DL835 BSc (Hons) in Creative Media Technologies – 2021/2022

Year 4 Final Project

Omni Wheel Vehicle

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Supervisor: Paul Comiskey

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Acknowledgements

I would like to thank my supervisor Paul Comiskey for helping me take this project to the greatest heights it could reach and general help with the various problems that prevented themselves throughout its construction.

I would also like to thank Sonia Nietubyć for her technical help with the mechanical calculations that were needed to even start this project.

Abstract

The aim of this project is to make a four wheeled vehicle that can move in four directions without turning (forwards, backwards, left and right). This idea was originally proposed for cars but only a three wheeled version exists. The next step was a four wheeled version to see how the wheels faired in comparison to the three wheeled version as well as the differences in movement and turning.

I needed to figure out how to move each wheel with a motor using the torque calculations. After this I needed to make a battery holder to power the motors when the vehicle started moving. I then had to test the motor driver moving the motor and wheel.

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Project Plan

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1. Introduction

This project aims to create a four-wheel vehicle that can move forwards, backwards, left and right without having to turn the vehicle, using ball shaped wheels able to roll no matter what position they are in. A vehicle with wheels like this wouldn't need to turn left or right, it could just move left or right. Using ball wheels instead of ordinary wheels also spreads out the wear over the wheels.

Figure 1 Three Wheeled Version

After the concept is proven and shown working the next step is to add some kind of technology like Arduino or Raspberry Pi and motors to control it by remote. Another option is to set up a pre-set path for it to follow showing off its unique movement method with as little input or draw away from the vehicle as possible.

2. Technology

2.1 Arduino

Figure 2 The Arduino

The Arduino is a microcontroller which allows us to control projects with inputs. A microcontroller like the Arduino has inputs from sensors and depending on the inputs it receives it can operate outputs like motors or led's. Software can be written for the Arduino to instruct it what to do with different inputs and outputs. (Arduino.cc, 2018).

2.2 Ball bearings

Figure 3

Ball bearings allow two parts to turn in opposite directions without making contact with each other. They are used for carrying loads and reducing friction. These bearings will be used to make each half of the wheels roll left or right independently of the other parts of the wheel.

2.3 DC Motors

Figure 4 A Motor

Motors are a basic electrical device that convert electricity into motion. Using a forward and reverse motor I can drive the wheels in two opposite directions. I will need a motor for each wheel meaning I'll need four motors to run the wheels.

2.4 Creality Ender 3-v2

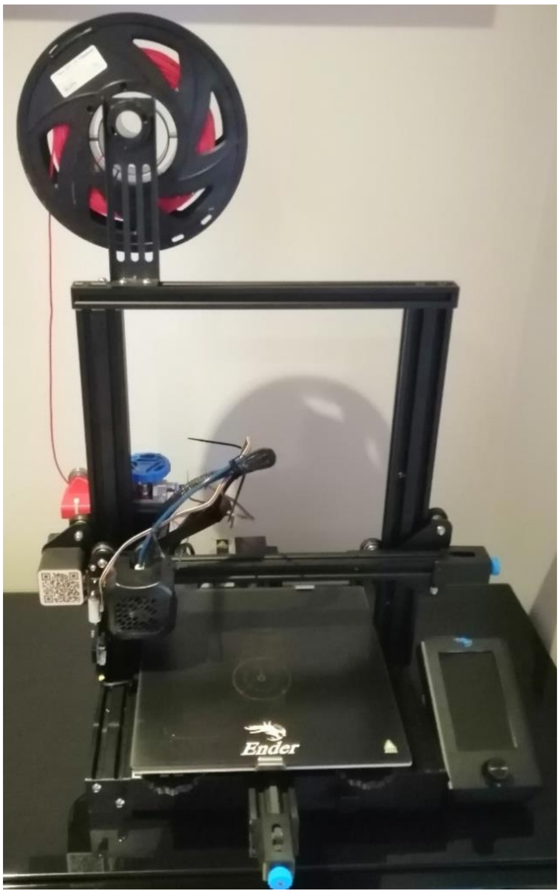

Figure 5 Creality 3D Printer

The Creality Ender 3-v2 is an F.D.M. (fused deposition modelling) 3D printer used for printing various plastics that are needed for the construction of the wheels. Like PLA or TPU.

PLA is a cheap and easy to use plastic filament for 3D printers.

TPU is a flexible plastic filament for 3D printers for making less rigid objects like bicycle handles.

2.5 Applications

While the basics of this project are to just get four wheels moving. There is a lot more to that then just attaching the wheels and rolling them.

The wheels need to roll in four directions so that it can move around. To have motorized movement in all four directions two wheels need to face left and right while two face forwards and backwards first they need to roll forwards and backwards, then left to right.

Once the wheels are motorized, I think it is a good idea to see the various ways it can turn using its unique wheel design. (Moving to the left), (Moving one wheel forward) and (Moving one wheel forward and one wheel left).

Once the wheels are motorized and its movement has been very well tested. The next logical step is to have it follow a preset path to show off its exceptional degree of movement.

One application it could be used for is car wheels. The original idea that inspired all the various research into ball shaped wheels was a car company.

Another application is Wearhouse robots similar to the ones that the likes of amazon use.

I also thought that this type of wheel would be useful for Wearhouse forklifts but after talking to people who work with forklifts. I was told these wheels would be a poor fit.

2.6 Requirements

This project requires a lot of physical assembly to construct the wheels as well as the knowledge to wire up the multiple motors to an Arduino and set a preset path for the omni wheels to follow. It also requires a lot of engineering mathematics.

2.7 Similar Systems

Spherical Maglev Tires

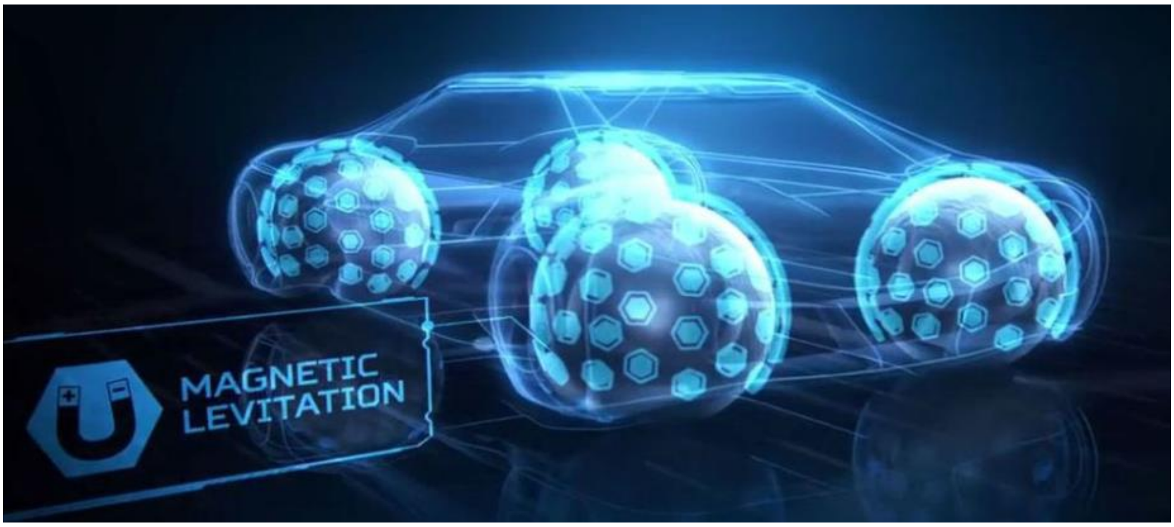

Figure 6 Magnetic Car Wheels

The link below shows the original idea that prompted research into this specific type of omni wheel. This also shown the full potential of the omni wheel idea and just how far it has the potential to go.

https://www.popularmechanics.com/cars/a19747/goodyear-eagle-360-spherical-tires/

Omni ball

Figure 7 Basic Ball Wheel Concept

This video shows the original concept that students at Osaka university came up with, that future designs could be built off of. While they built a crawler that runs on threads to accomplish this, they first had to design a simple wheel version of it which is what all future models of this type of omni wheel would be built off of.

https://www.youtube.com/watch?v=BTp2UAaihaI

Three-wheel version

Figure 8 Three Wheeled Version

This link shows the furthest depths this concept has been taken to so far and is a detailed look into using the omni wheels in a three-wheel vehicle.

https://www.youtube.com/watch?v=rHDCIng0Wak

2.8 List of requirements

1. The first requirement is to have the physical wheels and a frame built.
2. The second requirement is make sure the wheels can move freely in the four cardinal directions.
3. The next requirement is to motorize the four wheels.
4. The wheels need to be tested moving in various ways.
5. After the motorized wheels have been tested, they need to be put on a preset path to follow.

2.9 Timelines

My spreadsheet of the proposed work plan and dates for completion for my project.

Table 1 Project Timeline Vertical View

objective	description	date	month	year
get and convert the wheel files	converting and readying files for printing.	13th	July	2021
print wheel	print 1 wheel to see if its possible.	15th	July	2021
print the wheels	print all the parts for 3 more wheels.	10th	August	2021
assemble basics of the wheels		13th	August	2021
get the bearings	get the 16 bearings for the wheels	1st	September	2021
	and the 8 bearings for the axises			
fully assemble the wheels	assemble all four of the wheels	20th	October	2021
print legs	print legs that the wheels can stand on	24th	October	2021
	and connect to the frame			2021
find a frame	get a frame for the wheels and legs to connect to	24th	October	2021
test wheels	first tests of wheels movement	30th	October	2021
figure out wheel torque	figure out how much torque is needed to move a wheel.			
motorize a wheel	get a motor that can move a single wheel	30th	November	2021
	due to verious factors of the wheels a heavy motor will be required			
add microcontroller	add an arduino to control the motorized wheels	20th	December	2021
add a preset path	have the wheels follow a preset path	31th	January	2022
NOTE	anything from this point forward is extra stuff and might not be gotten to.			
	all of the above is the core of this project which is proving a ball shaped wheel			
	can work and testing its ability of movement.			
test wheel turning	test the turning of the wheels.	28th	Febuary	2022
add object avoidance	using an ultrasonic sensor for detecting and avoiding obstacles	7th	March	2022

On the next page is a bigger and easier to read version of the above spreadsheet.

Table 2 Project Timeline Horizontal View

objective	description	date	month	year
get and convert the wheel files	converting and readying files for printing.	13th	July	2021
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add object avoidance	using an ultrasonic sensor for detecting and avoiding obstacles	7th	March	2022

3. Design

3.1 Introduction

The general idea for this project is to see the different ways ball shaped wheels can move compared to normal wheels and how four of these wheels work together. Up until now only three wheeled versions have been made.

