

Introduction

For this report, we want you to tie together your understanding of the virtual labs and project. You may use your homeworks, labs, lab notes, and any other information you saved throughout the semester to help you. You may work together with your group of up to 4 people 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. For each lab in sections 1-10, 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.

Alongside this report, you will be submitting a “final demo” as well, detailed in the Integration lab, and listed under section 11 (Final Demo) in this pdf. There will be 2 separate Gradescope assignments: one for sections 1-10, and one for section 11 (Final Demo). The final demo part will account for 50% of your Integration lab grade. Both assignments are due by Friday, May 7th, at 11:00 PM PT. You will be submitting two separate pdfs, so make sure you submit each one to its corresponding assignment!

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.

2 Debugging

1. What is the purpose of the capacitor connected between 3.3V and GND?
2. What is the equation for the output voltage V_{out} of the inverting amplifier (Circuit 1 in Task 2) in terms of V_{in} (the voltage connected to P3.2), V_{ref} , and the resistors (R_1 , R_2 , R_{in} , R_{f1} , R_3 , and R_4)?
3. If you keep the resistor ratio the same for the inverting amplifier, do the base values 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

1. 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?
2. How do you measure the frequency response of a system?

5 Front End

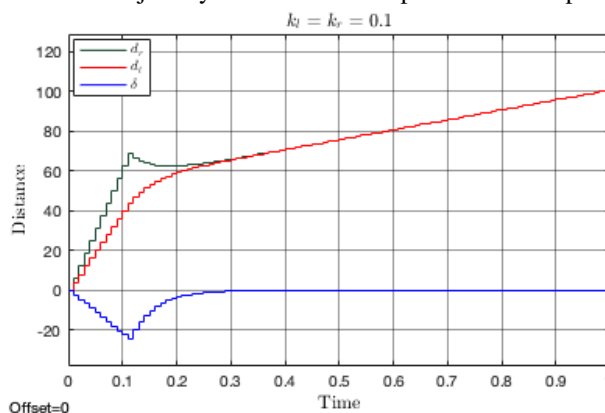
1. What is a PWM wave/signal? What does duty cycle mean for a PWM wave?
2. Why do we use the motor circuit we built instead of just directly plugging the Arduino pins into the motors and applying the PWM directly to the motor? What purpose does the BJT serve? What purpose does the diode serve?

6 System ID

1. Why do we have separate θ and β values for the left and right wheels? Why are they different between the wheels?
2. What do θ and β represent physically, not mathematically?
3. Why do we set v^* to the midpoint of our overlapping wheel velocity range, instead of closer to the boundaries?
4. 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. In what cases would 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.

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?

11 Final Demo

There is no summary or questions for you to answer here. Instead, follow the instructions at the bottom of the Integration lab ipynb (i.e. screenshot and save your 3 randomly generated command sequences and their corresponding trajectories, screenshot your centroids and word data, etc) and submit this part to the separate “Lab Lite: Final Demo” Gradescope assignment by Friday, May 7th, at 11:00 PM PT.