

## Introduction

For this report, we want you to tie together your understanding of the labs and car project. You have already answered many of these questions on your homework and during lab sections, especially during checkoff. You may use your homeworks, labs, lab notes, and any other information you saved throughout the semester to help you. Work together with your lab group to submit the final report to Gradescope by Friday, May 7th, at 11:00 PM PT. You can write up your report in  $\LaTeX$  or Word/Google Docs. Make sure to complete the following:

- Give a summary in your own words of what you have done in each lab this semester.
- Answer all of the questions listed below and explain your answers.
- Please cite any sources that were not provided with course materials.

## 1 Intro to Tinkercad & Op Amp Basics

1. Name at least one tool you can use to gain more information about what your circuit is doing and how you use it to do so.

## 2 Debugging

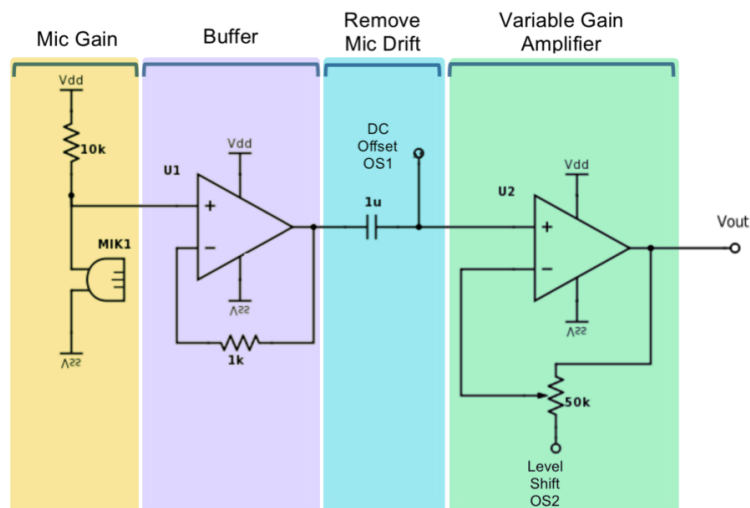
1. What is the purpose of the capacitor connected between 3.3V and GND?
2. If you keep the resistor ratio the same for the inverting amplifier, do the base value of the resistors matter (i.e.  $10\text{k}\Omega/1\text{k}\Omega$  vs  $100\Omega/10\Omega$ )? Why or why not?

## 3 DAC/ADC

1. 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?
2. Should we always strive for higher resolutions? Is increasing the resolution of our DACs and ADCs always a good thing? Why or why not?

## 4 Color Organ

For this section, refer to the mic board schematic below.



1. Why do we use a buffer in our mic board circuit?
2. Why do we connect OS1 to 1.65V through a 100k $\Omega$  resistor? Why specifically the value of 100k $\Omega$ ?
3. Why do we connect OS2 to 1.65V?
4. 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.
5. What is the definition of cutoff frequency in relation to filters? What is the expression for the cutoff frequency of an RC filter in rad/s?
6. How do you measure the frequency response of a system?

## 5 Front End

1. What do we use the low-pass filter for?
2. What is a PWM wave/signal? What does duty cycle mean for a PWM wave?
3. Why do we use the motor circuit we built instead of just directly plugging the Launchpad pins into the motors and applying the PWM directly to the motor? What purpose does the BJT serve? What purpose does the diode serve?

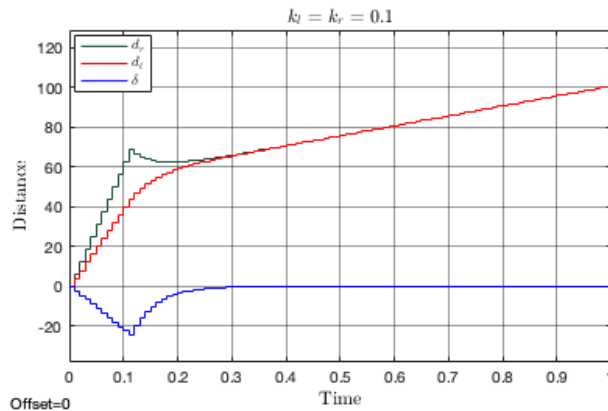
## 6 System ID

1. How do the encoders work? (**Hint:** They're called photo-interrupters.)
2. Why do we have separate  $\theta$  and  $\beta$  values for the left and right wheels? Why are they different between the wheels?
3. How did you choose the region to collect finer data on (data\_fine.txt) that you ultimately ran your least squares regression on? Why did you choose this region?
4. What do  $\theta$  and  $\beta$  represent physically, not mathematically?
5. Why do we set  $v^*$  to the midpoint of our overlapping wheel velocity range, instead of closer to the boundaries?
6. Name at least two different ways we can improve our model of the car so that it better fits the data we collected. You may not manipulate the data set in any way (i.e. remove outliers, collect more data points, etc).

## 7 Controls

1. Why does open loop fail? Why do we need to implement closed loop in order to have the car travel straight?
2. What are the closed loop model equations for our input,  $u$ ? Explain the purpose of each term.
3. Derive the system eigenvalue. Under what condition is the system stable (in theory)?
4. When testing out different  $k$ -values in practice, how do you know the system eigenvalue has gone from positive to negative based on the car's behavior?
5. What effect does setting both  $k$ -values to 0 have on the car's control scheme? How is this different from non-zero  $k$ -values? Why are non-zero  $k$ -values necessary?
6. What does a nonzero  $\delta_{ss}$  value tell you about your car's trajectory? What kind of error is it supposed to correct when we add it to our control scheme? Hint: Think about the difference between the trajectories for a nonzero versus a zero  $\delta_{ss}$  value.

7. Draw the trajectory of the car whose performance is plotted below.



## 8 SVD/PCA

1. What are length, prelength, and threshold for our data processing?
2. Why do we process our data so that the words are aligned before we run SVD/PCA on it?
3. Why do we use the  $V^T$  vectors for our lab instead of the vectors inside of the U matrix returned by SVD?
4. Why do we use SVD/PCA?
5. How many PCA vectors would we need to represent a data set that, when graphed, looks like a thin, straight line? How many would we need if the data set looks like a circle when plotted?

## 9 Advanced Controls

1. How did you change the model equations to allow the car to turn? Write the equations below and explain how they change for turning left, right, and going straight.
2. How is using STRAIGHT\_CORRECTION different from `delta_ss` from Controls?

## 10 Integration

1. Briefly discuss what you learned while building this project and going through these labs. What was your favorite part? Least favorite part?