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Abstract

With the development of the society, people are more willing to focus on their leisure activities. A growing number of new equipment are created nowadays. For example, automatic mahjong machine in China.

Inspired by the automatic mahjong machine, we propose to add some devices on the billiard table to achieve sorting balls automatically. It includes recognition system, ball-separating system, and sorting system.

We use Autodesk Inventor 2012 to model the billiards table. Some complex calculations and nonlinear analysis are completed by Matlab. Through our method, we can achieve the purpose of sorting balls automatically.

Keywords:

Automatically billiard table, color sensor, micro-controller, sort billiards, rack design.

Acknowledgements

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List of symbols

Symbol	Quantity	Unit
F	force	N
m	mass	kg
r	radius	m
d	diameter	m
I	The moment of inertia	$\text{kg} \cdot m^2$
T	torque	$\text{N} \cdot \text{m}$
α	Rotational velocity	rad / s^2
ω	Rotational velocity	rad/s
a	acceleration	m / s^2
v	velocity	m/s
F	frequency	HZ
θ	angle	degree
L	length	m
H	hight	m
s	displacement	m
F	force	N
m	mass	kg

List of acronyms

Acronym	Unfolding
RGB	Red, Green, Blue
HSV	Hue, Saturation, Value
PPS	Pulses per second
CMOS	Complementary Metal Oxide Semiconductor
PEROM	programmable and erasable read only memory
LED	Light Emitting Diode
DC	Direct Current.

1 Chapter: Introduction

With the development of the society, people are more willing to focus on their leisure activities. As a kind of intellectual sports, Billiards is good for young and old, suitable for people with various cultural backgrounds. At the same time, billiards is an indoor sport which is not affected by season, weather, time and other factors.

A game of billiards lasts about 7-10 minutes, while sorting the balls often require 1 minute. Even an experienced staff of billiard hall still needs more than 30 seconds. As a beginner, they even don’t know how to rack these 15 balls.

This thesis mainly explains a new design of billiard table. This kind of table has several functions as follows:

1.Distinguish the type of the ball, such as solid ball, stripe ball, cue ball (the white ball), and the black ball. In this section we refer to a lot of information, and finally we decided to use color sensor.

2.Separate these four kinds of balls into 4 pipelines. In order to work smoothly, this part requires a lot of hardware and software collaboration. We use Autodesk Inventor to design pipelines. As for the circuit, we use micro-controller to cooperate with hardware.

3.These balls are arranged in a certain order, and then make them gather in the rack. We transformed the rack with three sheets. Under the action of gravity, 15 balls can be gathered in the way we want.

2 Chapter: Survey of related work

2.1 Background

Billiards is a type of shot in cue sports, in general, including pool, carom billiards, snooker, etc. There are hundreds of pool games. Some of the more well-known include eight-ball, nine-ball, straight pool, one-pocket and bank pool. [1]

In the United States, the most commonly played game is eight-ball. The goal of eight-ball, which is played with a full rack of fifteen balls and the cue ball, is to claim a suit (commonly stripes or solids in the US, and reds or yellows in the UK), pocket all of them, then legally pocket the 8 ball, while denying one's opponent opportunities to do the same with their suit, and without sinking the 8 ball early by accident. [2]

According to the information that we learn, 15 balls have a fixed order in the rack, maybe we can ignore the number of these balls, but the position of different type of balls is a strict requirement in a normal eight-ball game. Because this order can ensure fairness of the game.

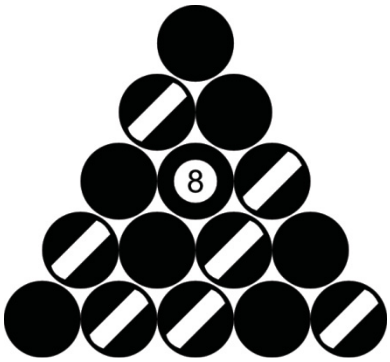


figure 2.1 Sequence of 8 pool ball [3]

2.2 Different types of billiard tables

2.2.1 Tilting billiard table

figure 2.2 Tilting billiard table [4]

This type of billiard table is commonly seen in the market and billiard hall. It differs from the original pool table, the bottom of it is inclined, so that it can make balls fall into the same side of the billiard table.

2.2.2 Coin operated billiard table

Coin operated billiard tables as certainly becoming as well accepted these days and for pleasant cause. It is a milestone in innovative billiard game. Although it is easy to manage for billiard hall owner, it still needs time to rack the balls for custom.

figure 2.3 Coin operated billiard table[5]

This kind of billiard table can distinguish the white ball from other balls. The sensor inside the table can discern the white ball. Each ball gets in the hole will be collected inside the table except the white ball. If the white ball gets in the hole between the games, it will come out through a special pipeline. All collected balls will come out until next slot.

Different type of coin operated billiard table has different ways to distinguish the white ball. Most of them mount a magnet in it. Some type changes the white ball's diameter which can just discern by the sensor.

This approach gives us a lot of inspiration. We hope to add some improvements by our own. The biggest improvement and also the biggest problem is to make 15 balls automatically placed into the rack.

2.3 Ball recognition

We did some survey about the ways to distinguish the different balls' color or type. After we check some thesis and patents on the internet, we found there are two mains ways to solve this problem:

2.3.1 Image processing

The method of image processing was put forward to automatically identify sixteen-billiard. The method of area-scale was put forward to identify solid ball and stripe billiard, transforming the RGB image to binary image, and getting the ratio of the area of main color region and the area of a total billiard in binary image. When it is between 0.71 and 1, shows that the billiard is solid ball. When it is between 0.2 and 0.71, shows that the billiard is stripe ball. Transforming the identified solid ball from RGB image to HSV image, identify the black ball and cue ball by H and S. When H is more than 0.5 and less than 0.6 and S is between 0.12 and 0.3, it is the black ball. When H is more than 0.1 and less than 0.2 and S is between 0.5 and 0.6, it is the cue ball.

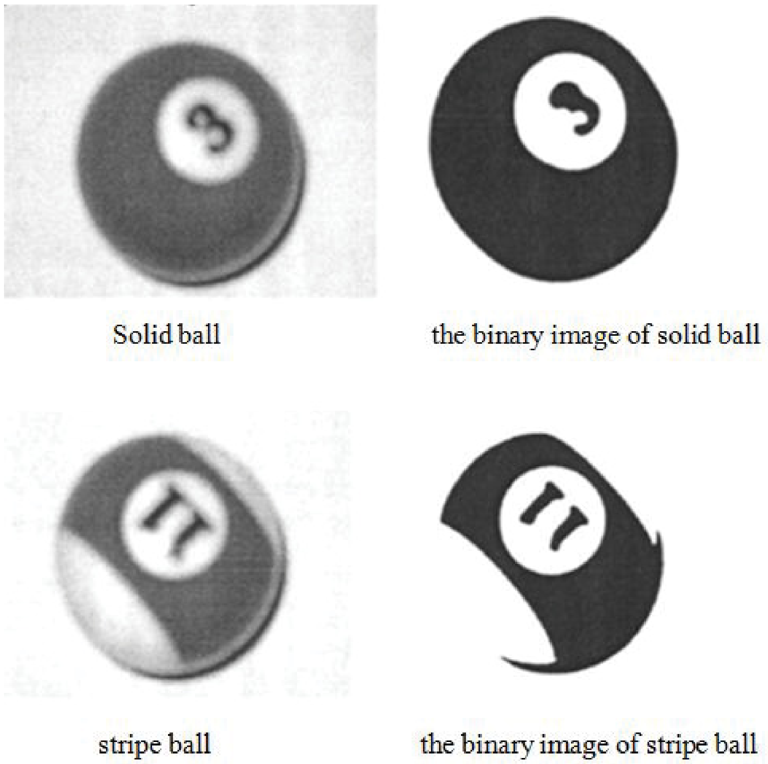


figure 2.4 The binary image of balls [6]

2.3.2 Color sensor

The following solution is a patent of a billiard table. This method uses multiple color sensors. At the same time, it is equipped with a central processor to deal with the information from color sensors. Compared with the information stored in the central processor, the strip ball will separate from the solid ball.

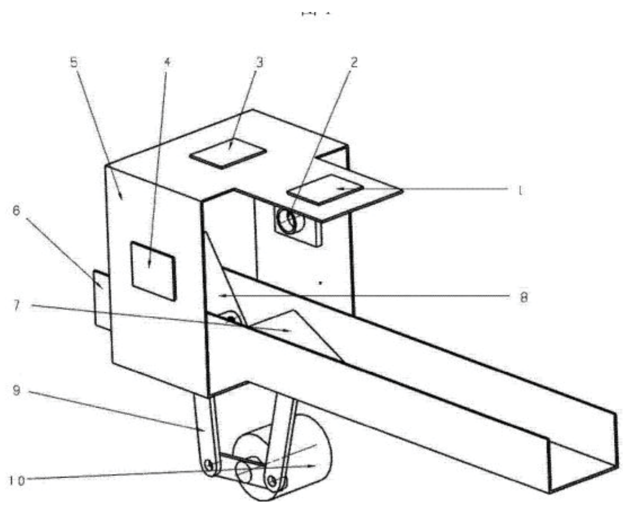


figure 2.5 Position of the color sensors [7]

2.4 Separation device

In order to enable the sensor to distinguish the color of the ball, the ball needs to stay for some time. It also need ensure the presence of only one ball within the detection range of the sensor. We need to design a blocking device. Here are two possible solutions of blocking system.

2.4.1 Lever-bezel system

The following method can control the ball falling one by one from the pipeline. This system applied mechanical principles. When the backsplash down, the front bezel will be supported by the lever which is connected with a rotatable pulley. This system ensures that the ball will fall one by one, rather than fall two or more with higher speed.

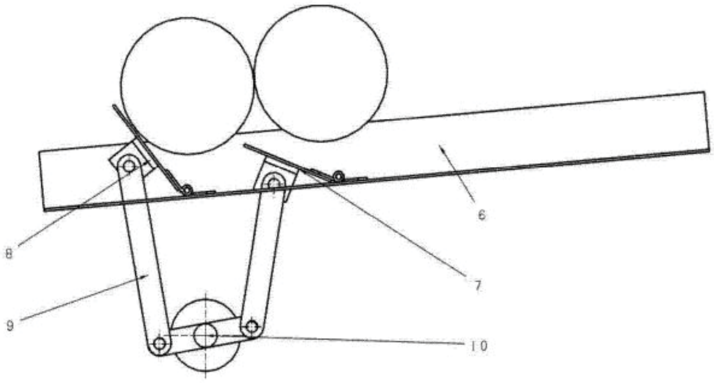


figure 2.6 Level-bezel system

2.4.2 Actuator driven device

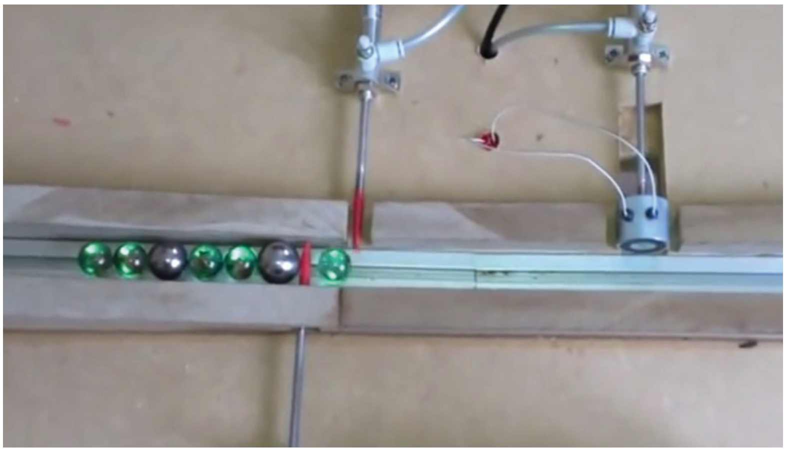


figure 2.7 Actuator driven device [8]

This is a device used to distinguish the glass balls and iron balls. It installed two actuator driven devices. They can expand and shrink. The back one is used to block the balls. And the front one can let the first ball roll out. This stopping method gave us a lot of inspiration, we believe that this method can also be applied to our billiard table.

3 Chapter: Problem statement, objectives and main contribution

The purpose of this thesis is to design a billiard table which can help people sort balls. This kind of billiard table is aimed to do the sorting automatically. In order to make our design accurate and rapid, we need sound cooperation and coordination of each section of our design.

We need to overcome 3 main problems. First of all, select sensor to distinguish balls and design a system to sort balls in a row. We need choose an appropriate method to distinguish different color. Second, use pure mechanical ways to make all balls gather in a rack. In order to make our billiard table simpler, we would like to use a simple way to achieve sorting balls instead of electrical ways. Last, design the circuit, and make sure that the software and hardware can match very well.

We have used Autodesk Inventor to create our 3D modeling. We also used Matlab to do analysis and calculation. In circuit part, we used Proteus to design our project. Main contribution of this thesis is to design a new type of billiard table to help people save their time when playing billiard games.

4 Chapter: Solution

4.1 Design of the billiards table

Billiard table consists of three parts. They are the main body of billiard table, the device used to sequence balls and the rack. The main body of billiard table has pipelines inside. The pipeline put balls together and sent balls to sequence device. Sequence device distinguish the types of the balls and rank balls, finally, get the ball to the rack. Triangular box using it structure place balls. When balls are all roll into the rack. People put ball on the table just like using normal rack.

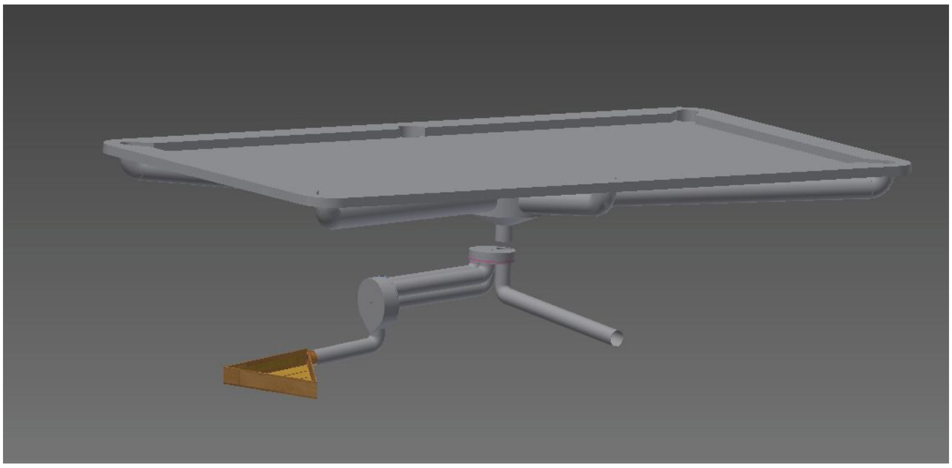


figure 4.1 The structure of billiard table

4.2 Design of racking part

4.2.1 Principle of racking

We can use electrical devices to discern different type of balls and arrange them in a fixed order. At the same time, we can of course use this method to rack balls with mechanical arm. But whether we can rack these 15 balls with pure mechanical ways to solve this problem.

We finally came up with a new way to rack the balls. As we all know, if a ball falls down into the rack, we will not know where the ball stops. So we decide to add fixtures for our rack. These fixtures should be as simple as possible. At the same time, we decide to take advantage of the gravity.

We decide to take advantage of the gravity. If we make the rack perpendicular to the ground, then all the balls will fall into the rack due to gravity. In order to secure the position of the ball, we also design three sheets. See it in figure 4.2.

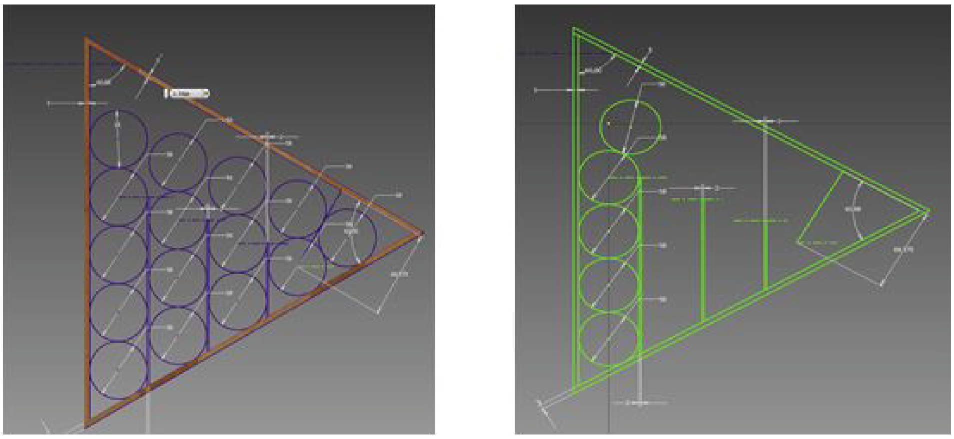


figure 4.2 Racking ways of billiards

In this way, we can obviously see that the first four balls will fall into the first slot due to gravity. When the fifth ball falls, because there is no barrier sheet, it will fall to the second slot. Using this method, we can make sure if we can control the balls dropped in the order, then we can let them arranged in the position we want.

