

Introduction

The midterm lab report tests your understanding of EECS 16B Labs 1-6, 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. **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 can be done individually or in a group of 2 using \LaTeX or Google Docs/Microsoft Word. Since this is a longer assignment, we highly recommend that you work in a group. **At the top of the report, please include the names and emails of all your group members.** Then, answer all of the questions listed under each section header (Sections 1-6). Remember to fully and clearly explain your answers. Some questions also require you to upload your work.

Under Section 8, 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 Sunday, July 24 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. Give a summary (in your own words) about what you did in this lab.
2. 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?
3. 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?
4. Explain the purpose of the reference voltage for the inverting amplifier. What would happen if we did not have one for Lab 1?
5. 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.

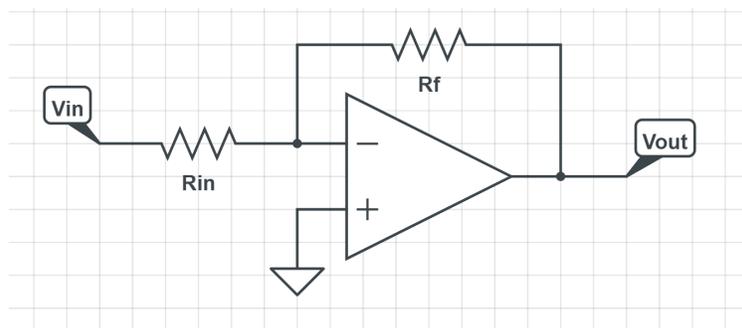


Figure 1: Inverting amplifier

- 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. Give a summary (in your own words) about what you did in this lab.
2. Why are Digital-to-Analog Converters (DACs) and Analog-to-Digital Converters (ADCs) important circuits in the world today?
3. 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?
4. Should we always strive for higher resolutions? Is increasing the resolution of our DACs and ADCs always a good thing? Why or why not?

3 Motion

1. Give a summary (in your own words) about what you did in this lab.
2. Why do we need voltage regulators for our circuits?
3. What is the purpose of the capacitor connected between 5V and GND on the breadboard rails?
4. What is a PWM wave/signal? What does duty cycle mean for a PWM signal?
5. What is the relationship between the duty cycle of a PWM signal and the rotation speed of the motor?
6. Why do we use the motor controller circuit we built instead of just directly plugging the Arduino pins into the motors and applying the PWM directly to the motor?
7. 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.
8. 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?
9. Describe the purpose of the diode in parallel with our motor in our motor circuits.

4 Sensing Part 1

1. Give a summary (in your own words) about what you did in this lab.
2. How do we measure the magnitude of the transfer function of a system?
3. 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?
4. What will happen if we directly drive the piezo speaker with RC filters?

5 Sensing Part 2

1. Give a summary (in your own words) about what you did in this lab.
2. 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?
3. 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?
4. Describe how you would build a second-order RC low-pass filter. Why are higher-order filters useful for practical applications?
5. Consider the following RLC filter in Figure 2 with $R = 20k\Omega$, $L = 100H$, and $C = 1\mu F$. Please upload all of your work for this problem.

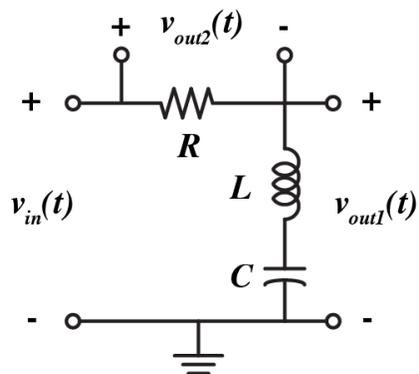


Figure 2: RLC filter

- a) Derive the transfer function from v_{in} to v_{out1} , $H_1(j\omega) = \frac{\tilde{V}_{out1}}{\tilde{V}_{in}}$. Calculate the notch frequency and plot the transfer function's magnitude as a function of frequency. (**Hint:** The plot can be generated through the Jupyter notebook for Lab 5 with minor modifications.)
- b) In your modified code, use different resistance values (e.g. $R = 200\Omega$, $2k\Omega$, $20k\Omega$, and $200k\Omega$) and plot their transfer function's magnitudes in the same figure. Describe qualitatively the impact of the resistance value on the frequency response of the notch filter.
- c) Derive the transfer function from v_{in} to v_{out2} , $H_2(j\omega) = \frac{\tilde{V}_{out2}}{\tilde{V}_{in}}$. Plot the transfer function's magnitude as a function of frequency. What kind of filter (low-pass, high-pass, or band-pass) is this? How does it compare with the similar-type filter only built with resistors and capacitors as you did in the lab?

6 System ID

1. Give a summary (in your own words) about what you did in this lab.
2. What do θ and β represent (physically, not mathematically)?
3. Why do we have separate θ and β values for the left and right wheels?
4. Why do we set v^* to the midpoint of our overlapping wheel velocity range, instead of closer to the boundaries? What would happen if we operated our car at a velocity outside of the overlapping velocity range?
5. Explain how using each of the following methods as our model can produce a better fit for the data we collected than our current linear model of the car: a) higher-order functions and b) piecewise-linear functions. You may not manipulate the data set in any way (i.e. remove outliers, collect more data points, etc.).

7 Feedback

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

8 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.