100^{th} Year Anniversary Token

Evan Liang Song Xun (2A205)
Ivan Tan Zheng Jie (2A208)
Ong Eugene (2A226)

ABSTRACT

Every year, Hwa Chong invites many guests for corporate or special events. Each guest receives a token of appreciation from the school. However, many of the same tokens of appreciation are being given out each year. Over time, the tokens may seem dull and no longer special for the guest receiving the token. As such, there is a need for a new, unique and meaningful token, especially since it is Hwa Chong's 100th Year Anniversary next year. We will be designing and producing a Hwa Chong Drawer Chest for 1 Guest-Of-Honour visiting our school next year. Through the use of engineering science concepts such as 3D-Printing and Arduino Programming, the Hwa Chong Drawer Chest is equipped with 4 drawers to hold items, a pen compartment and motorised doors with well-wishes for Hwa Chong's 100th Year Anniversary concealed behind. As we progressed through the development of the drawer chest, we found out that decreasing the pen compartment's width but increasing the overall length would not only reduce the huge width of the drawer chest but also increase the amount of space in each of the drawers. We also changed the Arduino programming and circuitry to allow for simply 1 switch to control both the power of the Arduino as well as the motors. While this token is not meant to be mass produced and is only for 1 guest, its simple design allows it to have an option of mass production.

INTRODUCTION

In a span of only 636 days, between 19 May 2016 – 13 Feb 2018, around 1,483 tokens of appreciation were given out. Out of this huge number of corporate gifts being presented, there were 518 notebooks, 437 executive pens and 320 thumb drives *(data from High School Admin Office).* As so many of the same tokens of appreciation are being given out, the probability of the guest receiving the same token of appreciation multiple times is high. Even more so, as next year is Hwa Chong's 100th Year Anniversary, there will be tons of events which require a guest to be present, thus drastically increasing the chances of a guest receiving the same token consecutive times. With so many of the same tokens of appreciation being presented each year, the tokens would seem boring for the guests and they might have the impression that Hwa Chong is insincere since the school did not bother to purchase or design new and unique tokens.

As such, we planned to design and create a new, unique and interesting token for 1 Guest-Of-Honour during Hwa Chong's 100th Year Anniversary. We plan to 3D print components of the token using the free 3D modelling software Autodesk Fusion 360. We also plan to use Arduino programming to enhance and add more value to the token of appreciation, so that it is both useful and meaningful while ensuring it is feasible by keeping the cost of production low. We also wanted the token to be able to be used even without the Arduino function being turned on, and for the token to be handmade to show our sincerity.

We had gone through multiple ideas, including an improved version of the current executive pen being given out, and a tissue box holder. As the pen will probably be too small to incorporate Arduino programming and the tissue box holder will be too bulky to be used as a token of appreciation, we eventually settled on the final idea, which was the Hwa Chong Drawer Chest.

SOLUTION DESIGN

We will be designing and fabricating a Hwa Chong Drawer Chest for a Guest-Of-Honour during Hwa Chong's 100th Year Anniversary next year.

Our token will be modelled to resemble Hwa Chong's clocktower. It will include the following features: 4 drawers, 1 stationary container at the front and 2 pairs of motorised doors *(See Figure 1A)*.

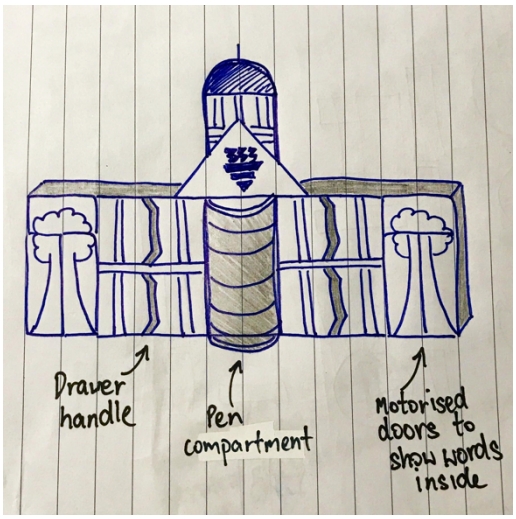

Figure 1A

Our design will incorporate 3D-Printing to create the components of the HC Drawer Chest and Arduino programming to allow motorised doors to swing open when a switch is turned on, revealing our well-wishes for Hwa Chong's 100th Year Anniversary.

