Automatic Ball Borrowing System

Project #38

Design Document

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1. Introduction

1.1 Objective

At the ARC of our university, sometimes we have to wait for a long line to borrow balls, like basketballs, from staff. It is time consuming for students and the university also need to spend money hiring people to give those balls to us. In addition, if students forget to bring their I-cards, they cannot get the balls. Finally, if students want to return the ball, they will need to wait for a long line again to return those balls to staff.

As a result, we decide to build an Automatic Ball Borrowing System to help both students and university. Our system will be used to dispense golf balls and collect balls from students. It will display the number of remaining golf balls inside the machine on an LCD screen. We provide a pin pad for students to choose whether they want to return the ball or borrow the ball. If students want to borrow the ball, they can scan the RFID to borrow the golf balls. Also, students can use the pin pad to type in their UIN to get the balls if they forget to take IDs. When balls are returned from students, students must provide their RFIDs or type in their UIN. Then the machine will check its size after the ball is put into the machine to determine whether it is a golf ball and not something else. If the size does not match a golf ball, the alarms will be turned on.

1.2 Background

Shortly after the invention of vending machine, it became prevalent in many countries. For example, there are 5.5 million [1] throughout Japan. Then around 2000-2010, here entered specialized and smart vending machines. These machines can automatically serve products while reducing costs from labors and time that people need to wait in line. Based on this concept, there came automatic book rental machines, power bank rental machines and so on. We choose to build a machine for golf balls due to the large number of participants in the United States. There were around 23.82 million [2] participants in golf ball in the United States in 2016. The total sales of golf ball and related clubs are more than 2 billion dollars [2] in 2016.

In the market, there are various products that focus on different aspect similar to the ideas of our project. For example, Tennis Cube [3] heavily emphasis its capability as a dispenser. It can eject a tennis ball at various speed and rotation, and it can eject multiple balls in a short period of time. However, there is no ball checking mechanism and closed container, which means the user can put in an object other than a tennis ball into the machine and the Tennis Cube will just repeat the machinery movement as if the object is a tennis ball and that could potential jam the machine. There is another type of machine that focus on precise checking. For example, the ever popular Redbox used to be the main gateway to watch movies and rent video game before streaming services like Netflix and online game distributor like Steam came into dominance. Redbox based its checking system on a barcode scanning mechanism, which can accurately track each item and corresponding user. The problem is the kiosk itself has very complicated machinery to store and dispense the items. As in consideration for our project, since we keep scalability in mind, not all balls have compatible material to print barcode or QR code on, and as the ball wears, the code will eventually fade away so that the machine cannot read it.

1.3 High-level Requirements

- After using correct RFID tag or ID number, the user can get a certain number of balls.
- After using correct RFID tag or ID number, the user can return the balls he/she borrowed previously.
- Upon returning wrong balls, the buzzer/alarm will be turned on.

2. Design

The power supply will get power from a wall plug. Then it will use an AC/DC adapter to get the 12 V DC. Then the DC power will be sent to three regulators, which will produce three different voltages for different parts of the system. The 5 V will be used to supply power for microcontroller. The 3.3 V will be used to supply power for sensors, alarms, PIN pad, LCD, and alarm. The 9V will be used to supply power for motor. The sensors and pin pad will collect data and send them to microprocessor. Then the microprocessor will use them to control the motor, LCD, and alarm.

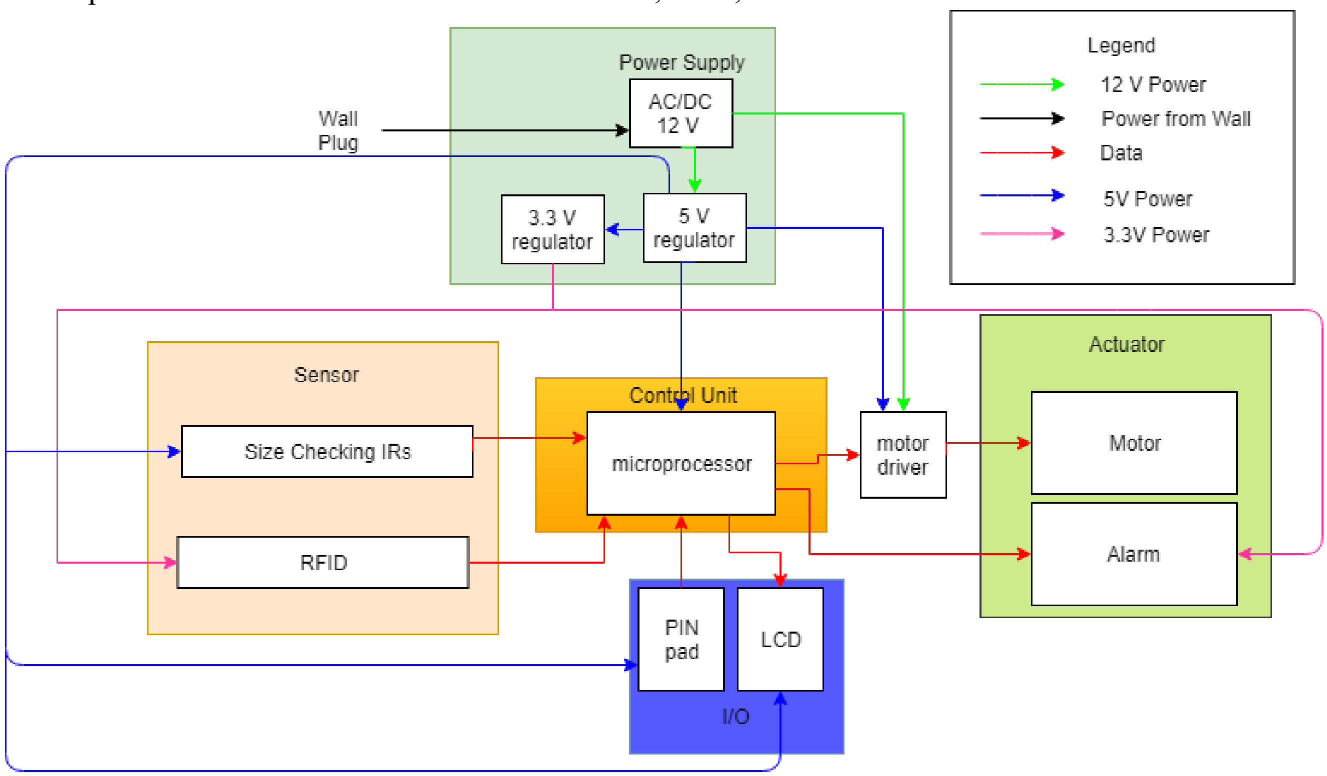

Figure 1. Block Diagram

The physical design consists of several parts. The main part is the tube that stores the balls. A 45-degree slope, which is also a tube, is connected to the top of the tube as the entrance to return the balls. There will be two IR sensors inside the sloped tube to check if there is a ball passing and if the size of ball matches the size of a golf ball. Then there is the motor, the turning wheel and a stationary disk for dispensing the balls. There is a cutout on the turning wheel that can hold exactly one ball so that when the wheel turns, only one ball at a time will get carried out of the tube. There is also cutout on the stationary disk. As the wheel turns, once the cutout on the wheel lines up with the cutout on the stationary disk, the ball in the turning wheel will fall through the cutout on the stationary disk and get caught by a bucket below the stationary disk. The motor is controlled by a microcontroller that gathers all the inputs from the sensors. There is also a IR sensor stick to the back of the storing tube and facing the turning wheel. There will be a marker on the turning wheel on the top side for the IR sensor on the tube to detect one full rotation.