The physical design is as important as the mechanical and electrical work. The physical size of the wheels make this a big project with various components that need to be assembled correctly otherwise the wheels won't work.

Figure 9 Traditional Wheel

At the top of each hemisphere is a normal wheel printed in red tpu. The hemisphere mounted to the bearings will turn freely until it reaches the top where it would stop and drag across the floor. This is why there is a normal wheel that rolls when the hemisphere stops.

3.2 Block Diagram

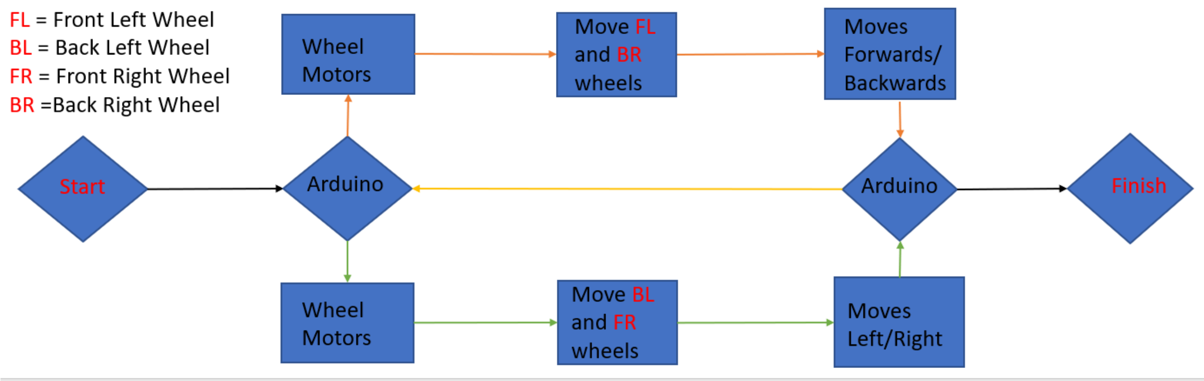


Figure 10 Block Diagram

The Arduino reads the pre-set path line by line of code. This is how it knows which wheels (sideways wheels or forward wheels) to move and which direction (forward of backwards) to move them. It will follow the direction laid out in the pre-set path and stop movement in-between directions to clearly show the new movement.

3.3 Schematic

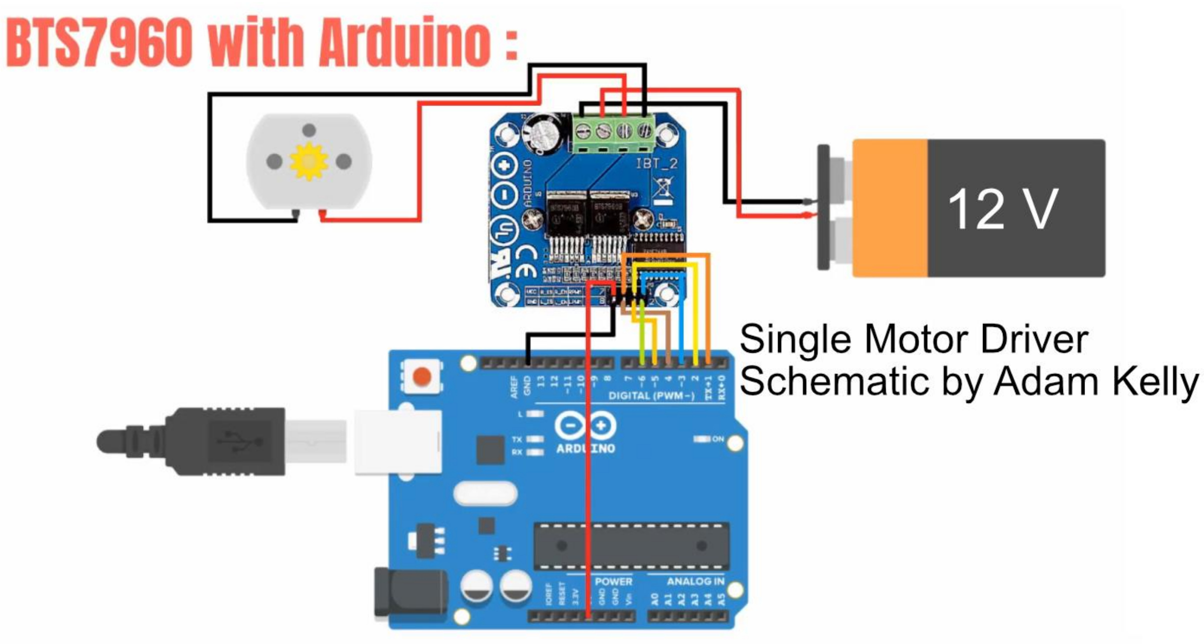


Figure 11 Single Motor Driver Schematic

While each motor will have its own motor driver since 2 motors will be going forward and 2 will be going sideways. I can wire 2 motor drivers to the same 6 pins on the Arduino using a breadboard. I can also power all four motor drivers using the same power source by daisy chaining the power cables from one motor driver to the next.

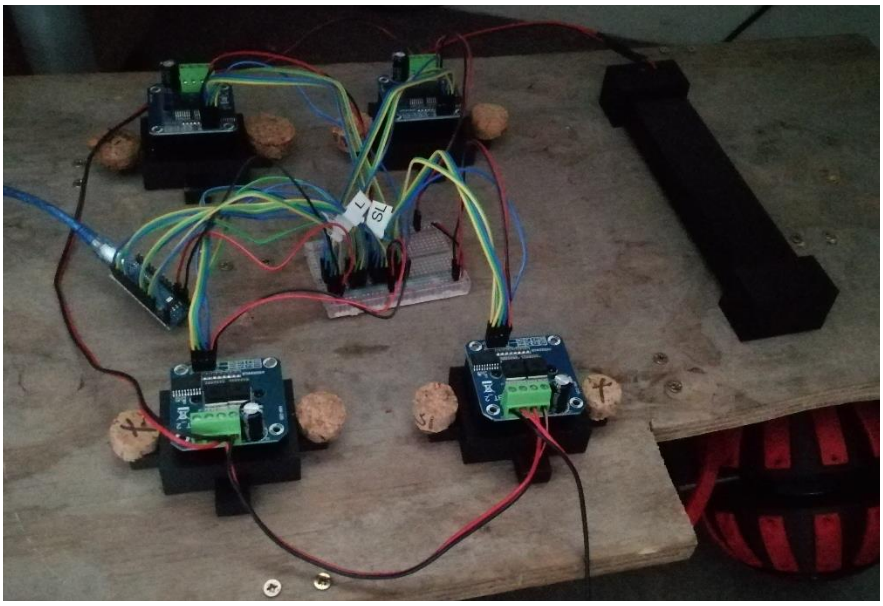


Figure 12 Daisy Chained Battery Power

3.4 Description of System Operation

The Arduino tells the motor drivers to move the motors for a pre-set amount of time at a set amount of speed (example motors run at 50% speed for 3 seconds going forwards). The Arduino reads the user inputted code to know which motor drivers to activate when to move itself.

3.5 Components

3.6 List of Components

Table 3 Components List

Componant	Specifics	Quantity
Jumper Wires	male to female	3 packs
Arduino	nano	1
breadboard	standard	1
BTS7960 Motor Driver	standard	4
Geared Motor	55rpm, 2Nm	4
Big Bearings	49mm hole	16
Small Bearings	6mm hole	8
PLA Filament	Black	2KG
TPU Filament	Red	1Kg
Screws	Verious	48
Wooden Frame	48X42cm atleast	1

3.7 Description of the Operation of Main Components

The wheels operate by rolling as a 6mm rod through the middle is rotated. The hemisphere on each wheel just rolls when the wheel gets dragged along in any other way. There is also a small wheel on the top and bottom of each wheel where the ball would be "to flat" to rotate normally.

The bearings that hold the hemispheres to the wheels roll side to side as the weight on them is shifted as the wheels move. They move faster as the hemisphere rotates closer to the top where the curve of the ball is smaller.

The motor drivers operate by taking power from a power source and code from a microcontroller to power the motors and control the speed of the motors as well as the direction of the motors. Using the motor driver to control the motors they can be made to follow a pre-set path coded into the Arduino.

The Arduino controls everything by giving the motor drivers the instructions to follow the pre-set path. The Arduino can detect inputs for things like an ultrasonic sensor that could be used in this project or to give commands to outputs like the motor drivers.

The motors are a geared motor that runs slower then normal motors but can move a much heavier load because it has a gear box attached to the motor. This results in one full rotation through the gear box for every 1o4 rotations of the actual motor.

3.8 Software Design

The code for this project is rather simple it is just moving a motor in one of two directions and then stopping it so another motor can move in one of two directions. The code involves two motors going forwards or backwards or two other motors going left or right or all four motors to be stopped. To make this easier I split the directions into functions named void Forwards, void Backwards, void Left, void Right and void Stop. I can make any pre-set path by running a function for a set amount of time and then running another function after it. Below is a picture of the list of functions that will run each function for 500 milliseconds at half of the motors max speed before stopping.

```
void loop() {
  // put your main code here, to run repeatedly:

}

void forwards (int i)
{
//Forward motors movement
  for(i = 0; i <= 255; i= 125){ //clockwise rotation
   analogWrite(R_PWM, i);
   analogWrite(L_PWM, 0);
   delay(500);
  }
  delay(500);
  analogWrite(R_PWM, 0);
  analogWrite(L_PWM, 0);
  delay(500);
}

void Left (int i)// could be right need to check
{
//Sideways motors movement
  for(i = 0; i <= 255; i= 125){ //clockwise rotation
   analogWrite(SR_PWM, i);
   analogWrite(SL_PWM, 0);
   delay(500);
  }
  delay(500);
  analogWrite(SR_PWM, 0);
  analogWrite(SL_PWM, 0);
  delay(500);
}

void Right (int i)// could be left need to check
{
//Sideways motors movement
  for(i = 0; i <= 255; i= 125){ //clockwise rotation
   analogWrite(SR_PWM, 0);
   analogWrite(SL_PWM, i);
   delay(500);
  }
  delay(500);
  analogWrite(SR_PWM, 0);
  analogWrite(SL_PWM, 0);
  delay(500);
}

void Backwards (int i)
{
//Forward motors movement
  for(i = 0; i <= 255; i= 125){ //clockwise rotation
   analogWrite(R_PWM, 0);
   analogWrite(L_PWM, i);
   delay(500);
  }
  delay(500);
  analogWrite(R_PWM, 0);
  analogWrite(L_PWM, 0);
  delay(500);
}

void Stop (int i)
{
  for(i = 0; i <= 255; i= 125){ //clockwise rotation
  analogWrite(R_PWM, 0);
  analogWrite(L_PWM, 0);
  delay(500);
  }
}
```

Figure 13 basic test code.

