ECEN 4213
Embedded Computer System Design

Lab 2: Feedback Control of a Ping-Pong Ball

Ex #	Max Points	Points Earned	Grading Criteria	Instructor Initial
1	3		Program is written correctly, compiles, and runs. (3.0) _____	
2	7		Program is written correctly, compiles, and runs. (7.0) _____	
Doc	2		Supplemental Questions (2.0) _____	
TOTAL:				

Team Members:	TA Observations:

OBJECTIVE

In this lab, students will learn how to program a sonar sensor for distance sensing. Then, they will use the sonar sensor and a motor-driven fan to control the hovering height of a Ping-Pong ball in a tube through PID feedback control.

INTRODUCTION

In this lab, you will finish the following two exercises:
1) Interfacing the RPi with a sonar sensor to measure distance
2) Using the PID algorithm to control the fan so that the Ping-Pong ball can hover at a desired height, which is indicated by a potentiometer.

⚠ **Warning!** Consult the lab TA before you connect the power to the RPi or any external hardware.

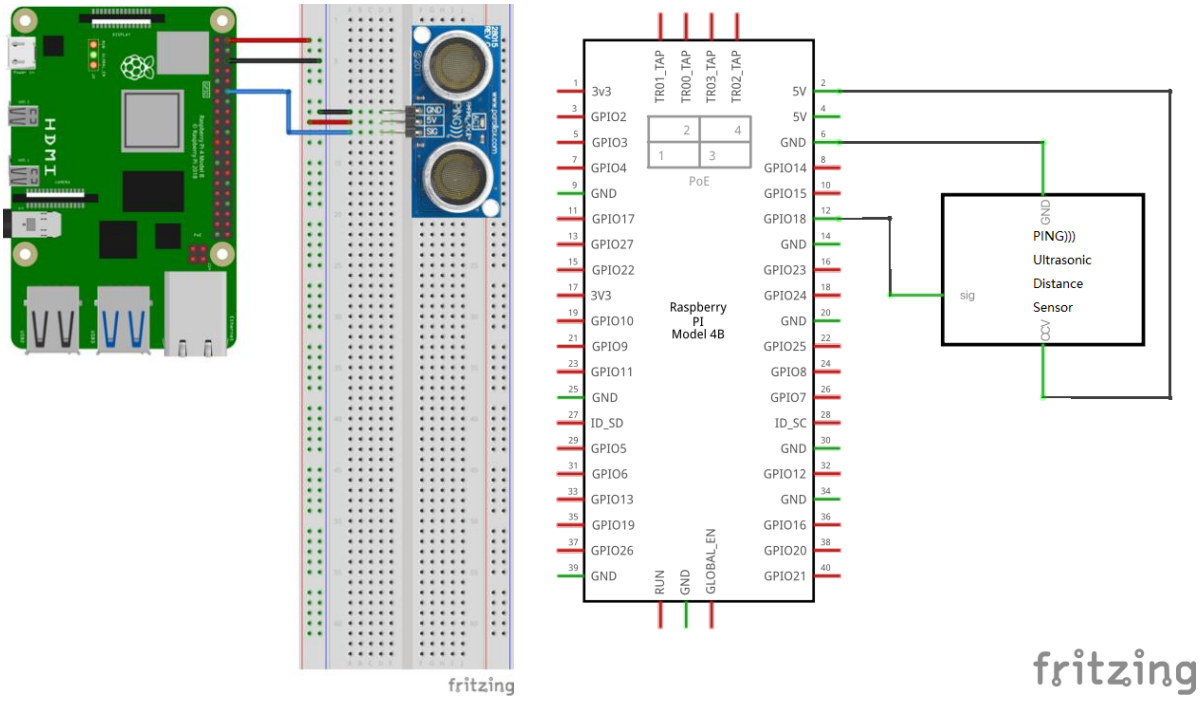
LIST OF DOCUMENTS USED IN THIS LAB

1. *ParallaxPING-SonarSensor.pdf.*
2. *High_Resolution_Clock_Reference.pdf*

Exercise 1

In this exercise, you will interface the RPi with a sonar sensor.