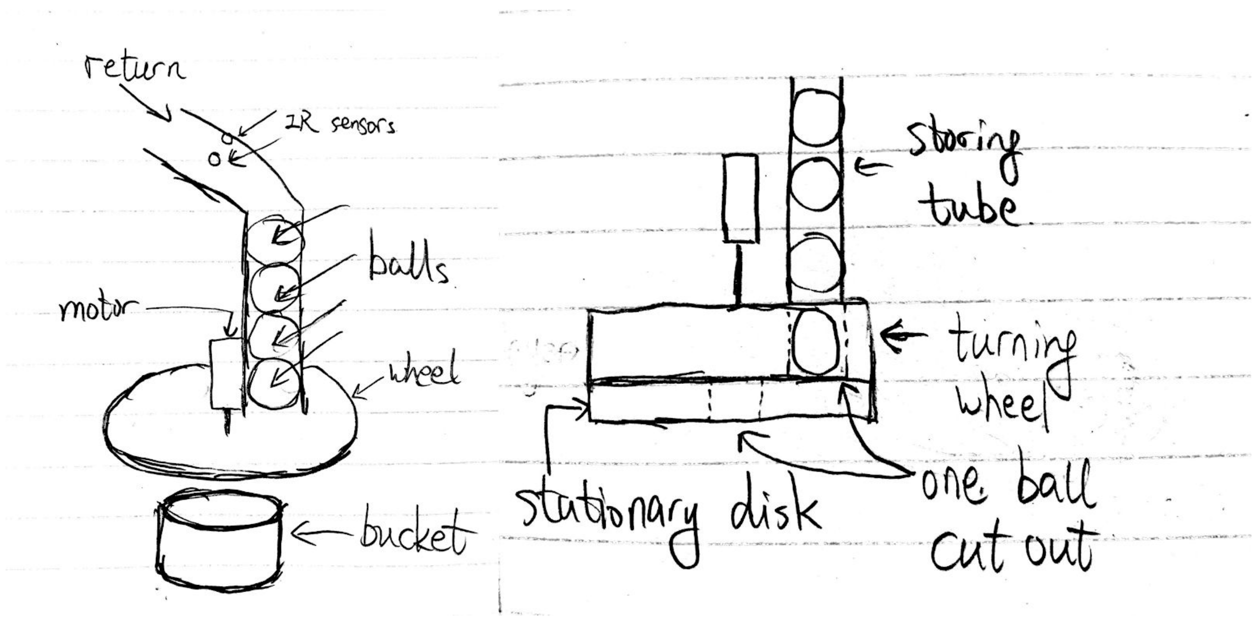

Figure 2. Physical Design Diagram (Left: overall view; Right: front view of dispensing part)

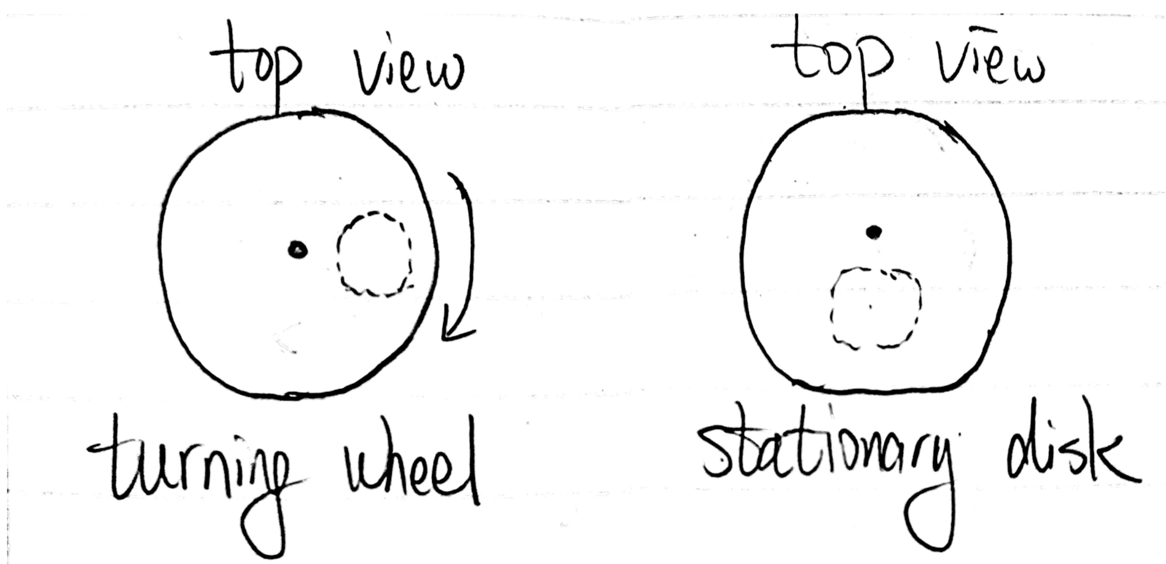

Figure 3. Top view of the turning wheel (left) and stationary disk (right)

2.0 Golf ball Measurement and statistics

We bought a set of 15 golf balls and measured the diameter of each ball using a vernier caliper borrowed from mechanical engineering department. The measured distances are logged into the chart below and relevant statistics are calculated. Note that the ball indices are just to make the chart readable, there are not actual indices on the balls themselves.

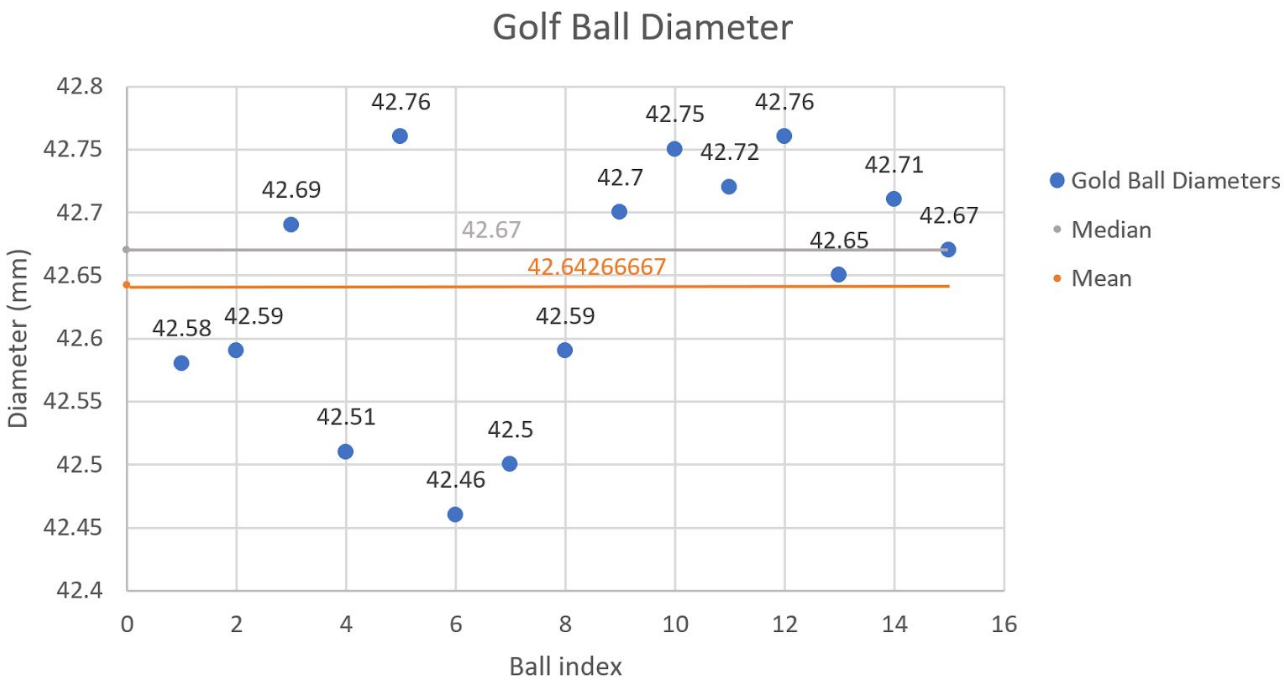

Figure 3. Golf Ball diameter distribution (15 balls)

Table 1. Golf ball Statistics

Statistics	**Value (mm)**
Maximum	42.76
Minimum	42.46
Mean	42.64267
Median	42.67
Standard Deviation	0.098812
Mean + 3 Standard Deviation	42.94
Mean - 3 Standard Deviation	42.34

According to normal distribution, there is a 68-95-99.7 rule [4] which says that around 99.7% of data will be within ±3 standard deviation away from mean. As a result, we expect the returned ball has diameter between 42.34 mm and 42.94 mm.

