PingPong Ball Launch System

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ECE445 Project Proposal-Spring 2020
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1 Introduction

1.1 Objective

Ping-pong is one of the most popular games in the world. Based on the data from the International Table Tennis Federation, there are 37620 professional players in various organizations (ITTF, 2019). For Ping-pong players, an efficient daily practice is essential for people who want to improve their skill. Swing is one of the most fundamental and important training items. To practice the swing, it is necessary to find a partner. In addition, According to the author of the website [1]“newgy”, finding a proper training partner is one of the most efficient methods to improve our skills and if we have to work alone, the training robot is also an alternative. However, it will take Ping-Pong players extra resources, such as money and time, to find a suitable partner.

To save these resources, we want to design a Ping-Pong Ball practice machine, which can launch the ball automatically. The practice machine adjusts the direction, speed and frequency of the ball. Other than these basic functions, we also want to minimize the amount of time and energy waste on setting up the machine. We will add the remote-control feature to the machine. This feature will allow users to adjust the direction, speed and frequency of the ball anytime during the practice. Moreover, the machine will also have designed launch models for the players. For example, the machine can launch the ball from low frequency to high frequency.

1.2 Background

Most of the existing Ping Pong Ball launcher machines are stationary and can only be controlled manually. If a player wants to change the ball direction, frequency or speed, he or she needs to stop the training process and manually set the machine to a different direction. Obviously, the existing Ping Pong Ball launcher is not efficient, since it will waste energy and time to adjust the machine. The second drawback of the launcher machines is that it can not adjust the ball direction, frequency or speed dynamically during the practice. In our Ping Pong Ball launch machine, the players will hold a remote controller and change the launch direction and launch speed by pressing the button. Therefore, with the ability to remotely change the different speed and direction, the player can simulate how to stroke the ball in different positions and different angles dynamically. Since we can control the launch system conveniently, we do not need to waste time to manipulate the machine and our efficiency improves significantly when we practice alone.

1.3 High-Level Requirement

- The Ping-Pong Ball launch system can launch the ball with different directions, speeds and frequencies.

  1.Direction ranges from -85 degrees(left) to +85 degrees(right) (0 degree means facing front).

  2.Speeds range from 5m/s to 15m/s.

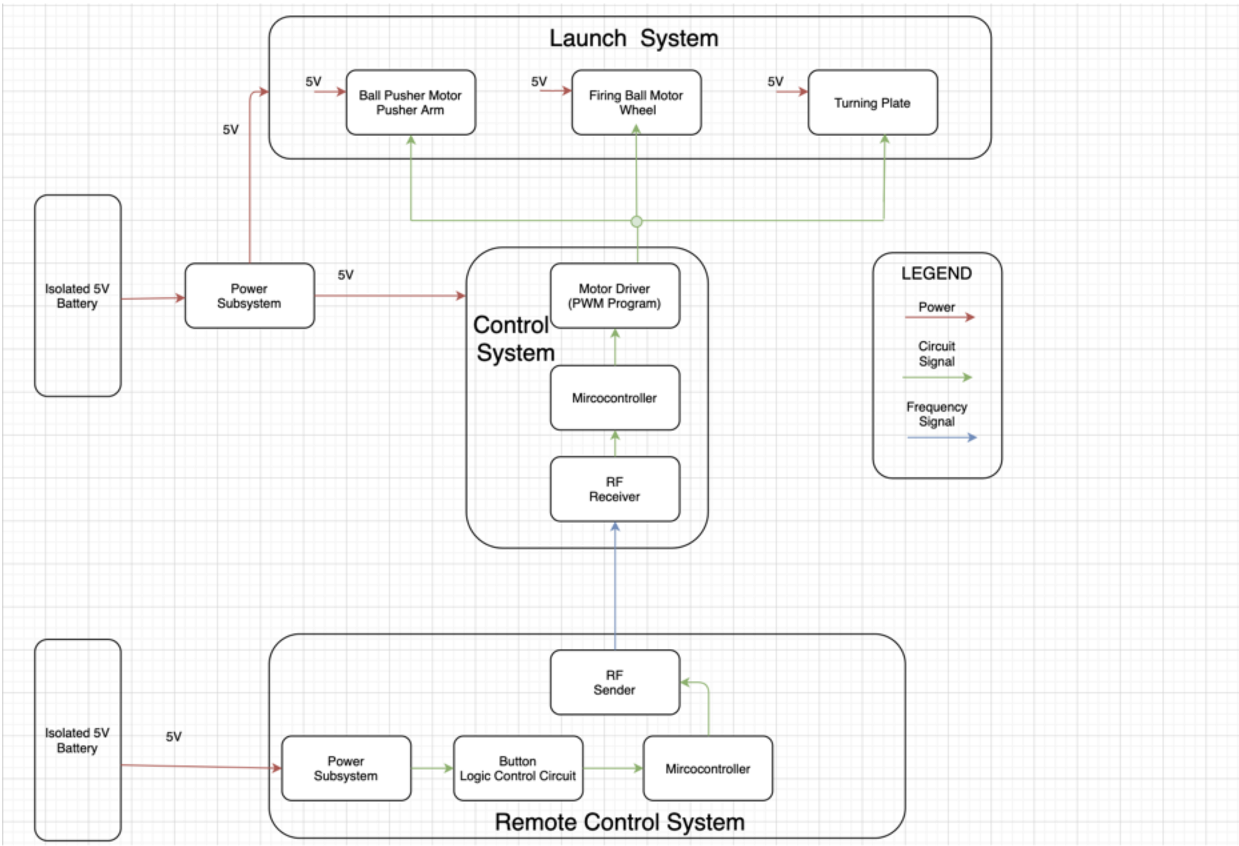
  3.Frequencies range from average 10 balls pers min or 20 balls per min or 30 balls per min.

