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WHY REVERSE ENGINEER A HOVERBOARD?

Ever since its creation in 2014 by Shane Chen, the hoverboard has become a global phenomenon. They have proven to be a great pastime for children. Moreover, their functionalities can be used to integrate them into everyday life as personal transport systems like bikes are now. However currently, they are not legal to drive on roads in the Uk and are limited to functionality as very Expensive 'toys'. However this decision has the best intentions mid after several reports in the past few years have been received of hoverboard batteries exploding after prolonged use, or during recharging. It is unfortunate that a creation with as much potential to improve daily commute as the hoverboard becomes dangerous to use due to some corners cut during the production line. It has urged our curiosity to find out the faults with this machine and how it could be improved.

SPECS

SPEED: 6- 8 Miles per hour

RANGE: 5 - 7 Miles

Figure1: This is the board which we will be disassembling, it has been modified by one of our team members previously to increase its functionality as a Go-Kart.

Figure 2: An example of an incident when a man filed a lawsuit after his hoverboard burned after being plugged into a charger for too long.

STATE DIAGRAM OF REVERSE ENGINEERING PROCESS

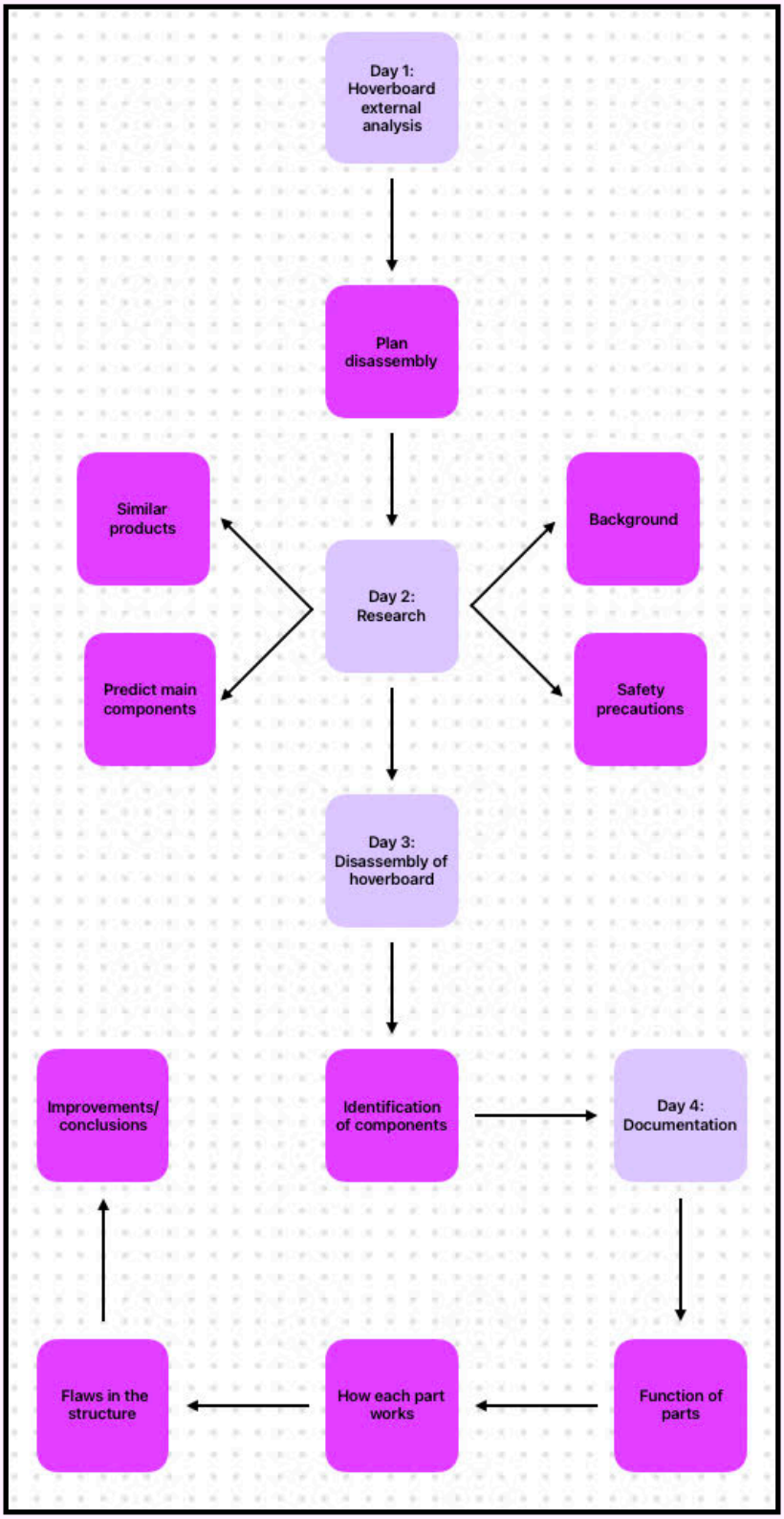
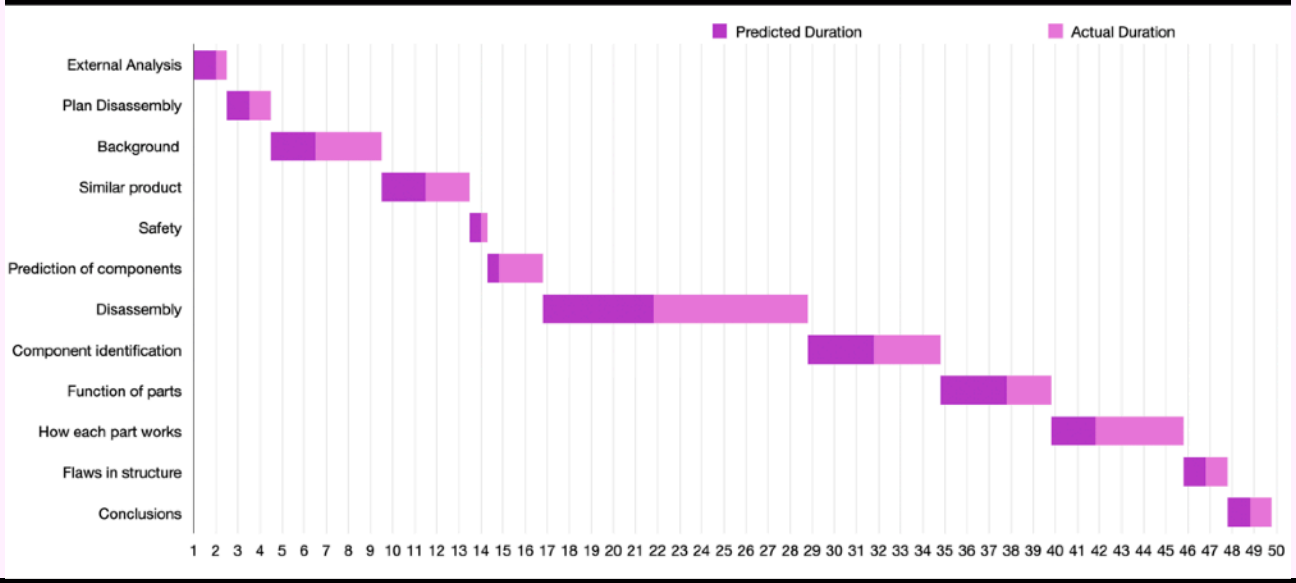


Figure 3: This is the diagram we created to organise our Reverse Engineering project.

GANNT CHART



INITIAL STRUCTURAL ANALYSIS (PRE-DISASSEMBLY)

This exemplary structural diagram will show us the different components to expect and how to conduct the disassembly.

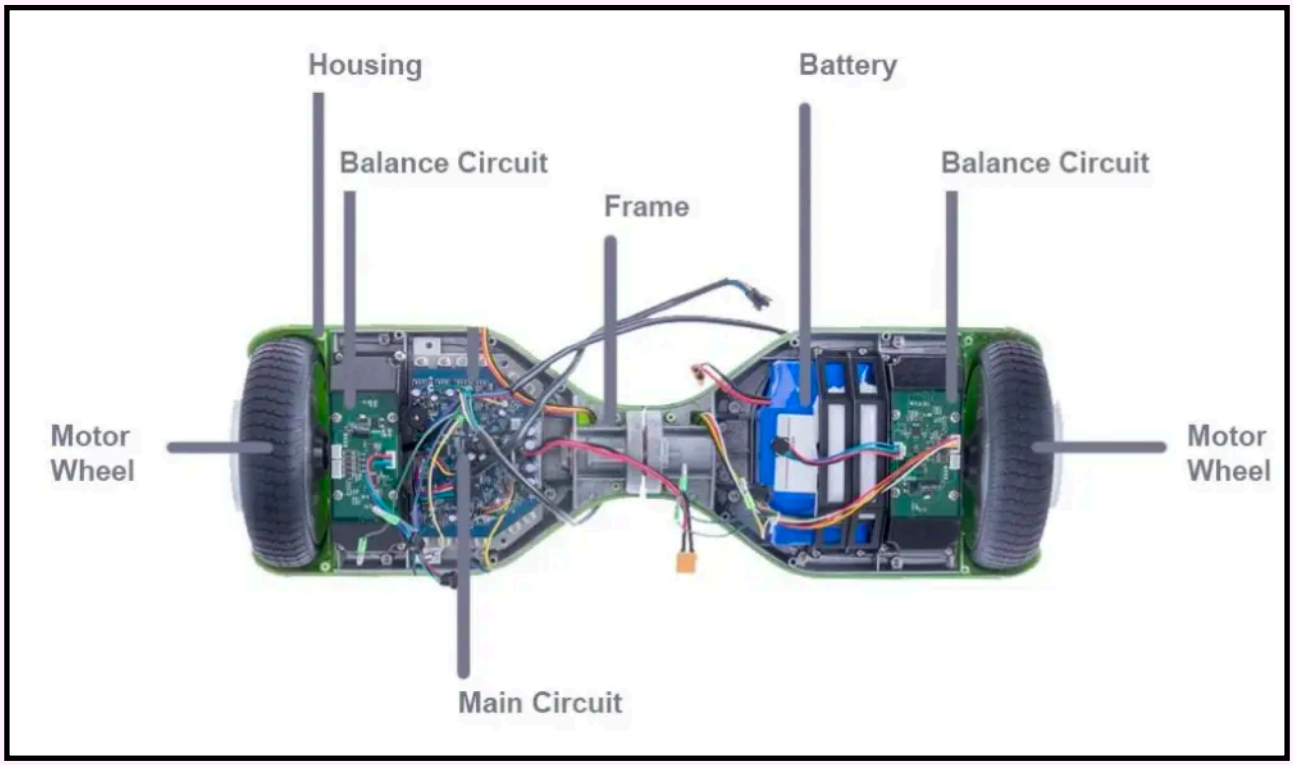


Figure 4: A diagram to show the innards of the hoverboard.

DISASSEMBLY

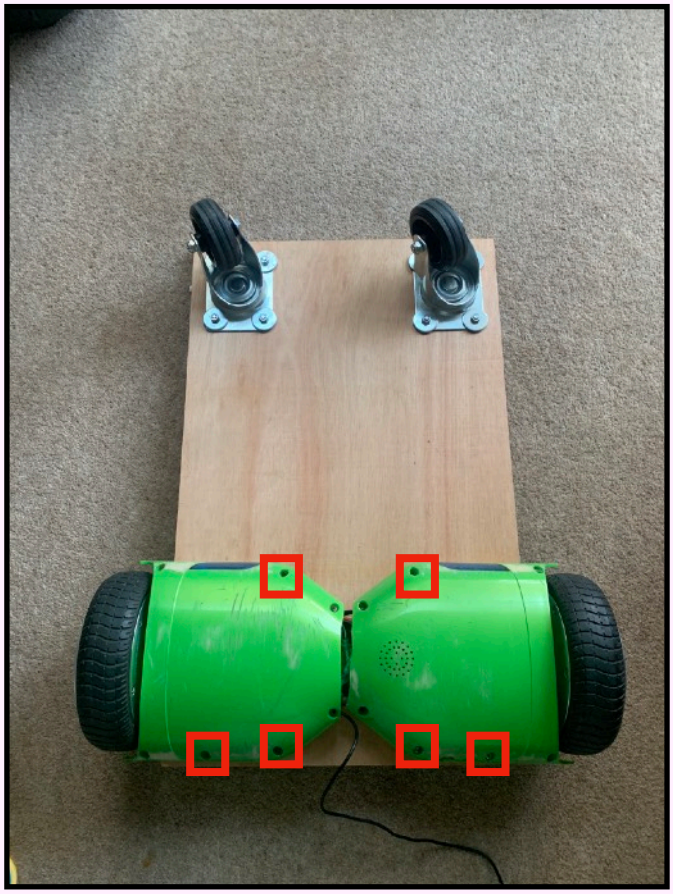


Figure 5: Bottom view with highlighted screws.