2.1 Power Supply Module

We will use power supply to power microcontroller, motor, data transmission, IR sensor (QRE1113), PIN pad (COM-08653), LCD and RFID reader (rc522). The microcontroller, IR sensor, LCD and data transmission need 5V. The motor needs around 12V. The PIN pad and RFID reader needs 3.3V power supply. We will use an adapter (TOL-09442 ROHS) to transfer 110V AC to 12V DC. 12V is enough for our use. 12v is for motor running. Then we use Voltage regulator-5V (COM-00107 ROHS) to provide 5V for microcontroller and data transmission. We use Voltage regulator-3.3V (COM-00526 ROHS) to provide 3.3V for PIN pad and RFID reader.

2.1.1 AC/DC Adapter

AC/DC is an adapter which will be used to convert 110V AC to 12V DC. The input to the adapter is 110V AC and the output is 12V DC to provide power to microcontroller, motor, IR sensors, PIN pad, LCD and RFID reader.

Requirement	Verification	Points
1. It should convert 110V AC to 12V±1V DC.	**Equipment**: 110V wall outlet, Oscilloscope, wire-to-BNC cable **Procedure**: a. Connect the adapter to the wall outlet. b. Connect to barrel plug to the power jack c. Connect the wire end of the wire-to-BNC cable to the two pins on the power jack d. Connect the BNC end of the wire-to-BNC cable to the bench oscilloscope e. Read the oscilloscope to determine the average voltage, and amplitude of ripple **Expected Results**: The average voltage should be around 12V and the amplitude of the ripple should be less than ±1V.	6

2.1.2 3.3 V regulator

3.3 V is the voltage used to supply power for PIN pad and RFID reader. Our adapter only provides 12V to the circuit, so we need 3.3V regulator to transfer 12V to 3.3V.

Requirement	Verification	Points
1. It should take 12V as input voltage and 3.3V as output to the circuit. The range is 2.8V to 3.8V.	**Equipment**: Oscilloscope, wire-to-BNC cable **Procedure**: a. Connect the 3.3 V regulator to the circuit. b. Connect GND to wire end of the wire-to-BNC cable.	5

	c. Connect the output to the other wire end of the wire-to-BNC cable. d. Connect the BNC end of wire-of-BNC cable to oscilloscope. e. Check whether the value is in the range 2.8V to 3.8V. **Expected Results**: The voltage is around 3.3V and the deviance is ±0.5V.	

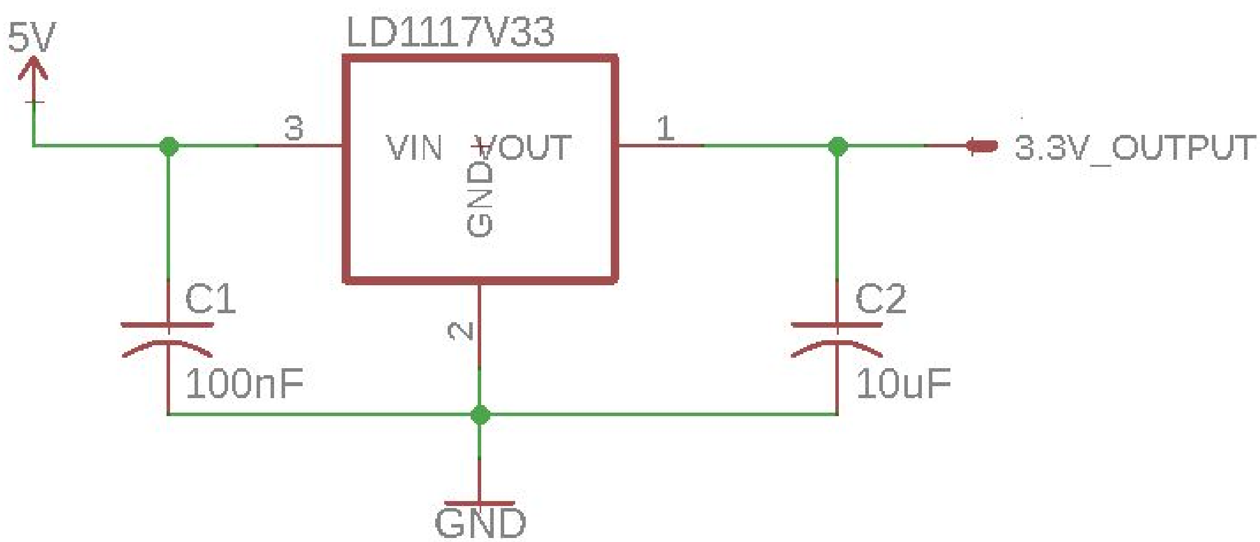

Figure 4. 3.3V voltage regulator

2.1.3. 5 V regulator

5V is the voltage used to supply power for the microcontroller, IR sensors, LCD and data transmission. Our adapter only provides 12V to the circuit, so we need 5V regulator to transfer 12V to 5V.

Requirement	Verification	Points
1. It should take 12V as input voltage and 5V as output to the circuit. The range is 4.5V to 5.5V.	**Equipment**:Oscilloscope, wire-to-BNC cable **Procedure**: a. Connect the 5 V regulator to the circuit. b. Connect GND to wire end of the wire-to-BNC cable. c. Connect the output to the other wire end of the wire-to-BNC cable. d. Connect the BNC end of wire-of-BNC cable to oscilloscope.	5

	e. Check whether the value is in the range 4.5V to 5.5V. **Expected Results**: The voltage is around 5V and the deviance is ±0.5V.	

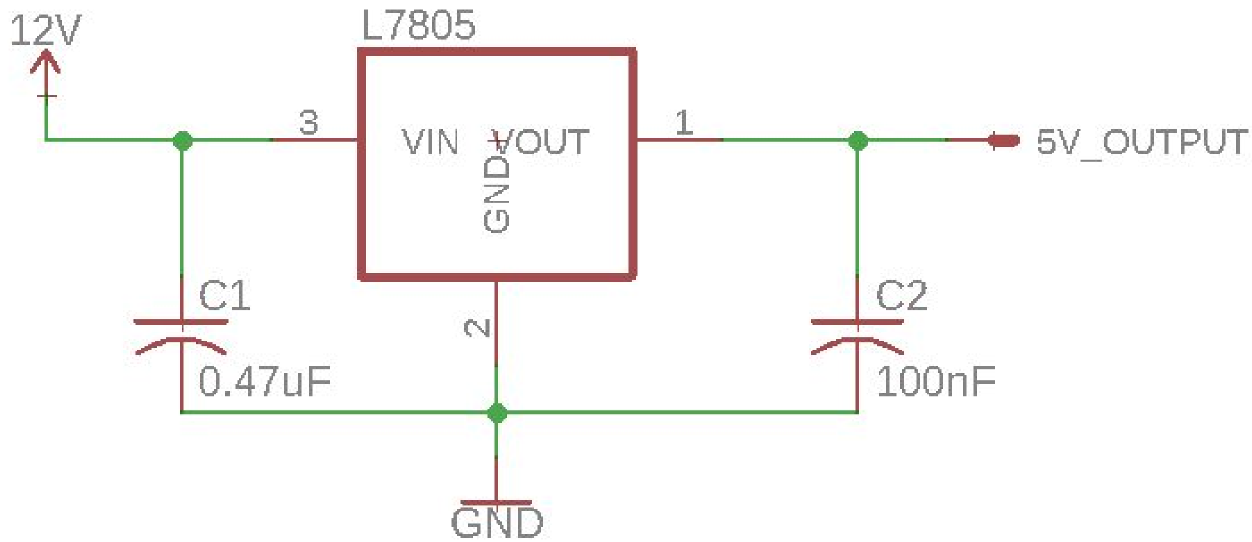

Figure 5. 5V voltage regulator

2.2 Control Unit

2.2.1 Microcontroller

The microcontroller will collect data from sensors and pin pad, then control the LCD screen and motor.