The sequence of the balls is required as: stripe, solid, stripe, stripe, solid, stripe, solid, stripe, black eight, solid, solid, stripe, solid, stripe, solid.

To make the balls slow down, and in order to match the angle of the pipeline, the angle between the rack's horizontal plane and the ground is 7 degrees.

4.2.2 Design of the rack

From the Figure 4.3, we can see that we need enough space to get the balls rolling inside the rack. So in this way, the rack we use will be bigger than the standard rack. (See the figure 4.3).

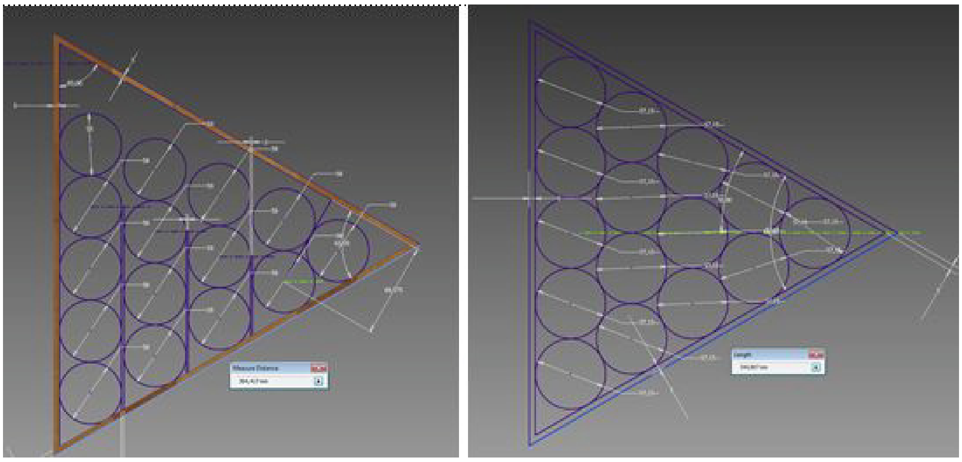


figure 4.3 Size of rack

As a result, when we remove the rack, the whole 15 balls will stay inside the bigger rack. We need design a device to change the bigger rack into the standard one.

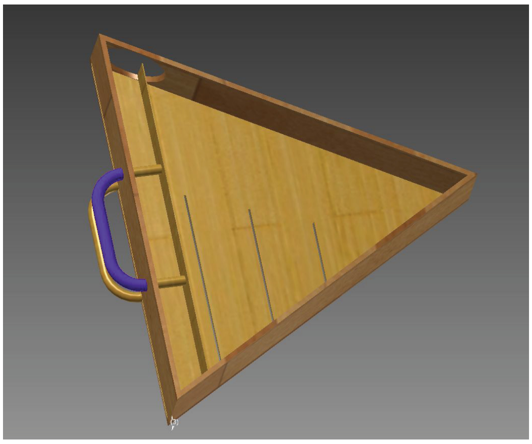


figure 4.4 Changeable rack

There are 4 parts in this rack: rack frame, handle, push plate, and bottom bezel.

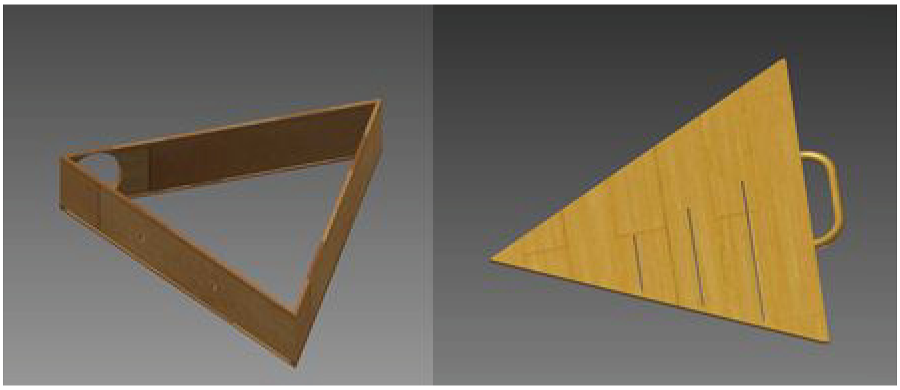


figure 4.5 Rack frame and bottom bezel

The rack has a hole at one side of the triangle. All the 15 balls fall down into the rack from this hole. Bottom bezel has three gaps which is used to insert sheets.

figure 4.6 Handle and push plate

The diameter of the handle is bigger than it in push plate. The length of the push plate is 345 mm, the same as a regular rack's diameter. Through calculation, the length of the bar should be 43.5 mm. When it reaches the limit position, the plate and two side of the frame formed a standard rack.

There are 4 steps to use this rack:

1.When all 15 balls fall into the rack, lift it and make it get rid of sheets which are fixed on the table.

2.Put the rack on the table. Push the handle, make balls close. Now, the rack is regular size as standard one.

3.Pull out the bottom bezel. When all balls are stable on the table, lift the rack.

4.Put the rack back as it used to be.

4.3 Design of the main body

The main body of billiard table is similar to normal type. It has same size but has pipelines inside. Pipelines connect six holes. Pipelines put balls roll into intermediate container. The intermediate container is a funnel-shaped design. Every time only one ball can enter the pipeline that beneath the funnel. Then balls are sent to the sequence device. Although pipelines occupied some space, but saves the sensor. This way eliminates the need for the color sensor installed at each hole.

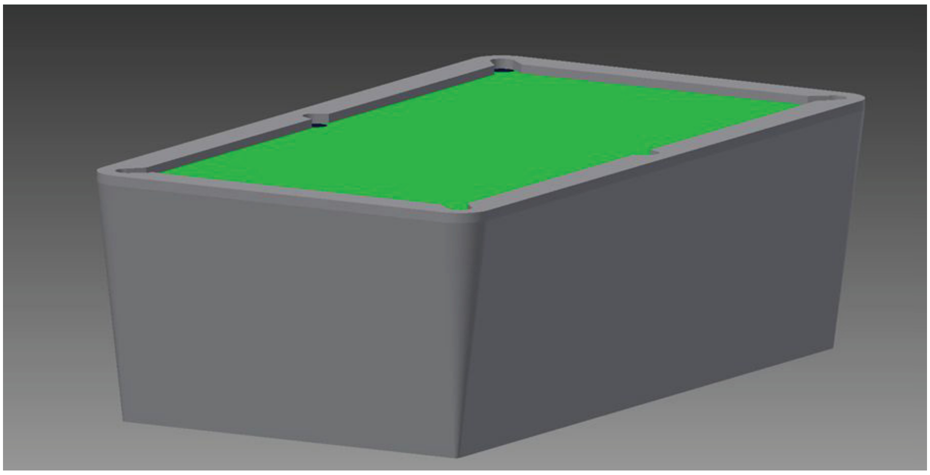


figure 4.7 Billiard table

Billiard table's length breadth and height is $2810\times1530\times840\,\text{mm}$. The slope of pipes is $3°$. The diameter of pipeline is 90 mm, which is the same as the diameter of the hole. [9]

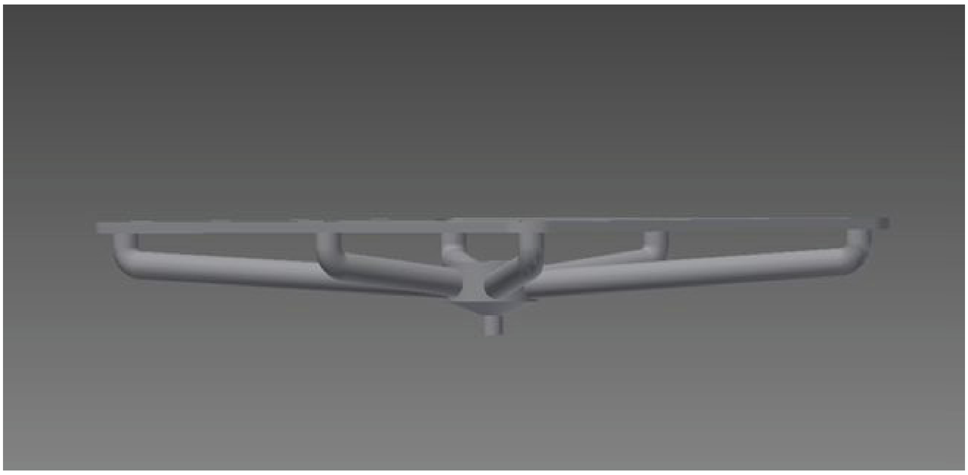


figure 4.8 The main body of billiard table

4.4 The device used to sequence balls

Sequence device is the most complex component of billiard table. Its function is to distinguish four types of balls. Four types are stripe ball, solid ball, black eight and white ball. Sequence device classify the ball, then make ball roll into triangular box by sequence. The sequence is “ stripe, solid, stripe, stripe, solid, stripe, solid, stripe, black eight, solid, solid, stripe, solid, stripe, solid,”. The mechanical part of it is comprised of five parts. The electrical parts are comprised by one color sensor, four laser sensors and micro-controller.

4.4.1 Design of disk 1 and disk 2

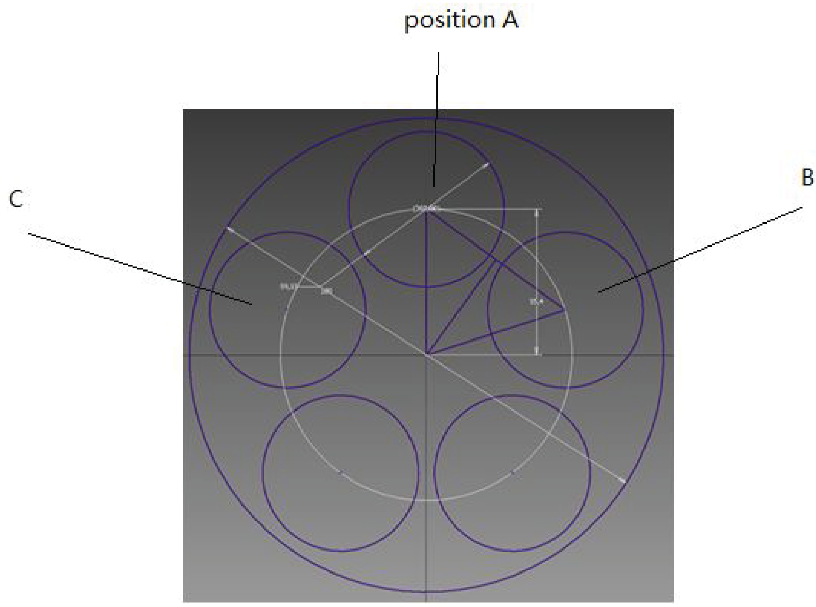


figure 4.9 Position of different holes

Disk 1 and Disk 2 is divided plate. They let balls be tested one by one and classified into Storage ball pipelines. Disk 1's initial position is A. A is beneath the pipe. Disk 2's initial position is C. The ball fall into the Disk 1, then Disk 1 rotate to position B. Color sensor Detect ball and sent signal (stripe ball) to micro-controller. Micro-controller control Disk 2 rotating to Storage ball pipeline (stripe ball). Then, Disk 1 rotates to that position (stripe ball). When Disk 1 and Disk 2 at same position, the ball fall into the pipeline (stripe). Disk 1 and Disk 2 are each driven by a stepper motor.

figure 4.10 Disk 1 and disk 2

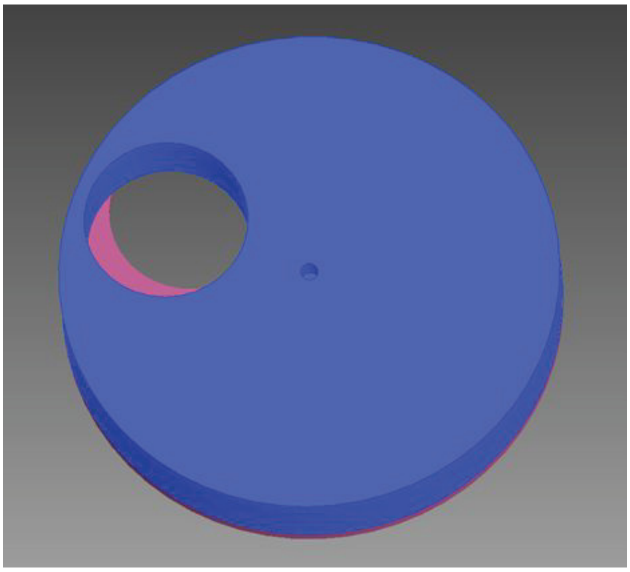


figure 4.11 Combination of disk 1 and disk 2

4. 4. 1. 1 **Part size design**

Separation plate need for high-speed rotating to divide balls and should control the number of balls get out. In order to reduce the load of the motor, we need to make the diameter of Separation plate as small as possible. Diameter of Disk 1 and Disk 2 is same as Separation plate. So, we need design a smaller diameter of plate.

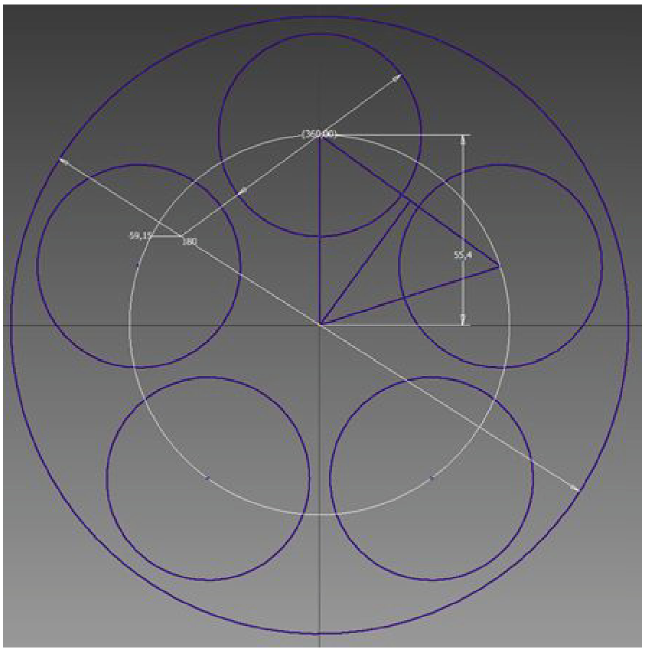


figure 4.12 Dimension of disk

The disk at last should have five positions. One is initial position. The others are corresponding to four pipes used to store balls. The diameter of each circle is 59.15 mm. The distance between the centers of circles is 65.15 mm. L is the distance between plate center and circle center.

$$\theta = \frac{360}{5} = 72°$$

$$L = \frac{65.15}{2} / \sin\frac{\theta}{2} = 55.4\ \text{mm}$$

Width of the edge is 6.025 mm.

$$R = 55.4 + \frac{57.15}{2} + 6.025 = 90\ \text{mm}$$

$$D = 180\ \text{mm}$$

Hence, their diameter is 180 mm. Next, we determine the thickness of Disk 1 and Disk 2. In order to make the ball in the hole is fixed. The thickness of Disk 1 must large than radius of ball. We let thickness of Disk 1 is 30 mm and thickness of Disk 2 is 5 mm. Disk 1 distance from the top of the pipe is

$$57.15 + 1 - 30 = 28.15\ \text{mm}$$

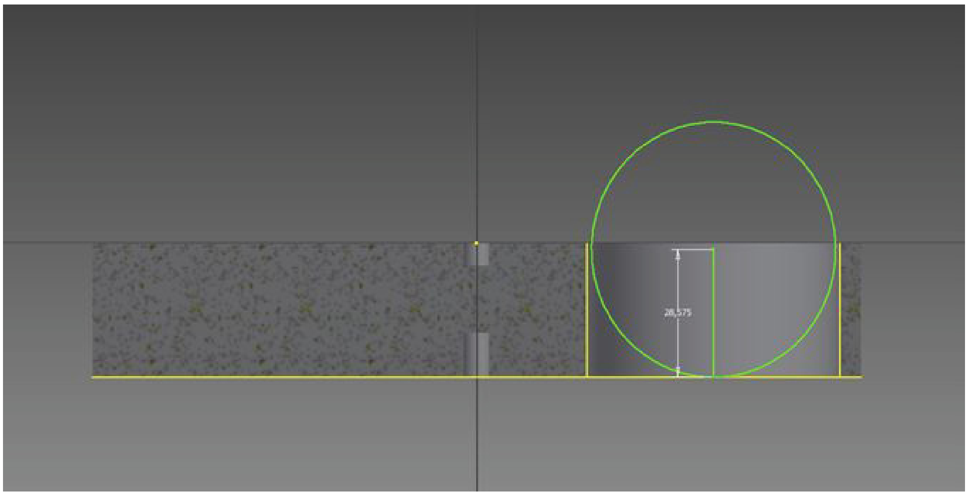


figure 4.13 Height design of Disk 1

4. 4. 1. 2 motor choice and control

Our choice is NEMA 17-size hybrid bipolar. Next, we determine rotational acceleration of Disk 1 and Disk 2 and draw graph of t-PPS (pulses per second). Disk 1 and Disk 2 have same acceleration and deceleration.