- The Ping-Pong Ball launch system will have a pre-designed training model. The pre-designed training model will change the frequency from low to high repeatedly

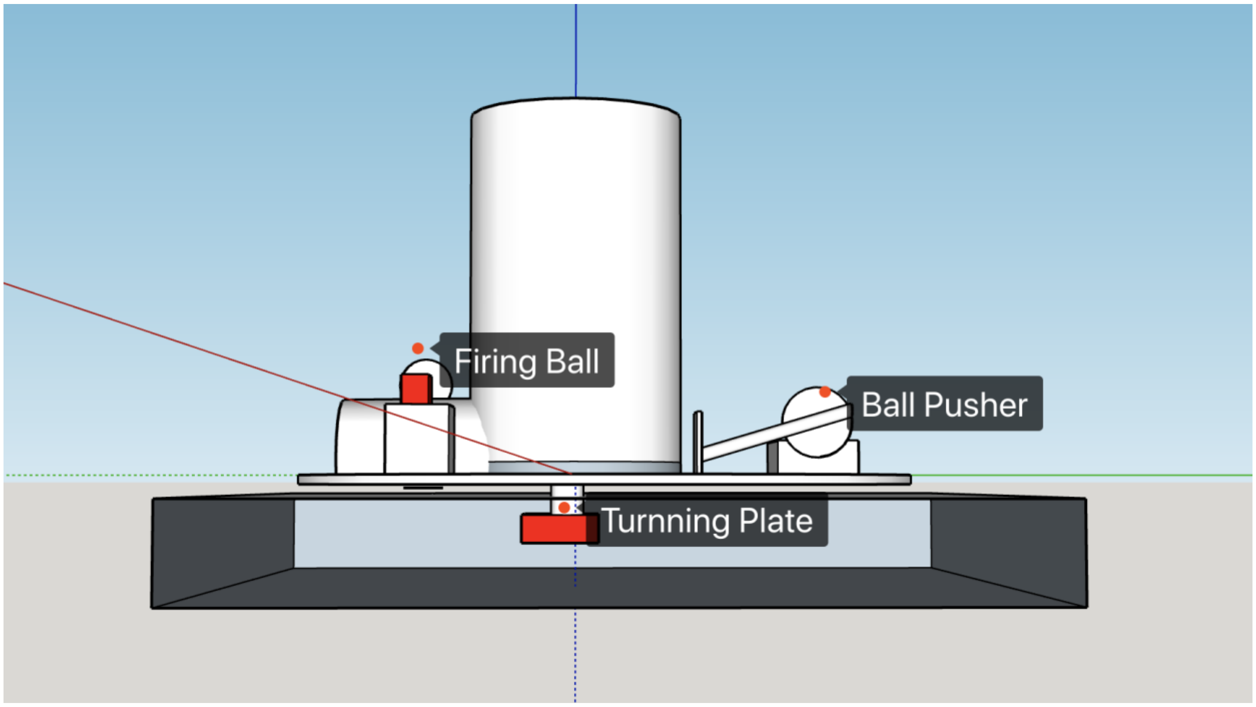
- Remote controllers can change the direction, speeds and frequencies from a distance 3 - 5m from the machine.