The final product will be 22 cm by 14 cm by 12 cm (in width, length and height respectively). Each of the drawers will be 7 cm wide and 13 cm long, each side component (doors and motors) will add up to be 2 cm in width and the clocktower will be 8 cm in width and height[A1].

We will be using the free 3D modelling software called Autodesk Fusion 360 to design the components of our prototypes and of the final product. The drawers, which are going to be 3D printed, will be designed to slide on runners while entering and exiting the main body of the token (similar to metal ball bearings at the sides of some drawers). The runners will be attached on the main body and they will also be 3D printed.

We wanted the Arduino to be programmed in such a way that when a switch is turned on, the Arduino sends a signal to the motors to spin, which in turn rotates the gears connected to it, which causes the doors to swing open. After a short pause, the motor will spin in the opposite direction, causing the doors to close[A2]. Hence, the function works as follows.

In the code[A3], the Arduino sends a current to Pin 1 of the H-Bridge[A4] when the Arduino was switched on using the on-off switch. The Arduino then sends current to Pin 2 of the H-Bridge. The current will flow through the motor in one direction, causing it to spin in that direction for a certain amount of time. To stop the motor, the Arduino stops sending the current to both of the pins for a certain amount of time. The Arduino would then send a current to Pin 7 of the H-Bridge. The current will travel in the other direction and the motor would spin in the other direction for a certain amount of time.

Therefore, the circuit which runs the motor will consist of a H-Bridge L293D[A5], an Arduino Uno R3 *(see Figure 2A)*, an on/off switch, a 9V battery and 2 DC motors. The switch will turn the Arduino on which will send a current to the H-Bridge. The H-Bridge will in turn direct a current towards the motors, depending on the direction of the pin the current was sent to. The motor would then spin in the same direction as the current. The 9V battery will supply the power to both the Arduino and the motor.

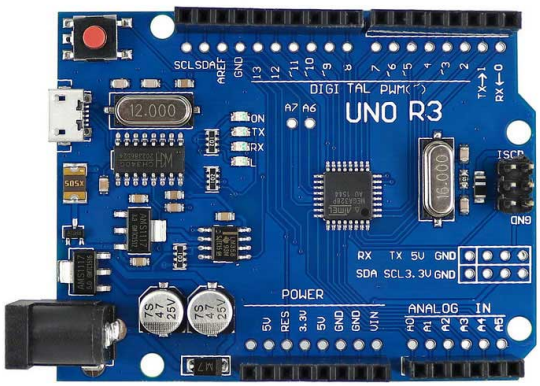

Figure 2A[5]

We will go about testing our solution design by progressing through multiple prototypes and assembling the components several times. Firstly, we plan to create a drawer prototype with runners to evaluate the feasibility and reliability of using runners. Secondly, after successfully programming the Arduino to make the motors spin on demand and for a specific period of time, we will print a thin version of the main body and attempt to insert the circuit and wires into it to see if our circuit is small enough to fit into the final product. Thirdly, after printing all the necessary components for the model that we are presenting during Final Evaluation, we will assemble them together using 3M Double Sided Tape and include the working circuit, motors and wires into the main body. Lastly, after Final Evaluation, we will deliberate the pros and cons of the current model to make our last enhancements before making the actual final product.