1. Connect your sonar sensor as shown below.

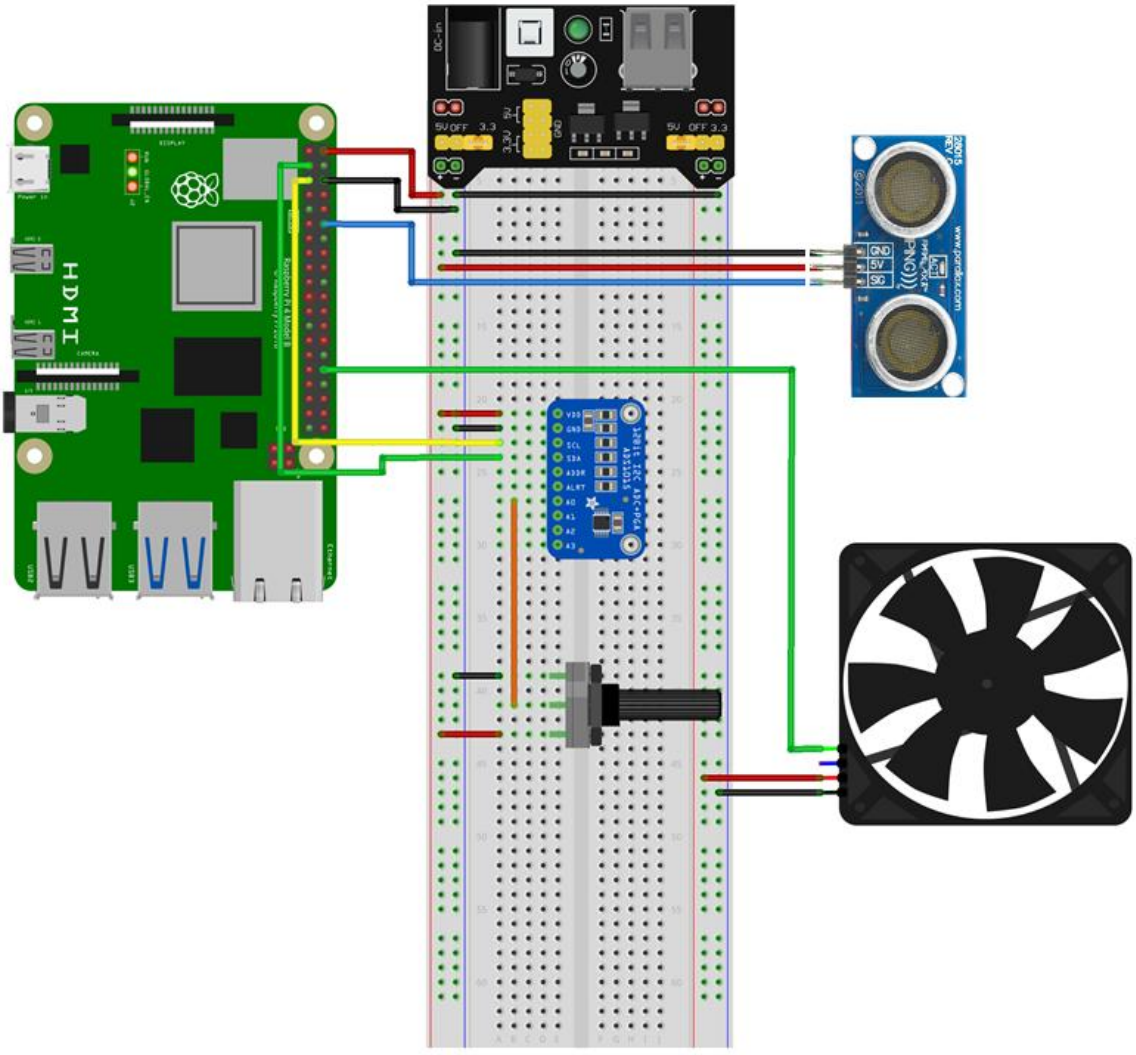


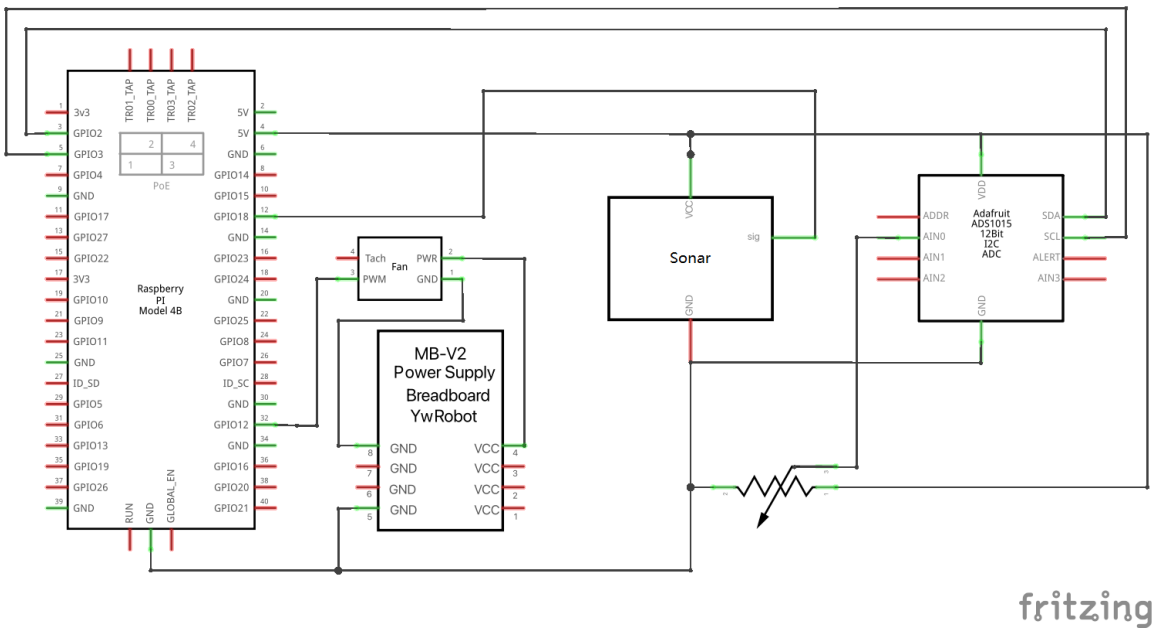
2. To understand how the sonar sensor works, study the documents *ParallaxPING-SonarSensor.pdf* and *High_Resolution_Clock_Reference.pdf.*
3. Complete the code in **Lab2EX1.cpp** to read the distance measurement from the sensor. The sensor requires a typical 5us pulse to be triggered.
4. Convert the pulse readings to distance (centimeters), and print the data on the terminal.
5. Demonstrate your program to the lab instructor.