2 Design

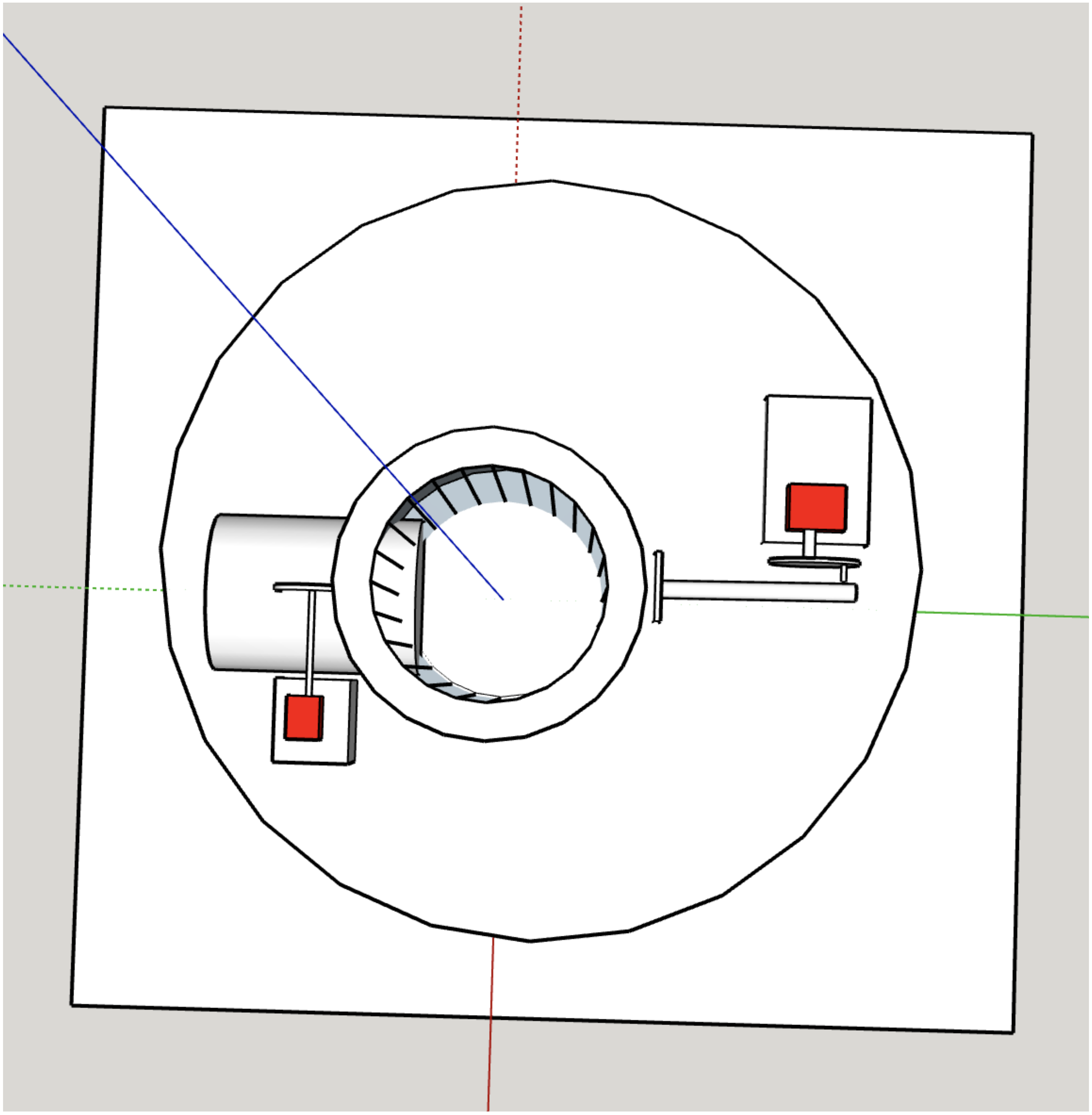
2.1 Block Diagram



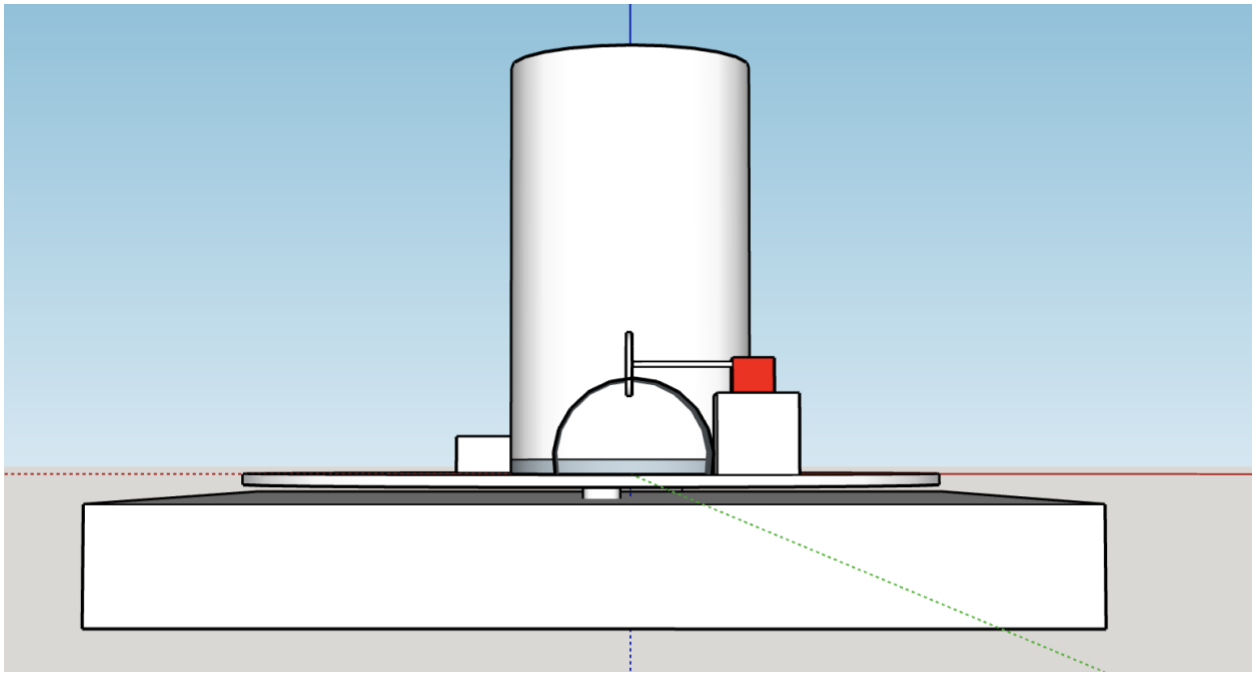
2.1.1 Physical Diagram



Right Side



Top View



Front view

2.2.1 Launch System - Ball Pusher Motor & Pusher Arm

The ball pusher will push the ball to the firing ball subsystem. The fundamental component will be a motor and a mechanic arm. The motor will move the mechanic arm backward and frontward and the ball will be pushed forward when the arm hits it. As shown in the top view and side view of the physical diagram. By changing the speed of the motor, in every cycle we can push one ball into the firing ball system.

Requirement	Verification
1.The ball should be launched with a frequency of average 10 balls pers min or 20 balls per min or 30 balls per min. 2.The motor should be able run on different speed average 10 RPM (revolutions per minutes) or 20 RPM or 30 RPM 3.The motor should take 5 - 10 seconds to change the speed.	1&2 : Step 1: 5 mins experiment, keep shooting the ball and record how many balls fired in total. Step 2: Calculate the average amount of balls fired per mins 3.Step 1: Adjust the speed from 10 to 30 every 30 seconds Step 2: Calculate the average amount of balls fired per mins

2.2.2 Launch System - Firing Ball Motor & Wheel