3.9 Conclusion

The motor drivers are able to handle all the voltage and current needed to move the motors and are easy to understand, use and implement into the project. They let me control the speed and direction of the motors as well as separate them into which motors go forwards and backwards and which go left and right.

4. Implementation

4.1 Introduction

My project is a ball shaped design for an omni-wheel (a wheel that can move in more ways than a normal wheel). Using ball shaped wheels my project can go forwards, backwards, left and right without having to turn. Two wheels move forwards and backwards while the other two just freely roll along and the other two wheels move left and right while the first two roll along.

The first prototype was just proving the concept by getting a motor capable of moving the wheel by figuring out the torque needed to move one wheel. And getting four wheels on a frame to roll it around and see it work and make sure everything works well together.

The second prototype was to wire up the motor drivers and test them with the motors and the wheels using some simple code. I also needed to make gears and a pulley belt to connect the wheels and the motors. As well as mounting brackets for mounting the motors and motor drivers to the frame. I also needed to make a battery holder to power the motors.

The third prototype was a full assembly of all the parts and mounting them to the frame. Using functions to create a pre-set path for the motor drivers to drive the wheels along. Once it work and I can move it in the four directions (forwards, backwards, left and right) I can experiment with things like turning on the spot using all four wheels.

4.2 Safety

4.2.1 Electrocution/Electric shock

The only electrical hazard was connecting the various components to the Arduino and the motor drivers that sit on top of my vehicle.

Connecting and disconnecting components was the only electrical risk in my project, I briefly used a power supply to power the wheel when checking the motor would work. To mitigate this risk, I made sure the power was turned off when I was changing or moving around components and wires in my project and that I did not touch any of the electrical components when the power was turned on.

4.2.2 Fire

I had to use a soldering iron to solder the wires to the motors and the battery holder. Before using a soldering iron, I had to go through the usual safety measures such as making sure the room was well ventilated, well-lit and that the workspace was clear of anything not needed when soldering. One added difficulty that posed a safety hazard was that the motors needed to be mounted when soldering resulting in a lack of space and myself needing to pay extra attention as I was soldering.

4.2.3 Burn injury

Using a soldering iron always carries the risk of burning yourself if you are not carful while handling the iron. While using the soldering iron I made a conscious effort to keep the heat as low as possible and that there was a clear way to the nearby sink in case any injuries did occur while I was soldering.

4.2.4 Fumes

The fumes produced while soldering are dangerous to consume and should not be inhaled. Once the room is well ventilated with a good airflow and the user makes a conscious effort not to inhale the fumes this is usually enough to mitigate this risk.

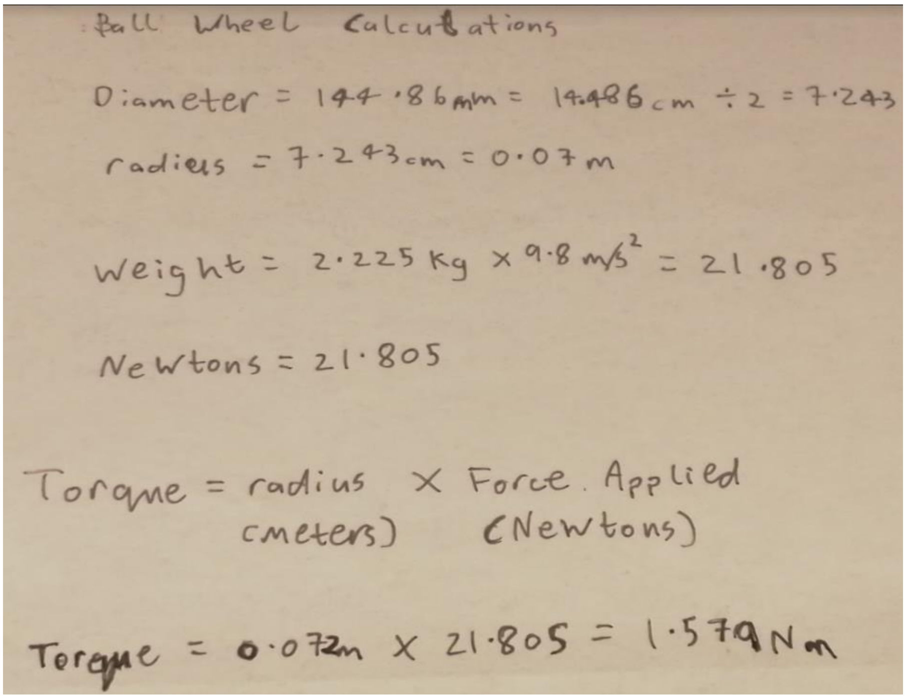
4.3 Prototype 1 Basic Wheel Assembly

4.3.1 Process

I had to physically build one of the wheels to make sure everything worked and fit together. Most parts were printed in basic black PLA. Once I knew all the parts fit together and that the tpu parts (red) were flexible enough to work I could start printing the other three wheels.

Figure 14 All the parts for 1 wheel

After assembling one wheel and testing it by rolling it around in various directions I learnt it was far heavier than I thought it would be with each wheel weighing roughly (2.225kg) when mounted to the frame. I also learnt that the wheels were far to heavy for a non-geared motor to run. Before I could go any farther, I needed to find out how powerful a motor I would need to move the wheels. After talking to someone who knew the math, I needed to figure out what the torque I needed would be I got her to double check my calculations and make sure I had done the right ones. (The calculations for moving two wheels with one motor are very different from moving one wheel with one motor). I would have two motors moving two wheels any time it was moving which made the calculations a little more difficult.



Ball Wheel Calculations

Diameter = 144·86 mm = 14.486 cm ÷ 2 = 7·243

radius = 7·243 cm = 0·07 m

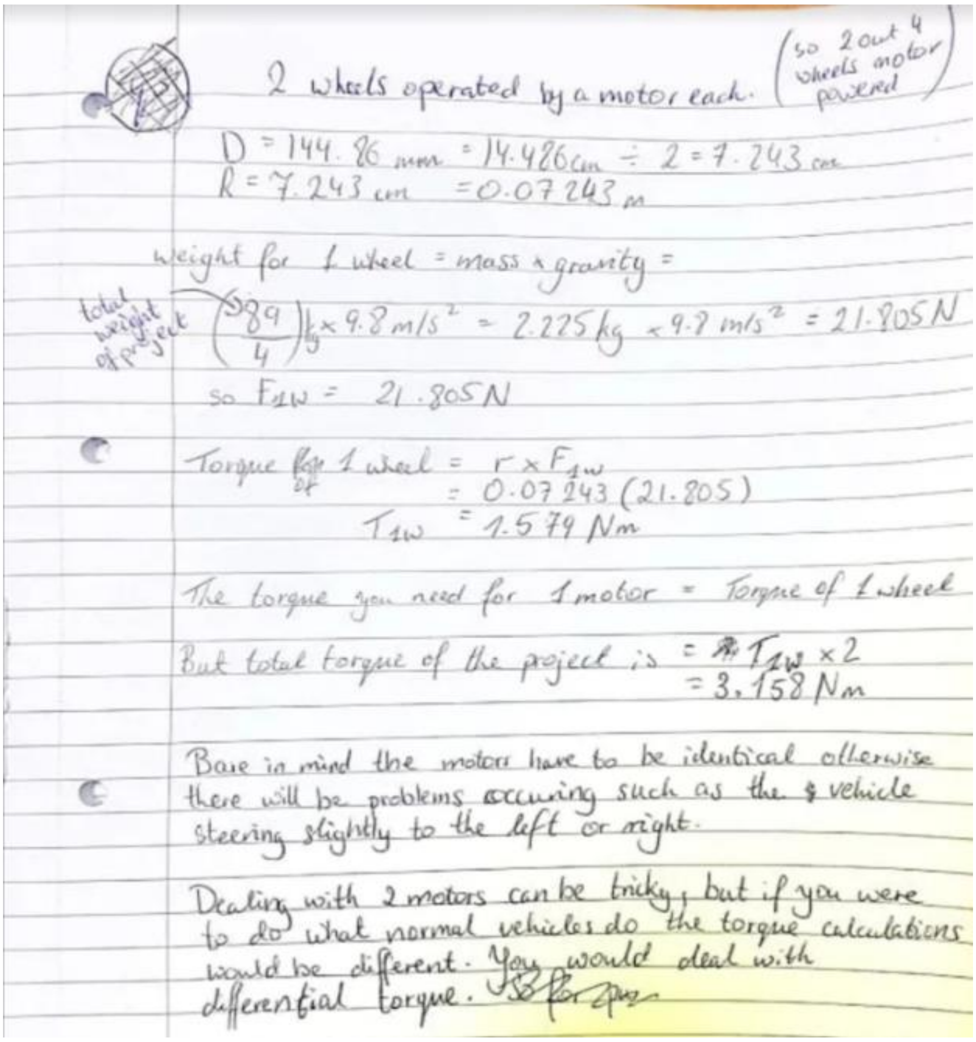
Weight = 2·225 kg × 9·8 m/s² = 21·805

Newtons = 21·805

Torque = radius (meters) × Force Applied (Newtons)

Torque = 0·072m × 21·805 = 1·579 Nm

Figure 15 Torque Calculations



2 wheels operated by a motor each. (so 2 out 4 wheels motor powered)

D = 144.86 mm = 14.486 cm ÷ 2 = 7.243 cm
R = 7.243 cm = 0.07243 m

weight for 1 wheel = mass × gravity =
total weight of project (8.9 / 4) kg × 9.8 m/s² = 2.225 kg × 9.8 m/s² = 21.805 N

so F_{1W} = 21.805 N

Torque of 1 wheel = r × F_{1w}
= 0.07243 (21.805)
T_{1w} = 1.579 Nm

The torque you need for 1 motor = Torque of 1 wheel

But total torque of the project is = T_{1W} × 2
= 3.158 Nm

Bare in mind the motors have to be identical otherwise there will be problems occuring such as the vehicle steering slightly to the left or right.