It should have at least 31 I/O pins. Here is the list of usage of those I/O pins.

Usage	Number of pins
Size Checking IRs	3
RFID reader	5
LCD	7
Keypad	7
Motor	2
Alarm	1
Programmer	6
Total	31

Table 2. I/O pin number requirement

As a result, we decide to use ATMega128 as our microcontroller. We draw the circuit according to its datasheet [5].

Requirement	Verification	Points
1. Microcontroller has at least 31 I/O pins that can be controlled by program.	**Equipment**: Pickit 3, breadboard, wire, LED, bench power supply. **Procedure**: a. Connect all the required I/O pins to LED. b. Write a simple program to make the LED blink. c. Use bench power supply to supply power for the circuit. d. Upload the program into the microcontroller using Pickit 3. e. Observe the LED to see if it blinks. **Expected Results**: The number of I/O pins are larger than 31 and the LED blinks.	6
2. Microcontroller can successfully distinguish high digital value from low digital value. If the input voltage is between 0 ~ 0.2 V, the microcontroller should consider input as low. If the input voltage is above 3 V, the microcontroller should consider the input as high.	**Equipment**: Pickit 3, breadboard, wire, LED, bench power supply. **Procedure**: a. Use bench power supply to supply power for the circuit. b. Connect one LED to one of the I/O pins. c. Connect the bench power supply to one of the I/O pins as input. d. Write a program that will turn on the LED if the input value is high. e. Upload the program into the microcontroller using Pickit 3. f. Observe the LED as we change the input voltage from 0V to 5V. **Expected Results**: The LED should be off at first. Then the LED should be on when the voltage is higher than 3V.	5

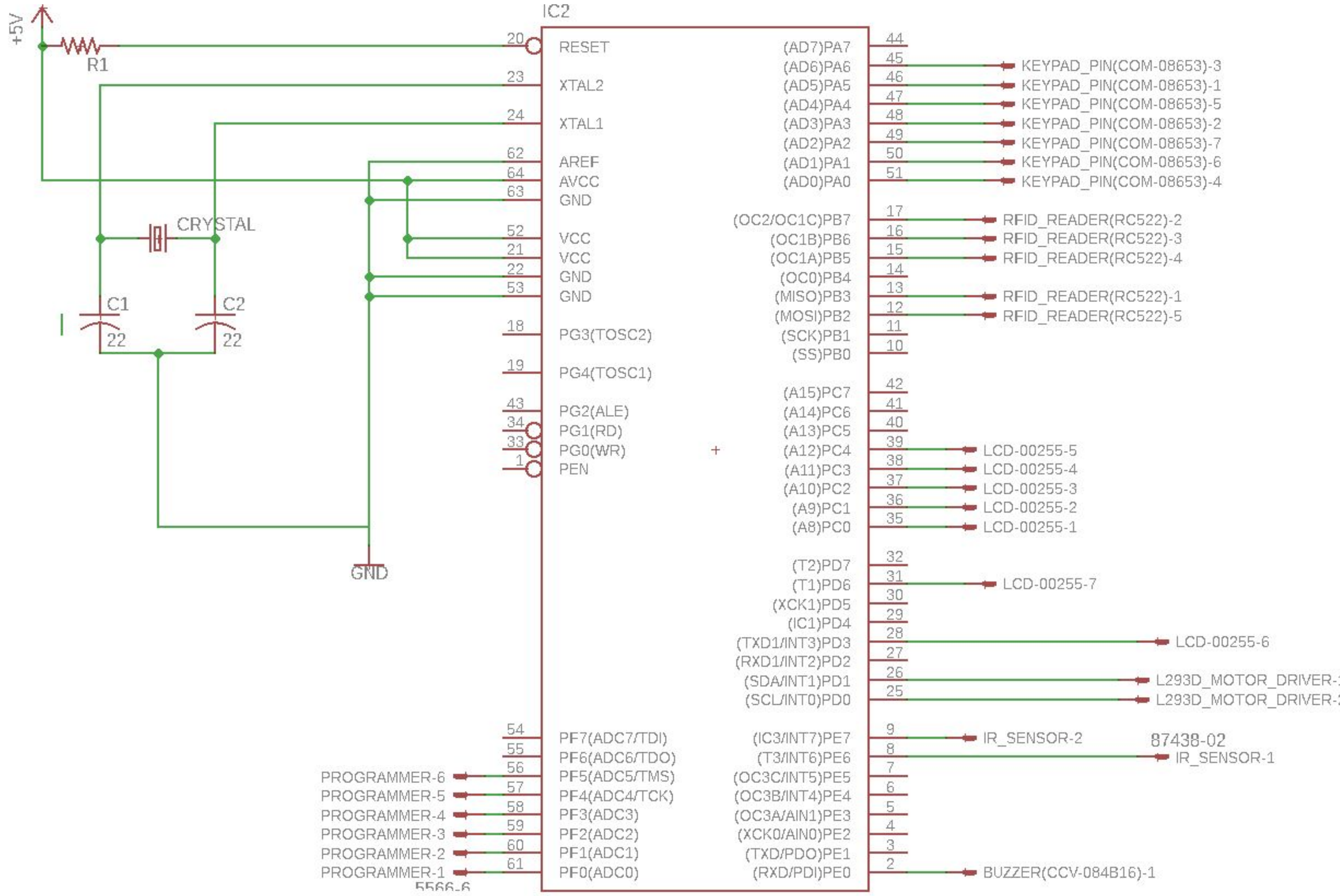

Figure 6. Circuit diagram for microcontroller

2.3 I/O

2.3.1 PIN pad

The PIN pad will be used to read inputs from user. The user can choose the action (return or borrow) for the machine. Also, it can allow the users to type their UIN to borrow the ball if he or she doesn't bring the ID card. The circuit schematic is drawn according to its datasheet [6].

Requirement	Verification	Points
1. All 12 input keys can generate different signals.	**Equipment**: Multimeter, breadboard, wire, bench power supply **Procedure**: a. Connect the keypad to breadboard. b. Use bench power supply to supply power for the circuit. c. Connect all the output pins to breadboard. d. Connect multimeter to each output pin. e. Press each button and record the output of each pin.	10

	f. Check whether all 12 presses lead to different output. **Expected Results**: All 12 keys lead to different records.	