The firing ball subsystem will accelerate the ping-pong ball. The fundamental component will be a motor and wheel. The spinning wheel will speed up the ping-pong ball and fire it. Similar to the ball pusher system, we will have a circuit to change the speed of the motor. As shown in the front view, the friction pulley will be on top of the ball.

Requirement	Verification
1.The Firing Ball Motor & Wheel should be able to speed up the ball to 5m/s to 15m/s.	1. We can use the Speed Gun to measure the speed of the ball.

2.2.3 Launch System - Turning Plate

The turning subsystem will move the direction of the ball. The fundamental component will be a motor and a plate. The launch system will be attached to the plate. When the motor rotates the plate, the direction of the ball will be changed. As shown on the side view, the motor is on the bottom of the machine. And all other component will be on the plate

Requirement	Verification
1.The Turning plate should be able to turn the launch system with a range -85 degrees(left) to +85 degrees(right) (0 degree means facing front)	1. physical measurement of angle with protractor

2.2.4 Control System

The control system will receive the signal from the remote controller and produce the control signal to change the duty cycle of the PWM signal for the motor. The microcontroller we will use is ATmega168P and the receiver we will use is NRF24L01. When the receiver receives the signal, the program running in the microcontroller will decode the signal and change the duty cycle for the output PWM signal.