Dealing with 2 motors can be tricky, but if you were to do what normal vehicles do the torque calculations would be different. You would deal with differential torque.

Figure 16 Doublechecked calculations and feedback

After finding the torque I needed to move one wheel (1.579Nm (Newton meters)). I used this number to find out the other numbers for the ideal motor. After finding these I could look for a motor that was as close to this as I could.

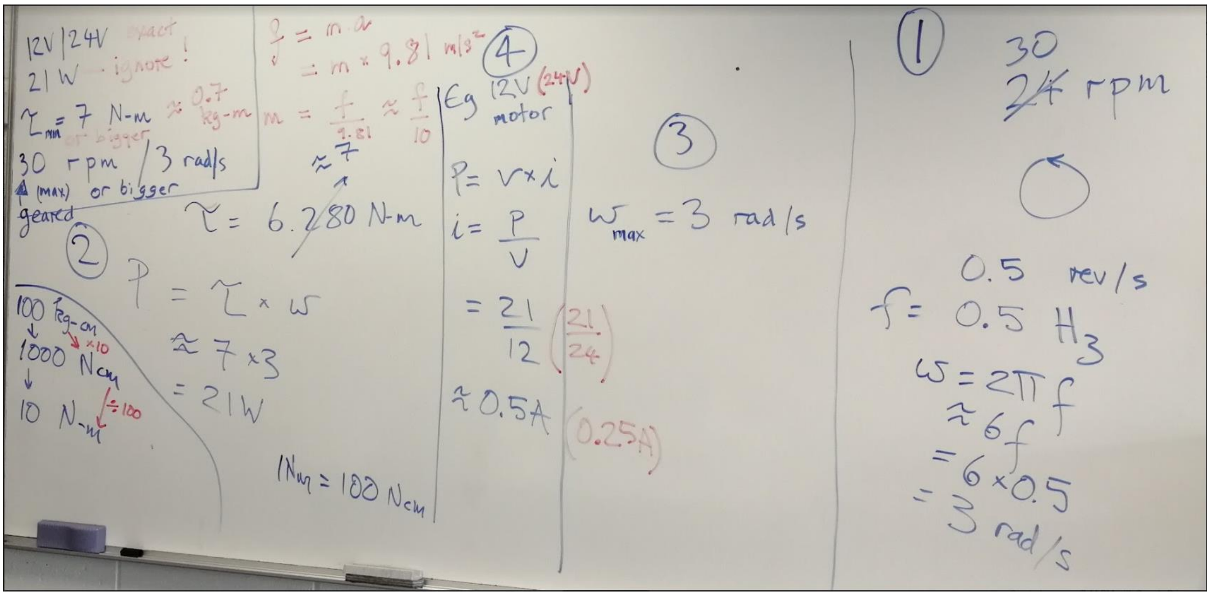


Figure 17 Ideal motor calculations

With a clear idea of the motor, I needed I went to radionics and found two motors that would work. I chose the slower one because I didn't need my project to go very fast.

Figure 18 Motor

With the motor that worked I needed to connect the wheel to the motor. I did this by making a pair of gears one for the 6mm rod used to turn the wheel and one for the motor. They were connected by a tpu belt to make a pulley system that would move the wheel.

4.3.2 Features

The motors have a gear box attached to them that lets the motor move things much heavier than it would be able to on its own. The gear ratio is 104:1 (this means the gear rotates 104 times before the motor rotates once).

Each gear features a herringbone gear system to help avoid slipping. Each gear also has taller sides to stop the belt falling off the gear and a flat side on the motor gear to avoid the motor slipping around the gear (the 6mm rod is held in place by two 6mm nuts tightened around it). The gears are both the same size, so the wheel turns on a 1:1 ratio from the motor.

4.3.3 Issues

Discovering the weight of the wheels was a big issue because the wheels were to light to weigh on their own. Without the weight of a wheel, I would have no idea how big a motor I would need.

The belt and gears needed to be the right size, or they wouldn't fit together, and the belt needed to be big enough to reach between the motor and the wheel. I also knew I needed to leave extra room for a way to mount the motor to the frame.

4.3.4 Resolution of Issues

I could resolve the weight issue by weighting the whole project and dividing it by four (it was divided by four because it rests on four wheels).

The belt and gears needed to be doubled in size before they were left a big enough gap to mount the motors. I also needed to add walls around the gears to stop the belt slipping off the wheels. I also had to add a flat side to the motor gear to stop it slipping in the gear when weight was applied.

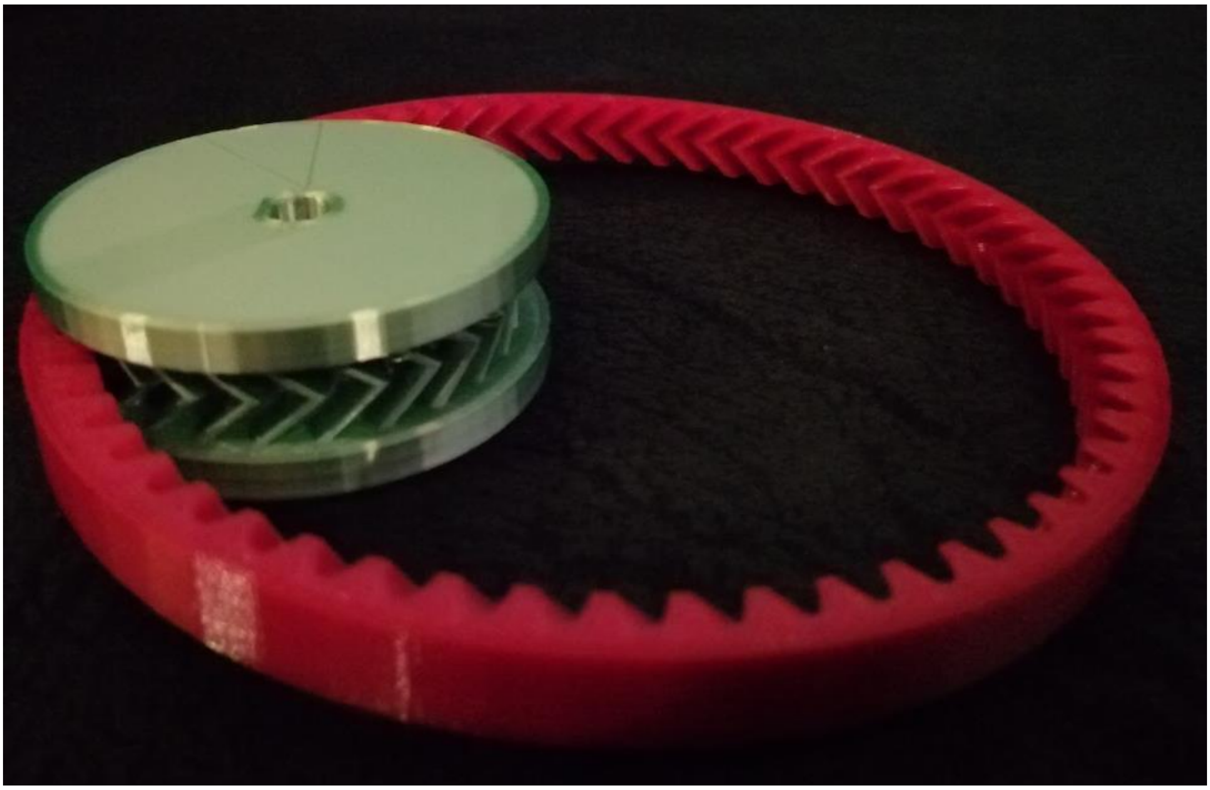


Figure 19 Motor Gear and Belt

4.4 Prototype 2 Electronics assembly

4.4.1 Process

With the basics of my project assembled and working I could move onto the next part. I needed to find a motor driver for able to handle the voltage and current needed for the motors. I also needed to find a way to mount them to the frame and wire them up to the Arduino so I could test them. I also needed to make mounts for the motors to hold them in place on the frame. I realised I also needed a way to move the motor without having it plugged into the wall.

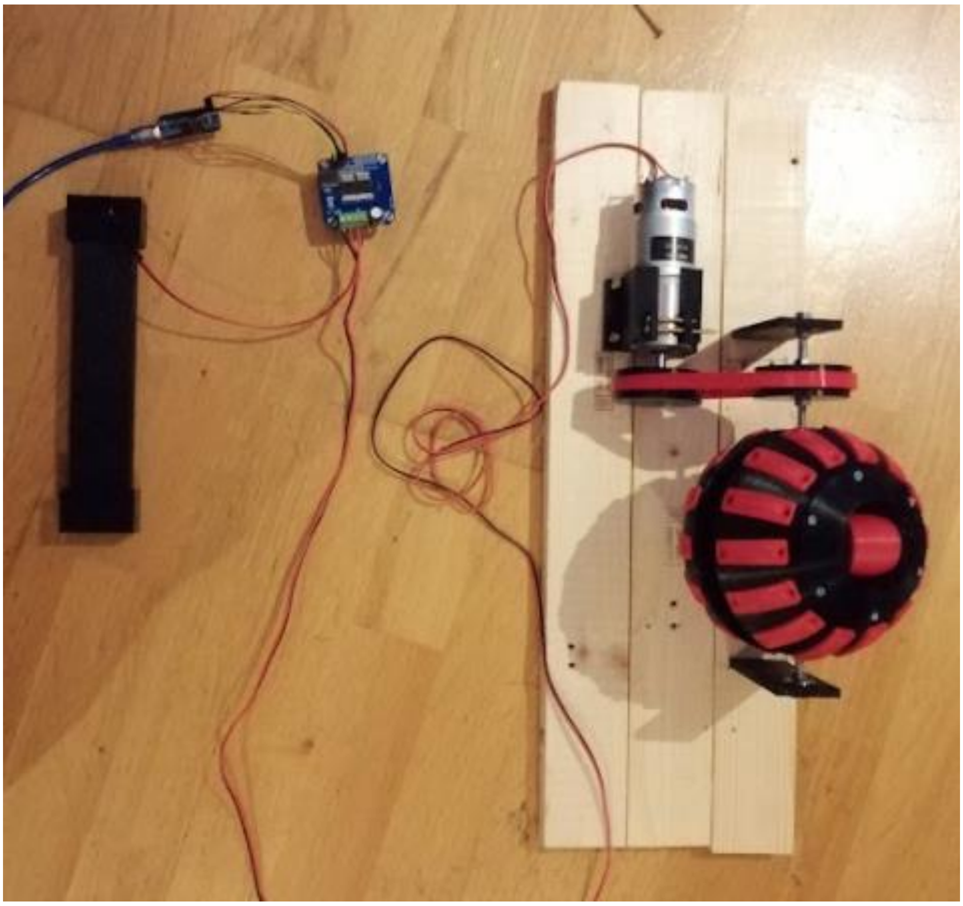


Figure 20 Motor Driver Test

4.4.2 Features

Battery powered supply to power the motors without restricting movement. I used 8 double A batteries to power it.