The estimated cost of production for 1 HC Drawer Chest is around $45, as shown below:

Object(s)	**Price of Object(s)**
Arduino Uno Board x 1	$6
Motor x 2	$2.75 x 2 = $5.50
Copper Plate x 1	$1
H-Bridge x 1	$5.16
Slide Switch x 1	$1
Wires (All)	$0.50
3D Printing + Materials	$25 (approximately)
Total Price:	$44.16

RESULTS & DISCUSSION

Drawer Prototype

The first prototype that we made based on our solution design was the drawer and runner model[A6]. We designed a hollow container, with runners at its sides, to have the same length as the drawer but for its width and height to be longer than the drawer's by 1 mm. However, despite providing some leeway for the drawer to fit into the runner model and also doing continuous filing on the runners after the runner model was printed, the drawer could only barely squeeze into the runner model. We realised that we had to resize the runners and we were later enlightened that the space that we had provided was insufficient as there had to be room for possible expansion of the 3D printed material immediately after printing. Therefore, in the end, we had to change the dimensions of the runner model by making its width, length and height at least 2 mm longer than that of the drawer before we could insert the drawer into the runner model smoothly.

Motors and Gears

Our original plan was to use 4 motors, each directly attached to 1 door, which when spinning will cause the doors to swing open. However, we felt that this would increase the overall size, weight and cost of the HC Drawer Chest, which was not ideal as the drawer would then be too bulky and more expensive. Hence, we came up with the idea of a gear system, where only 1 motor will be used for each pair of doors. The motor head, which is attached to a gear, will spin, which rotates another gear and so on until it moves the gears connected to the doors, causing them to swing open. We designed a 4-Teeth Gear and an 8-Teeth Gear[A7], and as the 8-Teeth Gear proved to have more contact and was more reliable, we used it while designing the doors with gears attached to them.

Unfortunately, when we put the gears in place and tested the opening of the doors, we realised that even though the gears turned fast, it did not have enough strength to push and move the doors, as the 3D printed doors were relatively heavy. Thus, we decided to use 4 gearboxes[A8] instead, one for each door, which reduced the rotation speed of the door but it gave the motors more torque and allowed the doors to swing open more smoothly. We did

this for our model presented during Final Evaluation, but because the addition of 4 gearboxes lead to the overall width of the product becoming 26 cm, we have already made plans either to reduce the total number of gearboxes from 4 to 2, or to return to our original plan of directly connecting the motors to the doors, so as to reduce the width of the drawer from 26 cm to 22 cm.

Arduino

The code that we used in the Arduino was adapted from "Project 10 (Zoetrope)" of the Arduino Projects Book[A9]. We discovered a vital part of the code that was sending a current to the H-Bridge through the pins.

One problem we faced was that when we removed everything except the essentials, the motors would not spin. We then realised that the analogWrite value actually used a value in a variable, and since the variable's value was no longer declared, the value was 0. Therefore, we had to manually input the value of the current sent in the code. This allowed us to easily control the speed of the motors.

Another problem that we faced was that two batteries were needed, 1 to supply power for the motors and the other for the Arduino. If we did not have an additional switch or button to turn on/off the battery supply, it will result in major battery wastage. However, we already had a switch that was meant to control the motors to spin, and 2 switches would be troublesome for the user. Therefore, as we needed 1 switch to turn the Arduino on and to get the motor to spin, we changed the code in such a way[A10] that when the Arduino was turned on, it would immediately send a current to the motors, removing the need for a second switch. We then went on to solve the battery wastage problem by connecting 1 battery to both the wires of the Arduino's power jack and to the H-Bridge that controlled the motors, thus reducing the number of required batteries to only 1.

We also added the delay() function in order to allow the motor to spin for a certain amount of time, which would be just enough for the doors to swing open 90 degrees.

We then removed the unnecessary parts from the circuit[A11], such as the buttons, the potentiometer and the pins connected to them.

CONCLUSION

We have successfully designed and fabricated an operational token of appreciation with various improvements made in several aspects. Our product has achieved our idea of a novel and meaningful gift that is based on a Hwa Chong reference, which further includes engineering science concepts such as Arduino programming and 3D printing. The dread of receiving the same token for consecutive times has been minimised by the creative touch on the facade of the drawer.

Our project has also managed to successfully achieve the Arduino function as planned. We have managed to get the doors to spin forwards and backwards when a switch is turned on, and for the doors to swing and stay open an amount of time that we can control. We can also control the speed of the motor such that it could spin at the speed we wanted, in order to make opening of the doors faster or slower in order to achieve a certain effect.