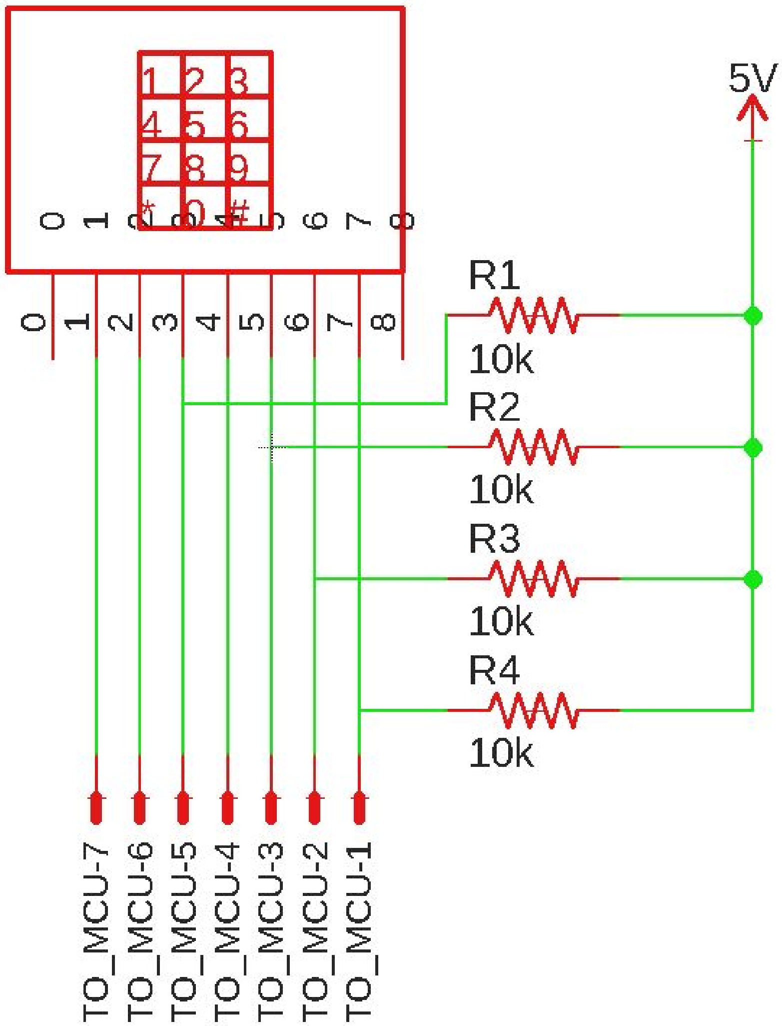

Figure 7. Pin pad circuit

2.3.2 LCD

The LCD screen will be used to display the remaining number of golf balls inside the machine. Also, it will give instructions to the user.

The LCD circuit is drawn according to the AVR sample circuit provided by sparkfun [7].

Requirement	Verification	Points
1. Can display all 26 letters and number from 0 to 9.	**Equipment**: Microcontroller **Procedure**:	12

	a. Connect LCD per circuit diagram of the MCU. b. Use print function to print char/string. c. verify if the LCD can display those char/string correctly. **Expected Results**: The LCD can display those char/string correctly.	

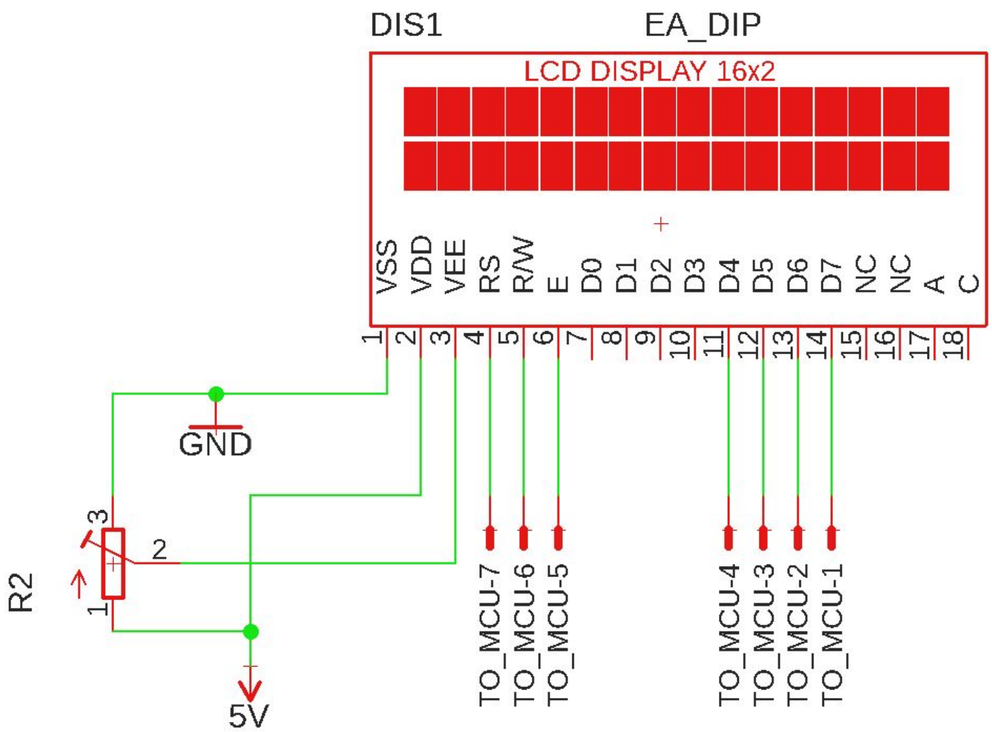

Figure 8. LCD Circuit

2.4 Sensors

2.4.1 IR sensors

There will be two return IR sensors and a borrow sensor. These sensors will be used to meet the third high-level requirement. Since the golf ball must have a diameter between 42.34 mm and 42.94 mm., we decide to place one IR sensor at 42.34 mm. The other return IR sensor will be placed at 10 mm above the tunnel. If the sensor at the lower height detects the ball but the sensor at higher height does not, it means the ball's diameter does not meet the requirement. As a result, the alarm will be turned on. Also, we will put one IR sensor at the exit of the machine to monitor the size of the ball coming out to make sure the thing is golf ball.

We decide to use QRE1113 IR sensors and its circuit schematic is drawn according to its datasheet [8] Since the expected diameter of a golf ball is between 42.34 mm and 42.94 mm, our tunnel should not have diameter that is significantly larger than 42.94 mm + 3.6 mm (the height of QRE1113 IR sensor) = 46.54 mm. As a result, we expect the signal read due to a golf ball (3.6 mm away from the sensor) is different from signal read due to the wall of tunnel (46.54 mm away from the sensor).

Requirement	Verification	Points
1. When there is a ball in front of the IR sensor, the signal generated by IR sensor should be different from the signal generated when there is nothing in front of the sensor.	**Equipment**:Multimeter, breadboard, wire, bench power supply **Procedure**: a. Connect IR sensors to breadboard. b. Use bench power supply to power the circuit. c. Use multimeter to measure the output of the IR sensor when there is an obstacle 47 mm away from the sensor. Then record the read of multimeter. d. Place a golf ball 3 mm away from the sensor. e. Use multimeter to measure the output of the IR sensor. f. Compare the output generated in two different situations. **Expected Results**: The signals generated in two different situations are different as well.	10