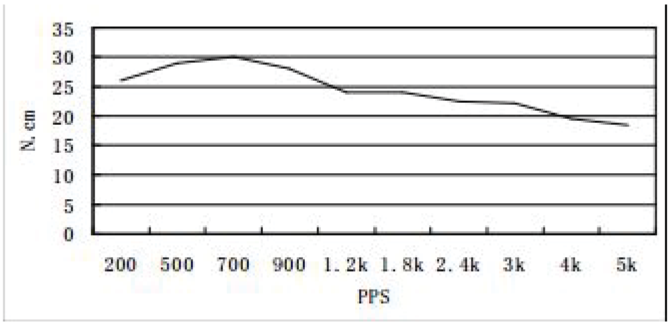


figure 4.14 T-PPS graph of engine 1

Step angle of motor is 1.8 degree. It rotate 72 degree need 40 signal. We let it four seconds rotated 72 degrees and the acceleration time and deceleration time is 2 seconds, respectively. [10]

Driving pulse rate is PPS (pulses per second). Start pulse rate is 0. The positioning time are 4 s. Acceleration/ deceleration time is 2 s . Necessary number of pulses is n=40.

$$PPS = \frac{n}{4-2} = \frac{40}{2} = 20 \text{ HZ}$$

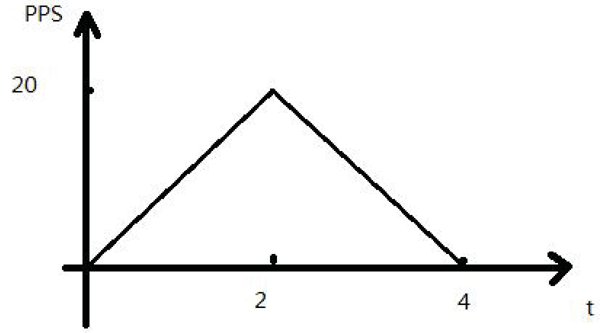


figure 4.15 PPS-t graph of engine 1

Then, we check is steeper motor will lose step. When PPS is 20 HZ. Rotational velocity is

$$\omega = 20 \times 1.8 = 36°$$

$$\omega = \alpha t = 2\alpha = 36°$$

$$\alpha = 18°$$

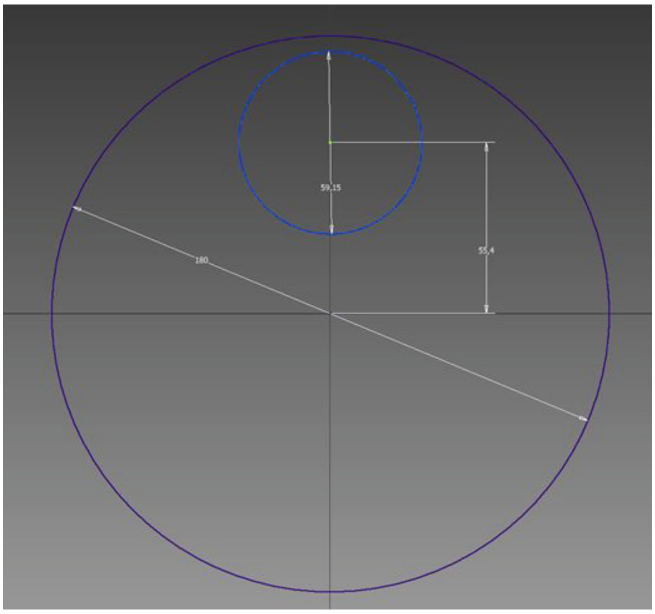


figure 4.16 Inertia calculation

We calculate the moment of inertia of the Disk 1 and Disk 2. The moment of inertia of Disk 1 is equal to inertia of big plate subtract inertia of small plate. have same Material is 7075 aluminum alloy. Density of 7075 aluminum is $2.81\, g/cm^3$.[11] The formula of thin plate is [12]

Disk 1

$$I = \frac{1}{2} mr^2$$

Parallel axis theorem

$$I = I_1 + \frac{1}{2} md^2$$

The mass of big plate is

$$m_1 = \pi r^2 hd = 9^2 \times \pi \times 3 \times 2.81 = 2145\,\text{g} = 2.145\,\text{kg}$$

The moment of inertia of big plate is

$$I_1 = \frac{1}{2} m_1 r^2 = \frac{1}{2} \times 2.145 \times 0.09^2 = 8.7 \times 10^{-3}\ \text{kg} \cdot \text{m}^2$$

The mass of small plate is

$$m_2 = \pi r_1^2 hd = 2.9575^2 \times \pi \times 3 \times 2.81 = 231\,\text{g} = 0.231\,\text{kg}$$

The moment of inertia of small plate is

$$I_2 = \frac{1}{2} m_2 r_1^2 + m_2 D^2 = \frac{1}{2} \times 0.231 \times (29.575 \times 10^{-3})^2 + 0.231 \times (55.4 \times 10^{-3})^2$$

$$= 8.1 \times 10^{-4}\ \mathrm{kg \cdot m^2}$$

The moment of inertia of the part 4 is

$$I = I_1 - I_2 = 8.7 \times 10^{-3} - 8.1 \times 10^{-4} = 7.89 \times 10^{-3}\ \mathrm{kg \cdot m^2}$$

$$[T_1] = I\alpha = 7.89 \times 10^{-3} \times 18 = 0.14\ \mathrm{N \cdot m} = 1.4\ \mathrm{kg \cdot cm}$$

According to the graph, the torque motor can provide greater than $1.4\ \mathrm{kg \cdot cm}$. Hence, the motor will not lose step. The moment of inertia of Disk 2 is smaller than Disk 1. So the torque of Disk 2 is smaller than Disk 1. The motor installed on the Disk 2 will not lose step too.

4.4.2 Design of Storage ball pipelines

Part 3 is Storage ball pipelines. It has four pipelines. They are stripe, solid, black eight and white. White pipeline is different to others. It sent white ball to the side of billiard table. If people hit white ball into the hole, they can get ball at the hole at the side of billiard table. Solid balls, stripe balls and black eight are fall into other three pipelines. Laser sensors are installed on the pipelines. The stripe pipeline and the solid pipeline are mounted on the position of seventh ball. The black eight pipeline is mounted on the position of first ball. When all balls are full into ball-storage pipelines, sensors send signal to the micro-controller. Separation plate starts work. It put the ball into the triangular box at sequence.

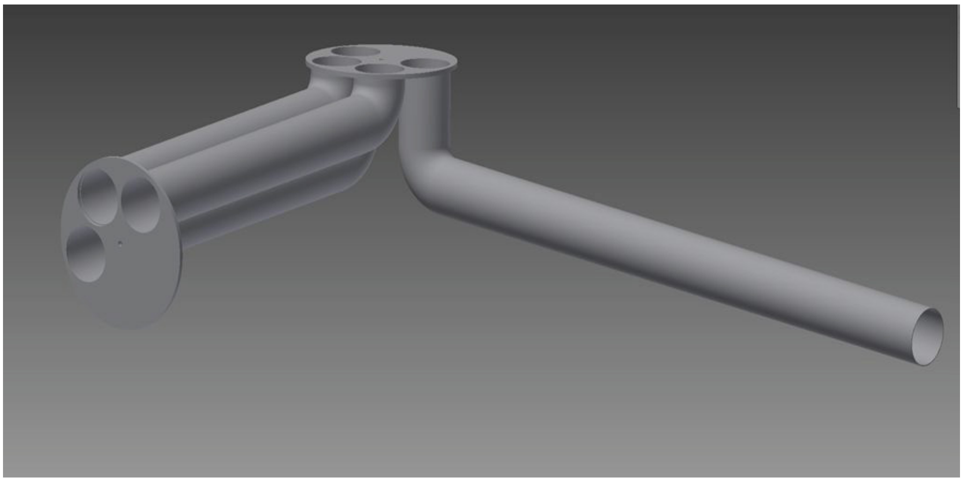


figure 4.17 Balls-Storage pipelines

4. 4. 2. 1 Size design of Storage ball pipelines

Length of seven balls is $57.15 \times 7 = 400.05\,\text{mm}$. Hence, the length of pipeline should longer than 400.05 mm. The position of seventh ball is $57.15 \times 6 + 57.15 \times \frac{1}{2} = 371.475\,\text{mm}$. The laser sensor is installed at this position. The position of first ball is $57.15 \times \frac{1}{2} = 28.575\,\text{mm}$. Diameter of pipeline is 59.15. It is little large than billiard ball. Because we do not want ball have too much move space, in process of divide balls we need to calculate the exact position of the ball.

Slope of the pipeline is very important. It determines the acceleration of the ball. Using acceleration we can calculate the speed of the ball and the time required for the ball to get out. These factors affect the speed selection of separation plate. We should choose a most proper slope of the pipeline.

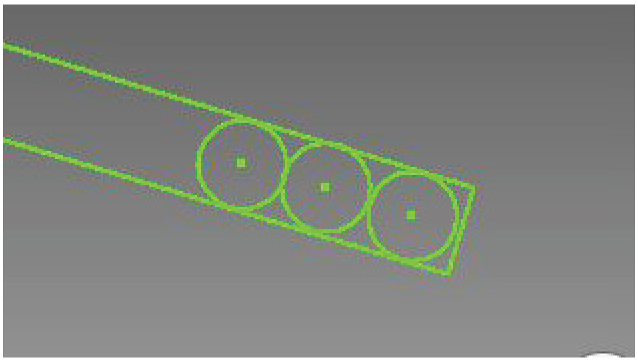


figure 4.18 Ball-storage pipeline

Most of the time, just get out of a ball once. Because follow the sequence. “stripe, solid, stripe, stripe, solid, stripe, solid, stripe, black eight, solid, solid, stripe, solid, stripe, solid”. For example stripe pipeline open, one ball get out, after stripe pipeline close. Later, solid pipeline open, one ball get out, then solid pipeline close. Device repeats these actions.

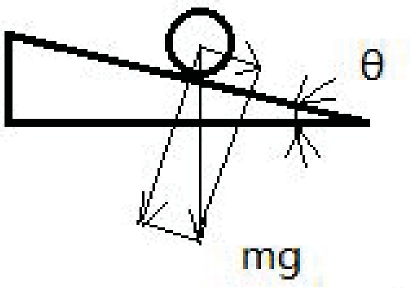


figure 4.19 Force diagram of ball

If only get out of one ball, the ball's displacement is its diameter. If friction is zero, the ball slides.

$$s = \frac{1}{2} g \sin\theta \cdot t^2 = \frac{1}{2} \times 9.8 \times \sin\theta \times t^2 = 57.15 \times 10^{-3}$$

$$\sin\theta \cdot t^2 = \frac{1143}{98000}$$

We want to let time is 0.4 seconds. This way allows calculation more simple and more accurate.

$t = 0.4 \quad t^2 = 0.16$

$$\sin\theta = \frac{1143}{98000 \times 0.16}$$

$\theta = 4.18°$

If the friction is big enough, ball will rotate. The friction is rotational friction.

$$mg\sin\theta\cdot r = I\alpha$$

$$mg\sin\theta\cdot r = \frac{7}{5}mr^2\cdot\frac{a}{r}$$

$$a = \frac{7}{5}g\sin\theta$$

$$s = \frac{1}{2}at^2$$

$$57.15\times10^{-3} = \frac{1}{2}\times\frac{5}{7}\times9.8\times\sin\theta\times0.16$$

$$\theta = 5.86°$$

Therefore， The slope of pipes is between 4.18° to 5.86°. That is determined by friction. No matter how much friction is. Acceleration is $0.71\,\text{m/s}^2$. The time one ball gets out is 0.4 s. We change slope to make acceleration and time not change.

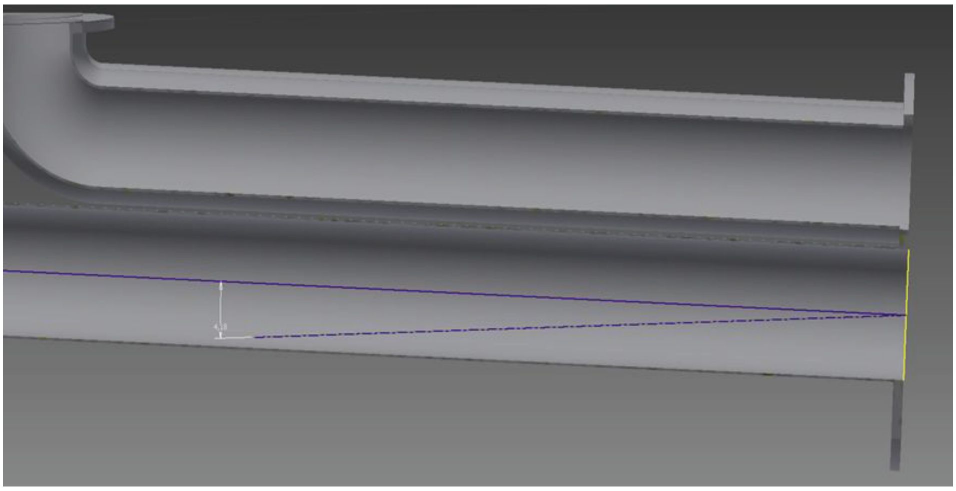


figure 4.20 Slope of pipeline

4.4.3 Design of Separation plate

Separation plate is a thin plate use to divide balls. It makes balls get out one by one and as sequence. When all balls full into Storage ball pipelines, Separation plate start work. We use a stepper motor accurate control the plate's rotation speed and time. The plate opens or cloths pipeline by rotation. The number of balls get out can be controlled by the pipelines opening time. Therefore use this device can sequence balls.

4. 4. 3. 1 Size design of Separation plate

Diameter of Separation plate is same as Disk 1 and Disk 2. The diameter is 180 mm. A small hole one the plate. Its diameter is 59.15mm . The thickness of the plate is 1 mm. In order to reduce the load of the motor, we need make mass of Separation plate as small as possible. The material of plate needs lightweight and high-hardness material. We choose 7075 aluminum alloy. Density of 7075 aluminum is $2.81\, g/cm^3$.

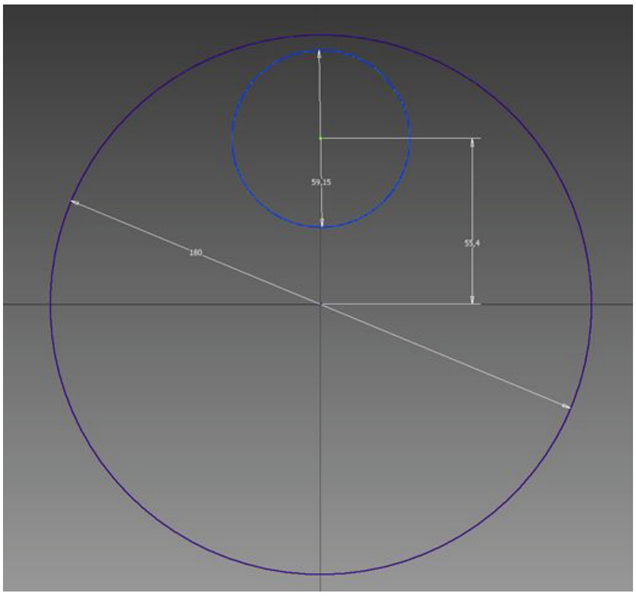


figure 4.21 Inertia of Separation plate

We calculate the moment of inertia of the Separation plate. The moment of inertia of Separation plate is equal to inertia of big plate minus inertia of small plate. The formula of thin plate is

$$I = \frac{1}{2}mr^2$$

Parallel axis theorem

$$I = I_1 + \frac{1}{2}md^2$$

The mass of big plate is

$$m_1 = \pi r^2 hd = 9^2 \times \pi \times 0.1 \times 2.81 = 71.5\,\text{g} = 7.15\times 10^{-2}\,\text{kg}$$

The moment of inertia of big plate is

$$I_1 = \frac{1}{2} m_1 r^2 = \frac{1}{2} \times 7.15 \times 10^{-2} \times 0.09^2 = 2.9 \times 10^{-4} \text{ kg} \cdot \text{m}^2$$

The mass of small plate is

$$m_2 = \pi r_1^2 hd = 2.9575^2 \times \pi \times 0.1 \times 2.81 = 7.7 \text{ g} = 7.7 \times 10^{-3} \text{ kg}$$

The moment of inertia of small plate is

$$I_2 = \frac{1}{2} m_2 r_1^2 + m_2 D^2 = \frac{1}{2} \times 7.7 \times 10^{-3} \times (29.575 \times 10^{-3})^2 + 7.7 \times 10^{-3} \times (55.4 \times 10^{-3})^2$$

$$= 2.7 \times 10^{-5} \text{ kg} \cdot \text{m}^2$$

The moment of inertia of the Separation plate is

$$I = I_1 - I_2 = 2.9 \times 10^{-4} - 2.7 \times 10^{-5} = 2.63 \times 10^{-4} \text{ kg} \cdot \text{m}^2$$

4.4.3.2 Working process of the Separation plate

Stepper motor controls Separation plate dividing balls. Separation plate accelerative rotates to position A. At position A, ball start get out. The position A is the hole and the pipe outlet is overlapped half. Then, Separation plate decelerating rotates to position B. At position B, Separation plate stops rotating. Then, Separation plate accelerative rotates to position C. When Separation plate rotates to position C, one ball is get out and the pipeline outlet is closed. Separation plate repeats this process to divide balls.