However, the way we had planned to transfer the power from the motor to the doors to swing open was flawed. We did not manage to get our 3D printed gears to work the way we had wanted, and had to resort to pre-made gearboxes (for Final Evaluation only).

While we had made many improvements to increase the convenience of using the Arduino function (such as using just 1 switch and 1 battery), there are still many improvements that we can make. For one, it may be worthwhile to consider the necessity of the gearboxes. We can cut down significantly on the exorbitant cost of production of the entire product by just using motors instead of gearboxes, as they are unnecessary since the motors have enough torque to move the doors if directly attached together. Stoppers can be added at the walls at the sides of the doors or on the doors themselves to prevent the doors from spinning past 90 degrees. In addition, while we were able to keep the width of the drawer smaller than 30 cm, it would be better if we could achieve our initial target of 22 cm through the use of smaller motors. This would make the drawer chest more compact and practical for one's everyday use.

In summary, while this token is not meant to be mass produced due to the high cost of production and the intention of it being unique, its simple design provides an option of mass production (3D components). Nonetheless, the Arduino requires soldering and programming, which requires manpower, and mass production of this token might reduce its sentimental value and its meaningfulness, which will only create another common and seemingly boring token of appreciation. Therefore, the choice of mass production needs to be well-deliberated.

REFERENCES

[1] *ARDUINO - HOME*
(Arduino.cc, 2018)
Arduino.cc. (2018). Arduino - Home. [online]
Available at: https://www.arduino.cc/ [Accessed 14 Aug. 2018].

[2] BOOK, FITZGERALD, S., SHILOH, M. AND IGOE, T.
Arduino Projects Book
(Book et al., 2018)
Book, Fitzgerald, S., Shiloh, M. and Igoe, T. (2018). Arduino Projects Book. [online] Goodreads.com.
Available at: https://www.goodreads.com/book/show/17935843-arduino-projects-book [Accessed 16 Aug. 2018].

[3] *CLOUD POWERED 3D CAD/CAM SOFTWARE FOR PRODUCT DESIGN | FUSION 360*
(Autodesk.com, 2018)
Autodesk.com. (2018). Cloud Powered 3D CAD/CAM Software for Product Design | Fusion 360. [online]
Available at: https://www.autodesk.com/products/fusion-360/overview [Accessed 14 Aug. 2018].

[4] *INDUSTRIES, A.*
DC Toy / Hobby Motor - 130 Size
(Industries, 2018)
Industries, A. (2018). DC Toy / Hobby Motor - 130 Size. [online] Adafruit.com.
Available at: https://www.adafruit.com/product/711 [Accessed 14 Aug. 2018].

[5] *L293D DUAL H-BRIDGE MOTOR DRIVER IC IN PAKISTAN - MICROSOLUTION LAHORE PAKISTAN*
(MicroSolution Lahore Pakistan, 2018)
MicroSolution Lahore Pakistan. (2018). L293D Dual H-Bridge Motor Driver IC IN PAKISTAN - MicroSolution Lahore Pakistan. [online]
Available at: http://www.microsolution.com.pk/product/l293d-dual-h-bridge-motor-driver-ic-pakistan/ [Accessed 16 Aug. 2018].

[6] *L293D MOTOR DRIVER*
(Instructables.com, 2018)
Instructables.com. (2018). L293D Motor Driver. [online]
Available at: https://www.instructables.com/id/L293D-Motor-Driver/ [Accessed 14 Aug. 2018].

[7] *MICRO USB ATMEGA328P DEVELOPMENT BOARD FOR ARDUINO UNO R3 - BLUE+BLACK*
(DX.com, 2018)
DX.com. (2018). Micro USB ATmega328P Development Board for Arduino UNO R3 -Blue+Black. [online] Available at: http://www.dx.com/p/micro-usb-socket-atmega328p-development-board-for-arduino-uno-r3-blue-black-370842#.W1wpR9UzbX5 [Accessed 14 Aug. 2018].