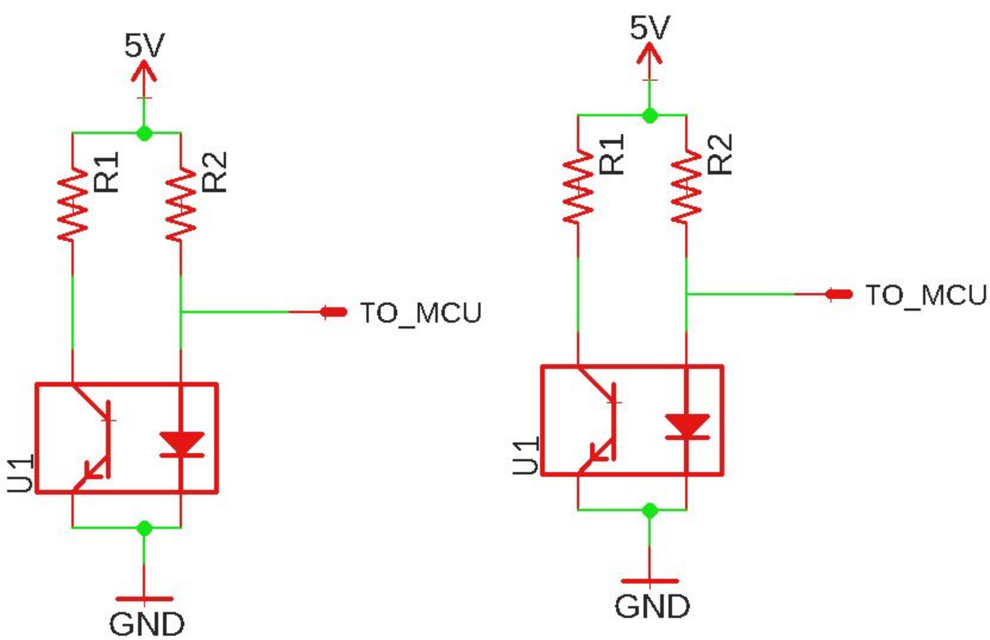

Figure 9. IR sensors circuit

2.4.2 RFID Reader

The RFID reader will be used to determine if a user can borrow a ball. If the user does not have a correct ID, the machine will not rent a ball. We decide to use RC522 as our RFID reader. The circuit schematic is drawn according to its datasheet [9].

Requirement	Verification	Points
1. Can read RFID tags	**Equipment**: Breadboard, wire, bench power supply, LCD, microcontroller **Procedure**: a. Connect RFID reader to breadboard. b. Use bench power supply to power the circuit. c. Put the RFID tag 30mm in front of the RFID reader. d. Check that whether LCD screen shows the ID number in the tag. **Expected Results**: When we put RFID tags 30mm in front of the reader, the LCD screen shows corresponding student ID numbers.	12
2. Different RFID tags will generate different signals	**Equipment**: Breadboard, wire, bench power supply, LCD, microcontroller **Procedure**: a. Connect RFID reader to breadboard. b. Use bench power supply to power the circuit. c. Put one RFID tag 30mm in front of the RFID reader. d. Put different RFID tags and other tags 30mm in front of the RFID reader. e. Check whether LCD screen shows different student ID numbers and whether LCD shows the ID number when we use other tags. **Expected Results**: Different ID numbers appeared on the LCD screen when different RFID tags shown in front of the reader. When we put other tags in front of the reader, nothing shown on the LCD screen.	7

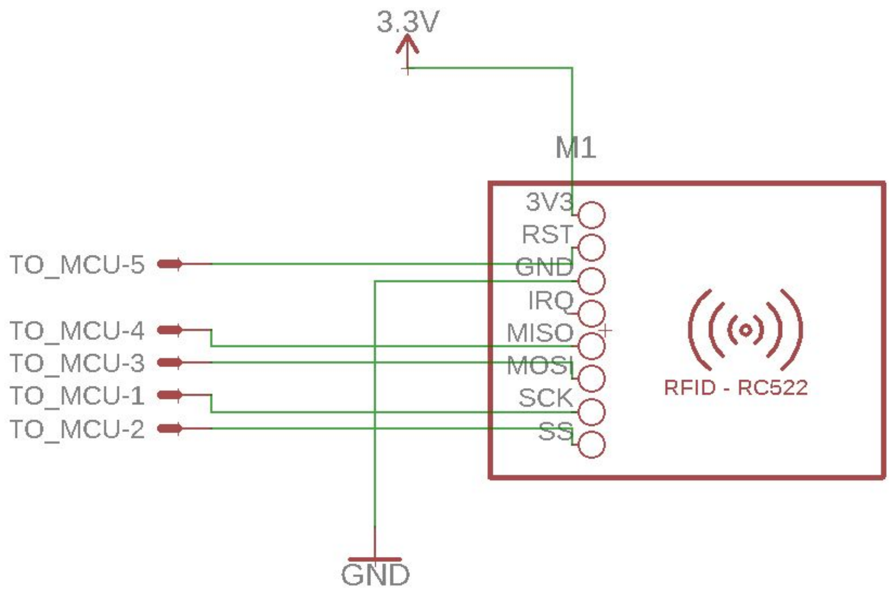

Figure 10. RFID reader circuit

2.5 Actuators

2.5.1 Motor

The motor will be used to rotate a machine part which can let one golf ball come out one time. It will be controlled by the microcontroller.

Requirement	Verification	Points
1. The motor has enough power to rotate the rotator to let the golf ball come out.	**Equipment**: Breadboard, wire, bench power supply, microcontroller, oscilloscope **Procedure**: a. Connect the motor to breadboard with the rotator. b. Use bench power supply to power the circuit. c. Connect GND to wire end of the wire-to-BNC cable. d. Connect the output to the other wire end of the wire-to-BNC cable. e. Connect the BNC end of wire-of-BNC cable to oscilloscope. f. Check that whether the rotator can be rotated to certain degree to let the ball out. g. Measure the output voltage of the motor **Expected Results**: The rotator can be rotated to a certain degree by the motor to let the ball out and the output voltage falls into the range from 11.5V to 12.5V.	10

2.5.2 Alarm

The alarm will be turned on if the size of the returned item or the item that will come out of the machine detected by IR sensors does not meet the first and second high-level requirement.

Requirement	Verification	Points
1. The alarm can make the sound loud enough to let people hear.	**Equipment**: Breadboard, wire, bench power supply, microcontroller, decibel meter **Procedure**: a. Connect the alarm to the breadboard. b. Use bench power supply to power the circuit. c. Check that whether we can hear the sound clearly. d. Use decibel meter to measure the loudness of the alarm **Expected Results**: We can hear the sound clearly even if we are 10m away from the alarm.	5

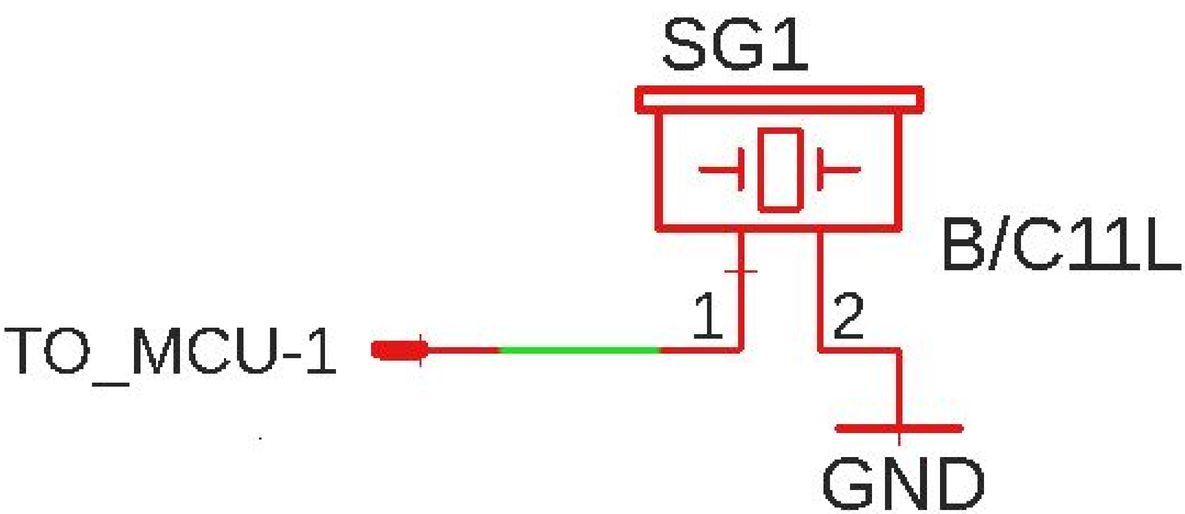

Figure 11. Buzzer circuit

2.6 Others

2.6 1 Motor driver

The motor driver will be used to control the motor. We decide to use L293D as our motor driver and its circuit schematic is drawn according to its datasheet [10]

Requirement	Verification	Points
1. The motor driver can control the motor and provide output current	**Equipment**: Breadboard, wire, bench power supply, microcontroller, ampere meter **Procedure**:	7

300mA.	a. Connect the motor driver to the breadboard with the motor. b. Use bench power supply to power the circuit. h. Use ampere meter to measure the output current from motor driver. **Expected Results**: The ampere meter should show the current is in the range from 290mA to 310mA.	