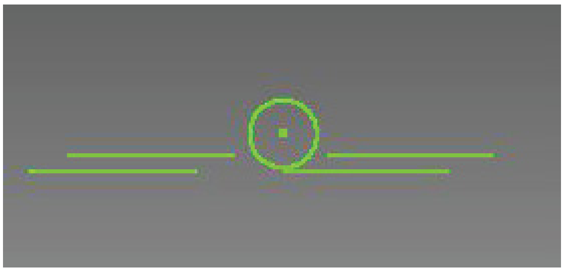


figure 4.22 Position A

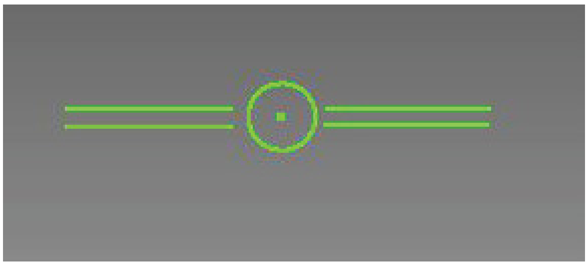


figure 4.23 Position B

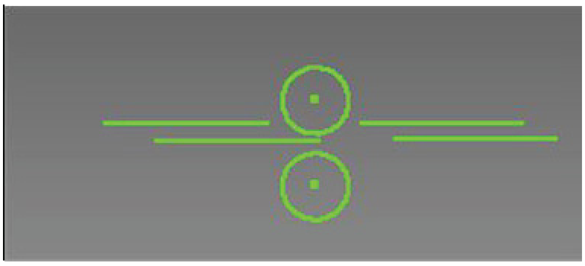


figure 4.24 Position C

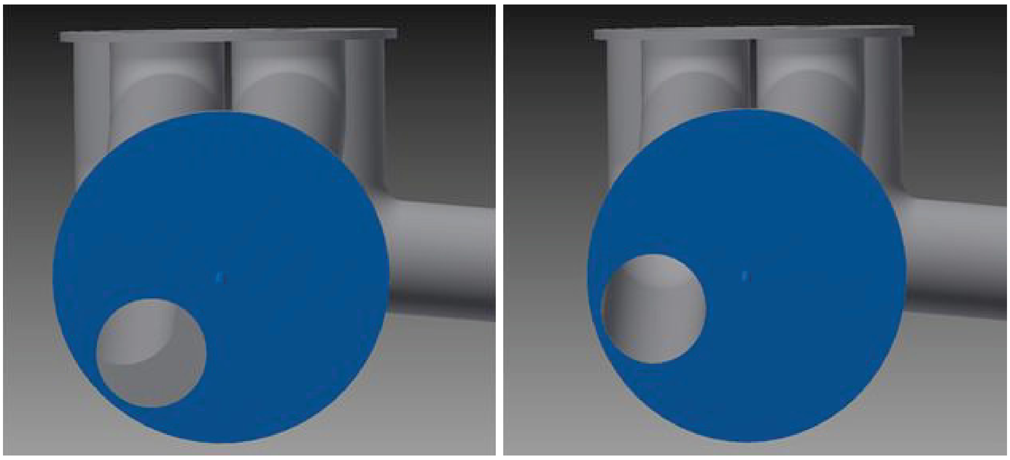


figure 4.25 Position A and position B

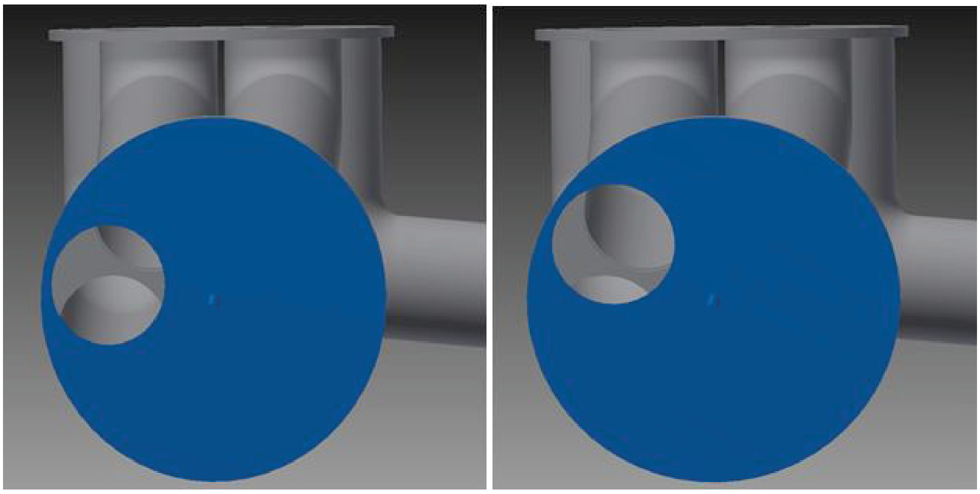


figure 4.26 Position C and position A

Picture 1 and picture 4 are not same position, but they are the position that ball start to get out.

4. 4. 3. 3 motor choice and control

The motor must be able to provide enough moment of the Separation plate. The moment must support plate accelerate to require speed at limited time. When ball rolls out the pipeline, the Separation plate is rotating at same time. We must exactly calculate the movement of ball and Separation plate to ensure that they do not collide.

We divide the process of the ball get out to the pipeline into two parts. Get out half ball is a part.

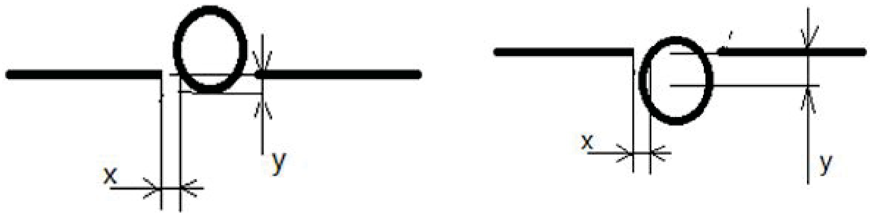


figure 4.27 Position A and position B

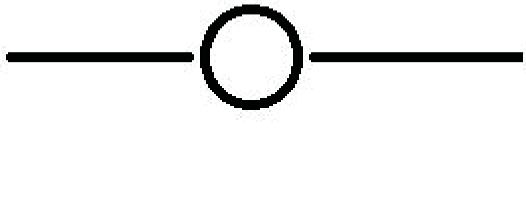


figure 4.28 Intermediate position

In the picture, x is the distance between the edge of ball and pipeline. y is displacement of the ball in the vertical direction. y is determined by t (time). Therefore we can find the function of x and t.

We can also choose the x,t function of the plate rotation. Use image of two functions we can ensure ball and Separation plate do not collide.

First we calculate the x,t function of part 2.

$$y = v_0 t + \frac{1}{2} a \cdot t^2$$

$$v_0 = a \cdot t_1$$

$$\frac{D}{2} = \frac{1}{2} a \cdot t_1^2$$

$$\frac{57.15 \times 10^{-3}}{2} = \frac{1}{2} \times 0.71 \times t_1^2$$

$$t_1 = 0.283\,\mathrm{s}$$

$$v_0 = 0.71 \times 0.283 = 0.2\,\mathrm{m/s}$$

$$\mathrm{y} = 0.2\mathrm{t} + \frac{1}{2} a \cdot t^2$$

Pipelines diameter is 59.15 mm. It is large than the diameter of ball. Every side has a space of 1 mm.

$$[r - (x - 0.001)]^2 + y^2 = r^2$$

$$[r - (x - 0.001)]^2 + (0.2t + \frac{1}{2} \cdot 0.71 \cdot t^2)^2 = r^2$$

$$[28.575 \times 10^{-3} - (x - 0.001)]^2 + (0.2t + 0.35t^2)^2 = (28.575 \times 10^{-3})^2$$

We change t to x and change x to y. The image of function is effective at $0 \le y \le 0.296$. Therefore, only the lower half of the image is valid.

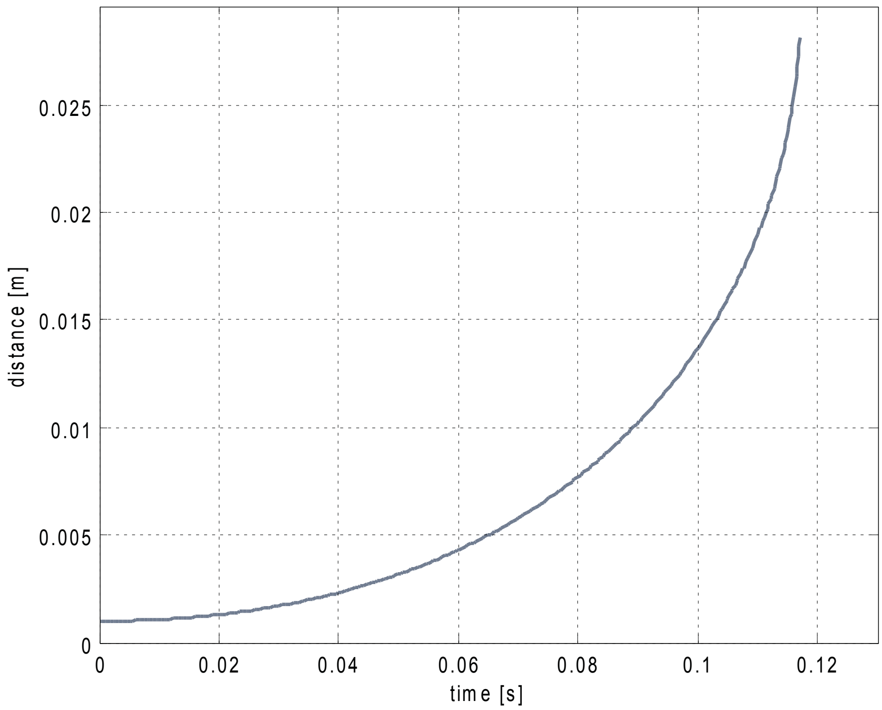


figure 4.29 Function 1

Establish a y,x function for Separation plate. The y is the distance of the edge of small hole on the Separation plate and the pipeline. The x is time. We set up a quadratic function. x_1 is part 4 start moving time.

$$y = b(x - x_1)^2$$

We choose $x_1 = 0.06$. The function through $(0.117, 29.575 \times 10^{-3})$.

$$29.575 \times 10^{-3} = b \times 0.057^2$$

$$b = 8.8$$

$$y = 8.8 \cdot (x - 0.06)^2$$

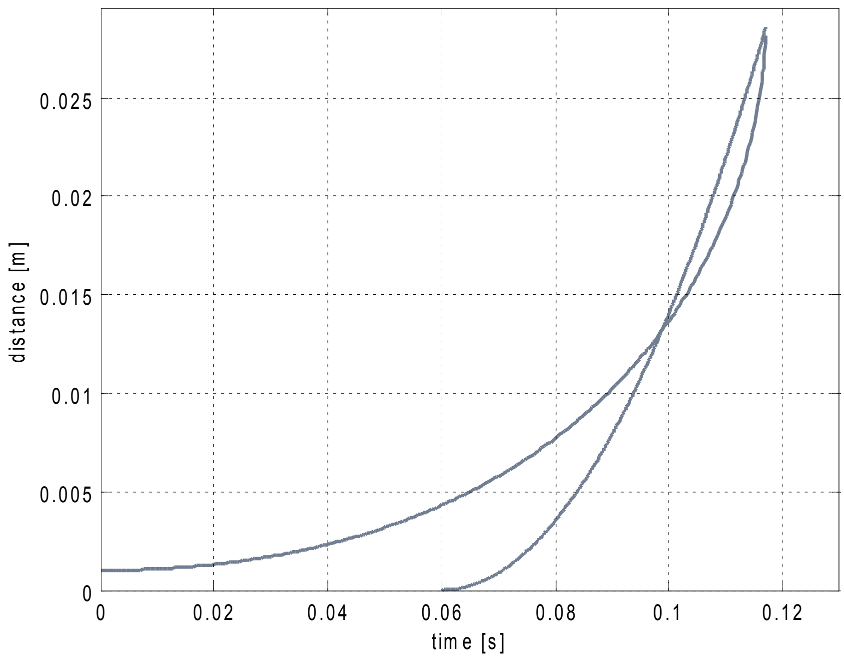


figure 4.30 Function 2

The function at $0.06 \le x \le 0.117$ is valid. Two functions cross, the ball and part 4 will collide.

Therefore, this equation can not meet the requirements.

We choose $x_1 = 0.09$. The function through $\left(0.117, 29.575 \times 10^{-3}\right)$.

$$29.575 \times 10^{-3} = b(0.117 - 0.09)^2$$

$$b = 39.2$$

$$y = 39.2 \cdot (x - 0.09)^2$$

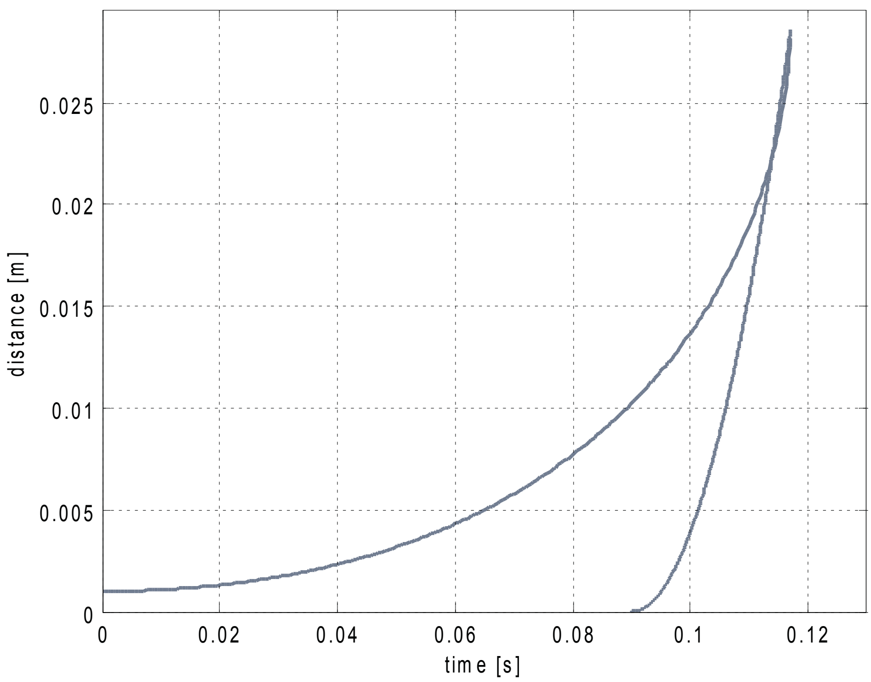


figure 4.31 Function 3

The function at $0.09 \le x \le 0.117$ is valid.Two functions cross, the ball and part 4 will collide.

Therefore, this equation can not meet the requirements.

We choose $x_1 = 0.1$. The function through $\left(0.117, 29.575\times10^{-3}\right)$.

$$29.575\times10^{-3} = (0.117-0.1)^2 \times b$$
$$b = 99$$
$$y = (x-0.1)^2 \cdot 99$$

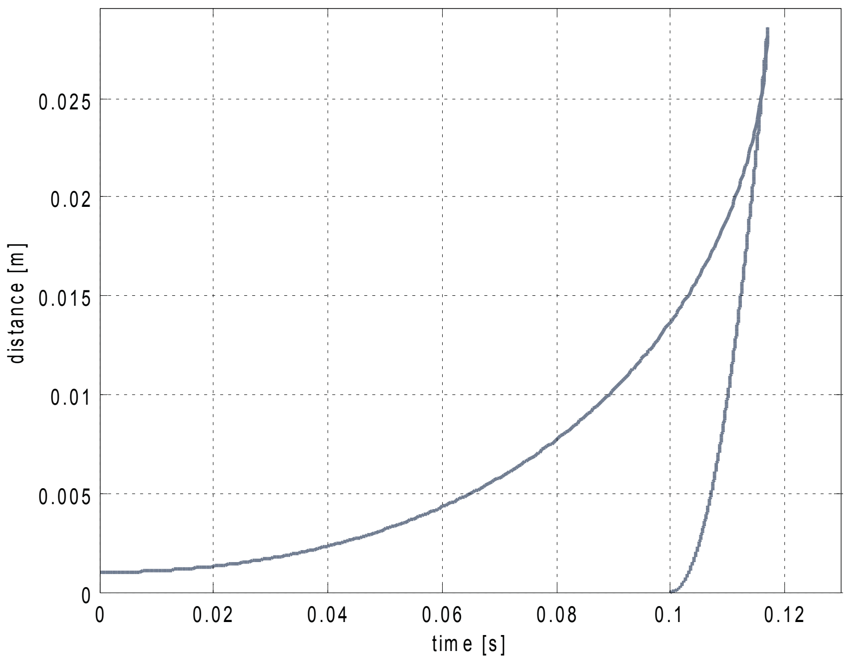


figure 4.32 Function 4

The function at $0.1 \le x \le 0.117$ is valid. When $x_1 = 0.1$ Achieved satisfactory results.