[8] *OTHERS, T.*
L293D - Rs. 75.00 : Probots - India's DIY Electronics and Robotics Superstore
(others, 2018)
others, T. (2018). L293D - Rs. 75.00 : Probots - India's DIY Electronics and Robotics Superstore. [online] Probots Techno Solutions.
Available at: https://probots.co.in/index.php?main_page=product_info&products_id=56 [Accessed 14 Aug. 2018].

[9] *VORTEX COMMERCE LTD, W.*
Push To Open - Touch Release - Ball Bearing Drawer Runners - Full Extension - 45kg Weight Limit - Zinc Plated
(Vortex Commerce Ltd, 2018)
Vortex Commerce Ltd, w. (2018). Push To Open - Touch Release - Ball Bearing Drawer Runners - Full Extension - 45kg Weight Limit - Zinc Plated. [online] G Johns & Sons Ltd.
Available at: https://www.gjohns.co.uk/push-to-open-touch-release-ball-bearing-drawer-runners-full-extension-front-disconnect-45kg-weight-limit-zinc-plated.html [Accessed 14 Aug. 2018].

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Our school mentor, Dr Kelvin Tan, for offering us invaluable insights and guidance along this journey. Regardless of any mistakes we made, you were extremely patient and answered the infinite queries that we had. You have been very supportive of us, and we thank you for that.

The SRC Lab staff, Mdm Chua and Mdm Foo, for bearing with our numerous 3D printing requests and supervising us in 3D printing and Arduino programming. Thank you for guiding us when we were learning how to fix the circuits. Your help has been vital in the making of the drawer chest.

Evan's cousin, for advising us on using gearboxes which were able to open the doors of the drawer chest smoothly, and taking the time of your busy schedule to coach us on the efficient methods of assembling the whole drawer chest together. Thank you as well, for assisting us in the 3D printing of some components as well as providing the necessary materials to needed to assemble the model together.

Last, but not least, a huge thank you to our friends and family members who had supported us during difficult times and provided countless constructive and important advice, without all of you, we would not have been able to make it this far.

APPENDIX

A1:

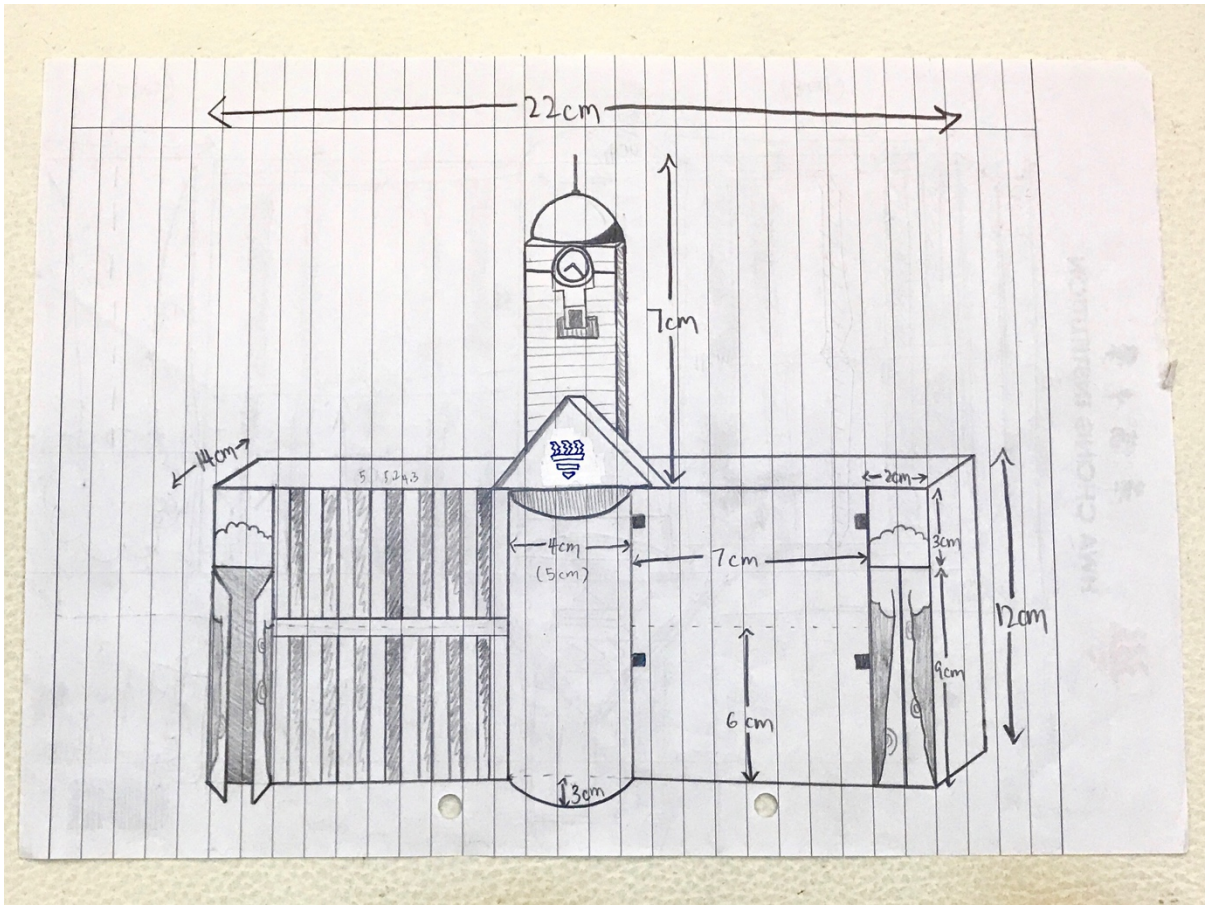

Figure 3A: Sketch of HC Drawer Chest with Dimensions

A2:

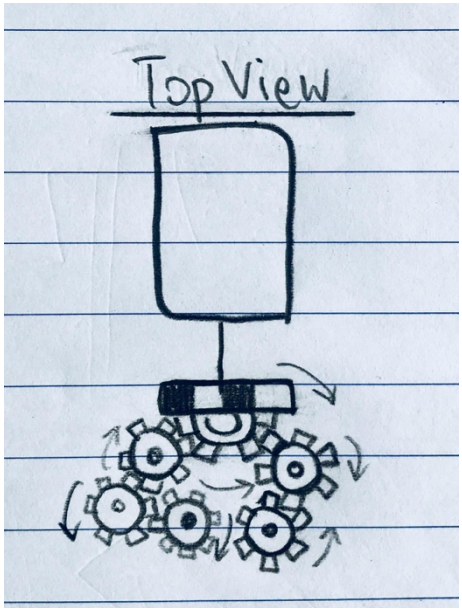

Figure 4A: Top View of Motor and Gears System

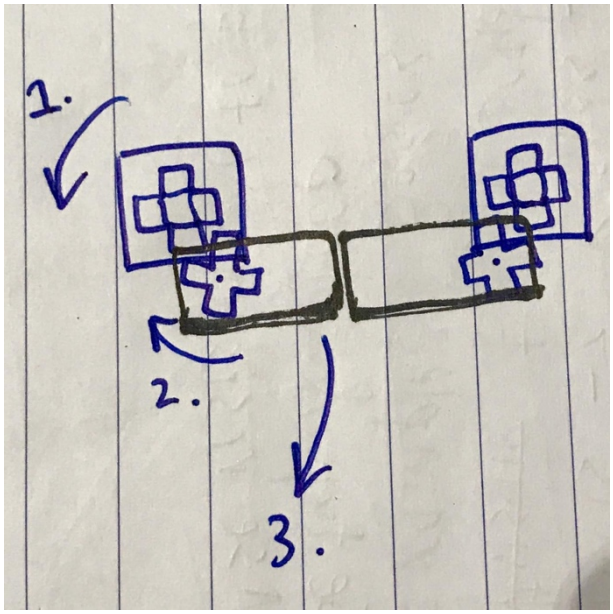

Figure 5A: Gears and Gears Attached to Doors

A3:

```
const int controlPin1 = 2;
const int controlPin2 = 3;
const int enablePin = 9;
const int directionSwitchPin = 4;
const int onOffSwitchStateSwitchPin =
const int potPin = A0;

int onOffSwitchState = 0;
int previousOnOffSwitchState = 0;
int directionSwitchState = 0 ;
int previousDirectionSwitchState = 0;

void setup() {
 pinMode(directionSwitchPin, INPUT);
 pinMode(onOffSwitchStateSwitchPin, I
 pinMode(controlPin1, OUTPUT);
 pinMode(controlPin2, OUTPUT);
 pinMode(enablePin, OUTPUT);
 analogWrite(enablePin,120);


  digitalWrite(controlPin1,HIGH);
  digitalWrite(controlPin2,LOW);
  delay(5000);
  digitalWrite(controlPin1,LOW);
  digitalWrite(enablePin,LOW);
  delay(5000);
  analogWrite(enablePin,120);
  delay(1);
  digitalWrite(controlPin1,LOW);
  digitalWrite(controlPin2,LOW);
  delay(1);
  digitalWrite(controlPin1,LOW);
  digitalWrite(controlPin2,HIGH);
  delay(5000);
  digitalWrite(enablePin,LOW);
}
void loop(){
}
```

Figure 6A: Our Arduino Code

A4:

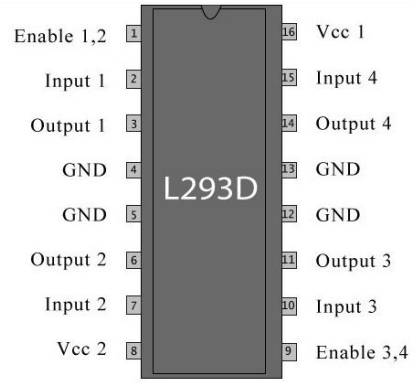

Figure 7A: Diagram of H-Bridge, specifically L293D[6]

A5:

Figure 8A: H-Bridge L293D[5]

A6:

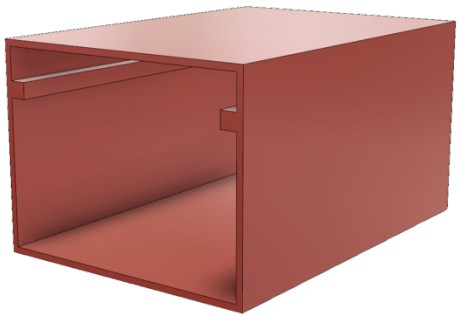

Figure 9A: Runner Model

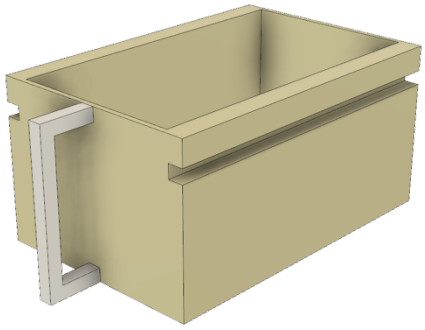

Figure 10A: Drawer Model

A7:

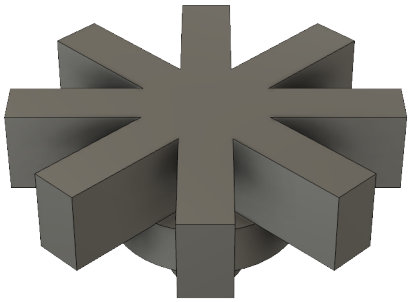

Figure 11A: 8-Teeth Gear Model

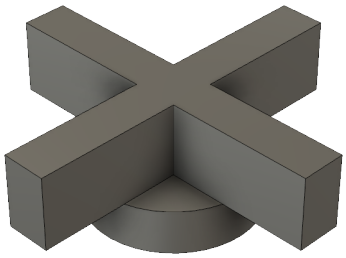

Figure 12A: 4-Teeth Gear Model

A8:

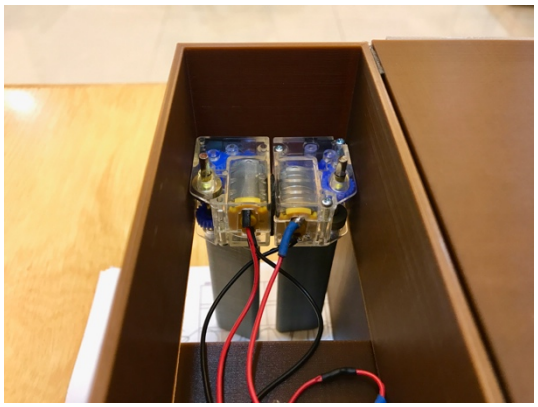

Figure 13A: Gear Box with Doors Closed

Figure 14A: Gear Box with Doors Opening

A9:

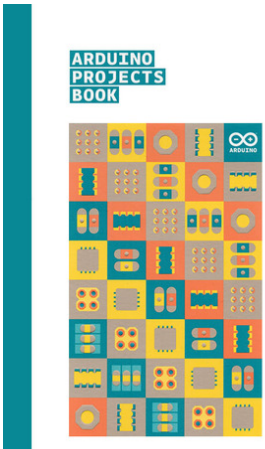

Figure 15A: Arduino Projects Book[2]

A10:

```
void setup() {
 pinMode(directionSwitchPin, INPUT);
 pinMode(onOffSwitchStateSwitchPin, INPUT);
 pinMode(controlPin1, OUTPUT);
 pinMode(controlPin2, OUTPUT);
 pinMode(enablePin, OUTPUT);
 digitalWrite(enablePin,LOW);

}
```

Figure 16A: Old Code Before Changes were Made

Code that controls the movement of motors was changed to be in the "setup" part instead of in the looping part of the code (which thus sends the current directly to the motors), and a "delay" function was added

```
void setup() {
 pinMode(directionSwitchPin, INPUT);
 pinMode(onOffSwitchStateSwitchPin, INPUT);
 pinMode(controlPin1, OUTPUT);
 pinMode(controlPin2, OUTPUT);
 pinMode(enablePin, OUTPUT);
 analogWrite(enablePin,120);

  digitalWrite(controlPin1,HIGH);
  digitalWrite(controlPin2,LOW);
  delay(5000);
  digitalWrite(controlPin1,LOW);
  digitalWrite(enablePin,LOW);
  delay(5000);
  analogWrite(enablePin,120);
  delay(1);
  digitalWrite(controlPin1,LOW);
  digitalWrite(controlPin2,LOW);
  delay(1);
  digitalWrite(controlPin1,LOW);
  digitalWrite(controlPin2,HIGH);
  delay(5000);
  digitalWrite(enablePin,LOW);
}
```

Figure 17A: Latest Code After Changes were Made

A11:

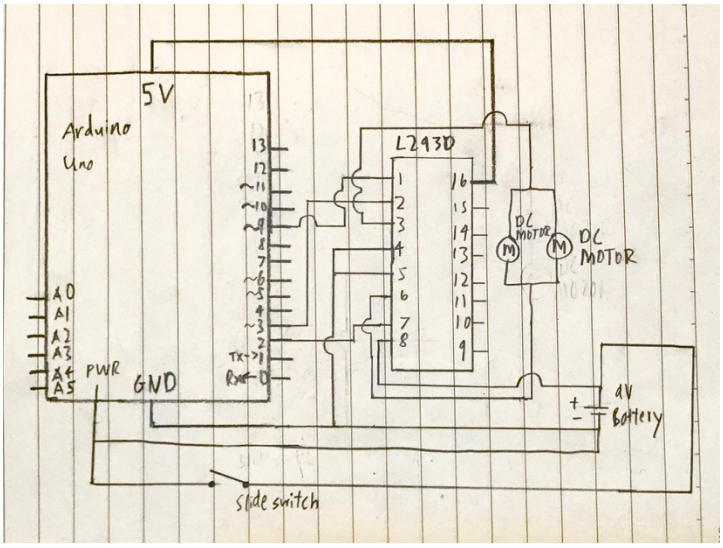

Figure 18A: Diagram of Final Circuit After All The Changes