Independent motor drivers to drive each wheel separately. Each motor has its own motor driver to run it either forwards or backwards at a speed that is controlled by the code for the motor driver.

The motor drivers also have a simple mount on top of the vehicle for easy removal if needed.

4.4.3 Issues

Looking for a remote-control car battery to power the motors was difficult because of the different connections needed.

Making mounts for the motors was very difficult because of the shape of the motors.

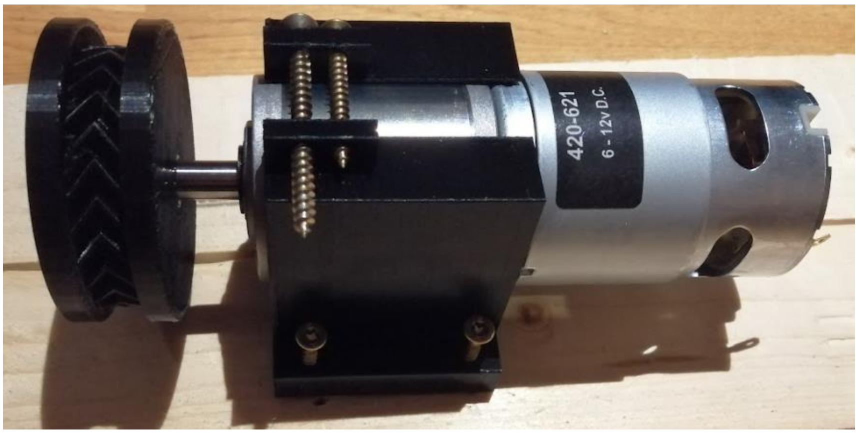


Figure 21 Motor Mount

The motors mount needed a hole of 41.6mm to fit the motor in it. It also needed screw holes to stop the motor from moving as well as to mount it to the frame.

Wiring up the motor drivers was a difficult task due to the amount of wire needed. I also had to make sure didn't wire

Mounting the motors to the frame was difficult because of the amount of space available on the frame. There wasn't enough room to mount all the motors without extending the belts which wasn't an option.

4.4.4 Resolution of Issues

The battery issue was resolved by just making a battery holder that would take Double A batteries and wiring it into the motor drivers to supply power to the motors. Each battery is 1.5 Volts so 8 of them in series add up to 12 Volts.

Figure 22 Battery Holder

The motor mount was just a matter of trial and error until I printed the right size to hold the motor in place without it moving. Eventually my measurements were right and then I just printed three copies for the other motors.

After wiring up and testing one motor driver to make sure it worked, I needed to wire up and test all four of them which required a breadboard and colour coded sets of wires to make sure everything was done correctly. The power cables were red and black, the pins on the motor driver were split into R_IS R_EN R_PWM and L_IS L_EN L_PWM

R_IS and L_IS = Blue Wire

R_EN and L_EN = Green Wire

R_PWM and L_PWM = Yellow Wire

The wires were then further organised by grouping wires with labels. Each group consisted on 1 blue, green and yellow wire. The wires for pins 1-3 (R_IS R_EN R_PWM) were labelled R, wires 4-6 (L_IS L_EN L_PWM) were labelled L. these wires went into a breadboard where matching wires went to the two motor drivers that drive the vehicle forwards and backwards. The motor drivers that handles side to side movement were labelled the same way with an S in front of the R/L making them SR and SL. The wires for pins 7-9 (SR_IS SR_EN SR_PWM) were labelled SR and the wires from pins 10-12 (SL_IS SL_EN SL_PWM) were labelled SL.

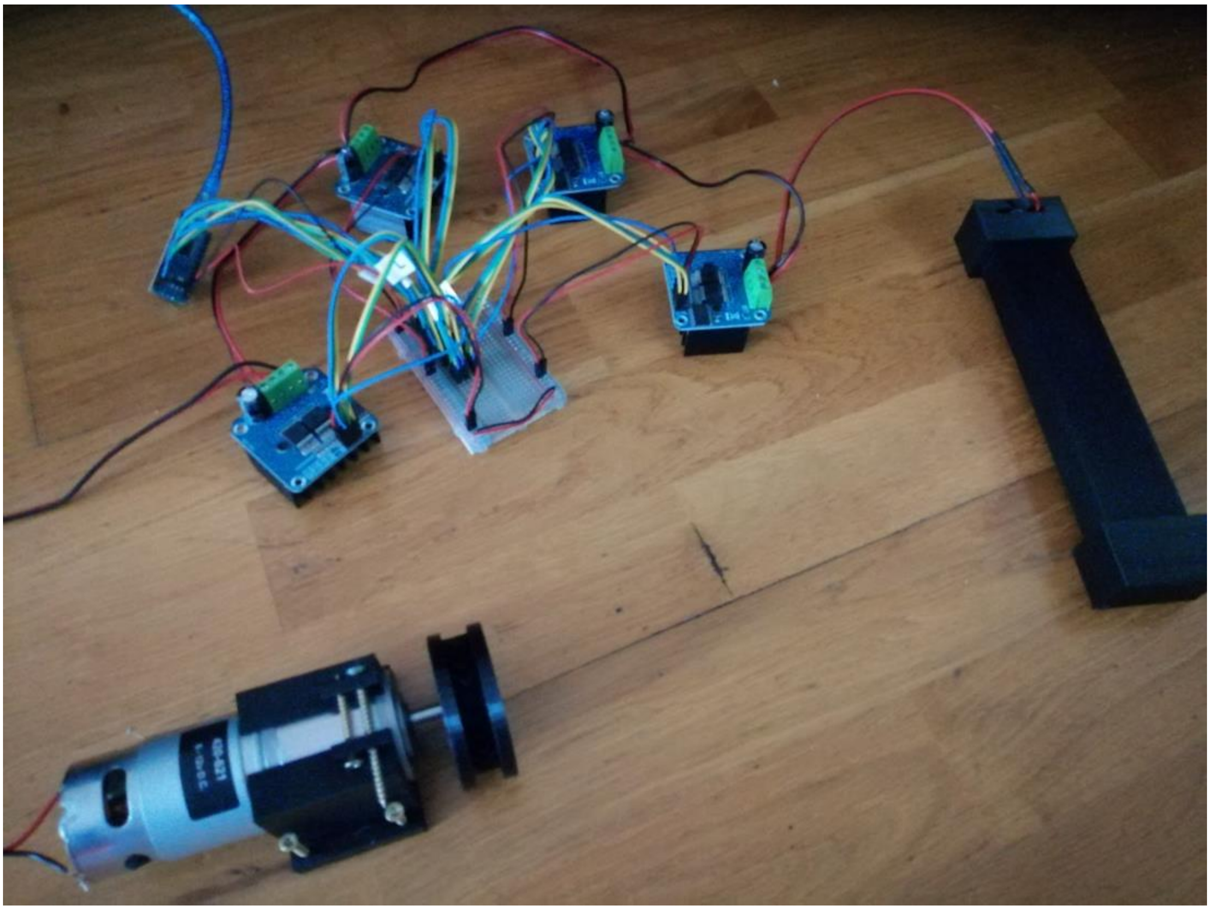


Figure 23 Full electronics Testing

Using an altered version of the initial test code I was able to just swap the motor I had from motor driver to motor driver and test that they were all wired up correctly and worked properly.

```
//BTS7960 motor driver sketch

int R_IS = 6; //blue wires
int R_EN = 2; //green wires
int R_PWM = 3; //yellow wires
int L_IS = 7;
int L_EN = 4;
int L_PWM = 5;

void setup() {
  // put your setup code here, to run once:
 pinMode(R_IS, OUTPUT);
 pinMode(R_EN, OUTPUT);
 pinMode(R_PWM, OUTPUT);
 pinMode(L_IS, OUTPUT);
 pinMode(L_EN, OUTPUT);
 pinMode(L_PWM, OUTPUT);
 digitalWrite(R_IS, LOW);
 digitalWrite(L_IS, LOW);
 digitalWrite(R_EN, HIGH);
 digitalWrite(L_EN, HIGH);
}

void loop() {
  // put your main code here, to run repeatedly:
  int i;
  for(i = 0; i <= 255; i= i+10){ //clockwise rotation
   analogWrite(R_PWM, i);
   analogWrite(L_PWM, 0);
   delay(500);
  }
  delay(500);
  for(i = 0; i <= 255; i= i+10){ //counter clockwise rotation
   analogWrite(R_PWM, 0);
   analogWrite(L_PWM, i);
   delay(500);
  }
  delay(500);
}
```

Figure 24 Test Code

```
  //Forward motors set up
 pinMode(R_IS, OUTPUT);
 pinMode(R_EN, OUTPUT);
 pinMode(R_PWM, OUTPUT);
 pinMode(L_IS, OUTPUT);
 pinMode(L_EN, OUTPUT);
 pinMode(L_PWM, OUTPUT);
 digitalWrite(R_IS, LOW);
 digitalWrite(L_IS, LOW);
 digitalWrite(R_EN, HIGH);
 digitalWrite(L_EN, HIGH);

//Sideways motors set up
 pinMode(SR_IS, OUTPUT);
 pinMode(SR_EN, OUTPUT);
 pinMode(SR_PWM, OUTPUT);
 pinMode(SL_IS, OUTPUT);
 pinMode(SL_EN, OUTPUT);
 pinMode(SL_PWM, OUTPUT);
 digitalWrite(SR_IS, LOW);
 digitalWrite(SL_IS, LOW);
 digitalWrite(SR_EN, HIGH);
 digitalWrite(SL_EN, HIGH);
}

void loop() {
  // put your main code here, to run repeatedly:

  //Forward motors movement
  int i;
  for(i = 0; i <= 255; i= i+10){ //clockwise rotation
   analogWrite(R_PWM, i);
   analogWrite(L_PWM, 0);
   delay(500);
  }
  delay(500);
  for(i = 0; i <= 255; i= i+10){ //counter clockwise rotation
   analogWrite(R_PWM, 0);
   analogWrite(L_PWM, i);
   delay(500);
  }
  delay(500);

    //Sideways motors movement
  int ii;
  for(ii = 0; ii <= 255; ii= ii+10){ //clockwise rotation
   analogWrite(SR_PWM, ii);
   analogWrite(SL_PWM, 0);
   delay(500);
  }
  delay(500);
  for(ii = 0; ii <= 255; ii= ii+10){ //counter clockwise rotation
   analogWrite(SR_PWM, 0);
   analogWrite(SL_PWM, ii);
   delay(500);
```

Figure 25 Four Motor Driver Test Code

After testing all the motor drivers, I printed mounts for them to mount to the top of the vehicle.