$y = 99 \cdot (x - 0.1)^2$

$v = 198t$

Angular acceleration is

$a = 198\,\mathrm{m/s^2}$

$$\alpha = \frac{a}{r} = \frac{198}{55.4 \times 10^{-3}} = 3574\,\mathrm{rad/s^2}$$

$$T = I \cdot \alpha = 2.63 \times 10^{-4} \times 3574 = 0.94\,\mathrm{N \cdot m} = 9.4\,\mathrm{kg \cdot cm}$$

Then we calculate the x,t function of part 1.

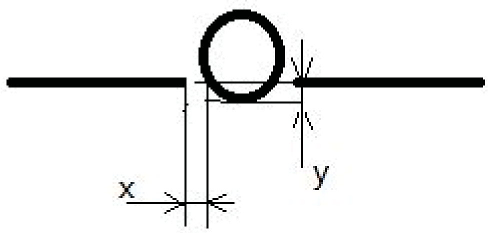


figure 4.33 Motivation of part 2

$$y = \frac{1}{2} a \cdot t^2$$

$$y = \frac{1}{2} \times 0.71 \cdot t^2 = 0.35t^2$$

Pipelines diameter is 59.15 mm. It is large than the diameter of ball. Every side have a space of 1 mm.

$$[r - (x - 0.001)]^2 + (r - y)^2 = r^2$$

$$[28.575 \times 10^{-3} - (x - 0.001)]^2 + (28.575 \times 10^{-3} - 0.35t^2)^2 = (28.575 \times 10^{-3})^2$$

We change t to x and change x to y. The image of function is effective at $0 \le y \le 0.296$. Therefore, only the lower half of the image is valid.

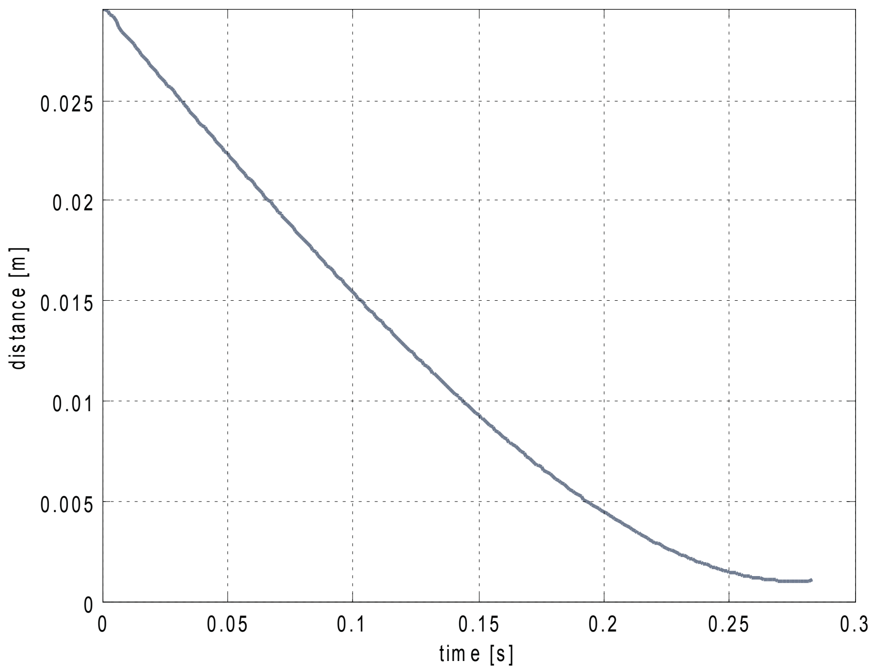


figure 4.34 Function 5

Establish a y,x function for Separation plate. The y is the distance of the edge of small hole on the Separation plate and the pipeline. The x is time. We set up a quadratic function. We choose same acceleration as the part 2. The function through $\left(0,29.575\times10^{-3}\right)$

$$y=-99x^2+29.575\times10^{-3}$$
$$v=-198t$$

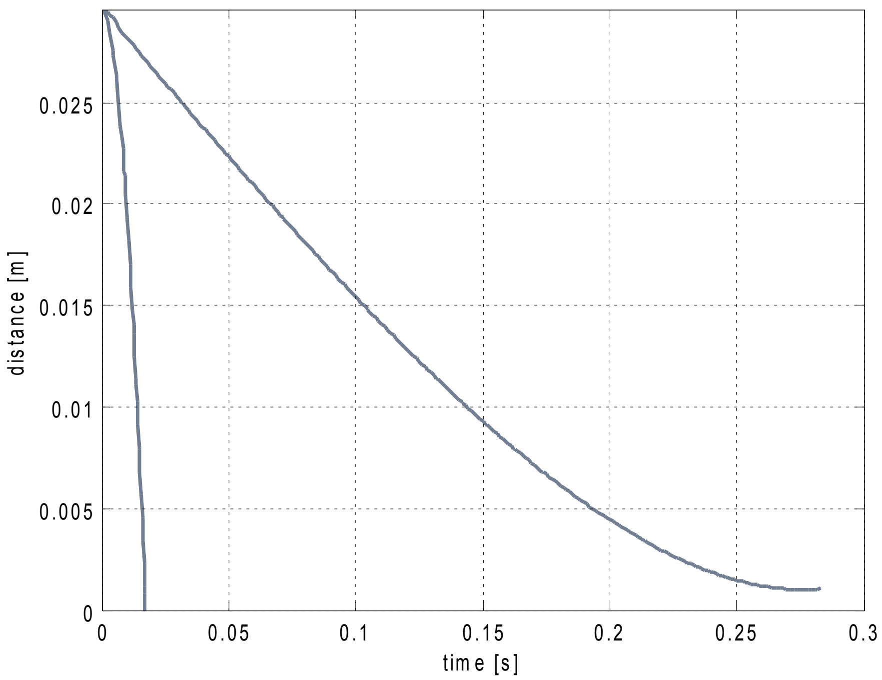


figure 4.35 Function 6

According to the image, Separation plate and ball are not collide. Therefore, acceleration time and Deceleration time are same. t = 0.017 S .

$$a = -198\ \mathrm{m/s^2}$$

$$T = 94\ \mathrm{kg \cdot cm}$$

If we choose to 1.8 degree step angle motors. The angle Separation plate rotation from one hole to second hole is 72 degrees.The signal micro-controller need to send is

$$n = \frac{72}{1.8} = 40$$

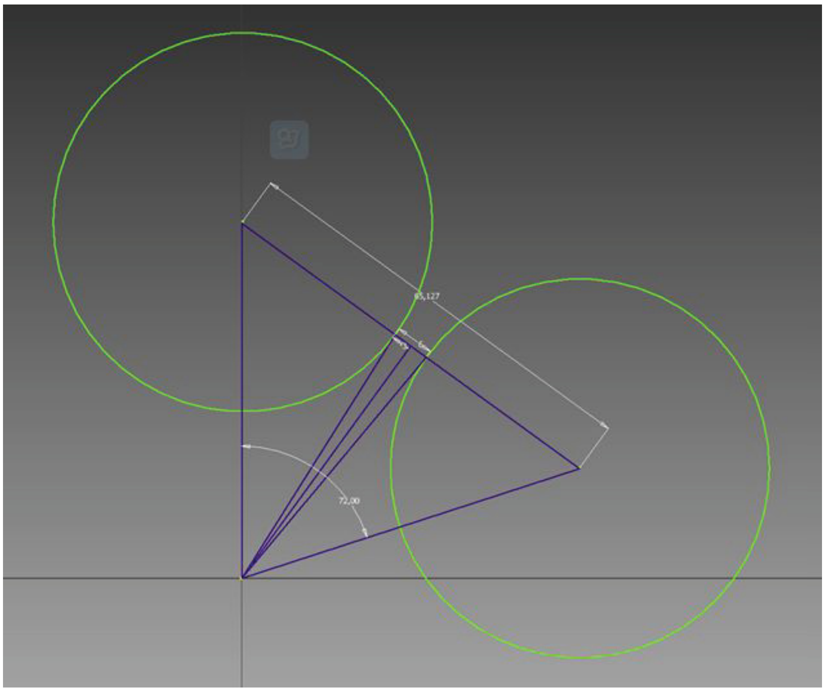


figure 4.36 Distance between two position

Separation plate in the middle short part does uniform motion. The length of it is 6 mm. Let's calculate the time required of this part.

$$\frac{\theta}{2} = \arctan\frac{3}{55.4\times\cos 36°} = 3.83°$$

$$\theta = 7.66°$$

$$t_M = \frac{\theta}{\omega}$$

$$\omega = \alpha\cdot t = 3574\times 0.017 = 60.8 \text{ rad/s}$$

$$t_M = \frac{7.66\times\frac{\pi}{180}}{60.8} = 2.2\times10^{-3}\text{ s}$$

The time Separation plate rotation from one hole to second hole is t.

$$t = 0.017 + 0.017 + 2.2\times10^{-3} = 0.0362\,\text{s}$$

Driving pulse rate is F. Start pulse rate is 0. The positioning time is 0.0384 s. Acceleration/ deceleration time is 0.017 s. Necessary number of pulses is

n=40

$$F = \frac{n - F_0 \cdot t_0}{t - t_0} = \frac{40}{0.0362 - 0.017} = 2083$$

One period time is

$t = 0.4 + 2.2 \times 10^{-3} = 0.4022$ s

We can draw the image about pulse frequency and time.

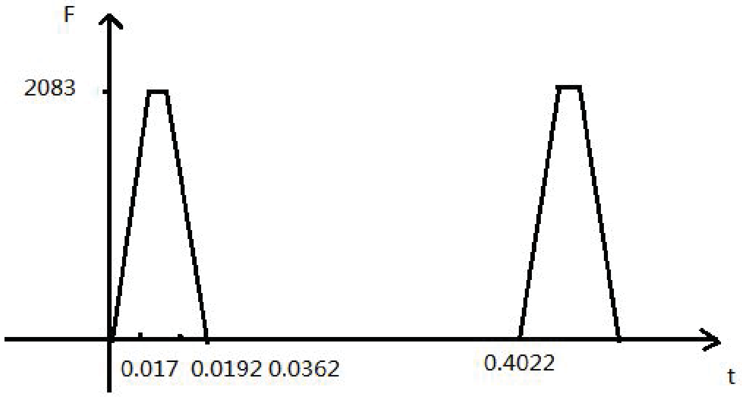


figure 4.37 PPS-t graph of one ball get out

According to the calculation results, motor must able to provide 9.4 kg•cm . Motors torque is change at different PPS. According image blow, the motor we choose is NEMA 23-size hybrid bipolar.

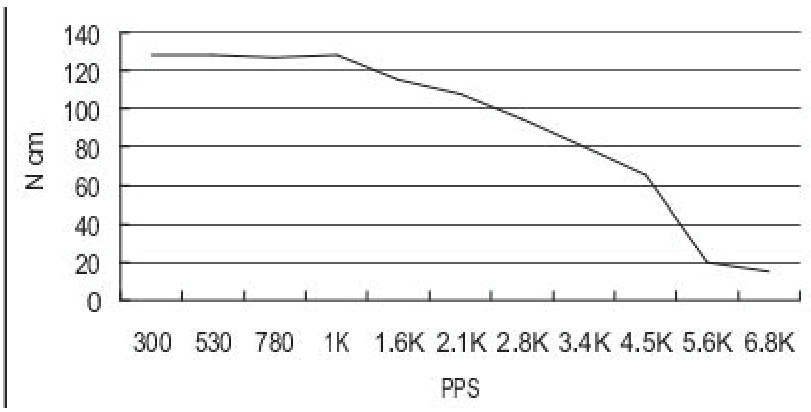


figure 4.38 T-PPS graph of engine 2

The sequence of balls is “ stripe, solid, stripe, stripe, solid, stripe, solid, stripe, black eight, solid, solid, stripe, solid, stripe, solid,”.

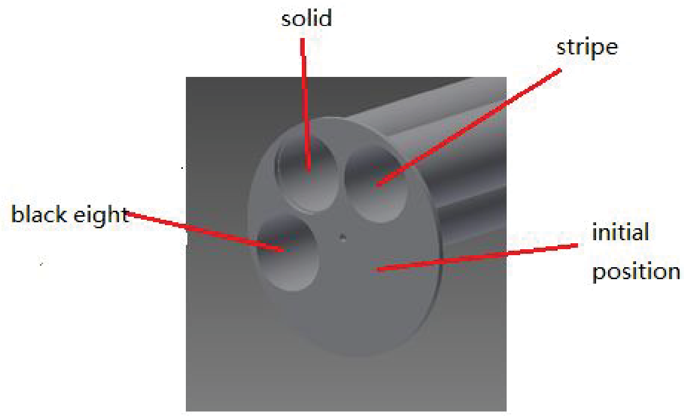


figure 4.39 Pipeline distribution

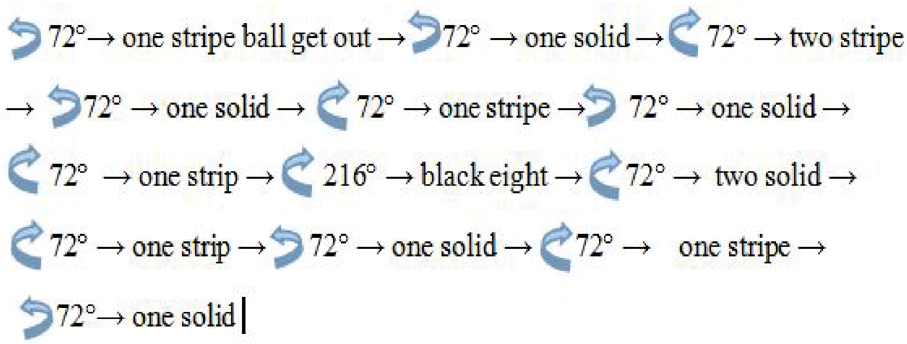


figure 4.40 Movement of separation plate

We calculate the t-PPS graph of rotation 216°. The acceleration and deceleration is same as rotation 72°.

$$n = \frac{216}{1.8} = 120$$

$$PPS = \frac{120}{T - t_0} = \frac{120}{T - 0.017} = 2083\,\text{HZ}$$

$$T = 0.075\,\text{s}$$

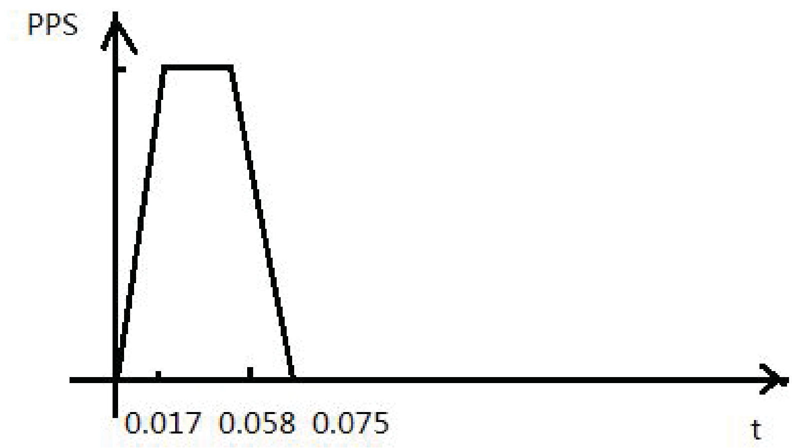


figure 4.41 PPS-t graph of rotation 216 °

We can found that some times two balls get out. The second ball has higher velocity. We need to check whether the previously acceleration of Separation plate is applicable. We just need to check the movement of the second half of ball.

$$v_0 = at_1$$

$$\frac{3}{2}r = \frac{1}{2}at_1^2$$

$$t_1 = \sqrt{\frac{3 \times 57.15 \times 10^{-3}}{0.71}} = 0.49\,\text{s}$$

$$v_0 = 0.71 \times 0.49 = 0.35\,\text{m/s}$$

$$y = v_0 t + \frac{1}{2}at^2 = 0.35t + 0.355t^2$$

$$\left(0.35t + 0.355t^2\right)^2 + \left[28.575 \times 10^{-3} - (x - 0.001)\right]^2 = \left(28.575 \times 10^{-3}\right)^2$$