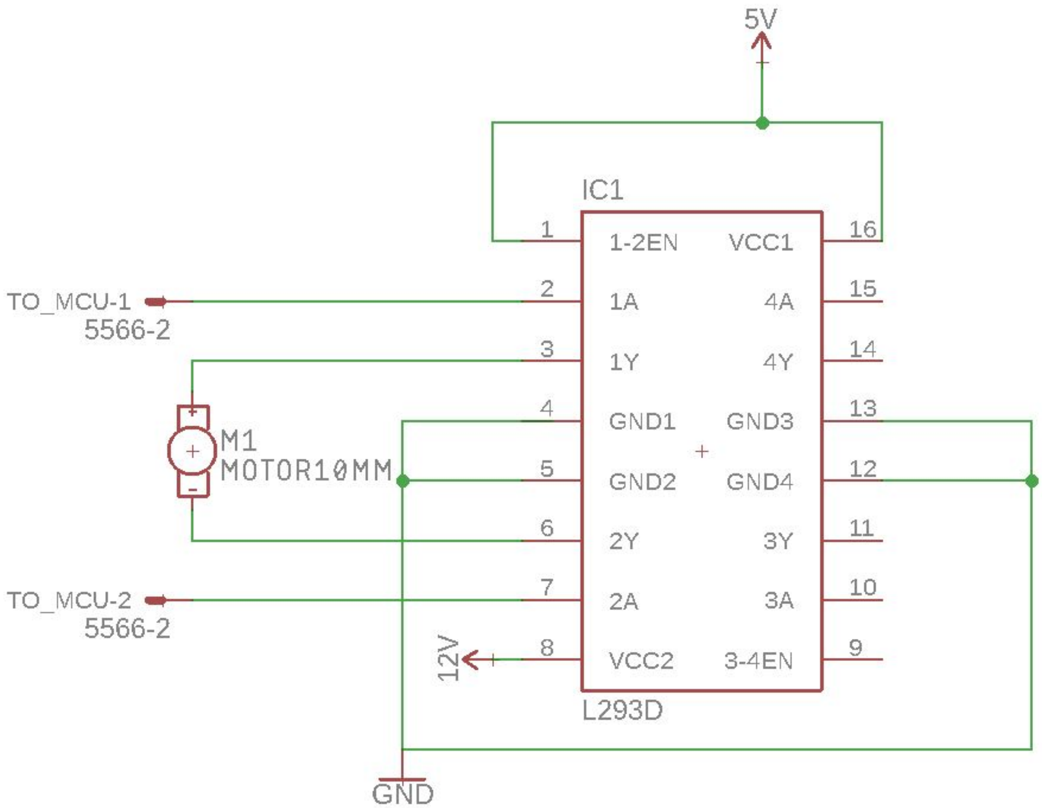

Figure 12. Motor and Motor driver circuit

2.7 Software Design

After starting the machine, the system will ask whether to return or to borrow a ball. If the user decides to borrow a ball, the system will check if there is any ball remaining inside the machine. If not, the system will stops renting. Otherwise, the system will ask the user to choose the method (RFID or type ID using keypad) to borrow the ball. After choosing the method, the system will read the ID and check if the ID is correct. If the ID is correct, the ball will be rented. If the user decides to return the ball, they will also choose the method to return the ball. Then the system will check if the ID is correct. If the ID is correct, it will allow the user to return the ball. After the ball is returned, the system will check the size of the ball. If the size does not match, the alarm will be turned on.

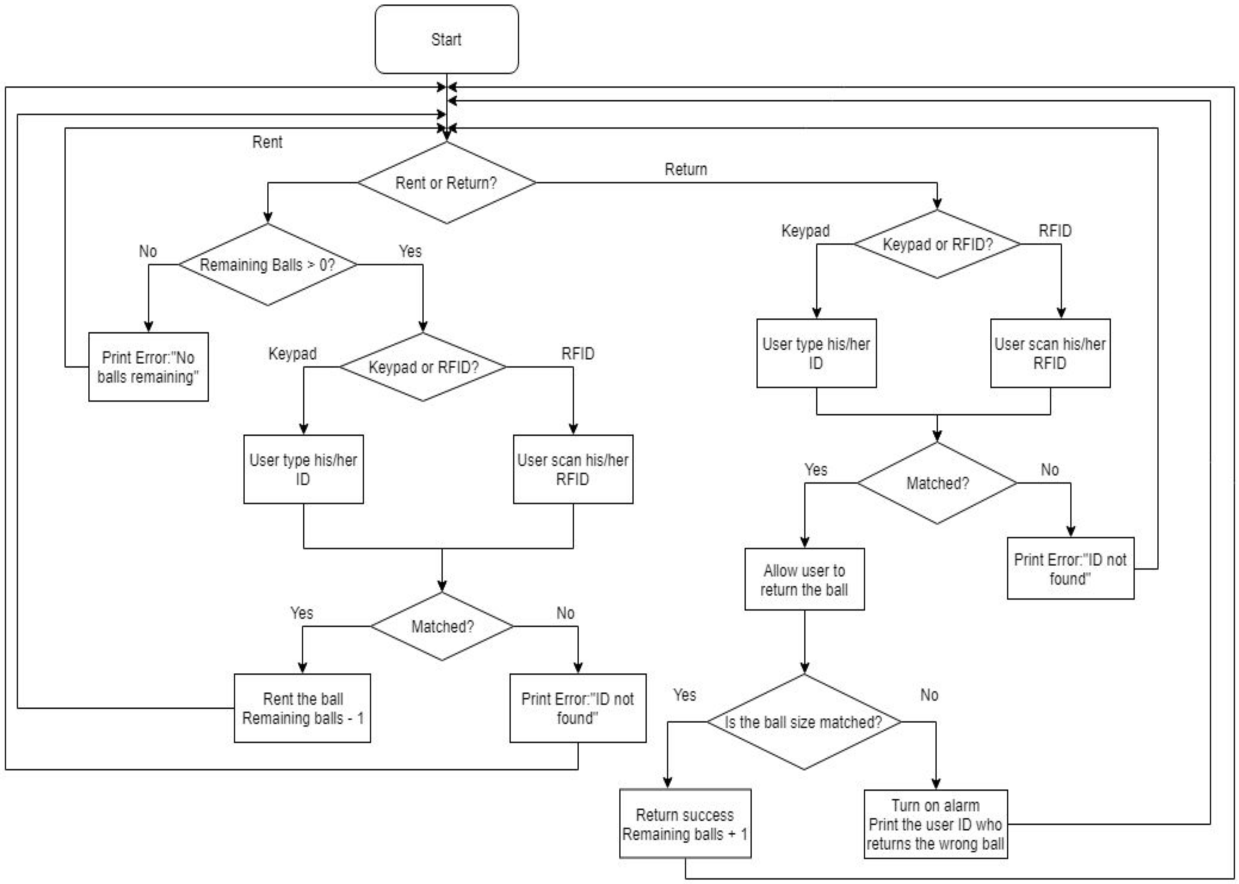

Figure 13. Software Flowchart

2.8 Tolerance analysis

The most important tolerance in our electrical design is the power supply. In the whole design, we have three different voltages feeding into various components. To maintain correct functionality of the overall build, we first need a powerful enough AC/DC converted that can provide enough current for all sensors, I/O devices, microcontroller and motor. Then we have to build 3 stable voltage regulator circuit to minimize ripples in power supply. Since the motor requires current around 300 mA, we decide to use AC/DC adapter that provide current higher than 1 A. The motor will be driven by current around 300 mA, so the remaining components can use current below 700 mA. The wall adapter can provide output current 1A. Since the motor needs 300mA and 5V regulator needs 500mA, then we need to add a resistor that has

$$1000\text{-}300\text{-}500=200\text{mA}$$

to pass through. The resistor should be

$$R=\frac{12V}{0.2A}=60\Omega$$

which is parallel to motor and 5V regulator.