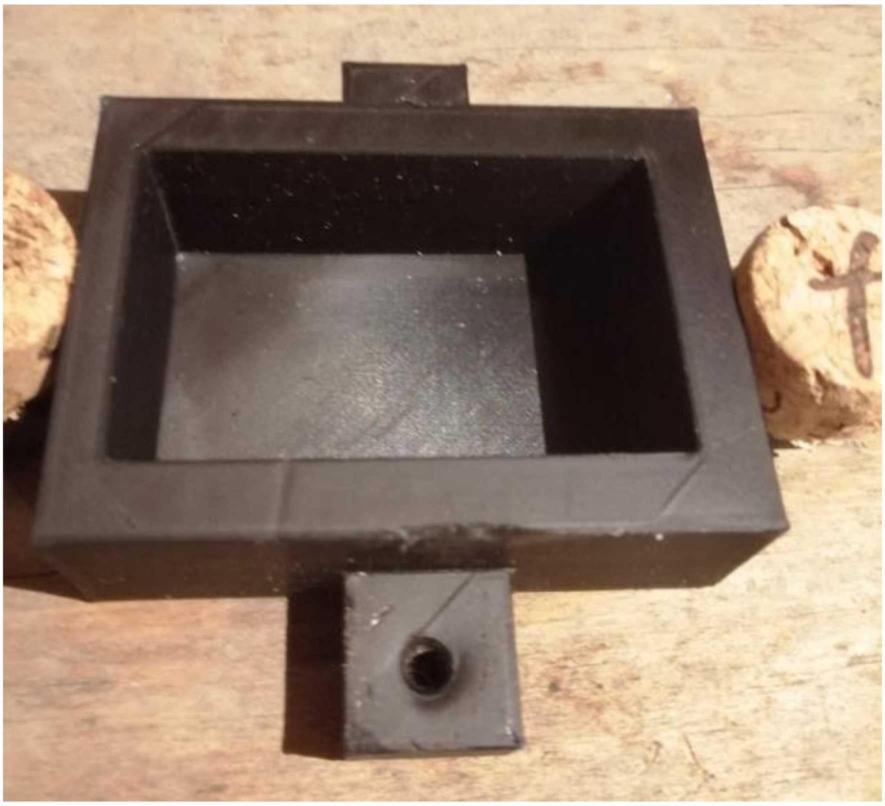


Figure 26Motor driver Mounts

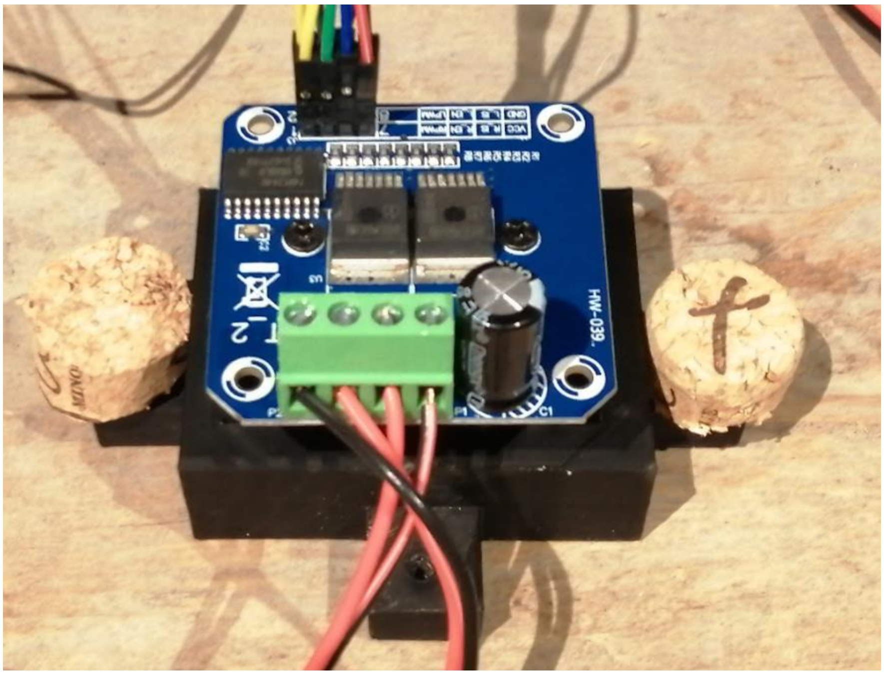


Figure 27 Motor Driver Mounted

The motor driver just sits in and is secure but can easily be removed and reattached without any major difficulty. The end of the screws used to secure it were covered using cork for extra protection and safety of the people around the project.

The last and biggest problem I ran into was a lack of space to mount the motors due to how close the wheels were to each other. This problem was solved by removing one of the motors and mounting it to a separate piece of wood on top of the base. I also removed one hex nut from each wheel and tightened the gear as close to the edge as I could this stopped the gear coming loose without the extra hex nut and made room for a motor to sit under one gears of another wheel. By doing this with two motors the other two have room to sit freely, meaning there's room for all four motors to mount to the frame without interfering with the wheels or other motors.

4.5 Prototype 3 Full Assembly and Testing

4.5.1 Process

I had to test everything to make sure all the components were mounted in the right way. I had to re mount one of the motor holders because the frame was slightly too small so the belt was loose, and this meant the wheel would slip when starting to roll. I also added a pair of lights to show which side was the front.

4.5.2 Features

Mounts for every component and space to see and admire the components and mechanisms that make up the project.

4.5.3 Issues

The battery holder broke and needed to be replaced or fixed. One of the motors needed to be moved away from the wheel to stop it slipping but there was no room on the frame. I also tried to add decorative designs to make it look more like a car.

4.5.4 Resolution of Issues

I replaced the battery holder with a plug-in battery. So now it just needs to be plugged in instead of plugged in and held together. By adding a piece of wood to the top of the frame that sticks out to the side I could mount the motor further away from the wheel. the designs didn't fit around the project and had to be removed. But there are lights to tell the front from the back.

Figure 28 Battery connection

5 Conclusions

This report describes the development of my project the four wheeled omni vehicle. The point of this project was to make a wheel that can roll in any and all directions without having to turn the wheels. A three wheeled version of this project exists but the original idea was to use this design on a car, so I took the next step and made a four wheeled version of it and then drive it forwards, sideways and diagonally to show off its incredible and unorthodox movement using motors to drive the wheels and motor drivers to control the speed.

This project was made using an Arduino which controlled four BTS7960 in two sets of 2 one for the wheels going forwards and backwards and one for the wheels going sideways. The motor drivers would each control one of the brushless geared dc motors. A pulley system connects each wheel to each motor and each wheel could turn because it was held together by bearings. The details for each of the pieces of technology above and other relevant parts used in the construction of this project can be found above in the project design chapter.

The design chapter details how the components in this project will work and give schematics, block diagrams and pictures about how the parts like the motor driver work. It also shows the basic code for running and testing the motors. It also has a components list of the necessary parts used to build this project.

The implementation chapter shows the steps of getting the different parts of the project running. Such as how I got the wheels turning, the software working and the issues that I ran into at each stage. There weren't prototypes in the traditional sense with this project. Each prototype in this report was a system that needed to work. The first prototype was the physical construction of the wheels and the motor calculations needed to get a motor able to turn the wheel, the second iteration was wiring up the motor driver and designing the software needed to move the motors using the motor drivers and the third iteration was to put the parts from iterations one and two together and make sure everything works together.

The first test was to mount the wheels and make sure they could freely roll in all directions.

The second test was to test if a motor could move a fully assembled wheel. No ordinary motor could move it so I needed to find the torque that was required to move one wheel and then test it with a motor.

The third test was driving the motor with a motor driver going forward and backwards using a simple bit of Arduino code.

Then I had a motor that could move the wheels, I had to mount them to the frame of my vehicle and make a new set of pulleys and gears to connect the motors to the wheels.

Now that all the physical components were tested, I had to mount them all to the frame and test the movement of the final assembly.

The software that I used to make the wheel turn was adapted into a version that could move all the wheels for a set amount of time and follow a simple pre-set path.

Time management was never a problem with this project because it was already split up into manageable chunks being wheel construction, motorising the wheel, physical assembly, circuit assembly and software and final assembly and testing. I also started this project at the start of summer so I would have the wheels constructed before the start of the school year. The biggest problem was having to figure out the torque for the wheels because I had to look very far and wide for help. The project had to be made in a very linear way because each step needed to be completed before the next step could be started. (For example, the wheels needed to be constructed before I could find a motor to move them). As I presented my project throughout the year, I just had to show the part I was currently working on and a video of the other parts I had already completed.

Over the course of this project, I learnt how to use a motor driver to control the speed of a big motor. I also learnt how to find the torque of a wheel and apply it to the motor to calculate the ideal motor I would need that could definitely move my fully assembled vehicle. I also learnt how to use an Arduino with enough space for two motor drivers to control four motor drivers using a breadboard, I also learnt how to orientate the wheels to minimize the drag that can occur with omni wheels.