The circuit to connect with Motor:

Requirement	Verification
1.The microcontroller should be able to receive 4 bits input signal from the RF receiver and decode it 2.The microcontroller generates the duty cycle of the PWM signal based on different input signal from the RF receiver	1. Step 1: we build a simple circuit using the LED to distinguish 0 and 1 signals. Step 2: We connect the circuit to the output pin of the RF receiver and microcontroller. And record the signal. Step 3: Verify if the signal is the same as our designed output. 2. Step 1: Collect the output pin of the microcontroller to the oscilloscope Step 2: We check the wave of oscilloscope to see if we get the right cycle duty

2.2.5 Remote Control System - Button Logic Control Circuit

The button logic circuit will generate different signals for different buttons to the RF sender component. Remote Control System will run on a separate power supply. Basically, we will put a small battery packet on it, so that the Remote Control System can be portable.

Requirement	Verification

1.Button Logic Control Circuit generates 7 different signals to control the RF sender. 1). Power ON/OFF 2). Increase Frequency 3). Decrease Frequency 4). Turn Left 5). Turn Right 6). Increase Speed 7). Decrease Speed	1. Step 1: we build a simple circuit using the LED to distinguish 0 and 1 signals. Step 2: We connect the circuit to the output of Button Logic Control Circuit. Now we can check if we get the same diagram as the following table.

We use 4-bits signal to encode the Button:

Button:	**Encoded signal:**
Power ON/OFF	0001
Increase Frequency	0010
Decrease Frequency	0011
Turn Left	0100
Turn Right	0101
Increase Speed	0110
Decrease Speed	0111

2.2.6 Remote Control System - RF Transmitter & Control System - RF receiver

When the user presses the button, the Remote Control System will receive the control signal and the RF Transmitter will send the 4-bit signal to the Control System. In the Control System, RF receiver will catch the signal sent from the RF transmitter and decode the signal.

Requirement	Verification
1.RF Transmitter should be able to transmit 4 bits information wirelessly 2.RF Transmitter should be able to send with distance 3 - 5 wirelessly 3.The error rate of transition should lower than 10% 4.RF receiver should decode the information with an error rate lower than 10% 5. The input voltage for RF receiver and transmitter should be around 3.3v.	1. Step 1: we build a simple circuit using the LED to distinguish 0 and 1 signals. Step 2: We connect the circuit to the output pin of the RF receiver. And then we send 10 buttons and record the output on the RF receiver Step 3: Verify if the signal is the same as the 10 buttons we pressed 2. The same steps as in 1. But we need to put the RF Transmitter 3-5 away from each other 3. We want to send 4bit/s and transit 1000 bits. And we calculate the error rate using the formula Bit Error Rate = Total Number of Bit in Error / Total Number of Bit Transition 4. Measure the open-circuit voltage with a voltmeter, ensuring that it is sound be around 3.3V.