3. Costs and Schedule

3.1.1 Labor and Cost

Labor:

The design and implementation cost of each person in our three people group is estimated to be \$30/hour, 10 hours/week. We have around 8 total weeks to finish this project. Thus the total development labor cost is:

$$3 \cdot \frac{\$30}{hour} \cdot \frac{10\ hours}{week} \cdot 8\ weeks\ =\ \$7,200$$

Cost table:

Components	Quantity	Total Price
RC522 RFID Reader	1	\$7.98
COM-08653 ROHS Keypad	1	\$3.95
LCD-00255 LCD screen	1	\$13.95
L293D motor driver	1	\$7.99
COM-13940 ROHS Alarm	1	\$2.95
PCBs (PCBway)	1	\$3.10
ATMega128 Microcontroller	1	\$11.50
Motor	1	\$39.95
QRE1113 IR sensors	3	\$5.85
Container (Machine shop)	1	
LD1117V33 Voltage regulator	1	\$1.95
L7805 Voltage Regulator	1	\$0.95
12V DC adapter	1	\$5.95
16 MHz crystal	1	\$0.95
1206 SMD Resistor Kit	1	\$7.99
SMD Aluminum Electrolytic Capacitors Assortment Kit	1	\$11.99
Total		**\$126.55**

Total Cost = Labor + components costs = \$7200 + \$126.55= \$7326.55

3.1.2. Schedule

Week (Mondays)	**Events/Turn-in**	**Jingyang Liu**	**Qihao Wang**	**Yang Xiao**
2/26	**Design Review**	Finalize physical design	Start writing software framework	Ordering electrical components
3/5		first version PCB design	Verify LCD works with MCU	Test and verify sensors functionality
3/12	**1st Round PCB**	Finalize first version PCB design	Write program to read value from keypad	Verify the functionality of keypad and connect it to MCU
3/19	**Spring Break**			
3/26	**Final Round PCB**	PCB version 2	Write program to get input from RFID reader	Verify the functionality of RFID reader and connect it to MCU
4/2		Verify PCB circuits	Write program to get input value from IR sensors.	Testing power supply circuits
4/9		Verify the physical design and place sensors and actuators on the machine.	Write program to communicate with user to get user input from keypad and RFID.	Test and verify the functionality of alarm and connect it to MCU.
4/16	**Mock demo**	Verify the functionalities of motor and motor driver, and connect them to MCU.	Write program to check the size of golf balls.	Write program to control motor and alarm.
4/23		Test the functionality of	Debug the software code for edge cases.	Test all the functionalities

		the machine part of the project.		related to power supply and hardware.
4/30	**Final**	Summarize the details related to PCB and machine part of the project. Write the final report.	Summarize the software functionalities of the project. Write the final report.	Summarize the process and functionalities of circuit and power supply. Write the final report.

4 Ethics and Safety

Since our machine is an automated system, the main safety concern when using the machine are the moving parts. People's hands or clothing could get stuck in the machine if people try to access the inside of the machine. In our design, we keep the moving parts of the project to the minimum, only one motor should be used and we will build in safety protocols based on the sensors in the machine to uphold the IEEE Code of Ethics, #1: "to hold paramount the safety, health, and welfare of the public…" [11].

When working with power supply units, and other electronics, components could carry an excessive amount of current which may lead to harmful situation. When working inside the lab, it is critical to follow the safety guideline and remember the lab safety training.

According to IEEE Code of Ethics #8, our product will target on all users and "treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression" [11].

During the process of making the project, we may collect wrong data or some unexpected results. We will not make up data or results on our reports. We will follow IEEE ethics that we will treat wrong data and results honestly [11]. We will honestly report the actual data and analyze which part we do wrong. Then, we will correct errors.

Since our project has many electric parts, it is possible to have some risks of exploding if we did some steps wrong. So, when we do electrical parts, we will make sure no other people around to ensure we don't injure other people. We also follow the safety guidelines, for example, never let current to excess safety current limits [12], when dealing with any electrical component to prevent risks. If we need to handle the high voltage, we will report our action and complete additional training.

We will treat our project professionally and strive to make higher quality of our product. This is to not only improve the quality of our project, but also make sure we are safe when making the project.

We promise that we will not do the project individually in the lab. We will always make sure at least two people deal with the project at lab.

5 References

[1] Wikipedia, '*Vending machine*', 2018. [Online]. Available: https://en.wikipedia.org/wiki/Vending_machine. [Accessed: 13-Feb-2018].

[2] Statista, '*Golf-Statistics & Facts*', 2018. [Online]. Available: https://www.statista.com/topics/1672/golf/. [Accessed: 15-Feb-2018].

[3] Sports tutor, *'TENNIS CUBE'*, 2018. [Online]. Available: http://sportstutor.com/tennis-cube/. [Accessed: 25-Feb-2018].

[4] Wikipedia, '*68–95–99.7 rule*', 2018. [Online]. Available: https://en.wikipedia.org/wiki/68%E2%80%9395%E2%80%9399.7_rule. [Accessed: 15-Feb-2018].

[5] Microchip.com, *'ATmega32 Datasheet'*, 2011. [Online]. Available: http://ww1.microchip.com/downloads/en/DeviceDoc/doc2503.pdf. [Accessed: 21-Feb-2018].

[6] Sparkfun.com, *'COM-08653'*, 2011. [Online]. Available: https://cdn.sparkfun.com/datasheets/Components/General/SparkfunCOM-08653_Datasheet.pdf. [Accessed: 18-Feb-2018].

[7] Hispeed.ch, *'Interfacing a HD44780 Based LCD to an AVR'*, 2003. [Online]. Available: http://homepage.hispeed.ch/peterfleury/avr-lcd44780.html. [Accessed: 21-Feb-2018].

[8] Sparkfun.com, *'QRE1113 Datasheet'*, 2009. [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/QRE1113-Digital-Breakout-v11.pdf. [Accessed: 21-Feb-2018].

[9] Elecrow.com, *'MFRC522'*, 2007. [Online]. Available: https://www.elecrow.com/download/MFRC522%20Datasheet.pdf. [Accessed: 21-Feb-2018].

[10] Texas Instruments, *'L293x Quadruple Half-H Drivers'*, 2016. [Online]. Available: http://www.ti.com/lit/ds/symlink/l293.pdf. [Accessed: 21-Feb-2018].

[11] Ieee.org, *'IEEE Code of Ethics'*, 2018. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 15-Feb-2018].

[12] Illinois.edu, *'SAFETY'*, 2018. [Online]. Available: https://courses.engr.illinois.edu/ece445/guidelines/safety.asp. [Accessed:15-Feb-2018].