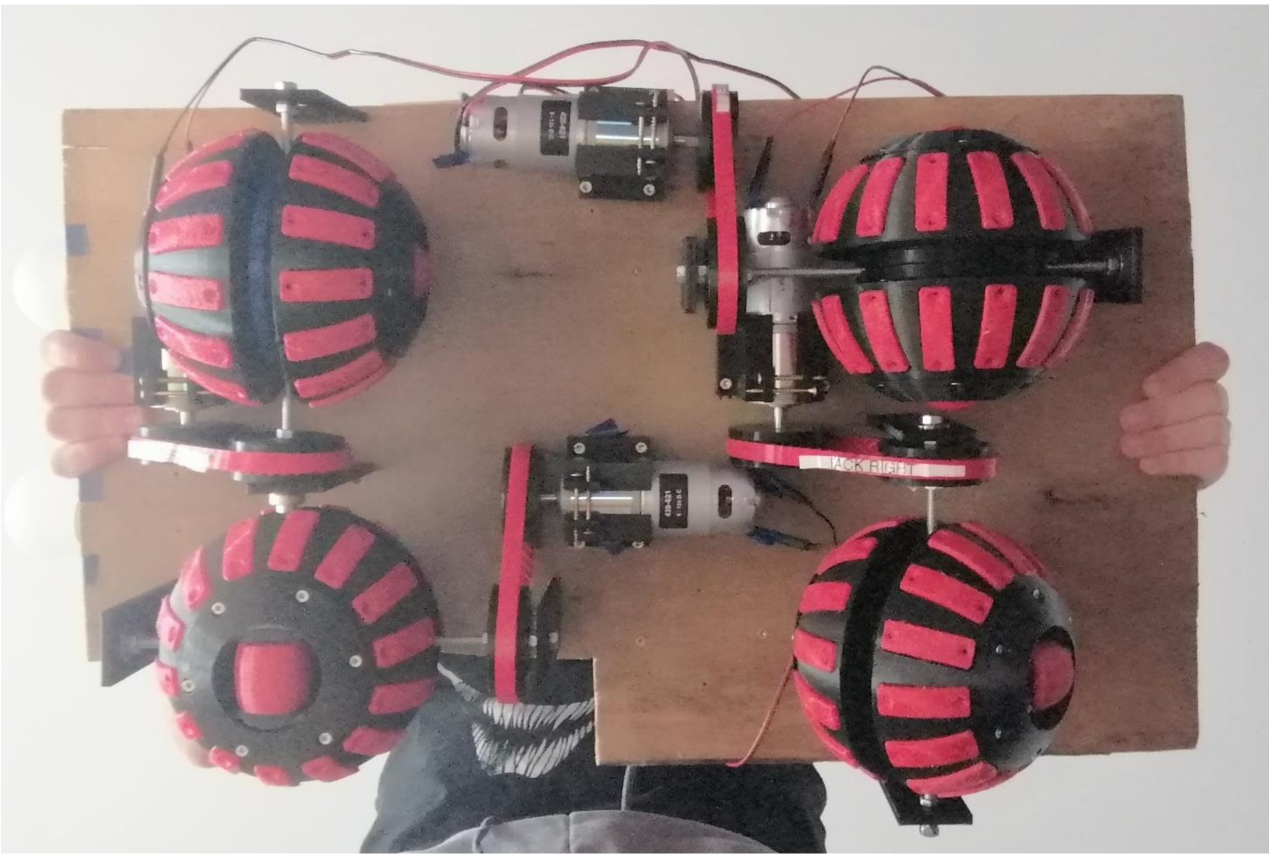


Figure 29 Completed underside

Overall, this project was a great success and did everything it was supposed to. The ball wheels moved forwards and backwards, sideways, and diagonally without any problems. At the start of this project, I thought the wheels would have a slight problem stopping but they're stopping power was far greater than I thought it would be. They can stop from full speed almost on the spot. Due to mechanical problems the front right wheel doesn't move as smoothly as the others meaning sideways movement results in a slight turn at the front but due to the ball shape of the wheels this didn't affect the movement of the wheels because they don't need to turn. While the pre-set path isn't as finished and complete as I would like it to be it does do the job and can make the vehicle move in any direction. I would have liked to improve this if I had more time with this project. I would also of liked to try and add a way of detecting obstacles using an ultrasonic sensor.

The first step in building this was downloading the files to print the parts for the wheels and then printing the parts in the right materials. I chose red for the tpu parts that needed to be flexible and grip the ground and black for the pla parts that needed to be sturdy. Once I had a wheel printed, I needed to assemble it with all the necessary parts (I needed 8mm rod for the centre but used 6mm rod instead). After this I needed to find bearings big enough to fit into the middle of the wheel. after getting all the bearings for the wheels and fully assembling a wheel I realised the weight of each wheel was far greater than I expected. I made a simple pulley to turn the wheel, but no simple motor would move the wheel.

I had to find out how much torque I needed to move one wheel. I spend weeks asking people and trying to figure out the calculations on my own. After I contacted a mechanical engineering student, I figured out the torque needed for each wheel. I then applied these calculations to the motor to try find the ideal motor. I found two motors that would work for my project.

After selecting the motor that suited my project the best, I started contracting the project once physical construction was completed, I started on the circuit construction. Once both of these things were done, I focused on problem solving. Problems like the battery holder or lack of room for the pulley. I added lights to the front of it for design and also to help tell the front from the back. Due to the shape of wooden base, I couldn't add any more design elements. While everything worked on as intended the base was just slightly too small for all the wheels and all their parts. One wheel didn't turn so only the forward and backwards motion goes without any problems.

Figure 30 Complete project view

6 References

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7 Appendix

```
//BTS7960 motor driver sketch

int R_IS = 1; //blue wires
int R_EN = 2; //green wires
int R_PWM = 3; //yellow wires
int L_IS = 6; //blue wires
int L_EN = 4; //green wires
int L_PWM = 5; //yellow wires

//Sideways facing 2 motors
int SR_IS = 7;    //blue wires
int SR_EN = 8;    //green wires
int SR_PWM = 9;   //yellow wires
int SL_IS = 12;   //blue wires
int SL_EN = 10;   //green wires
int SL_PWM = 11;  //yellow wires

void setup() {
  // put your setup code here, to run once:
 pinMode(R_IS, OUTPUT);
 pinMode(R_EN, OUTPUT);
 pinMode(R_PWM, OUTPUT);
 pinMode(L_IS, OUTPUT);
 pinMode(L_EN, OUTPUT);
 pinMode(L_PWM, OUTPUT);
 digitalWrite(R_IS, LOW);
 digitalWrite(L_IS, LOW);
 digitalWrite(R_EN, HIGH);
 digitalWrite(L_EN, HIGH);

 //Sideways motors set up
 pinMode(SR_IS, OUTPUT);
 pinMode(SR_EN, OUTPUT);
```

```
 pinMode(SR_PWM, OUTPUT);
 pinMode(SL_IS, OUTPUT);
 pinMode(SL_EN, OUTPUT);
 pinMode(SL_PWM, OUTPUT);
 digitalWrite(SR_IS, LOW);
 digitalWrite(SL_IS, LOW);
 digitalWrite(SR_EN, HIGH);
 digitalWrite(SL_EN, HIGH);
}

void loop() {
  // put your main code here, to run repeatedly:
  int i;
  for(i = 255; i <= 255; i= i+10){ //clockwise rotation
   analogWrite(R_PWM, 0);
   analogWrite(L_PWM, i);
   delay(2000);
   analogWrite(R_PWM, 0);
   analogWrite(L_PWM, 0);
  }
  delay(500);
  for(i = 255; i <= 255; i= i+10){ //counter clockwise rotation
   analogWrite(SR_PWM, i);
   analogWrite(SL_PWM, 0);
   delay(1000);
   analogWrite(SR_PWM, 0);
   analogWrite(SL_PWM, 0);
  }
  delay(500);
  for(i = 255; i <= 255; i= i+10){ //clockwise rotation
   analogWrite(R_PWM, i);
   analogWrite(L_PWM, 0);
   analogWrite(SR_PWM, 0);
   analogWrite(SL_PWM, i);
   delay(1500);
   analogWrite(R_PWM, 0);
```

```
  analogWrite(L_PWM, 0);
  analogWrite(SR_PWM, 0);
  analogWrite(SL_PWM, 0);
 }
  delay(10000);
}
```

CMT (DL835) Student Projects
20/21 – Home working and Covid-19
‘Low Risk+’

Standard Risk Assessment Template
For activities carried out in the School of Creative Technologies facilities **and at the student’s home.**
These are projects where all Hazards are Ranked as a 3rd Rating.
See Risk Rating Matrices on Pages 10 and 11.

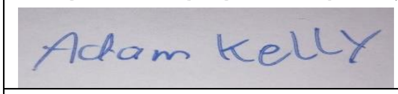
Project Risk Assessments and the methodology are needed to comply with the Safety, Health and welfare at work act 2005 and all other relevant Legislation. This document is based on the ‘Joint Risk Assessments’ procedure – IADT – December 2010.

The document has been updated to now include:

- Home working risk identification and control – highlighted in italics
- Covid-19 risk identification and control – highlighted in bold
- The Low Voltage Directive, LDV (previously in a separate document

PLEASE NOTE: HOME-WORKING AND COVID-19 HAS RAISED THE LEVEL OF THE RISK OF HOME WORKING AND LAB WORKING, SO THAT THE LOW RISK TEMPLATE IS NOW OF A LEVEL IN BETWEEN THE LOW AND MEDIUM RISK LEVEL AS DEFINED IN THE PREVIOUS ACADEMIC YEAR.

PROGRAMME/YEAR:

STUDENT NAME Mr. Adam Kelly	**SUPERVISOR:** Dr. Paul Comiskey
DIGITAL SIGNATURE: 	DIGITAL SIGNATURE: 
DATE:29/04/2022	DATE:

By signing this assessment, it is agreed by all parties that:

- The student has taken part in the relevant class session and/or seen the accompanying powerpoint presentation
- The full facts relating to the health and safety aspects of the project have been declared by the student
- All parties are fully aware of the safety risks
- All parties will implement the control measures detailed, in order to reduce the contribution of the hazards to the level of the risks detailed.

