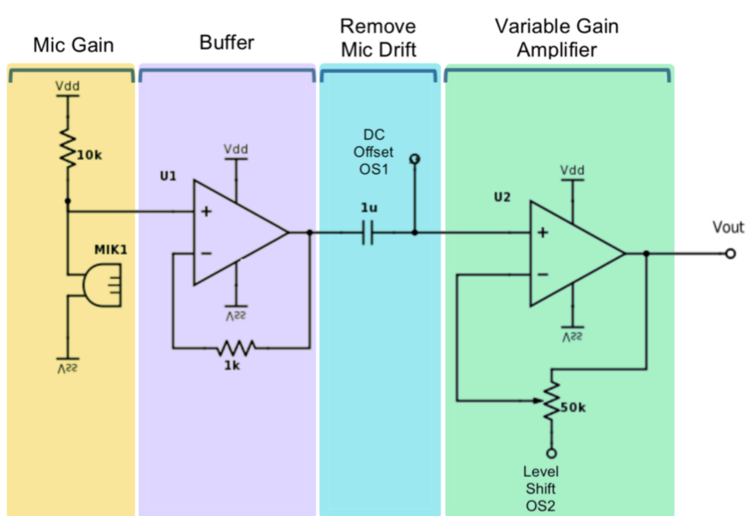

Figure 2: Mic board schematic

1. Why do we need voltage regulators for our circuits?
2. What is the purpose of the capacitor connected between 3.3V and GND on the breadboard rails?
3. What is the purpose of the buffer in our mic board schematic?
4. Why do we connect OS1 to 1.65V through a 100kΩ resistor? Why specifically the value of 100kΩ?
5. Why do we connect OS2 to 1.65V?
6. Why can't we amplify the microphone signal centered at 0V first and then offset it, instead of offsetting first and then amplifying it like we do currently? (**Hint**: Think about the voltage range we have access to.)
7. How do we measure the magnitude of the transfer function of a system?
8. Why do we need to determine the magnitude of the transfer function of the speaker-microphone system separately from the ideal filter behavior?

5 Sensing Part 2

1. What is the definition of cutoff frequency in relation to a general filter? What is the expression for the cutoff frequency of a first-order RC filter in Hz?
2. Why do we set the output impedance of the function/waveform generator to High-Z?
3. How did you build a band-pass filter in lab? What is the relative relationship between the cutoff frequencies of the low-pass and high-pass filters you used in the band-pass filter?
4. In the band-pass filter, why did we have to connect the two filters using a buffer, instead of directly connecting the output of one filter to the input of the other?
5. In the band-pass filter, why did we connect the end of the resistor in the high-pass filter that isn't the filter's output to HALF_RAIL instead of GND? Why isn't this necessary to do for the capacitor in the low-pass filter?
6. We will now explore and analyze higher-order filters and the importance of considering the effect of loading on transfer functions and cutoff frequencies. Let's say we decide to build a second-order low-pass RC filter by chaining two first-order low-pass RC filters together with a buffer in between them. Assume that each of these first-order low-pass RC filters has the same cutoff frequency of f_c and that the op-amp we use for the buffer is ideal.
   a) Would the cutoff frequency of the overall second-order filter also be equal to f_c? Why or why not?
   b) Suppose you forgot to use a buffer to connect the filters you chained, and instead just directly connected the second first-order filter to the output of the first. Would the cutoff frequency of the first filter in the chain still be the f_c? Justify your answer by giving a qualitative explanation (no calculations).

6 Feedback

Please provide any feedback you have about 16B lab or anything we can do to better support you.

7 Collaborators and Sources

Please detail each group member's contributions to the lab report. Also, cite any sources you used that were not provided with the course materials.