Exercise 2:

In this exercise, you will use the Proportional Integral and Derivative (PID) control algorithm to control a fan so that the Ping-Pong ball can hover at a particular height specified by a potentiometer.

1. On the breadboard, construct the following circuit.



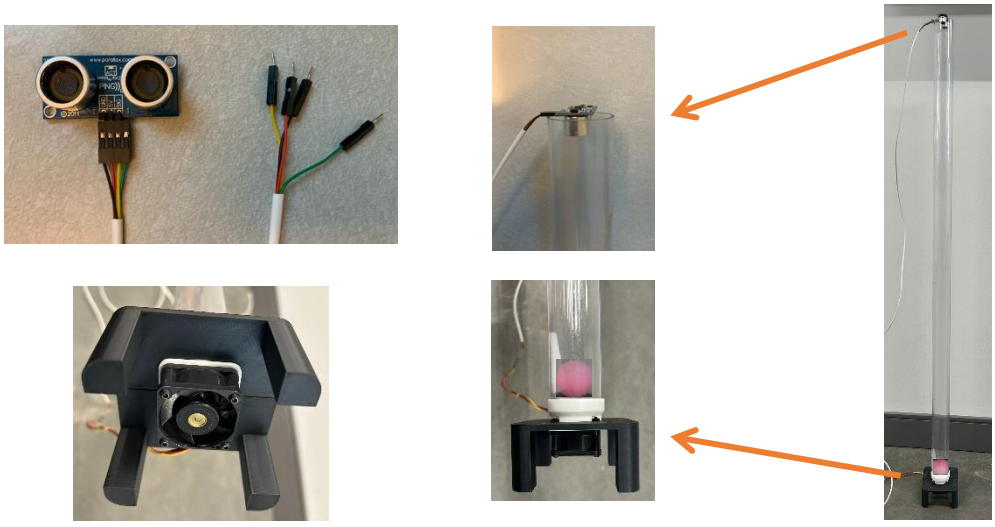


2. Fan connection can be seen as follows:

Function	Fan	Wiring Harness
Analog Ground GND	**Black**	**Black**
Supply Voltage +5V	**Red**	**Red**
RPM Control (Digital In)	**Brown**	**Green**
RPM Sensor (Digital Out)	**Yellow**	Not Used

   a. Control à **Green** to **GPIO**
   b. VCC à **Red** wire to **+5Volts**
      Do not use RPi to provide power for the Fan. Use an external power supply.
   c. GND à **Black** wire to the ground **GND**

3. The following picture shows the whole setting.



4. After completion, check with a TA to confirm the wiring.
5. The sonar sensor is used to measure the actual height of the ball. The sonar sensor will be mounted on the top of the tube. Vary the potentiometer to change the desired height. Complete the code in **Lab2EX2.cpp** to control the fan speed using PID control so that the ping-pong ball hovers at the desired height. You should use hardware PWM to control the fan.
6. After you have completed this exercise, demonstrate the result to your TA.

Thoroughly comment your code and print out the listing of the program. Make sure your name and the exercise number clearly appear in the comments.

Supplemental Questions

1. Briefly summarize what you learned from this lab.
2. In PID control, how will the values of the P, I and D parameters affect your control performance?
3. How did you decide the value of the P, I, D parameters to achieve a good control performance?

Submission

Submit your lab report through **Canvas**. Your lab report should include code, supplemental questions and answers of all exercises, along with the screenshots or pictures of the circuit. Put your supplemental questions and answers of all exercises, along with the screenshots in a word file or PDF file. Your code should be in the *.cpp* file. Make sure your code is thoroughly commented. Zip all files into one when you submit.