Location of Work:	*Relevant Campus facilities such as the laboratories, and at the student's home*

Brief RELEVANT Details of project: 20 words, highlighting the current drawn from the power supply and any processes that may be dangerous in the lab or at home.	Dangers: None Current: Batteries

Step 1: Initial Hazards Identification

Risk Assessment No.	INITIAL HAZARD
1	Electrocution
2	Fire
3	Cutting injuries
4	Drilling injuries
5	Heavy equipment
6	Burn Injury
7	Fumes

Step 2: Risk Assessment Forms

Significant Hazard and consequences:	**1. Electrocution**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	*Develop projects that consume low current (less than 1A) and use batteries or well-maintained AC/DC conversion units, particularly for the home environment.* Circuit design must include features that will minimise likelihood of electrocution of anybody, when in an unsafe mode, e.g. use of fuses and circuit breakers *in lab and home devices and supplies***.** Short circuits should be identified and removed before the testing stage. Cable and insulation should be checked before testing stage. Power supply equipment should be PAT tested on a regular basis in the lab. *Faulty power supply equipment at home should be identified and repaired by a qualified electrician before being used again.* *Liquid* sources should be kept away from the project, when in operation. Components, whether connected to power supplies or not, should be fully discharged before inspections – isolated from power supplies, are commenced. Eg discharge capacitors greater than 50µF via a 100Ω resistor. Be aware of the locations of first aid kit and fire extinguishers, *in the laboratory or in the home; familiarise yourself and* use these items if suitably competent/trained. *Be aware of actions that need to be taken in the event of electrocution, such as calling emergency services, resuscitation, and wearing insulation if touching the person electrocuted.*

Significant Hazard and consequences:	**2. Fire**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches, the laboratory environment and *household surfaces.* Keep combustible materials, eg paper, plastic, away from heat sources, such as soldering irons. Stow heat sources away safely when not in use, eg use a sturdy soldering iron stand. Circuit design must include features that will minimise likelihood of a fire, when in an unsafe mode, e.g. use of fuses and circuit breakers. Short circuits should be identified and removed before the testing stage. Suitable cable and insulation should be used, with a safety margin on the rating and size. *Liquid* sources should be kept away from the project, when in operation. Be aware of the locations of first aid kit and fire extinguishers, *in the laboratory or in the home; familiarise yourself and* use these items if suitably competent/trained. *Put in place measures that make the home working area is fire separated from other parts of the home, make that place relatively free of combustible materials, ensure there is some form of smoke detection in place, ensure there is a clear path to the nearest exit of the house.* In the event of a fire, leave the laboratory/building *or household working area/home* in an orderly manner, and sound the fire alarm if it has not already automatically activated.

Significant Hazard and consequences:	**3. Cutting injuries**

Who might be exposed to the hazards:	*Students and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches/ laboratory environment *and on household surfaces*. Develop projects with the minimum requirement for cutting any jagged edged in the final manufactured item. Use of quality, maintained tools and clamps if necessary. Use of a cutting board and goggles. Clear a space around the cutting area before commencing work. Tie back hair and loose clothing from the cutting area. Remove jewellery. Be aware of the location of the first aid kit *in the laboratory and at home* and use the kit if suitably competent/trained.

Significant Hazard and consequences:	**4. Drilling injuries**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	*In the laboratory*, only use the drill equipment if training, given by staff, has been undergone. *At home, follow all manufacturer's instructions in using a drill.* Use of quality, maintained drilling equipment and goggles. Secure drill bit and table. Use the drill guard. Check all fastenings are complete before switching on the drill machine. Drill machine *and equipment* should be tested and checked on a regular basis. Develop projects with the minimum requirement for cutting any jagged edged in the final manufactured item. Use of quality, maintained tools and clamps if necessary. Use of a cutting board and goggles. Clear a space around the cutting area before commencing work. Tie back hair and loose clothing from the cutting area. Remove jewellery. Be aware of the location of the first aid kit *in the laboratory and at home* and use the kit if suitably competent/trained.

Significant Hazard and consequences:	**5. Heavy equipment**

Who might be exposed to the hazards:	*Students, staff and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches and the laboratory environment. Undertake heavy lifting only if suitable advised and/or trained. Correct posture and lifting procedures. Use mechanical lifting aids where possible and appropriate. One or more persons to be involved in lifting or supervising the lifting of heavy equipment. *Take help from a household co-habitant where necessary, appropriate and possible.* Clear a space around the lifting area before commencing work. Tie back hair and loose clothing from the cutting area. Remove jewellery. Use protective footwear, and also headwear if necessary.

Significant Hazard and consequences:	**6. Burns**

Who might be exposed to the hazards:	*Students and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	Maintain tidy work practices on benches and the laboratory environment. Only use soldering irons and other hot-works appliances if training, given by staff, has been undergone. Keep combustible materials, e.g. paper, plastic, away from heat sources, such as soldering irons. Stow heat sources away safely when not in use, eg use a sturdy soldering iron stand. Cable and insulation should be checked before using soldering irons, or electrically powered hot-works appliances. Use gloves, goggles and other personal protection equipment where necessary. Use cooling equipment, such as wet sponges for soldering irons. Do not allow water from any source to penetrate electrical cables and wires. *Let members of the household know you are using a hot device. Keep soldering irons and other hot devices away from children and vulnerable adults.* *Make the sure the device is placed stably on the working surface, away from combustibles including mains cables, particularly that belonging to the device.* Tie back hair and loose clothing from the cutting area. Remove jewellery. Be aware of the locations of first aid kit and fire extinguishers, *burn gel and plasters, in the laboratory and at home*, and use these items if suitably competent/trained. In the event of a fire, leave the laboratory/building *or household working area/home* in an orderly manner, and sound the fire alarm if it has not already automatically activated. Electrically powered hot-works equipment, such as soldering irons, should be checked and tested on a regular basis. *If found to be faulty, particularly at home, tt should be repaired by a competent electrician before being used again.*

Significant Hazard and consequences:	**7. Fumes**

Who might be exposed to the hazards:	*Students and household members.*

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	Use fume extraction equipment, eg. for solder fumes. Keep laboratories *and household working areas* well ventilated. Take frequent breaks from activities generating fumes, *in the open air*. Employ a higher level of control measures when an individual suffers from a respiratory condition, such as asthma, taking advice from a GP**. In particular, take advice from a GP before you use a device which generates fumes, particularly if you have or have had a respiratory condition or disease such as Covid-19.** Solder fume extraction equipment and other similar items, should be maintained checked and tested on a regular basis.

Significant Hazard and consequences:	8. Infection of Covid-19

Who might be exposed to the hazards:	Students, Staff, and household members.

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	Follow ALL government guidelines, those from the Health Services Executive and the Health & Safety Authority. Keep updated daily on changes to these guidelines via their authorises websites. These include, and interpreted thus, but not limited to: Use personal protective gear for the face, such as a recommended mask for a professional environment, or a close fitting vizor, or both, in the lab, Be aware of all laboratory provisions for Covid-19 safety. Be aware of the Covid-19 safety station in the laboratories – containing hand sanitiser, blotting paper, disposable gloves. Use these items before commencing the lab session, during if necessary and afterwards especially if food is consumed before and after the lab session. At home, set up an equivalent Covid-19 station, and use the equipment as you would in the lab. It is expressly forbidden to eat in the labs, and it is recommended to do the same at home. Wipe down all surfaces before, during (if compromised) and after the lab sessions and at home, including touch points such as door and equipment handles. Do not touch the face, head unless the hands are clean with sanitiser. Cough into your elbow if necessary or into a tissue which you should then dispose of the tissue in the flip-top bins in the lab and wash your hands with soap or use hand sanitiser. Keep more than 2m in distance from anybody else in the laboratory. Navigate yourself around the lab to avoid close contact. Keep laboratories and household working areas well ventilated. Take frequent breaks from activities generating fumes, in the open air. Employ a higher level of control measures when an individual suffers from a respiratory condition, such as asthma, taking advice from a GP. Take advice from a GP before you use a device which generates fumes, particularly if you have or have had a respiratory condition or disease such as Covid-19. Enter and leave the lab in an orderly manner, ensuring social distancing, even in an emergency, such as a fire incident. Follow the regulations of disposal or high temperature cleaning, relating to your personal protective equipment.

Additional Hazards and Control Measures to be identified here, in the same format as the preceding sections. Paste in more pages if necessary:

Significant Hazard and consequences:	

Who might be exposed to the hazards:	

Proposed Control Measures – to be written in conjunction with project supervisor and revised at key project milestone dates	

Risk Rating Matrices

By looking at the hazard and asking how many people will be exposed to it, decide on the probability of an incident/accident occurring.

Example: Take an extension lead trailing along the floor up against the wall. The extension lead is a hazard and if it is in an office with one person working in it the probability and likelihood is “improbable” (see table No.1) because the lead is along the wall. However, if the lead is in a corridor with 200 people walking by there is a chance that someone could kick it out from the wall accidentally and create a greater probability/likelihood of a loss occurring thus upping its rating to “remote”.

When this is done you must decide on the seriousness of the loss, using the four columns on the left side of the Table No.2 below.

Example: Firstly taking the one person office example from above the possibility/likelihood is “improbable “but the result might be a “minor injury” e.g. scrape or a bruise. This gives us an “acceptable risk no action required” If we were to put the lead on a building site across an unguarded stairwell with 50 people using it the result is now possibly “fatal”. This gives us a “1ST rank action”.

Table No. 1:

PROBABILITY/LIKELIHOOD	DESCRIPTION
Likely/frequent	Occurs
Probable	Not Surprised. Will occur several times.
Possible	Could occur sometimes.
Remote	Unlikely, though conceivable.
Improbable	So unlikely that probability is close to zero.

Table No. 2:

	LIKELY	PROBABLE	POSSIBLE	REMOTE	IMPROBABLE
Fatal	1st	2nd	2nd	3rd	
Major Injury/ permanent disability	2nd	2nd	3rd		
Minor Injury	3rd	3rd			
No Injury					

By using the matrices above we now have an action needed ranking system. This means we can prioritize the hazards depending on their ranking.

Table No. 3:

	1st rank actions - requires measures to be put into place within a few hours
	2nd rank actions - requires measures to be put in place within a few days
	3rd rank actions - requires measures to be put in place within a few weeks
	4th Rank action – requires measures to be put in place within a few months.

Taking all this information and pooling it in the Initial Hazard Identification log we can now prioritise the hazards in the left hand column "Risk Assessment No." This number will appear on the top left of the risk assessment forms for easy referencing.

Low + Risk Project – Risk Rating Summary

Risk Assessment No.	INITIAL HAZARD	Probability	Ranking
1	*Electrocution*	*Possible*	*3rd*
2	*Fire*	*Possible*	*3rd*
3	*Cutting injuries*	*Possible*	*3rd*
4	*Drilling injuries*	*Possible*	*3rd*
5	*Heavy equipment*	*Possible*	*3rd*
6	*Burns*	*Possible*	*3rd*
7	*Fumes*	*Possible*	*3rd*

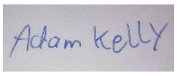
‘Low Voltage Directive’ Compliance Statement.

DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits (codified version) (Text with EEA relevance)

Otherwise known as the Low Voltage Directive (LVD).

If the electrical aspects of your project have a voltage between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current, for voltages at the **electrical input or output** (not internally), then you are signing to **confirm that it complies with all the safety requirements of the LVD**. You must read the LVD and analyse your project before signing, taking advice where necessary.

Student name: Adam Kelly

Digital signature: 

Date: 29/04/2022

Project supervisor or delegated representative who is an engineer by discipline:

Name:

Digital Signature:

Date: