CS4126: 3D Modelling and Digital Fabrication

Assignment Report

Live Bus Tracker

Annika Jungfleisch (22359923)

Table of Contents

Introduction

We were tasked with designing, modelling, and documenting a prototype device using the integrated touchscreen and ESP32. I needed to decide what to use the ESP32 and touchscreen device for and design a prototype around this use. Once I decided on a design, I needed to go through a prototyping process, from sketches and ideation to low-fidelity and higher-fidelity prototypes.

Ideation

Before starting my prototyping process, I researched the different projects people had previously done with the ESP32 and touchscreen device. I got stuck on two designs and came up with one more while waiting at the bus stop in front of my house. After brainstorming these ideas further, I started sketching them to see what they could look like.

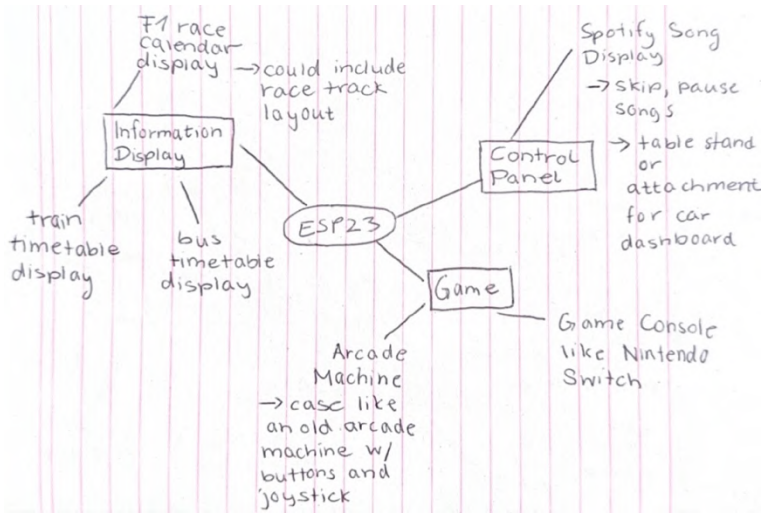

Figure 1 - Brainstorming of different ideas

The first idea I liked included an F1 racetrack calendar. The screen would display the next upcoming race, and the times of the individual sessions related to that race in the local time. My idea was to design a low-detail F1 car and integrate the ESP32 and touchscreen into the DRS flap.

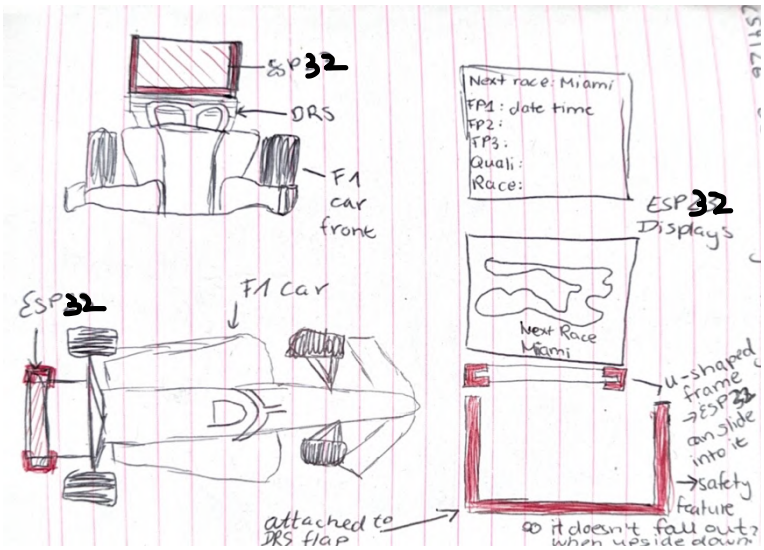

Figure 2 - Sketches of the F1 car idea

My next idea was a Spotify car play display. The touchscreen and ESP32 would control the Spotify music from one's phone without interacting with the phone itself. The touchscreen would be mounted in a car phone holder that clips into the car's radiator or sticks onto the dashboard.

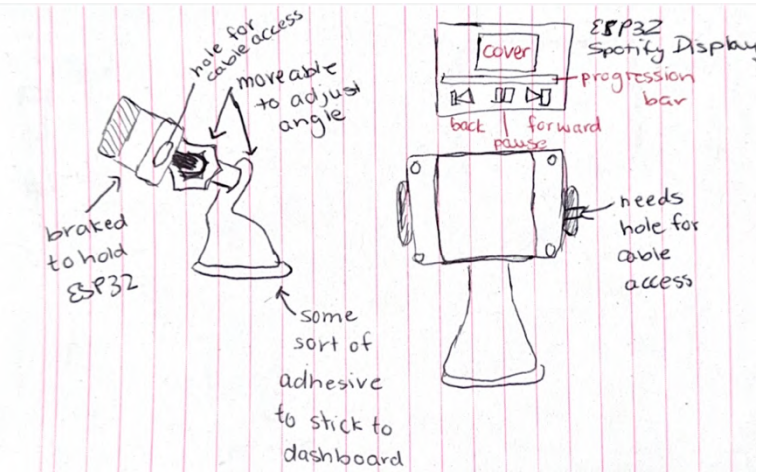

Figure 3 - Sketch of the Spotify idea

My last idea was a bus stop timetable display. The ESP32 and touchscreen would function as a real-time bus timetable, and the casing would resemble a bus stop sign.

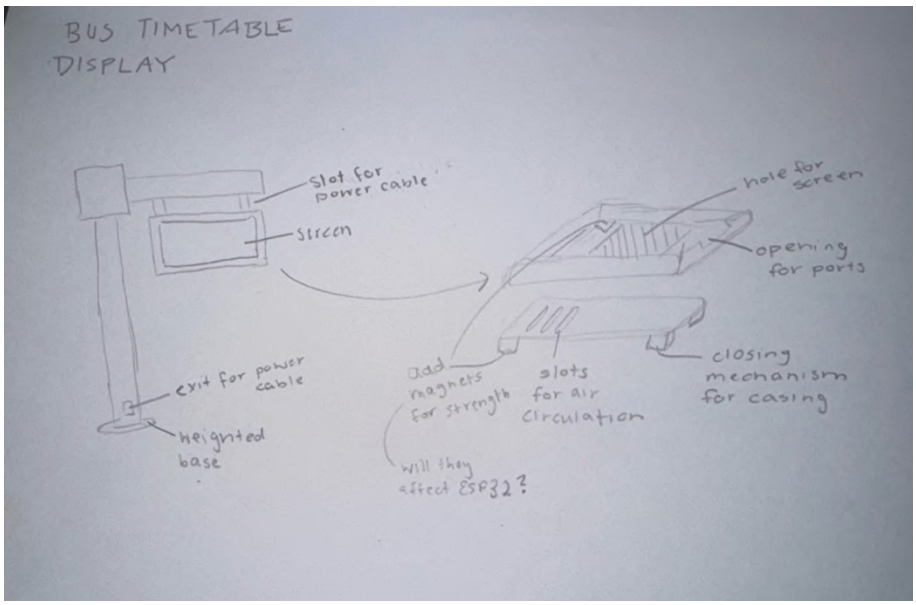

Figure 4 - Sketch of the bus stop sign idea

This is the design I chose as my final design. It would allow for a tightly fitting touchscreen case while allowing for creative thinking and problem-solving.

Research

Before finalising my design idea, I researched the National Transport Agency API. This would allow me to access the real-time data of the buses I wanted to display on my touchscreen. Once I got access to the API, I was able to request the data for the specific bus stop I had chosen, the Opp Hurlers bus stop.

I used the GitHub notes [gtfs-realtime] to access the National Transport Agency API as a REST API hosted with Docker. This allowed me to integrate the data onto the touchscreen. Because the code is in C++, I used ChatGPT to edit the data displayed until I was satisfied.

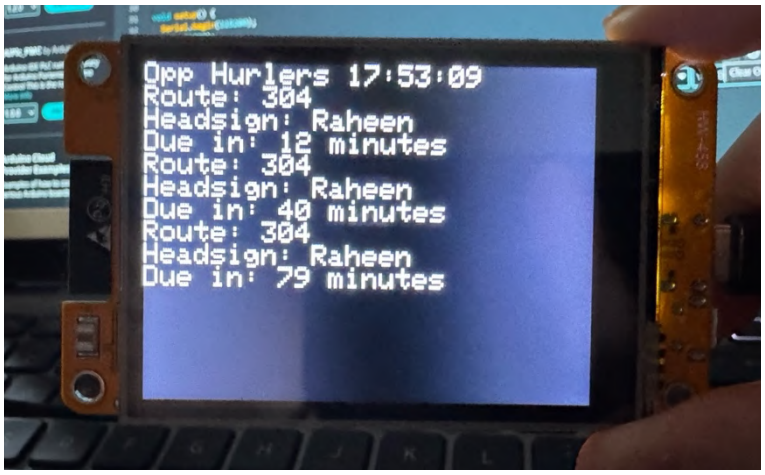

Figure 5 - Original display of bus times before modifying the Python code

Figure 6 - Modified display of bus timetable

I also included a standby screen that shows when the touchscreen is powered up but cannot connect to the API.

Figure 7 - Standby Screen

Additionally, I researched weighing down the base, assuming one side of the bus stop would be much lighter than the ESP32 and touchscreen. I came across multiple options to add weight to the vertical pole, such as epoxy, sand, and craft weights. I decided to go for craft weights as they were the least messy to work with.

Sketching

I began sketching the ESP32 and touchscreen, and measured it with the help of digital callipers.

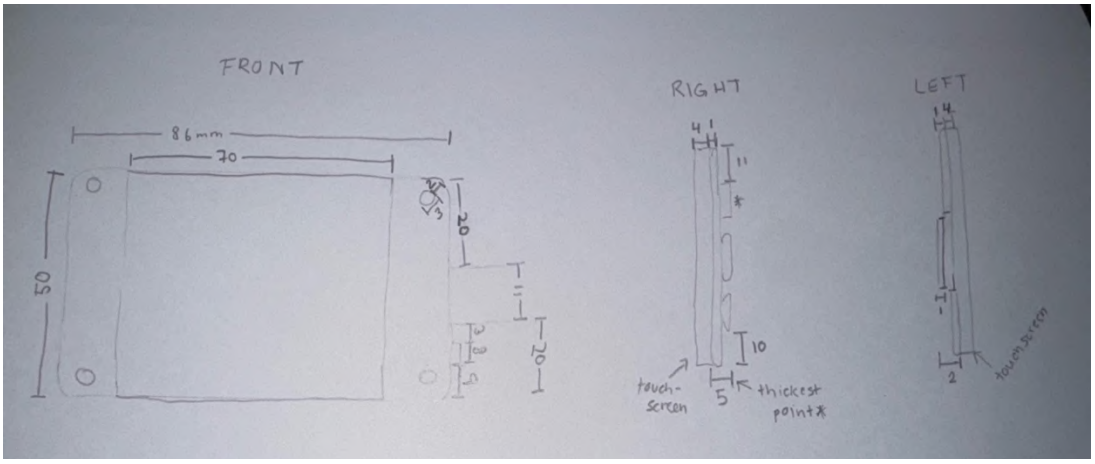

Figure 8 - Sketch of ESP32 and touchscreen measurements

This would help me later when imagining the size of the bus stop and the dimensions of the printer bed.
I then sketched the bus stop sign in more detail, adding rough measurements to help me visualise my idea.

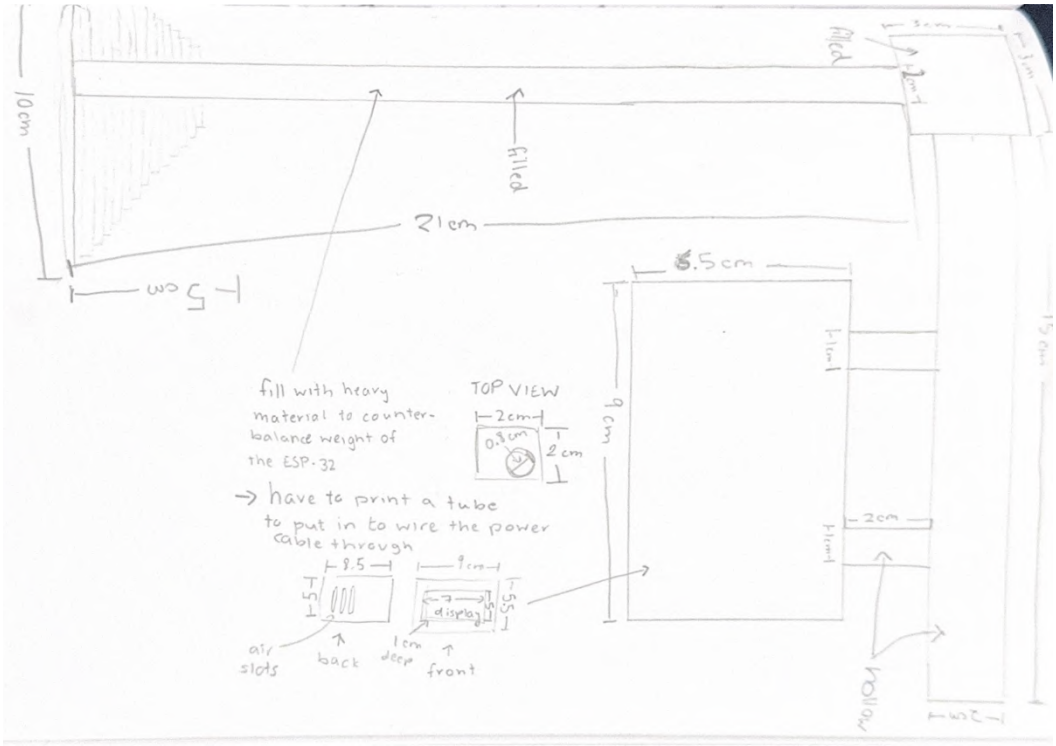

Figure 9 - Sketch of the bus stop sign idea with rough measurements

While sketching, I considered two ways to display my idea. One was the previously illustrated bus stop. The other was to 3D model a Bus Éireann bus and integrate the ESP32 and touchscreen into the side of the bus.
I sketched both ideas, outlining the placement of the touchscreen. Since the printer I used had a printing bed measuring 180x180x180 mm, I was unable to make the bus idea work and decided to focus on the bus stop concept. I began to map out where each of the four parts would connect and how the cable would be positioned. A forced cable arrangement would ensure a clean appearance, as the design is meant to be displayed on a desk or shelf. I also appreciated the design because it resembled the real-life version.

Prototyping

I started prototyping by creating my bus stop idea out of cardboard. I utilised different techniques to create a low-fidelity prototype of my bus stop idea.
To fold the cardboard, I made some light cuts into the cardboard that didn't go all the way through. I used some string and tape to attach the individual parts to each other. Additionally, I tried to make the base heavier by using multiple cardboard circles on top of each other, rather than just having the bottom of the pole as the base.

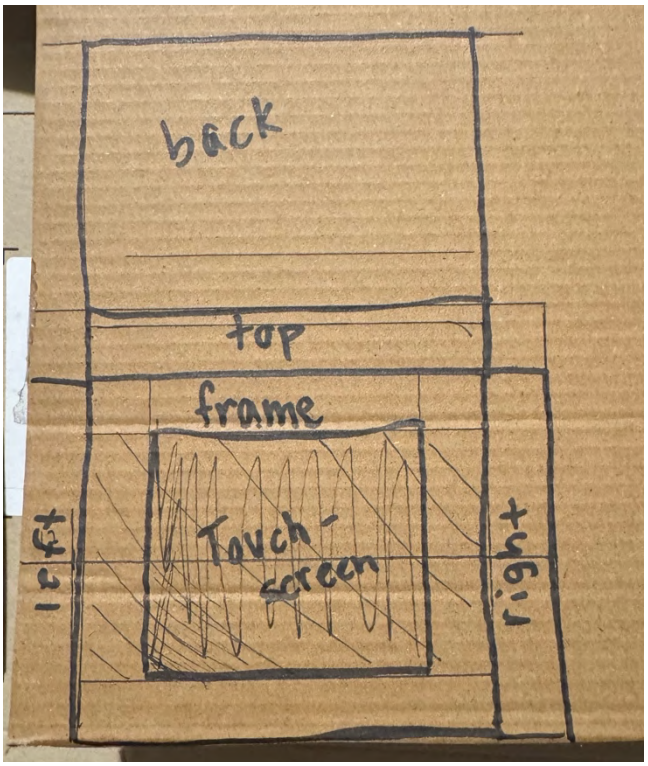

Figure 10 - Sketch on cardboard to help with cutting out the ESP32 and touchscreen case

Figure 11 - First cardboard prototype

Figure 12 - First cardboard prototype standing up

My first prototype functioned surprisingly well, which is why I continued in the same direction with my next prototype. I split the prototype into four individual parts for two reasons. The first reason was the size of the print bed, and the second was structural integrity. Inserting the poles into each other and then into the base provided the prototype with more stability than if there were one big piece.

For my second prototype, I measured my individual pieces and ensured the touchscreen fit into its casing. Rather than just taping pieces together, I made sure I could stick them together like I planned to do with the 3D-printed version.

Figure 13 - Vertical pole and connecting cube of the second cardboard prototype

Figure 14 – Front of the cardboard prototype of the case

Figure 15 - Back of the cardboard prototype of the case

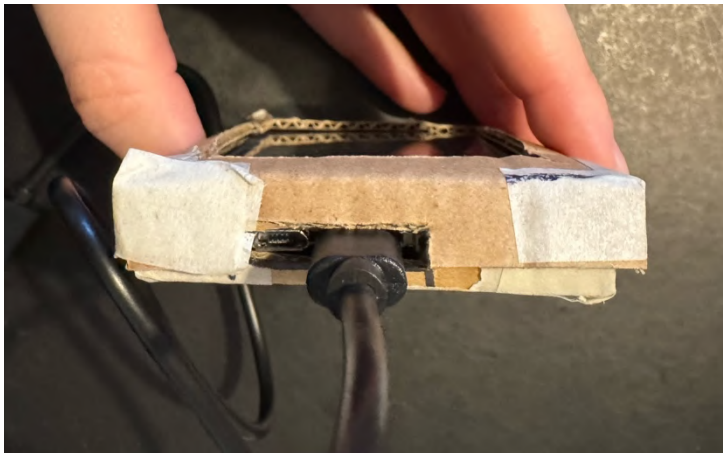

Figure 16 - Side of the cardboard prototype of the case

I also added a cutout for the cable, which made me realise that I had designed the previous prototype the wrong way around, as the cable port was not on the side of the pole. This meant the cable would have hung freely from the casing, making the design look cluttered.

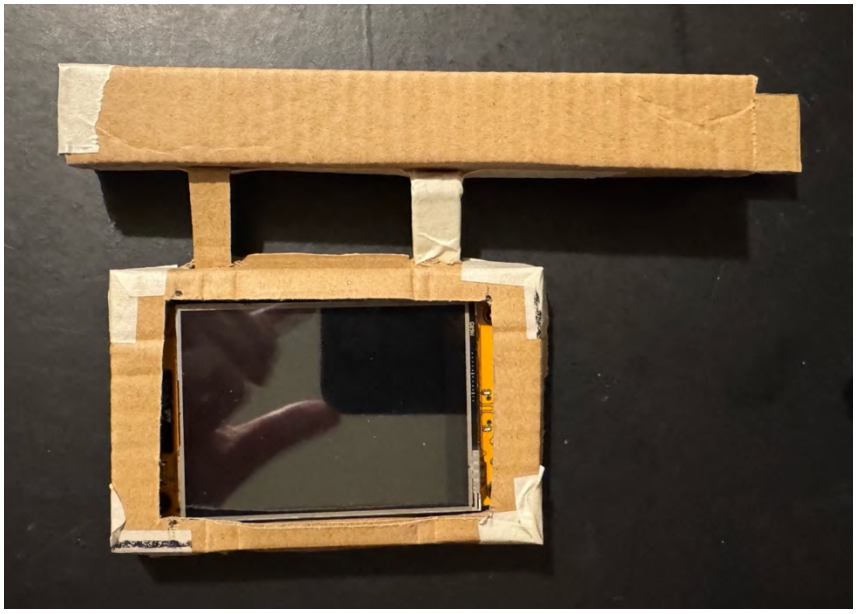

Figure 17 - Cardboard prototype of the case and horizontal pole

Figure 18 - Full cardboard prototype with ESP32 and touchscreen device

When testing this prototype, I confirmed my suspicion that the touchscreen made one side of the bus stop sign so heavy that the base couldn't stand. This is why I included inserts for

craft weights in my 3D design. I also devised a loop system to attach the case to the pole. I had to revise this later as I struggled to design it in FreeCAD.

3D Modelling

When I started working on the base, I had a solid idea of how to design it in FreeCAD because I had previously prototyped it in cardboard. I created multiple circles, each with a height of 5 mm and a radius 5mm smaller than the previous one. I initially designed seven circles stacked on each other, but revised that later due to aesthetic reasons.
After I merged the seven circles with a Boolean command, I designed a cube slightly bigger than the vertical pole and subtracted the cube from my base, creating an opening for the vertical pole to be stuck in.
Once the base was completed, I created the vertical pole by creating a cube and adjusting the height, width, and length to my desired measurements. I originally planned to have the pole be 21 cm tall, but due to the size of the printing bed, I reduced it to 17.5 cm.
I aligned the pole and base to check if everything fit. Once I was sure everything fit, I went and started the horizontal pole design.

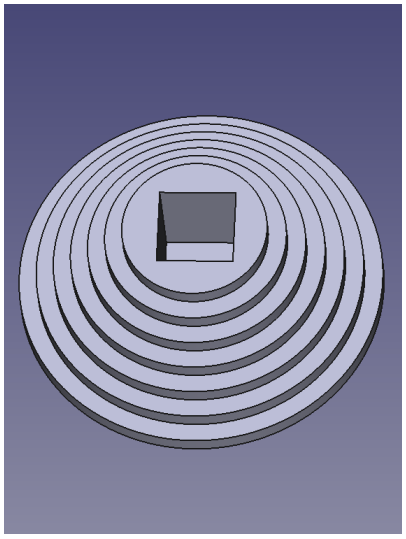

Figure 19 - FreeCAD design of the base

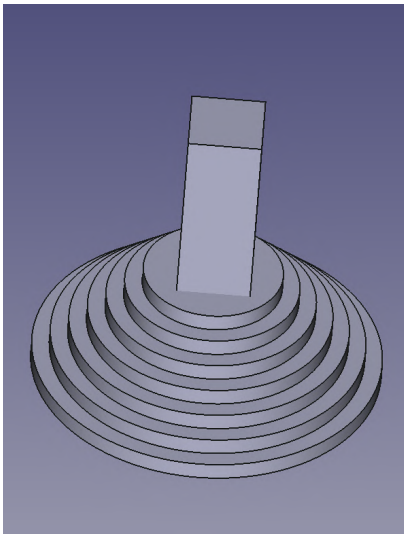

Figure 20 - FreeCAD design of the base before using Boolean subtraction

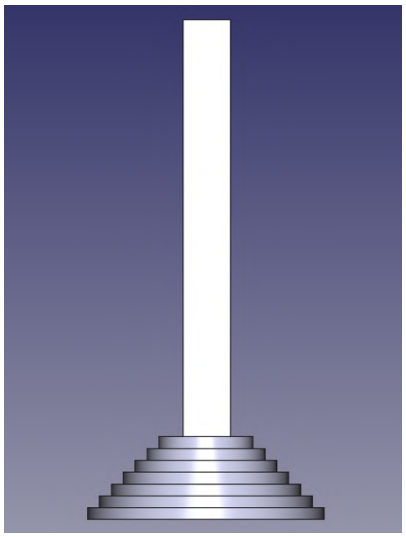

Figure 21 - FreeCAD design of base and vertical pole

Similarly to my cardboard prototype, I created a cube as the connecting joint for the vertical and horizontal poles. The connecting cube is 30 mm tall, wide, and long, 10 mm more than the poles. Using the Boolean subtraction, I created a cutout in the cube for the vertical pole to fit into. I then made the horizontal pole by creating another cube, adjusting the height, width, and length to my desired measurement, and combining it with the connecting joint.

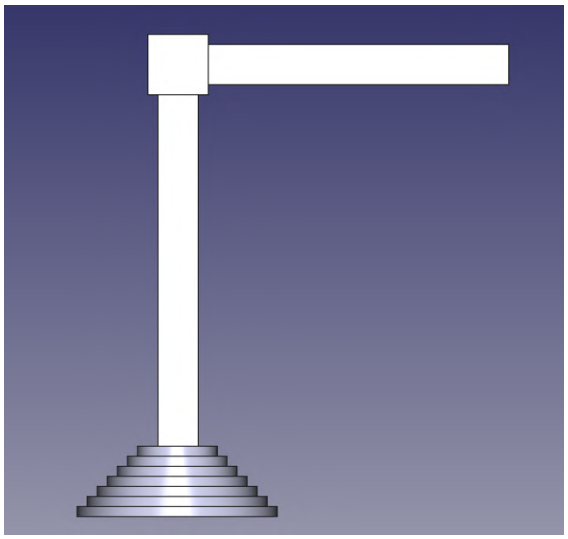

Figure 22 - FreeCAD design of the bus stop structure

After I was satisfied with the outcome, I continued to work on the component that would connect the bus stop to the case for the ESP32 and touchscreen that I had yet to design. After some brainstorming, I created hooks to connect the two parts.
Using cylinders and toruses, I created two hooks. Unfortunately, I later realised that they were facing the wrong direction. Utilising the transformation tool in FreeCAD, I was able to rotate them, having them face in the right direction.

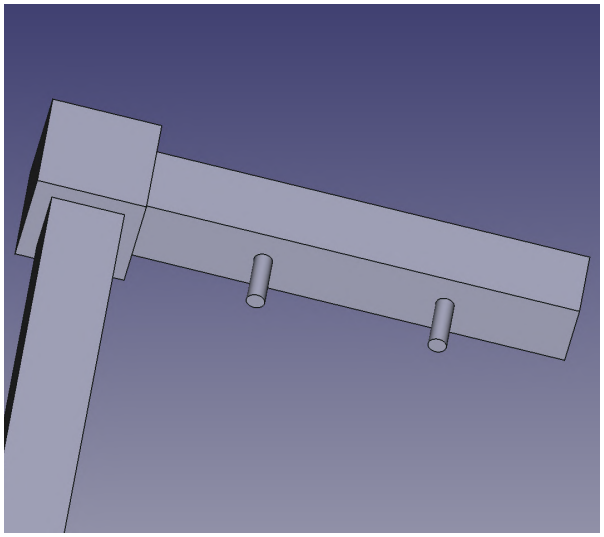

Figure 23 - FreeCAD design of the cylinders

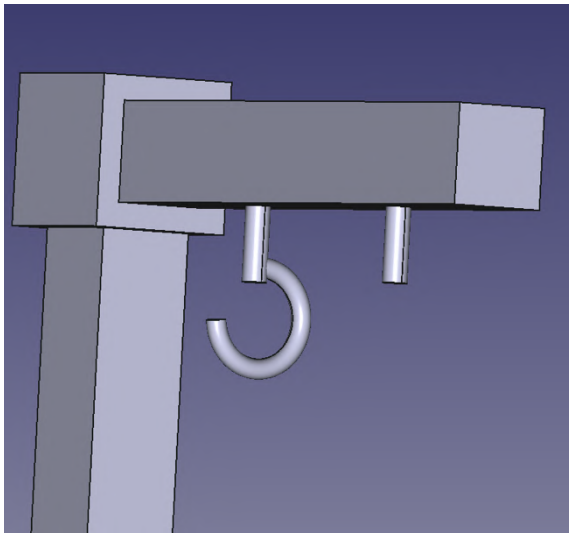

Figure 24 - FreeCAD design of the hooks

As I discovered through cardboard prototyping, the base would not be heavy enough to stay upright once the touchscreen was integrated into the design. I bought craft weights to make

it heavier. After measuring the weight, I created circular cutouts in the base so I could glue the weights to it.

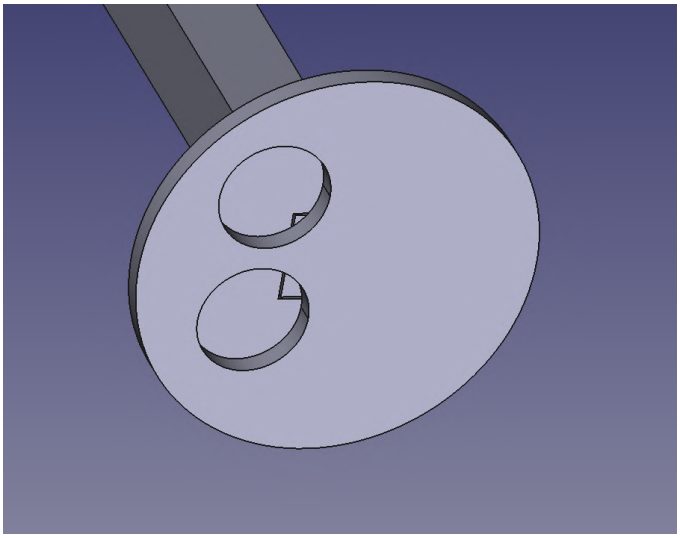

Figure 25 - FreeCAD design of cutouts for the weights

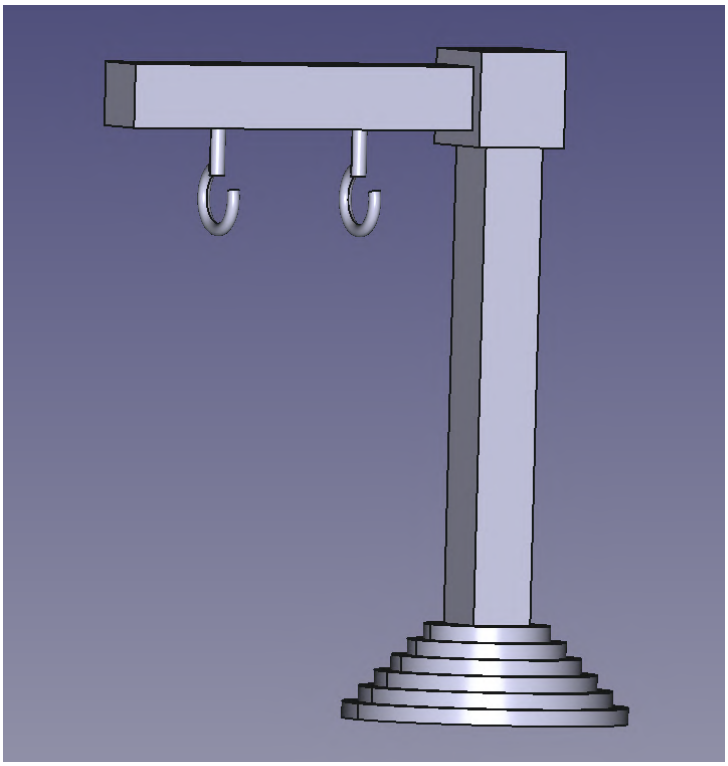

Figure 26 - FreeCAD design of the bus stop structure

Once I was happy with the bus stop design, I moved on to the touchscreen and ESP32 case. For this case, I wanted to use 4 mm magnets for the closing mechanism. The lid would have a 1 mm lip to add security to the closing mechanism. I choose magnets over screws as that was what I had available to me.
Furthermore, I decided on a square case with rounded edges. The front of the case would have a cutout for the touchscreen, and the back would have cutouts for ventilation.

As I had difficulty finding the correct measurements for the case, I decided to print it first and see how the print looked. Once it was printed, I would mark and measure directly on the print. During the first print, I realised I would need guides to secure the touchscreen in place, as I had decided to make the case bigger than required for aesthetic reasons.
To design the case, I used the Part Design bench and sketches rather than the Part Bench and Boolean tools, which I used for the bus stop structure.

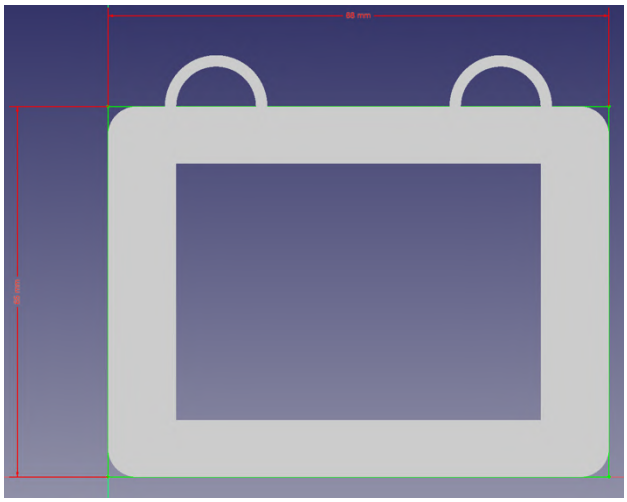

Figure 27 - Sketch of the case

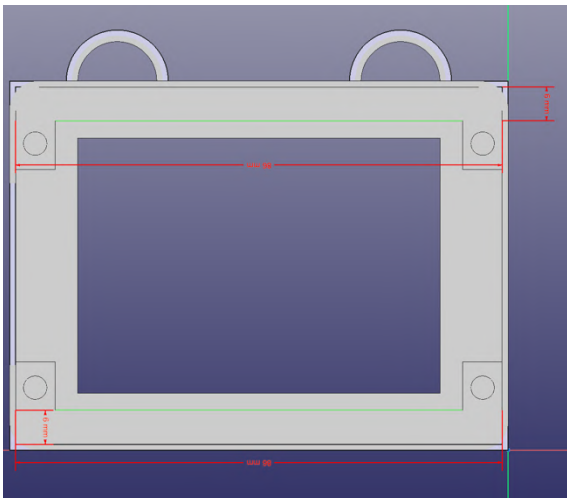

Figure 28 - Sketch of the magnet enclosures

I created little pockets for the magnets to fit into. I decided to raise them so that the display would comfortably sit on them without sliding within the case. The magnet cutouts, therefore, function as guides and closing mechanisms.
For the arc design, I used the measurements from the hooks I created earlier.

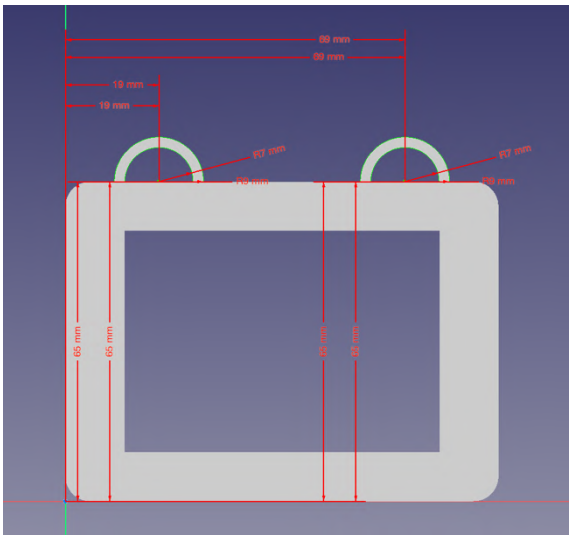

Figure 29 - Sketch of the arcs

Based on the measurements I took of the touchscreen earlier in my prototyping process, I created another pocket for the ports on the side of the touchscreen.

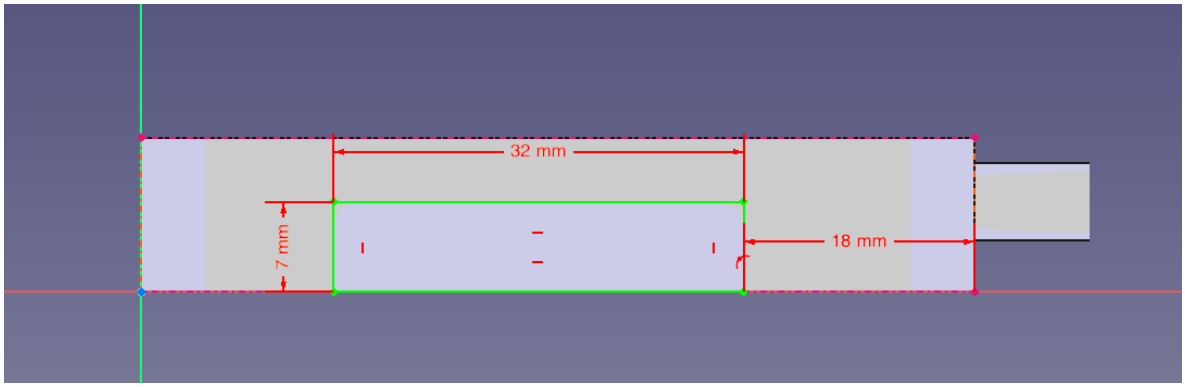

Figure 30 - Sketch of the pocket for the ports

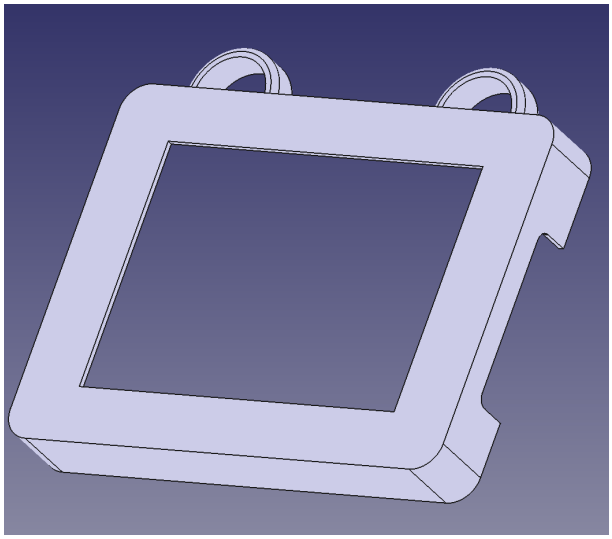

Figure 31 - FreeCAD design of the box part of the case

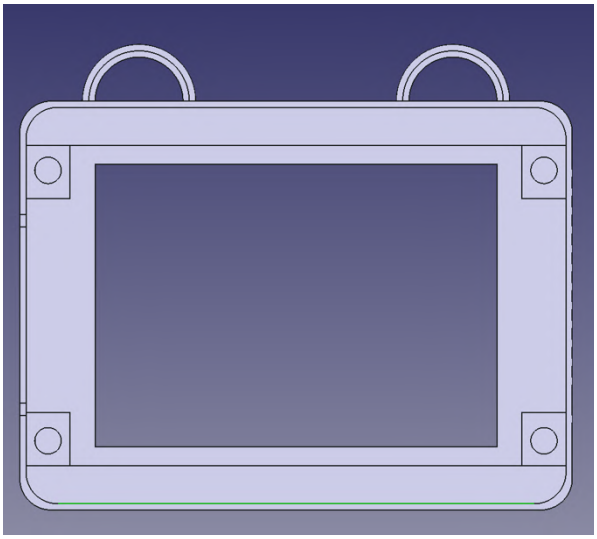

Figure 32 - FreeCAD design of the inside of the box part

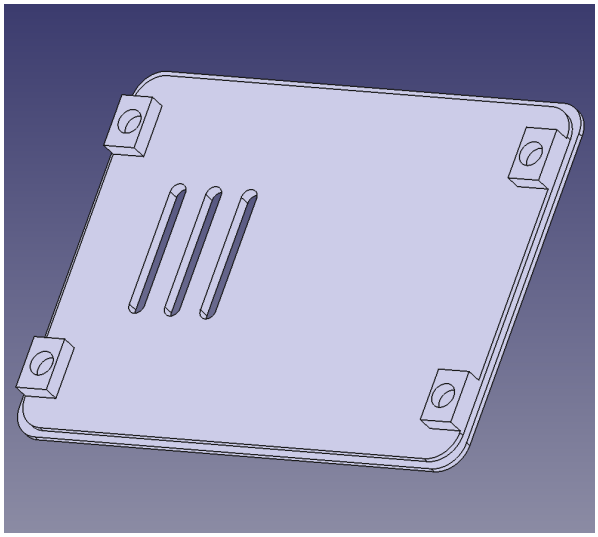

Figure 33 - FreeCAD design of the lid

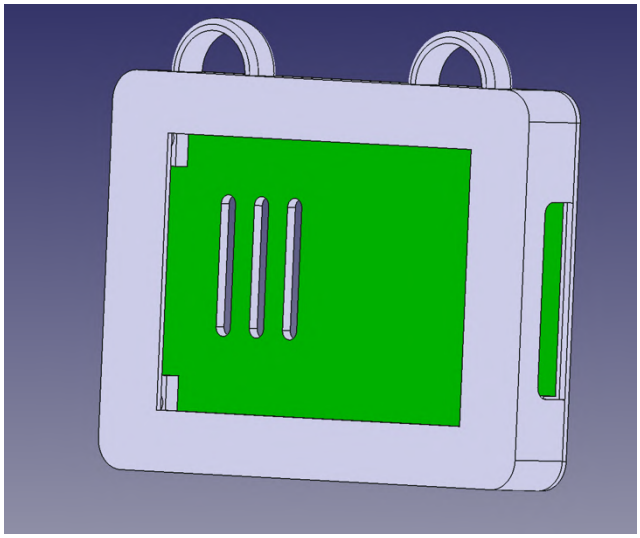

Figure 34 - FreeCAD design of the case (front)

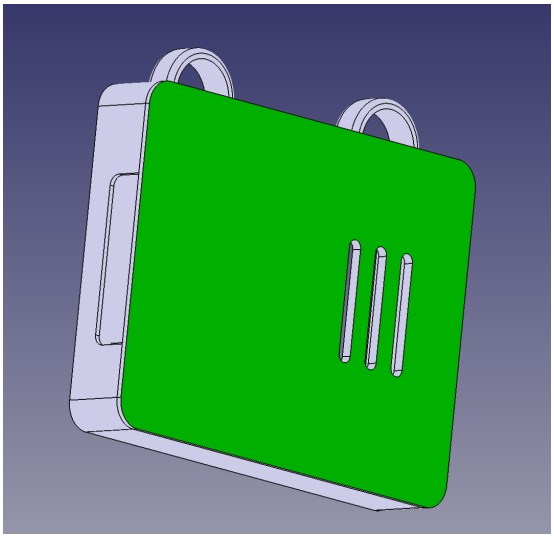

Figure 35 - FreeCAD design of the case (back)

3D Printing

I used the Bambu Lab A1 mini with the PLA Matte Charcoal filament for my final print and the Sunlu PLA Plus Filament in Blue Grey for prototyping.

As I designed the base and poles first, I printed them before designing the case. The first print had a few errors that needed to be corrected.
Firstly, the size of the holes that were used to connect the individual pieces of the bus stop needed to be smaller by about 0,8 mm and the indents for the weights required to be 1,5 mm deeper. Additionally, the horizontal pole had some printing errors, and I discovered that printing it vertically rather than horizontally is safer. For aesthetics, I also decided to make the base smaller, e.g., removing one of the circles.

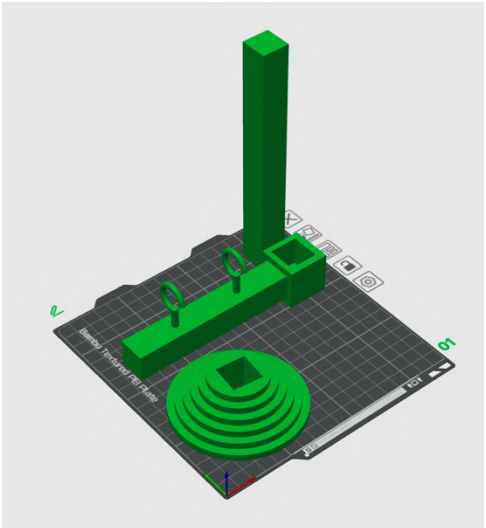

Figure 36 - First print in Bambu Studio

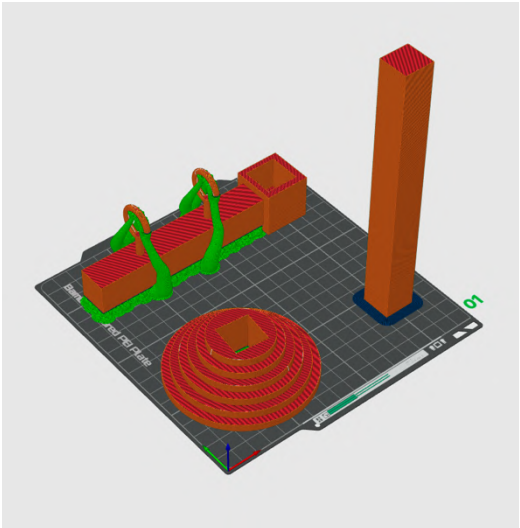

Figure 37 - First print sliced

The picture below shows the base's first print and how the weights' indents were too shallow. Moreover, the image of the bus stop shows the printing error of the horizontal pole. The right end of the pole is printed faultily as the supports lifted off the printer bed during printing. The

horizontal pole is also slightly sloped, as the holes for the vertical pole were too big and the pieces had too much room to move.

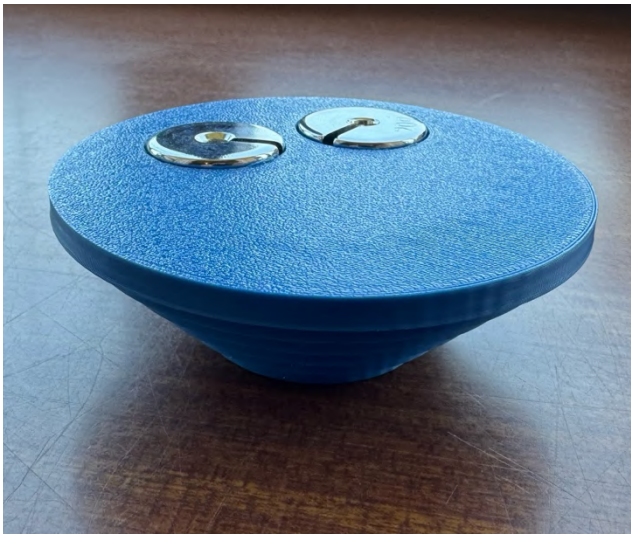

Figure 38 - Base print with weights sticking out

Figure 39 - First print of the bus stop structure

While those pieces were printing, I designed the case without the lid and printed it once the previous pieces were finished.
I quickly realised that the display cutout and the whole case were way too big. I reduced the height of the display cutout by 7 mm and subtracted 10 mm of the height and 3 mm of the width from the case. Due to the hook being printed in the wrong direction, the cutout for the ports was also on the wrong side and had to be changed.
This print made me realise I would need guides for the touchscreen to sit securely in the case.

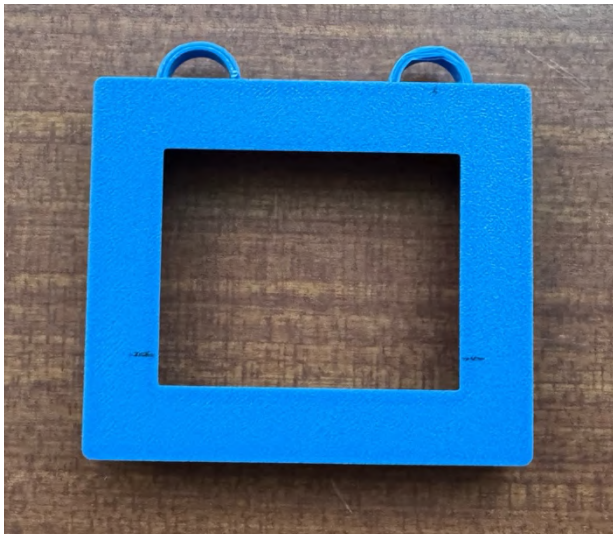

Figure 40 - Photo of the first print of the case (front)

Figure 41 - Photo of the first print of the case (back)

Figure 42 - First print of the case with the ESP32 and touchscreen

After incorporating all the noted changes, I reprinted the case without its lid. Here, I realised that the touchscreen guides were too deep and needed to be reduced by 6 mm, as the touchscreen was sitting on top of them and was not being held in place by them. The magnet cut-outs were also too shallow and needed to be further apart.

Figure 43 - Photo of the second print (back)

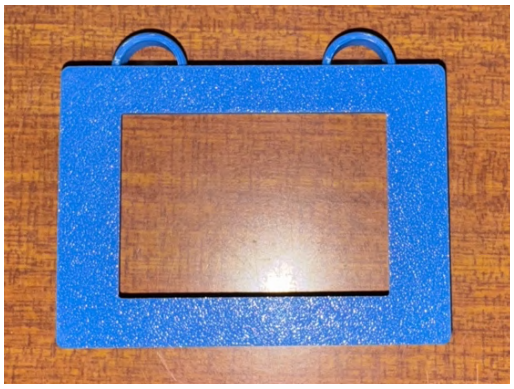

Figure 44 - Photo of the second print (front)

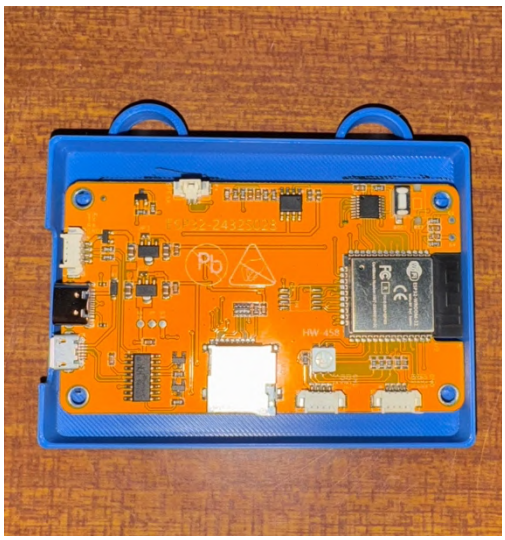

Figure 45 - Photo of the second print with the ESP32 and touchscreen

The next print of the box revealed that the guides needed to be higher and the bottom guide deeper to hold the touchscreen in place. Additionally, the touchscreen cutout needed to be 1 mm bigger on each side, as the information meant to be displayed on the touchscreen was very close to the edge (see figures 6 and 7). I had also moved the magnet indents too close together and had to move them by 1 mm. For this print, I had increased the fillets for aesthetic reasons. I liked the roundness of the edges and decided to keep it for the next iterations.

Figure 46 - Third print with ESP32 and touchscreen.

Figure 47 - Third print with magnets

For the fourth print, I decided to include the lid as I was pretty sure the box part of the case would fit this time. Unfortunately, I didn't include a brim when printing, which resulted in a printing error. However, I was correct in my assumption that the box would fit the touchscreen in this iteration.

Figure 48 - Third print with touchscreen.

Figure 49 - Third print (side)

Figure 50 - Printing error of the lid

Figure 51 - The four iterations of the box part of the case

For the next print, I concentrated on the base and poles again, as I hadn't reprinted them since I incorporated the changes from the first print. Everything went well in this print, and the pieces fit together smoothly. I also reprinted the lid of the case, including a brim. The printing went smoothly, and the lid fit tightly on the box part of the case.

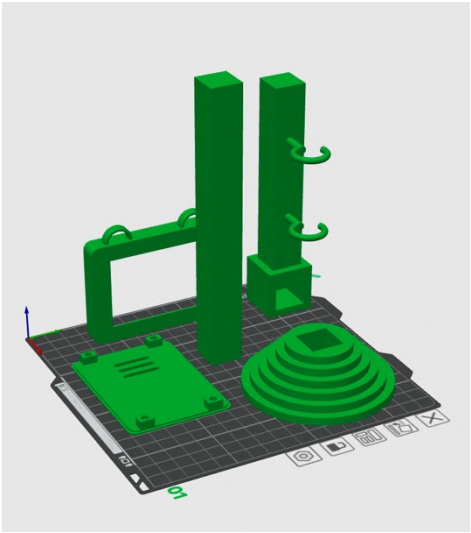

Figure 52 - Screenshot of the print in Bambu Studio

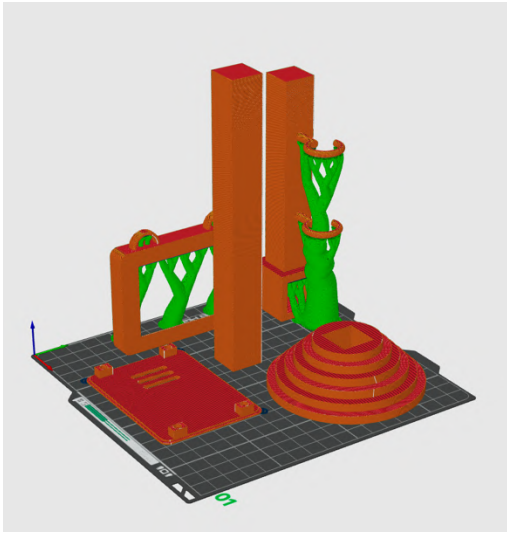

Figure 53 - Print sliced

Figure 54 - Photo of successful print (front)

Figure 55 - Photo of successful print (lid)

Figure 56 - Successful print assembled

Figure 57 - Successful print assembled with the touchscreen

As I was very happy with the outcome of this print, I decided to switch to black, which is the colour I wanted the bus stop to be. I printed all the pieces together for the next print.

Figure 58 - Black version printing

I tried out a new printing orientation for the box part of the case, hoping the arcs would print smoother. Unfortunately, this caused the layers on the inside not to stick together and loosen. Similarly, the horizontal pole showed some printing errors due to the length of the print. I reprinted the box part and the horizontal pole in a different orientation, and both showed no printing errors in the reprint.

Final Print

Figure 59 - Photo of the final print (outside)

Figure 60 - Photo of the final print (inside)

Figure 61 - Photo of the final case print assembled

Figure 62 -Photo of the final case print assembled (side)

Figure 63 - Photo of the final case print assembled (side)

Figure 64 - Photo of the final print of the case assembled with the ESP32 and touchscreen

Figure 65 - Photo of the final print of the base with the weights glued in

Figure 66 - Photo of the final print of the vertical pole

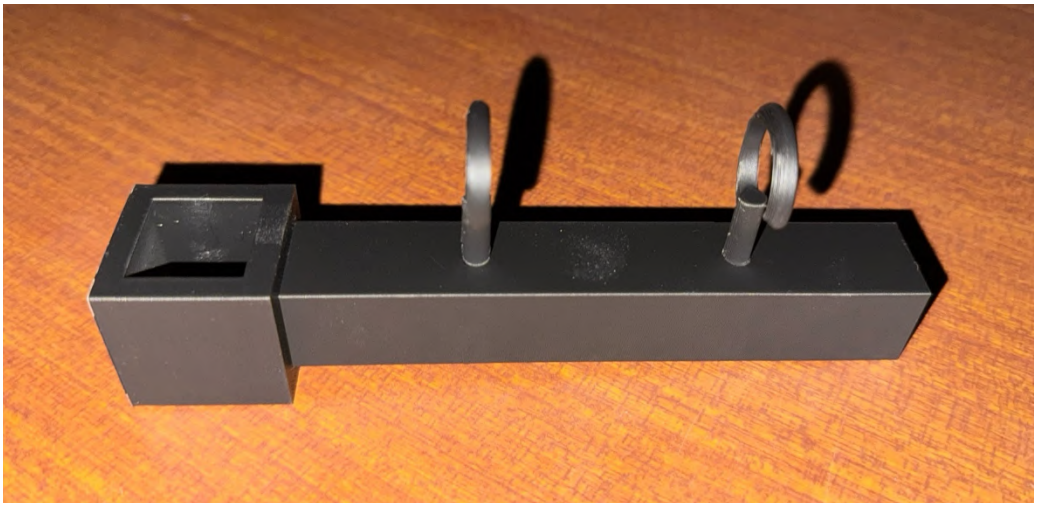

Figure 67 - Photo of the final print of the horizontal pole

Figure 68 - Photo of the final print assembled (left)

Figure 69 - Photo of the final print assembled (right)

Figure 70 - Photo of the final print assembled (back)

Figure 71 - Prototype assembled with ESP32 and touchscreen turned on and connected to the API

Technical Drawings

The technical drawings were created using the TechDraw workbench in FreeCAD.
I used the A4 Portrait minimal template, which allowed enough space for all the pieces of my prototype on a 1:1 scale. The technical drawings were exported to SVG and saved as PDFs for better accessibility.

Function

The bus stop is a live tracking bus tool shaped like a bus stop sign, designed to replicate traditional bus stop signs. The device can be placed on a desk, where it will display the live bus timetable for a user-selected bus stop. Inside the device, there is an ESP32 and a touchscreen. The ESP32 connects to the National Transport Agency API, automatically updating every 30 seconds. This device is ideally used to inform users when a bus is arriving at their nearest bus stop, helping them time their travel correctly.
Most of the prototype is aesthetic, as the bus stop sign elements have no other purpose besides displaying the touchscreen in a readable position and providing cable management.
The case is mainly practical, as it secures the touchscreen. The base is also mostly practical, as it holds the weights that allow the bus stop sign to stand upright.

Manufacture

This prototype has been 3D printed, as 3D printing is relatively fast and cheap compared to other options.
Printing all pieces took a little over 5 hours, and assembly took less than 10 minutes.
As this project required 3D geometry and tight tolerances, 3D printing was the most efficient process compared to laser cutting and CNC Milling. Additionally, it allowed for fast changes and iterations with low material costs.

The prototypes were printed on a Fused Deposition Modelling (FDM) printer using PLA instead of a more costly printer or material to keep costs down. Design rules for FDM printing were followed when modelling the device, meaning the pieces could be printed confidently. As the vertical pole of the device is 175 mm, a 3D printer with a large print bed is required. The Bambu Lab A1 mini was used as it has a 180x180x180 mm print bed, making it ideal for this project.
The meshes of each body must be sliced. Since I was using a Bambu printer, I had to use Bambu Studio to slice my meshes.
The .stl files were imported into Bambu Studio, where the correct printer was selected. Bambu Studio optimised the rotation and placement for the safest and fastest printing process. Supports and brims were enabled as the prototype has many overhangs. The print time is 5 hours and 5 minutes. The Bambu Lab A1 mini printer has a camera to monitor the printing process even from afar. Matt Charcoal filament will be used for this device. All pieces should not be printed together. For optimal printing, the base, lid and vertical pole should be printed first. Then, the vertical pole and box part of the case should be printed. All pieces should use the same filament. The lid will need a brim to be added for printing. All pieces except for the vertical pole will need supports.

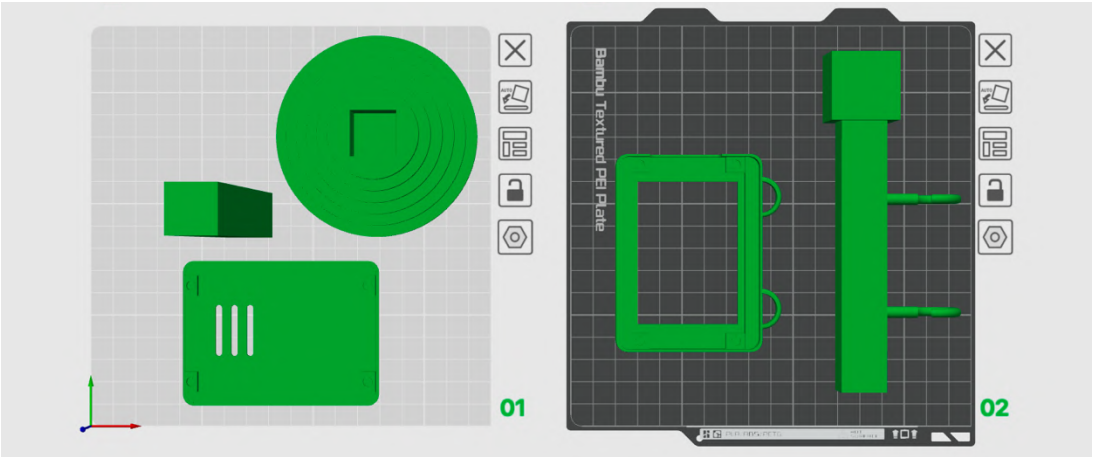

Figure 72 - Screenshot of the ideal piece placement in Bambu Studio

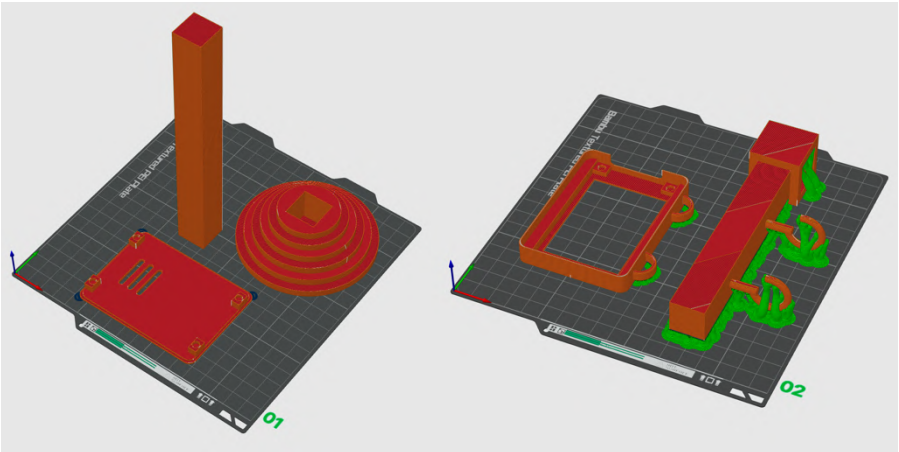

Figure 73 - Print sliced

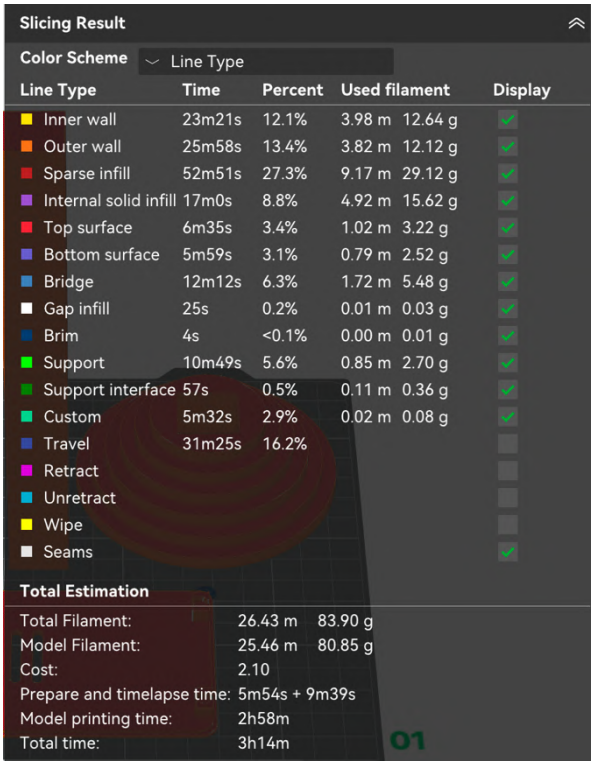

Figure 74 - Slicing Results for the first plate

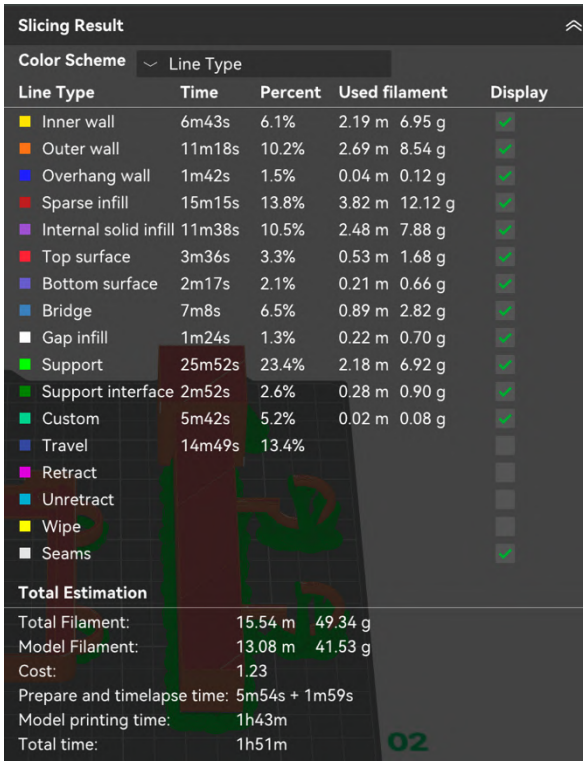

Figure 75 - Slicing Results for the second plate

After printing, the pieces should be cleaned by removing the brim and supports. The weights will have to be glued to the base, and the magnets will have to be glued to the case. The rest can be assembled without glue by sticking the pieces together.

Parts List

Printed Pieces

1x Base
1x Vertical Pole
1x Horizontal Pole
1x Case Box
1x Case Lid

Fasteners

4x Round Magnet - D4x2 mm
1x Cable Clip

3D Print Materials

1x Bambu Lab A1 mini
1x PLA Matte - Filament with spool / 1kg / Matte Charcoal

Electronics

1x USB-C to USB-C Right Angle Cable
1x ESP32 Cheap Yellow Display Board – CYD (ESP32-2432S028R)

Conclusion

Overall, I am happy with the outcome of this assignment. My prototype is minimal while still being aesthetically pleasing and functional. It doesn't take up a lot of space on the desk while still being readable and usable.
I enjoyed the prototyping process and being able to build something physical. If I would create this prototype again, I would try and use a bigger printer so the prototype can be taller. This would allow me to incorporate the cable into the vertical pole making it less noticeable.
Besides that, I am very pleased with my prototype. I am considering buying an ESP32 and touchscreen device to be able to continue using my prototype after the end of the semester.