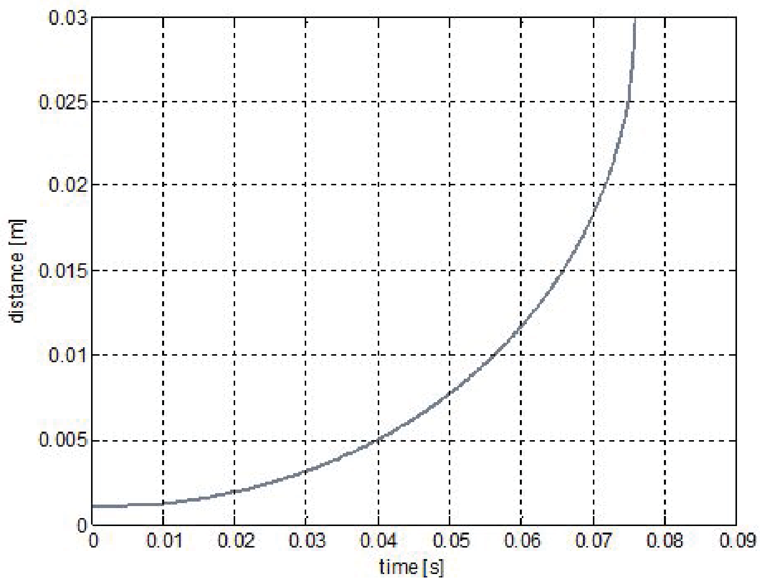


figure 4.42 Function 7

$$2r = \frac{1}{2}a{t_2}^2 = \frac{1}{2} \cdot 0.71 \cdot t_2^2$$

$$t_2 = 0.567\,\text{s}$$

$$t_2 - t_1 = 0.567 - 0.49 = 0.077$$

$$t_3 = 0.077 - 0.017 = 0.06\,\text{s}$$

$$0.49 + 0.06 = 0.55\,\text{s}$$

Therefore Separation plate begins to move in 0.55 seconds. We draw the image of function (displacement -time). Two curves are not intersecting. So , Separation plate and ball will not collide. The previously acceleration is applicable. $a = 198\,\text{m/s}^2$.

$$x = 99 \cdot (t - 0.06)^2$$

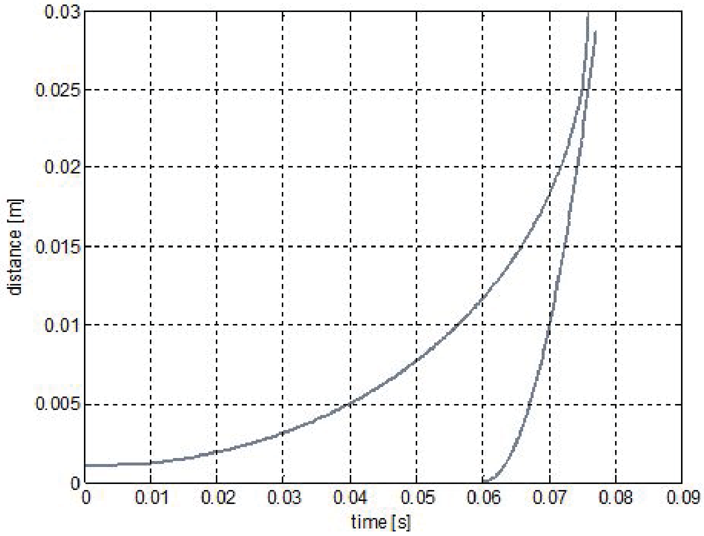


figure 4.43 Function 8

t-PPS graph of two balls rolling out is

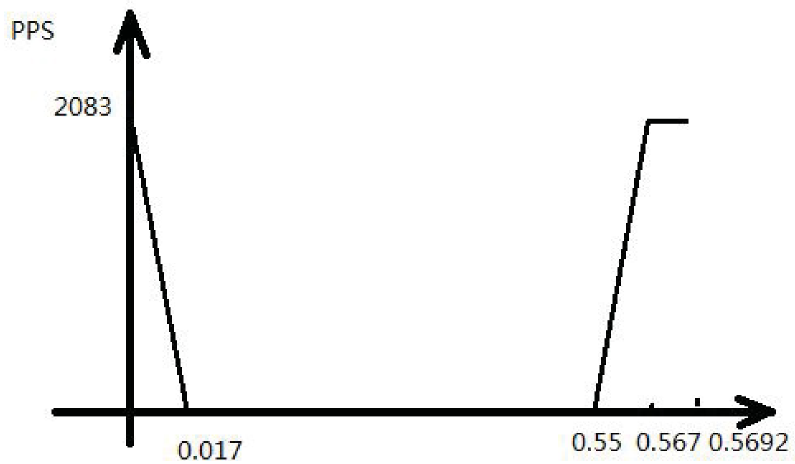


figure 4.44 t-PPS graph of two ball rolling out

4.4.4 Design of Connection pipeline

The last component is use to connect the triangular box. We call it Connection pipeline. It must ensure that the ball will not be disrupted. Ball rolls into the round box. The channel width is 60 mm. It make balls role into pipeline meanwhile ball's sequence is not changed. It's the bottom of the funnel-shaped design to ensure balls smoothly go into the pipeline.

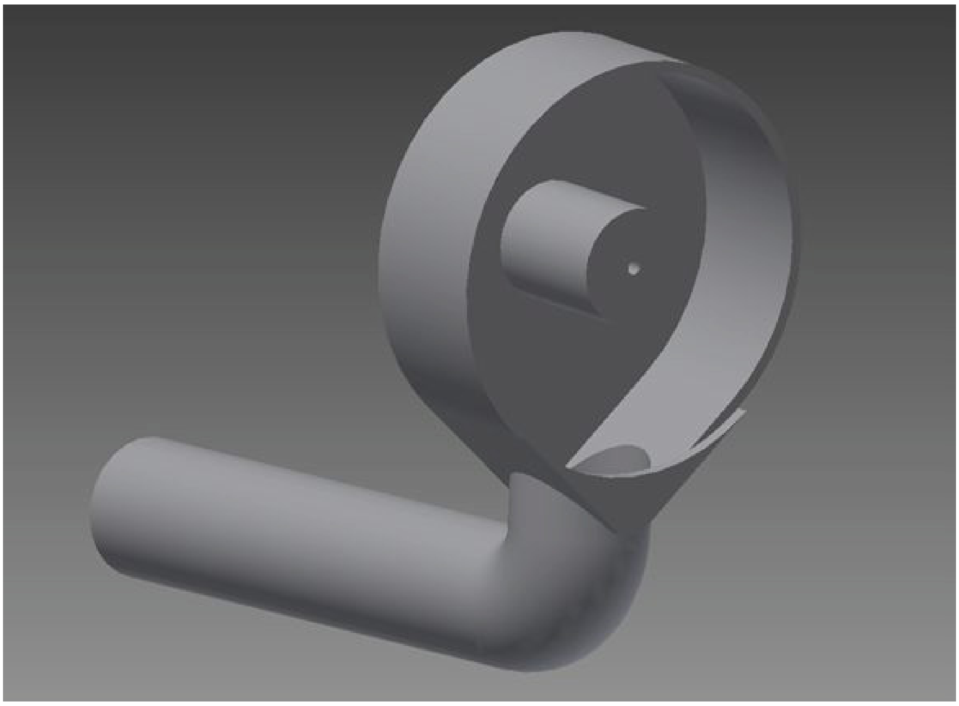


figure 4.45 Connection pipeline

The detail dimension is shown on 2D draw at back.

4.5 Design of the circuit

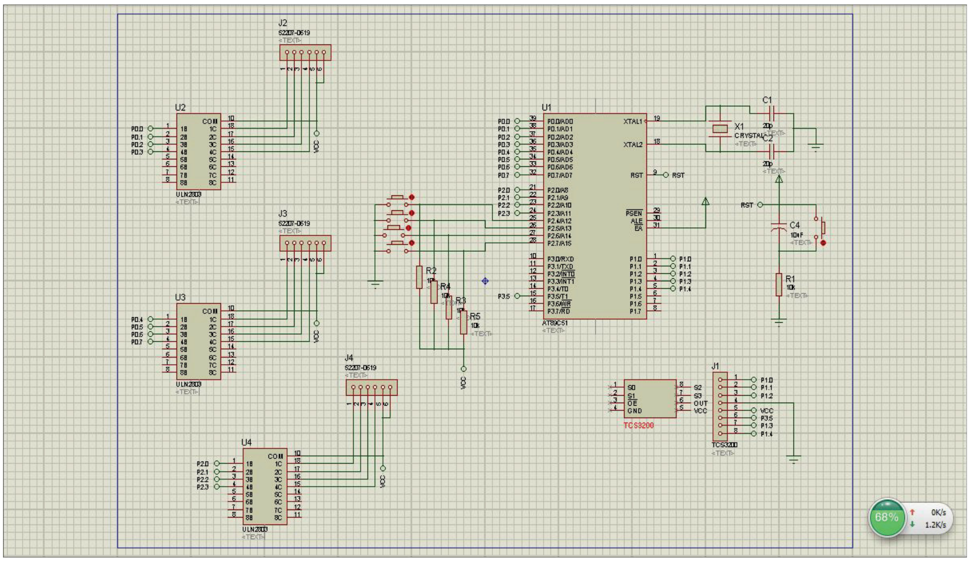


figure 4.46 Circuit design

In this circuit, we choose a 12MHZ crystal, a color sensor TCS3200, three laser sensors, three stepper-motors and three stepper motor drivers ULN2803 and one button. We use three buttons instead of three laser sensors here. (There is no laser sensor component in the Proteus7).

We use three drivers to drive three stepper motors because we need to control these three motors doing different work at the same time precisely. If you need these motors doing the same work, you can only use one driver. So we need three drivers to control the motors work separately. When the system comes to specified conditions, the micro-controller will give the driver a pulse signal to drive the stepper motor. The drivers turn the pulse signal into stepper angle to drive the stepper motors. One pulse signal drives the stepper motor to rotate one step angle. In this case, we can achieve a precise control of the stepper motor.

We've also added a button to release all the billiards. The button is used to prevent specific situations such as the black ball being hit into the hole in advance. If the players want to re-start the game, they can press the button. Then all the billiards will come out to the triangle rack directly.

4.5.1 Micro-controller

Our design use AT89C51 micro-controller. The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory (PEROM). The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the industry-standard MCS-51 instruction set and pin out. The on-chip lash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control application. [13]

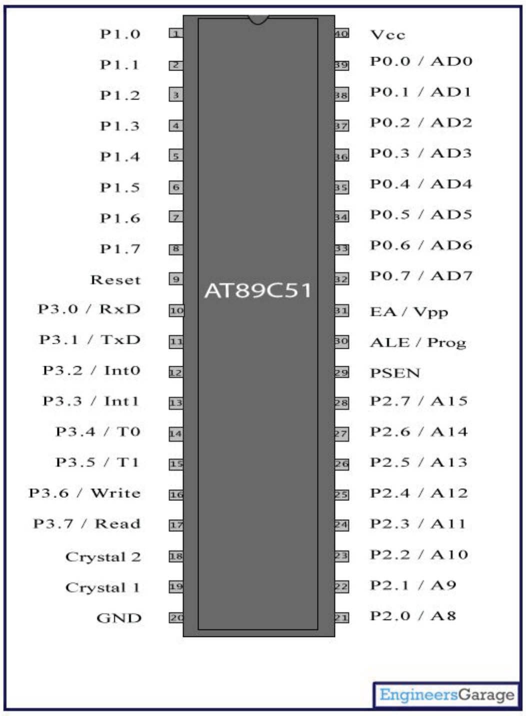


figure 4.47 Component figure of micro-controller [14]

The AT89C51 provides the following standard features: 4Kbytes of Flash, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, a two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry. In addition, the AT89C51 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port and interrupt system to continue functioning. The Power-down Mode saves the RAM contents but freezes the oscillator disabling all other chip functions until the next hardware reset.

In 40 pin AT89C51, there are four ports designated as P1, P2, P3 and P0. All these ports are 8-bit bi-directional ports, *i.e.*, they can be used as both input and output ports. Except P0 which needs external pull-ups, rest of the ports have internal pull-ups. When 1s are written to these port pins, they are pulled high by the internal pull-ups and can be used as inputs. These ports are also bit addressable and so their bits can also be accessed individually.

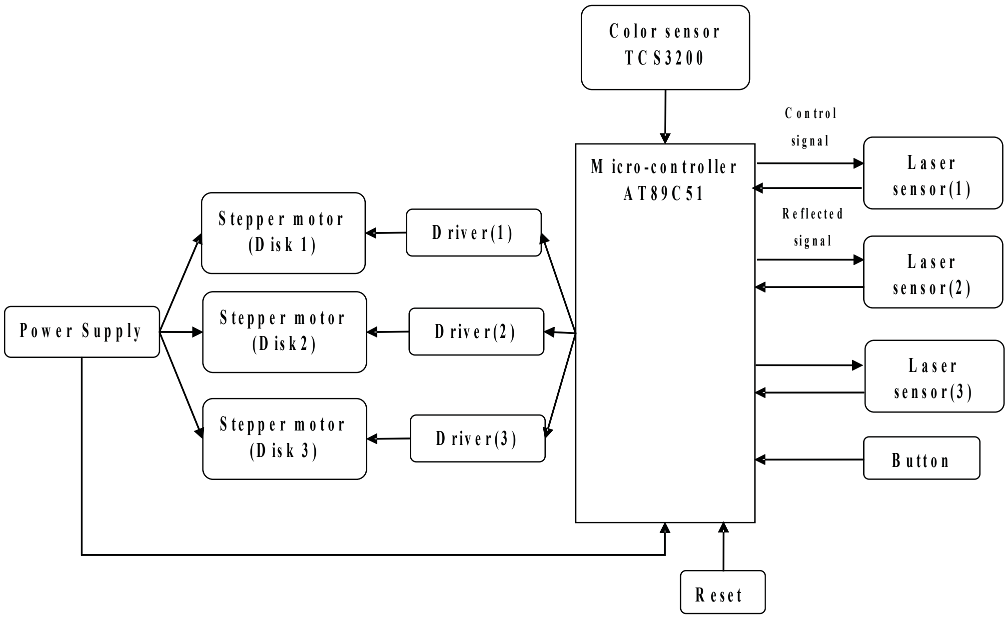


figure 4.48 System diagram

Port P0 and P0 are also used to provide low byte and high byte addresses when connected to an external memory.

We connected four input pins of the driver to P0.0~P0.3. Input pins of another two drivers are connected to P0.4~P0.7.and P2.0~P2.3. These ports are all used as output pins of the micro-controller.

Port 3 has multiplexed pins for special functions , hardware interrupts, timer inputs and read/write operation from external memory.

Port Pin	Alternate Functions
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (timer 0 external input)
P3.5	T1 (timer 1 external input)
P3.6	$\overline{\text{WR}}$ (external data memory write strobe)
P3.7	$\overline{\text{RD}}$ (external data memory read strobe)

figure 4.49 Special functions of Port 3

We connect the output of the color sensor to P3.5.The output of the color sensor is the value of RGB (This will be introduced in the color sensor part).So we use P3.5 as a counter. The other pins of the color sensor are connected to P1.0~P1.4.

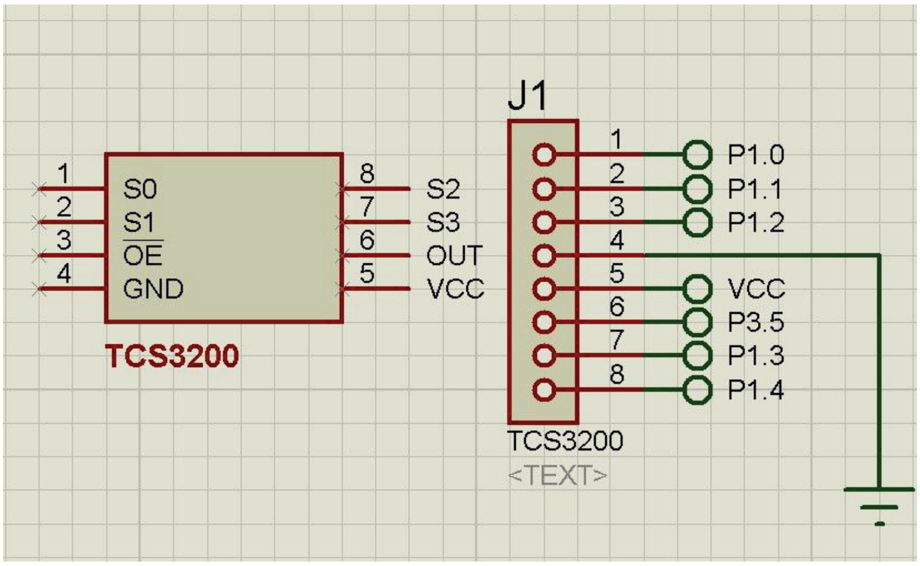


figure 4.50 Color sensor TCS3200

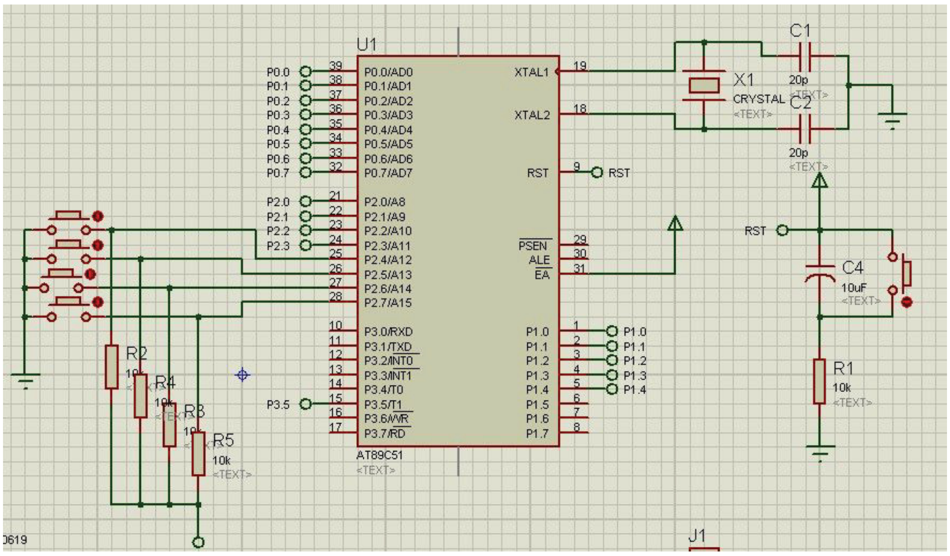


figure 4.51 Circuit of the Micro-controller part

4.5.2 Color sensor

We choose color senor to distinguish the color of the pool ball, the solid and the stripe one. After our research, we choose the TCS3200 color sensor.

TCS3200 color sensor is produced by an American company named TAOS. It is a programmable converter which can turn colorful light into to frequency. It has more advantage than the other color sensors in performance.TCS3200 has a large light range, its standard output frequency range is 2Hz ~ 500kHz, TCS3200 has two programmable pins, the user can choose the module output ranges of 100%, 20%, 2% .TCS3200 can be used without DCs system. It can provide for each color channel at least 10 bytes resolution. TCS3200 can be used in color printers, medical diagnostics, LED detection, liquid color recognition, computer color monitor standard, color processing control, paints, textiles, cosmetics , printing materials and color detection products.

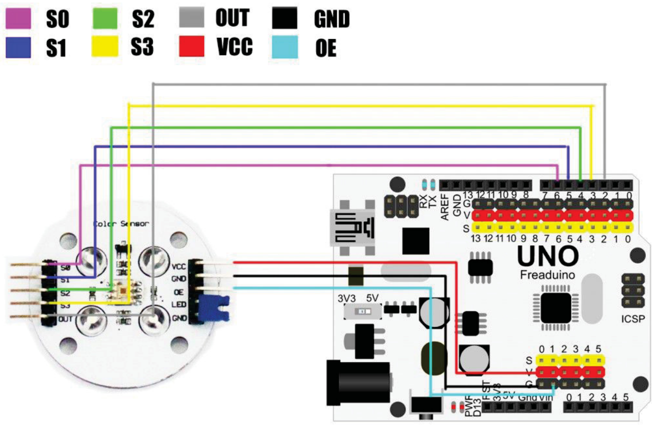


figure 4.52 Schematic diagram of color sensor [15]

4.5.3 Principle of the color sensor

According to the trichromatic theory, different colors are consists of the three primary colors (red, green, and blue) mixed together in different proportions. If we know the value of the three primary colors of the object, it is possible to know the color of the object. The color filter of TCS3200 can be adjusted to let specific colors through, blocking other colors, so as to measure the light in red, green and blue color components. For example, when selecting the red filter, the red light is obtained, and the blue-green light can not pass, then the red light is obtained in the content of this color.

TCS3200 has four photodiode types. We can choose the different type of photodiode by different combinations of S2 and S3. Look at the form as follows.[12]

table 4.1 Pin function 1 [16]

S2	S3	PHOTODIODE TYPE
L	L	Red
L	H	Blue
H	L	Clear (no filter)
H	H	Green

TCS3002 can output the frequency of different square wave (occupies empties compared 50%), different color and light intensity correspond with different frequency of square wave. There is a relationship between the output and light intensity. The range of the typical output frequency is 2HZ~500KHZ. We can get different scaling factor by different combinations of S0 and S1. Look at the form as follows.

table 4.2 Pin function 2

S0	S1	OUTPUT FREQUENCY SCALING (f_o)
L	L	Power down
L	H	2%
H	L	20%
H	H	100%

The color sensor can only distinguish the white ball and the black ball. After the color sensor sample the color, we can get the value of RGB. If we want to distinguish the stripe and the solid ball, we must do some calculation or use some software to process these values. We are not familiar to these parts. We can do it in the future work.

4.5.4 TCS3200 driver module

TCS3200 use eight pin SOIC surface mount package, integrated on a single chip. There are sixty four diodes. These diodes are divided into four types .Sixteen of the diodes has a red filter, sixteen diodes are with a green filter, sixteen diodes are with a blue filter, and the other diodes are without any filters. These photodiode chips are arranged in a cross. It is possible to minimize unevenness of the incident radiation, thereby increasing the accuracy of color identification. In the other hand, the sixteen same color photodiode is connected in parallel, uniformly distributed in the diode array, and then the position error can be eliminated c. The module includes TCS230 initialization, timer initialization and color collection.

4.5.5 Laser Sensor

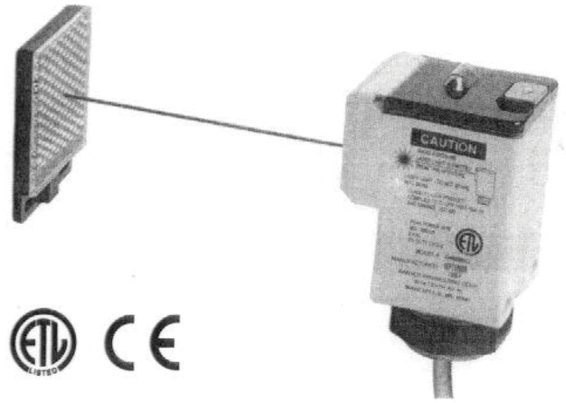


figure 4.53 Laser sensor [17]

To ensure the system can run automatically, we need to know that all the billiards are in the pipeline waiting for sending to the triangle rack. Then the separation part can put them into the rack in its correct order.

We install laser sensors in each pipeline. The laser sensor in the stripe-ball pipeline and the one in the solid pipeline are installed at seven balls high position. The laser sensor in the black-ball pipeline is installed at one ball high position.

If three laser sensors give the micro-controller high electrical level at the same time, we know that the billiards is all in the pipeline.

4.5.6 Stepper motor

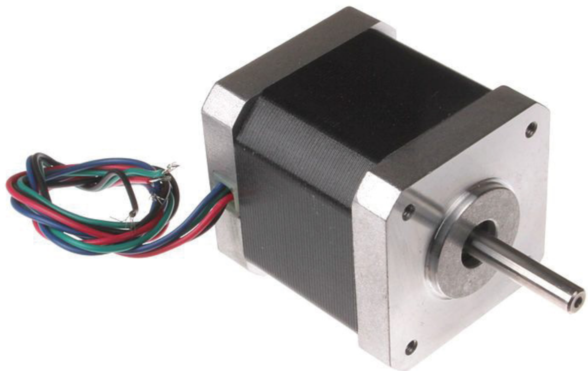


figure 4.54 Stepper motor [18]

Advantages of the stepper motor:

1. High precision
2. Good overload performance
3. Convenient to control
4. Simple structure

Principle of the stepper motor:

When the driver receives a pulse signal, it will drive a stepper motor to rotate a fixed angle, called "step angle". Its rotation is based on a fixed rotation angle operating step by step. The rotation can be controlled by the number of the pulse signal to control angular displacement, so as to achieve the purpose of accurate positioning.

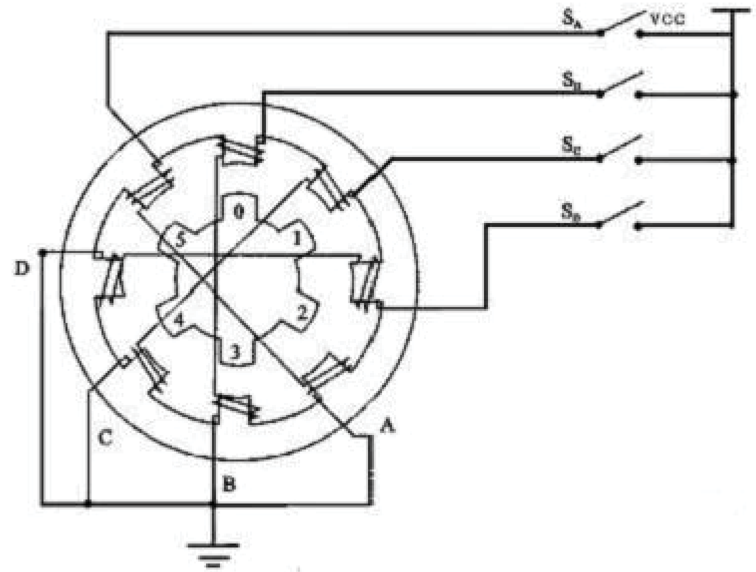


figure 4.55 Schematic diagram of stepper motor

http://www.seekic.com/circuit_diagram/Electrical_Equipment_Circuit/Four_phase_stepper_motor_step_signal_circuit.html

We use four-phase stepper motors in our system.Four-phase stepper motor has three different working ways. The working ways are differentiated according to different .power-on sequence

(1)If the stator A, B, C, D phase is energized in this order (A → B → C → D → A ）, the stepping motor will continue to rotate in the clockwise direction. Every pulse signal-transfer 1.8°, every four times to finish a pitch. It's called one-phase excitation.

Advantage: low power consumption

Disadvantage: small output torque, large vibration

(2)If the stator A, B, C, D phase is energized in this order (AB→ BC → CD → DA → AB ）, the stepping motor will continue to rotate in the clockwise direction. Every pulse signal-transfer 1.8°, every four times to finish a pitch. It's called two-phase excitation.

Advantage: large output torque, small vibration

Disadvantage: high power consumption

(3)If the stator A, B, C, D phase is energized in this order (A → AB → B → BC → C→ CD → D → DA → A）, the stepping motor will continue to rotate in the clockwise direction. Every pulse signal-transfer 0.9°, every eight times to finish a pitch. It's called one-two-phase excitation

Advantage: High resolution, smooth operation

According to the calculation we need to operate the stepper motor in a high accuracy way. We also need a large torque. The torque of two-phase excitation is two times to the torque of one-phase excitation. The two-phase excitation also has a smaller vibration during its operation. As we all know, the billiards is a high accuracy game.We need to minimize the effects of external interference as much as possible to ensure the players have a good game.

This hybrid bipolar stepping motor has a 1.8° step angle. If we want to rotate it 72°, we need to input 40 pulse signals.

Clockwise

AI=0;BI=0;CI=1;DI=1;

AI=1;BI=0;CI=0;DI=1;

AI=1;BI=1;CI=0;DI=0;

AI=0;BI=1;CI=1;DI=0;

Anticlockwise

AI=1;BI=1;CI=0;DI=0;

AI=1;BI=0;CI=0;DI=1;

AI=0;BI=0;CI=1;DI=1;

AI=0;BI=1;CI=1;DI=0;

The sample code is attached after the thesis.(written in Keil)

4.5.7 Stepper motor driver

The stepper motor driver is used to turn the pulse into angle displacement. When the stepper drive receives a pulse signal, it will drive a stepper motor to rotate a fixed angle.

The stepper motor driver using segmentation capabilities to eliminate low-frequency resonance phenomenon, reducing vibration and reducing noise.

We can use a click dedicated module as the stepper motor driver, such as L298, FT5754, etc., These driver module is simple and easy to operate, they can not only drive stepper motors, but also DC motors. You can also use the transistor structures, but it is very troublesome, reliability will be reduced too. In addition, there is another way, ULN2803 . The chip can drive eight-lane stepper motor, so four-lane and six-lane can also be driven. So our design chooses ULN2803 stepper motor driver.

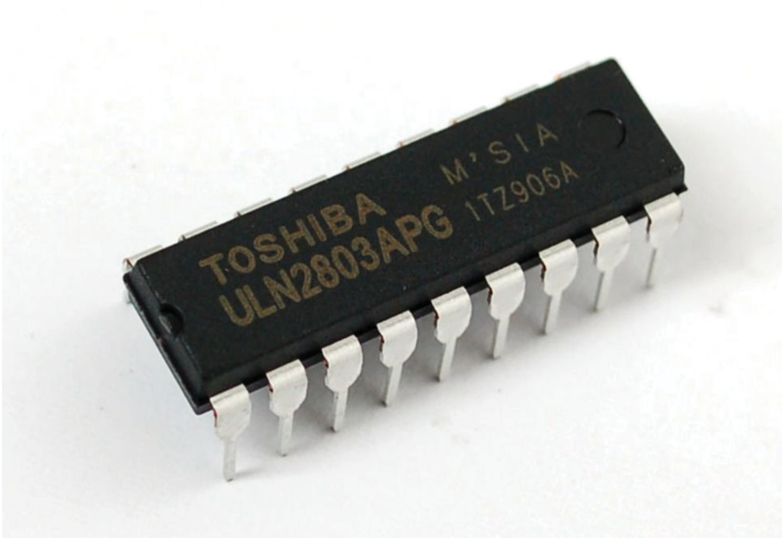


figure 4.56 Physical map of the stepper motor driver [19]

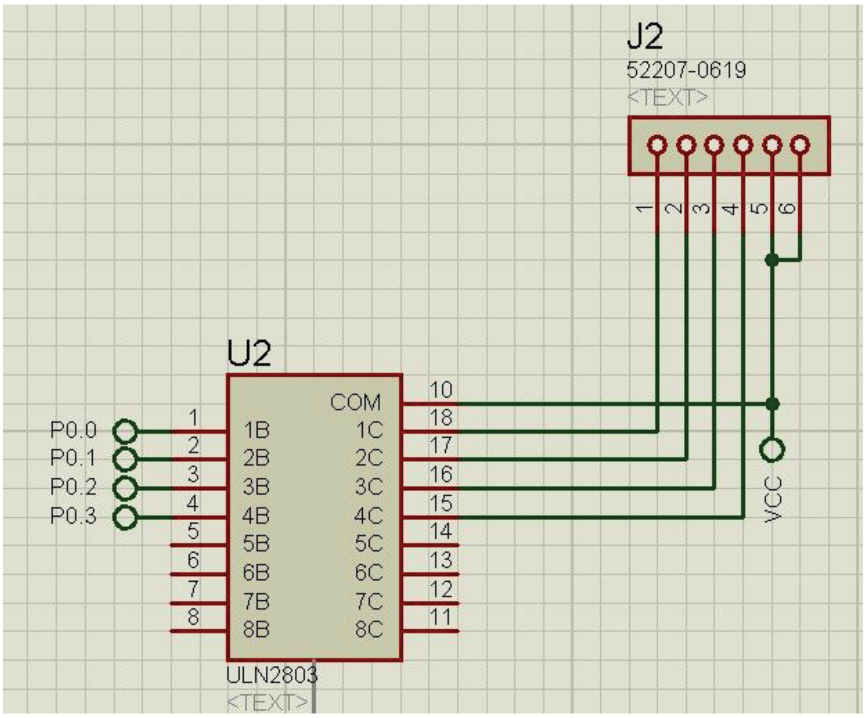
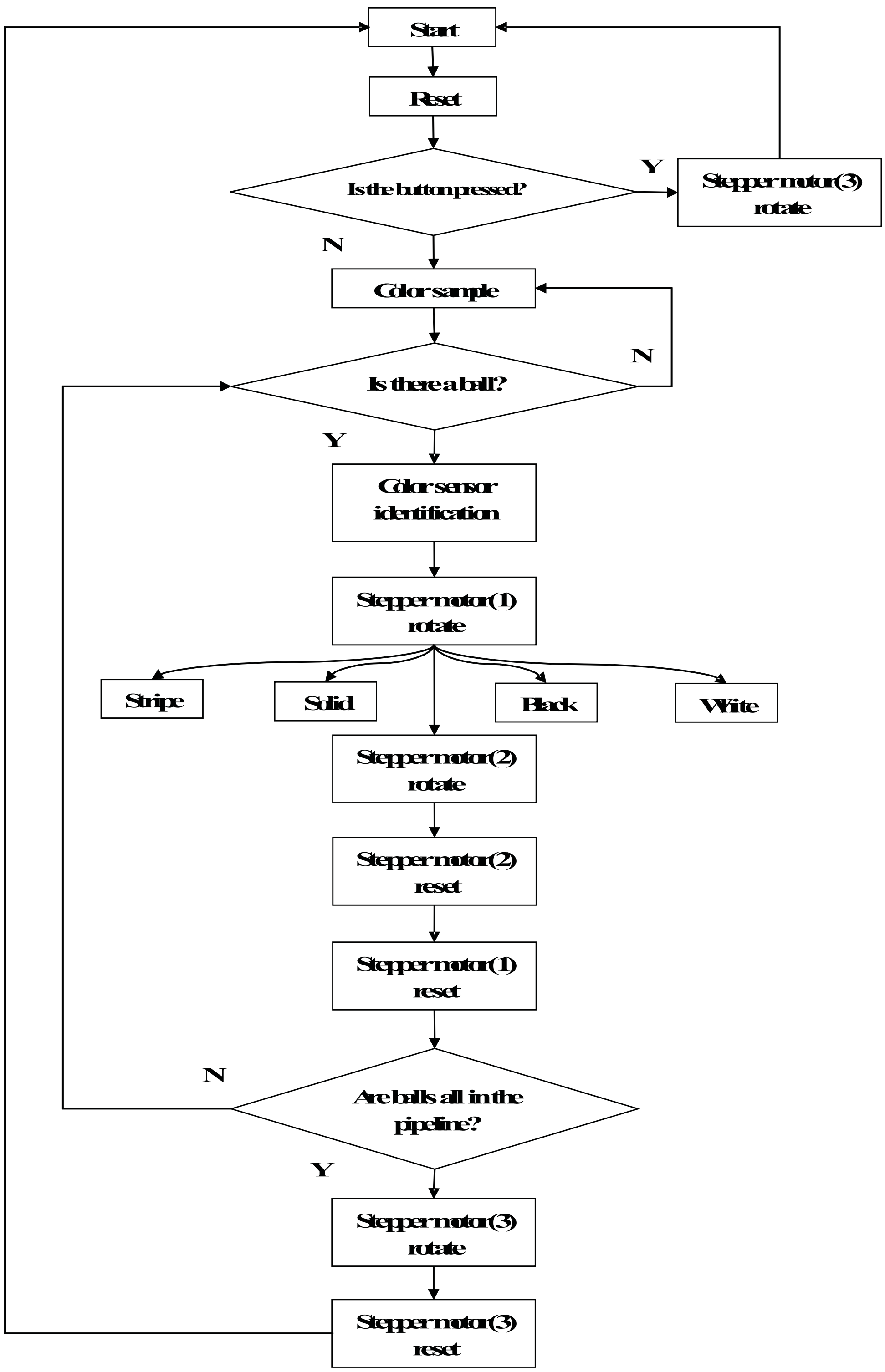


figure 4.57 Connection between the driver and the stepper motor

4.5.8 Software flowchart


Start
Reset
Is the button pressed?
Y
Stepper motor(3) rotate
N
Color sample
N
Is there a ball?
Y
Color sensor identification
Stepper motor(1) rotate
Stripe
Solid
Black
White
Stepper motor(2) rotate
Stepper motor(2) reset
Stepper motor(1) reset
N
Are balls all in the pipeline?
Y
Stepper motor(3) rotate
Stepper motor(3) reset

During operation of the entire system, the system maintains the operation in loop.

First of all, the system resets and determines whether the player has pressed the button or not (whether the micro-controller has received a high electrical level from the button or not). If the player has pressed the button, the stepper motor3 will rotate the Disk3 in a pre-set program. This action will release all the billiards. If no player has pressed the button, the color sensor TCS3200 will sample the color and determine whether there are balls in the Disk1. If there are balls in the Disk1, the TCS3200 color sensor will distinguish the balls (stripe, solid, black or white). Then the stepper motor1 rotate the Disk1 to the position of the pipeline. The stepper motor2 will rotate the Disk2 to the same position.

All the billiards will enter into their respective pipelines. The white ball will come out directly. If there is no ball in Disk1, the system will sample color and determine whether there are balls in the Disk1 or not in loop. After entering respective pipelines, the stepper motor2 will reset first and the stepper motor1 will reset after it.

Subsequently, infrared sensors in the pipelines will determine if all the billiards is in the pipelines or not. If the balls are not all in these three pipelines, the system will continue to determine if there is a ball in Disk1 or not. The steps will run in loop. If the billiards is all in the pipelines, three laser sensors will give the micro-controller high electrical level at the same time. Then the micro-controller will give stepper motor3 pulse signal to rotate in a pre-set program. The billiards will be all in the triangle rack after the program being executed the stepper motor3 will reset after it execute the pre-set program. After all, the entire system will run in loop again.

5 Chapter: Conclusion and future work

This thesis mainly talks about our new thinking upon billiard game. It is also a combination of mechanical and electronic project.

We successfully modeled the ideal Inventor 3-D modeling. Each section can carry out their duties. We used Proteus to draw schematics. Program is written in Keil.

Our design meets the needs of people. It increases the game's entertainment by saving custom's time. At the same time, it can help people who are novices rack the balls, ensure the fairness of the billiard game. The entire system that we designed costs about 3000 SEK. Relative to the price of a normal billiard table (about 18,000 SEK), our system is not that expensive.

Our main future work is focus on how to make a small change to make this billiard table adapt to different billiard games, such as nine-ball game and US billiard game. At the same time, we want to design a more accurate identification to separate 15 balls.

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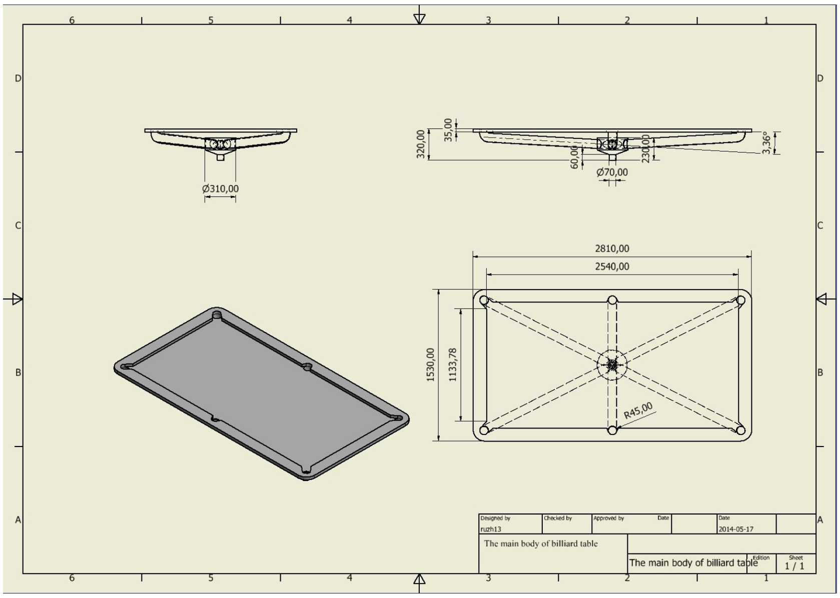
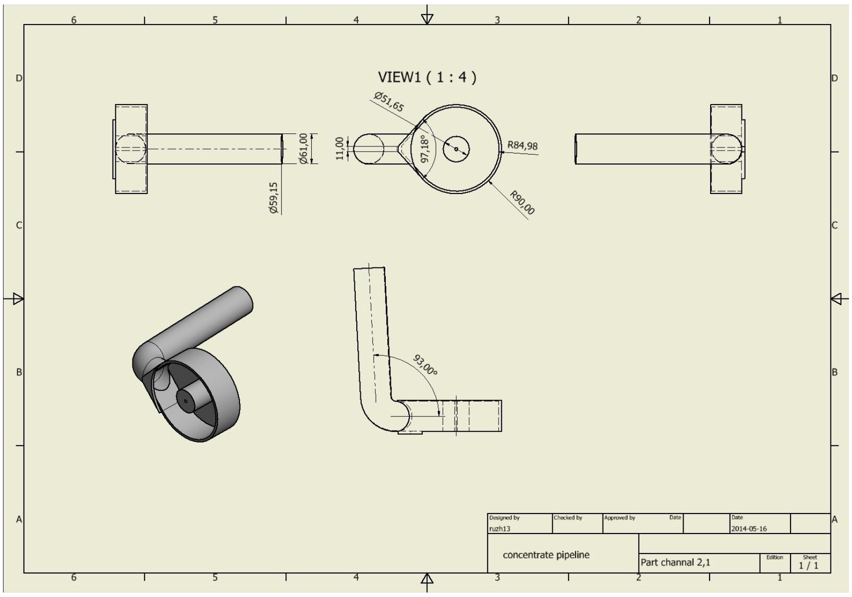
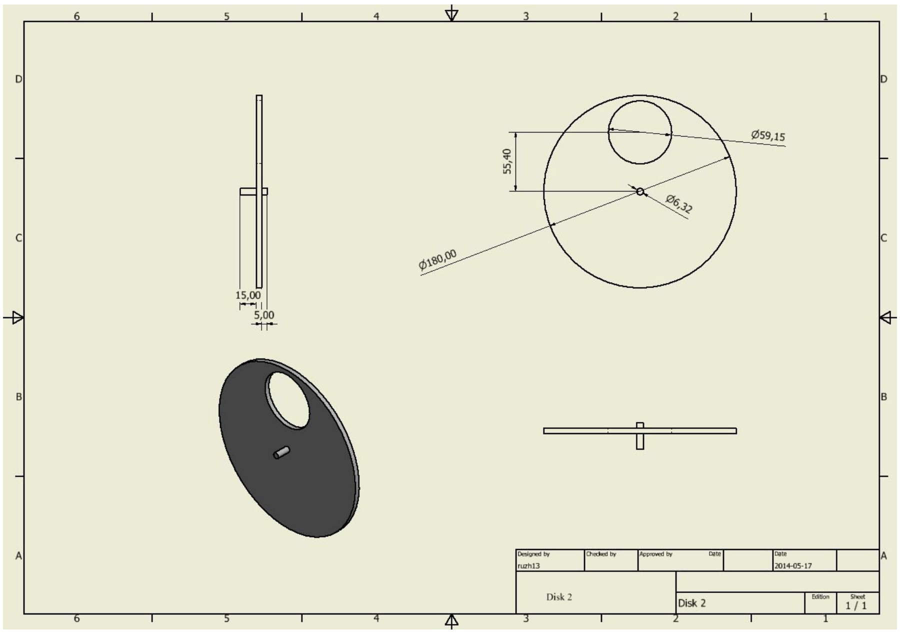
Appendix 1:
The drawing of billiard table parts



Body



Concentrate pipeline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Ø6,32
Ø180,00
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ruzh13
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Disk 2
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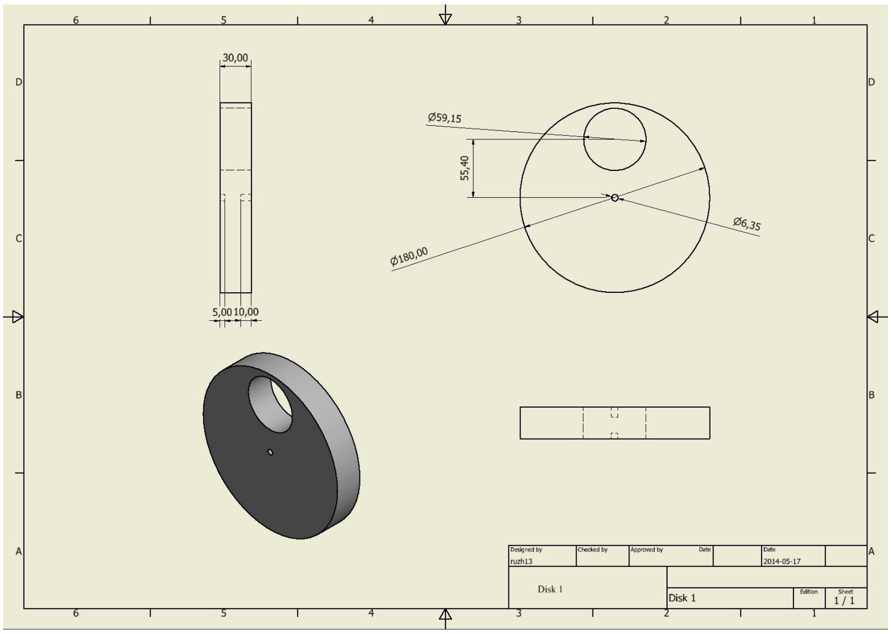
Sheet
1 / 1

Disk 1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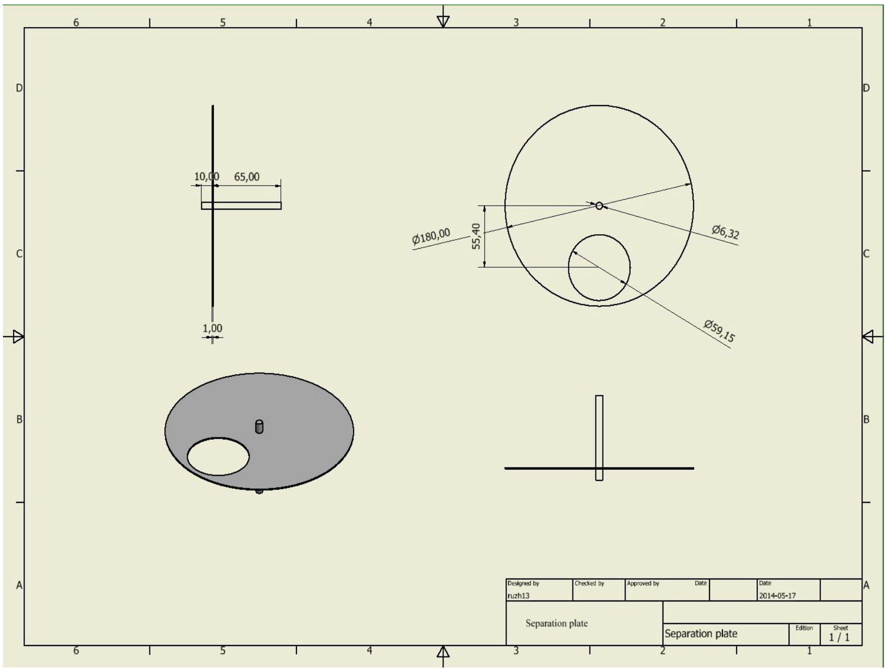
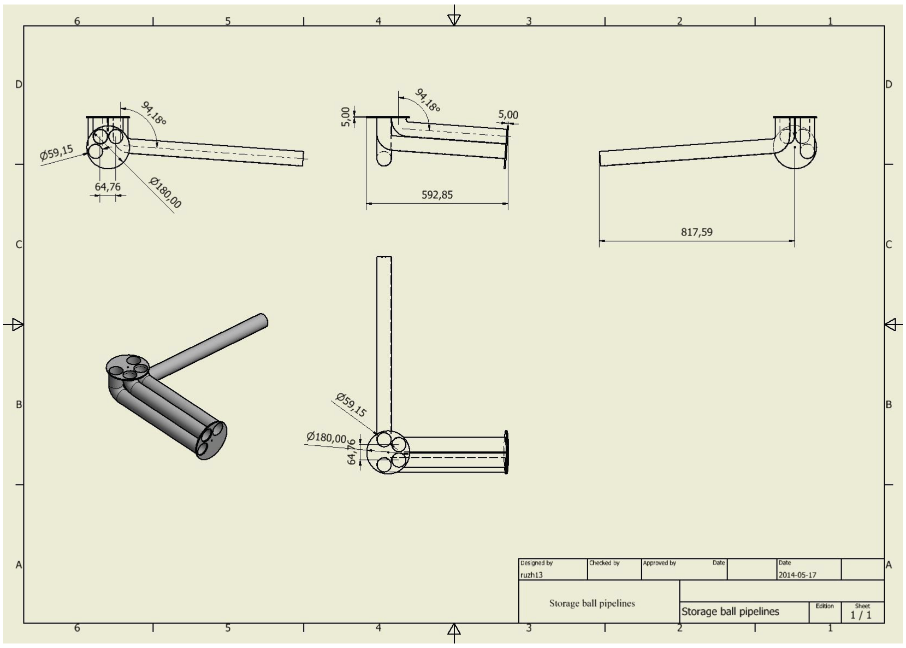
Disk 2



Separation plate



Ball-storage pipeline

Appendix 2:
Sample code of the separation part

```
#include<reg51.h>
#define uchar unsigned char
#define uint unsigned int
#define ctrl P2
sbit key1=P2_4
sbit key2=P2_5
sbit key3=P2_6
uchar code_f[]={0x33,0x66,0xcc,0x99};//anticlockwise
uchar code_z[]={0x99,0x88,0xcc,0x44,0x66,0x22,0x33,0x11};
uint start
uint phs
unit is1=0
unit is2=0
unit is3=0

void scan();
void delay()
{
  unsigned char a,b;
  for(b=199;b>0;b--)

  for(a=1;a>0;a--);
}
void act1()
{
  uint i;
  for(i=0;i<40;i++)
  {
    delay(5);
     ctrl=code_f[phs];
     phs++:
     if(phs>=41):
     phs=40:
    }
}
void act2()
{
```

```
   uint i;
   for(i=0;i<40;i++)
   {
     delay(5);
      ctrl=code_z[phs];
      phs++;
      if(phs>=41);
      phs=40;
    }
}
void act3()
{
   uint i;
   for(i=0:i<120:i++)
   {
     delay(5);
      ctrl=code_z[phs];
      phs++;
      if(phs>=121);
      phs=120;
    }
}
void scan()
{
    if(key1==1)
     {
       is1=1;
     }
     if(key1==0)
     {
       is1=0;
     }
     if(key2==1)
     {
       is2=1;
     }
     if(key2==0)
     {
       is2=0;
     }
```

```
    if(key3==1)
    {
      is3=1;
    }
    if(key3==0)
    {
      is3=0;
    }
void main()
{
   TMOD=0x01;
    EA=1;
    ET0=1;
   TH0=-1000/256;
    TL0=-1000%256;
    TR0=1;
    while(1)
    {
      keyscan();
      {
        if(is1==1;is2==1;is3==1);
         {
         act1();
         delay(400);
         act1();
         delay(400);
         act2();
         delay(700);
         act1();
         delay(400);
         act2();
         delay(400);
         act1();
         delay(400);
         act2();
         delay(400);
         act3();
         delay(400);
         act2();
         delay(700);
```

```
          act2();
          delay(400);
          act1();
          delay(400);
          act2();
          delay(400);
          act1():
          delay(400);
        }
    }
}
```