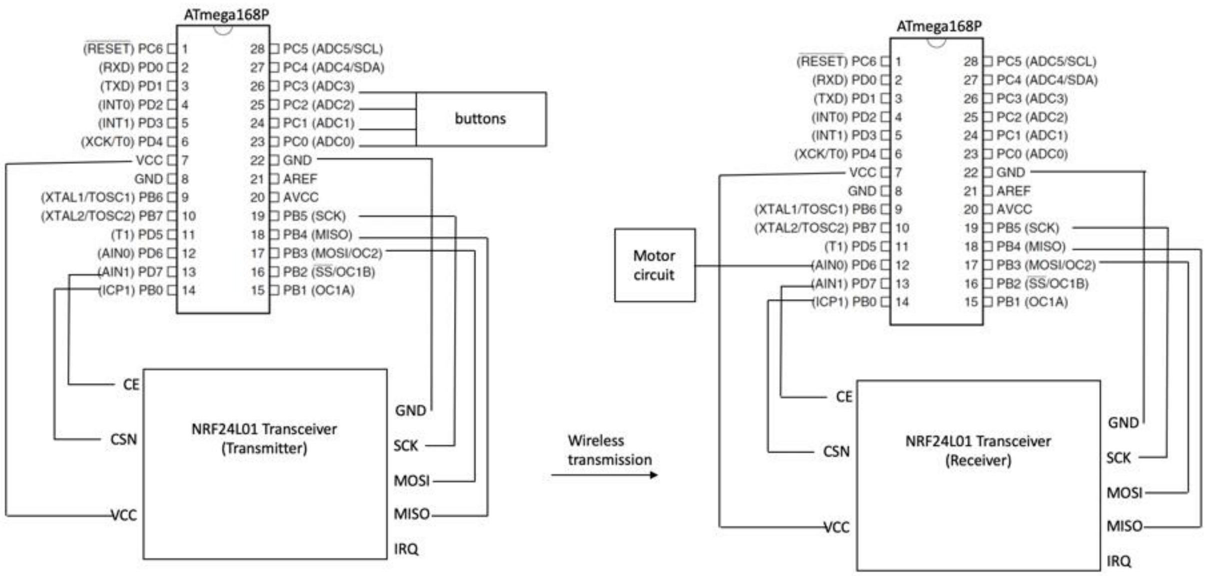
2.2.7 Power System

The power system will provide power to all the other systems.

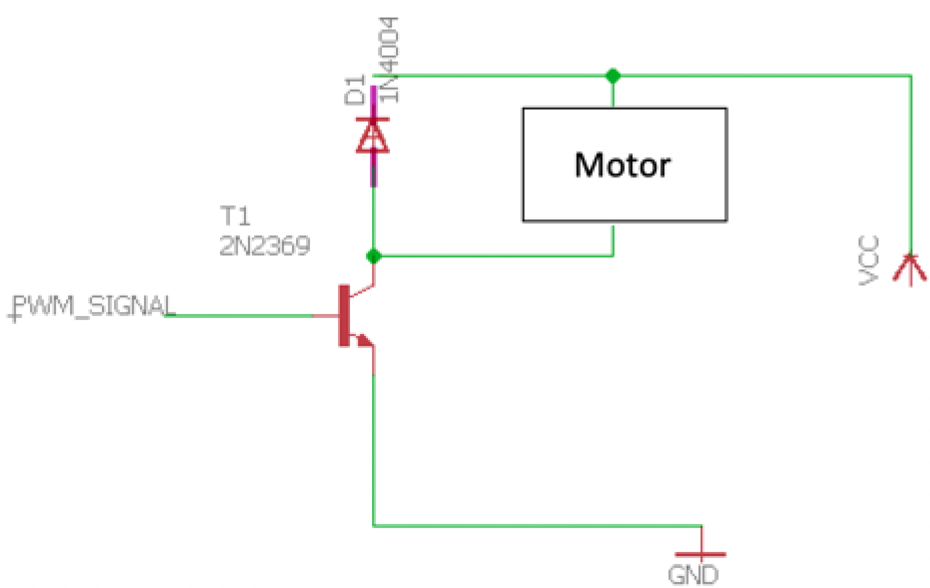
Requirement	Verification
1.Output voltage between 3.0V-7.00V	1. Measure the open-circuit voltage with a voltmeter, ensuring that it is below 7.00V

3 Schematics

Remote Control System & Control System circuit:

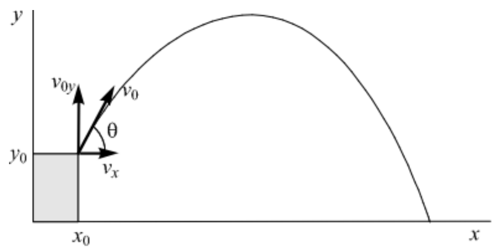


Motor circuit:



4 Tolerance Analysis

The motion of ping-pong from our launch system can be modeled as a projectile motion. Given the initial launch speed and angle, we can calculate the distance that the ball is going to travel before landing on the table. From that model we can do several calculations to help us choose motor and some other components.



Motor Requirement

Motor requirement is an important calculation when designing the launching device. There are two factors to consider when choosing a motor: Power of the motor (in hp) and Spinning speed of the motor (in rpm) .The following calculation is based on the minimum requirement for the motor to launch the ball at a fixed 10º angle to a distance of 3m.

Requirement and given information:

Desired distance: D = 3m

Fixed launch Angle Θ = 10º

Ping-Pong ball weight Wb= 2.7g

Weight of the spinning wheel W0= 0.34kg

Wheel diameters d = 3.8cm

Coefficient of Friction u= 0.3

Calculations:

First, we can calculate the initial launch speed required for the Ping-Pong ball by projectile model

V0 = D*g/sin (2 Θ) ^ (1/2) = 3*9.81/sin (2*10) ^1/2 = 3.8m/s

And convert it into RPM

R0 = 95.49 RPM

Force to compress the wheel to above gain speed

Fwheel = 0.2*95.49 = 19.05N

Friction force is a factor that we must add on our motor load.

f = u*Fwheel = 0.3*19.05 = 5.715N

Calculate Total force Ft

Ft = Fwheel+f = 24.765N

Converted total force to torque on wheel

T0 = Ft*d = 24.765*0.038 = 0.94107 N*M

Then we can calculate the initial motor spinning speed (R1) for that torque

T0 = W0*(V1^2 -V0^2)/2g

V1 = V0 + sqrt(T*2g)/W = 3.8+sqrt(0.94*2*9.81)/0.34 = 16.43m/s

Converted it into RPM

R1 = 412.88 RPM

The last velocity listed is the initial required revolutions per minute to launch the ping pong ball

The next step is to calculate the power required for our motor

Convert above initial motor revolutions to Angular Velocity and further to angular acceleration

V1rads = R1*2 π/60 = 44.179rad/s

a = 0.736rad/s^2

Calculate Torque on motor (Tm) based on acceleration and Rotational Inertia.

Tm = a * I where I is Rotational Inertia I = m * r^2

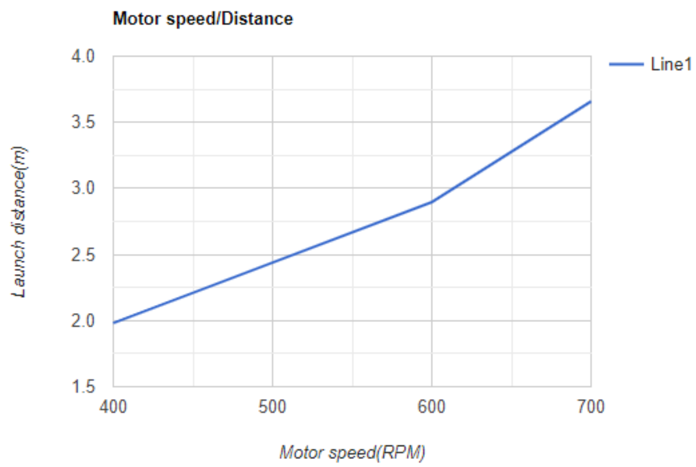
Tm = a * m * r^2 = 0.736*0.34*3.8^2 = 3.613N*M = 2.6648 ft-lb

Last calculate required power based on Torque and spinning speed

HP = Tm * R1 = 2.6648*412.88/5252= 0.209hp

This is the minimum horsepower required for the motor to launch the ping pong ball 3m

Conclusion: The minimum requirement for our motor is 412.88RPM at 0.209hp



The graph above is the motor speed/Launching distance graph at a fix 10 degree launching angle

5 Costs

Our fixed development costs are estimated to be $40/hour, 10 hours/week for three people.

$$\text{Labor Cost} = \frac{\$40}{hr} * \frac{10hr}{week} * 16weeks * 3 * 2.5 = \$48000$$

Our parts and manufacturing prototype costs are estimated as following:

Parts	quantity	cost	description	manufacturer
DC Toy / Hobby Motor - 130 Size	1	$1.95	We will use this motor to speed up the ball	Adafruit
Continuous Rotation Micro Servo - FS90R	2	$15	We will use this motor to change the ball pusher frequency and the turning plate	Adafruit
ATmega168 microcontroller	2	$3.36	We will use the microcontroller to as encoder, decoder and runs the PWM program to control the speed of motor	Microchip Technology
receiver/transmitter NRF24L01	2	$4.2	The RF receiver and RF sender, which is the necessary part for our remote controller	Nordic Semiconductor
AAA battery	6	$3	Power Source	AmazonBasics
3 x AAA Battery Holder with On/Off Switch	2	$3	Power Source	Adafruit

Ping-pong Ball	6	$2.96	Ping-pong Ball	Pro-Penn
PCBs	2	No Cost	Our design of PCB should be 2 layers, the website says it is not cost	ECE SHOP
Total		$33.47		

Our calculation of cost is based on the minimum price in the market at this time and we do not consider the shipping cost. Therefore, we would like to put a $20 possible extra cost to the total cost.

In conclusion our total cost is

$$\begin{aligned}\text{Total Cost} &= \text{Labor Cost} + \text{Parts Cost} + \text{Extra Cost} = 48000 + 33.47 + 20 \\ &= \$48053.47\end{aligned}$$

6 Schedule

week	Jiayi Wu	Qihao Wang	Ruofan Hu
1/27/2020	Research about the background about ping-pong launch machine	Research about the possible design and suitable hardware design for the remote controller	Not Joined the team yet
2/3/20	Finalize the high-level requirement for the project	Research about the utilization of microcontroller in the project	Research about the possible choice for the motors
2/10/20	Designing the physical design	Designing the prototype circuit for the launch system and remote controller	Doing the tolerance analysis on the relation between motor and motion of the ball
2/17/20	Writing the design part of Document Design.	Writing circuit part of the Document Design based on the DDC	Writing tolerance part of the Document Design based on the DDC
2/24/20	Changing the design part of Document Design. Talk to ECE Machine Shop for the physical design	Changing circuit part of the Document Design based on the DDC Start Design the PCB	Writing tolerance part of the Document Design based on the DDC Start Design the PCB
3/2/20	Finish the prototype physical model. And order the necessary parts from the ECE Shop	Test the prototype circuit of launch system on breadboard	Finish the prototype physical model. And order the necessary part from the ECE Shop

3/6/20	Programming microcontroller so that it has the function of the decoder and encoder programmer for the RF receiver and RF sender.	Test the prototype circuit of controller system on the breadboard	Programming microcontroller so that it has the function of PWM and changes the power of the motor.
3/9/20	Combine all parts and do the Prototype machine version 1 test	Finish and order version 1 PCBs (Early Bird)	Combine all parts and do the Prototype machine version 1 test
3/23/20	Adjust the microcontroller programming based on the result of machine version 1 test	Adjust the PCB design based on the Prototype machine version 1 test (Round 1)	Continue on the Prototype machine version 1 test with change of circuit on the breadboard or physical design of the machine
3/30/20	Combine all parts and do the Prototype machine version 2 test	Combine all parts and do the Prototype machine version 2 test	Combine all parts and do the Prototype machine version 2 test
4/6/20	Running the verification of launch subsystem requirement	Adjust the PCB design based on the Prototype machine version 2 test (Round 2)	Running the verification of remote controller subsystem requirement
4/13/20	Reserve 1 week for any delay of previous schedule	Reserve 1 week for any delay of previous schedule	Reserve 1 week for any delay of previous schedule
4/20/20	Prepare mock demo	Prepare mock demo	Prepare mock demo
4/27/20	Begin final report	Begin final report	Begin final report
5/4/20	Prepare final presentation	Prepare final presentation	Prepare final presentation

7 Ethics and Safety

There are several safety concerns involved in our system. The user of our device will be involved with the operation through a remote control system and the ping pong balls that our system launches. So, it is crucial that we ensure the safety of both the user and our system.

The first potential hazard is our launching system. It is possible that high speed ping pong balls could injure our user and others around. In this case we need to limit the launch speed of the ping pong ball when we build our pushing motor so that it won't hurt our users or any others. If users really need safe insurance, we can add a distance sensor to the machine so that if an object is too close to the machine, the machine will not shoot the balls.

Moreover, according to the [2] IEEE code of ethics term No. 1 , we must paramount the safety, health, and welfare of the public. Our system will be using some rechargeable or lithium battery for power source of launching and controlling system. Thus we must prevent batteries from being exposed to dangerous conditions like overcharging by monitoring the temperature of the battery and warn our users of the potential hazards the batteries can do.

Lastly, we also want to prevent some abnormal behavior if the user accidently hits the machine with the balls. We will likely use some shells to protect the central circuit, especially the motor circuits so that our machine will remain stable in emergency cases. And therefore it will not shoot the ball to random directions in emergency cases.

8 Citations and References

[1] “10 Key Tips to Advance Your Table Tennis Game”

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[2] “IEEE Code of Ethics.” IEEE. Accessed February 13, 2020.

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[3]Haponiuk, Bogna, and Hanna Pamu. “Projectile Motion Calculator.” Omni. Omni Calculator, January 29, 2020. https://www.omnicalculator.com/physics/projectile-motion.

[4]Boundless. “Boundless Physics.” Lumen. Accessed February 28, 2020. https://courses.lumenlearning.com/boundless-physics/chapter/torque-and-angular-acceleration/.

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