Figure 6: Bird's eye view

Figure 7: The place where the board was cut to be modified.

Figure 8: Side view

DISASSEMBLY

The first step is to remove the 6 combination head screws to uncover the electronics under the cover plates:

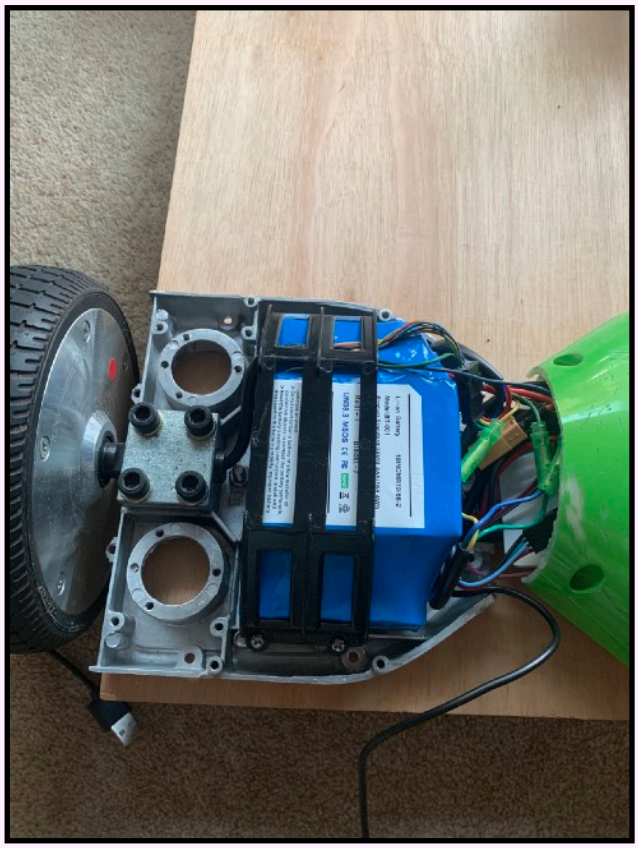


Figure 9: Left cover plate removed

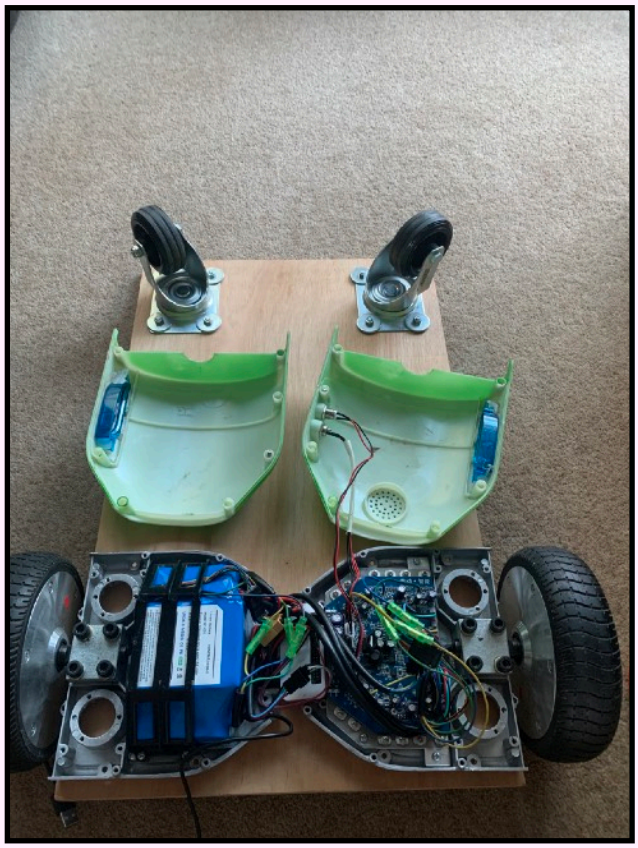


Figure 10: Both cover plates removed.

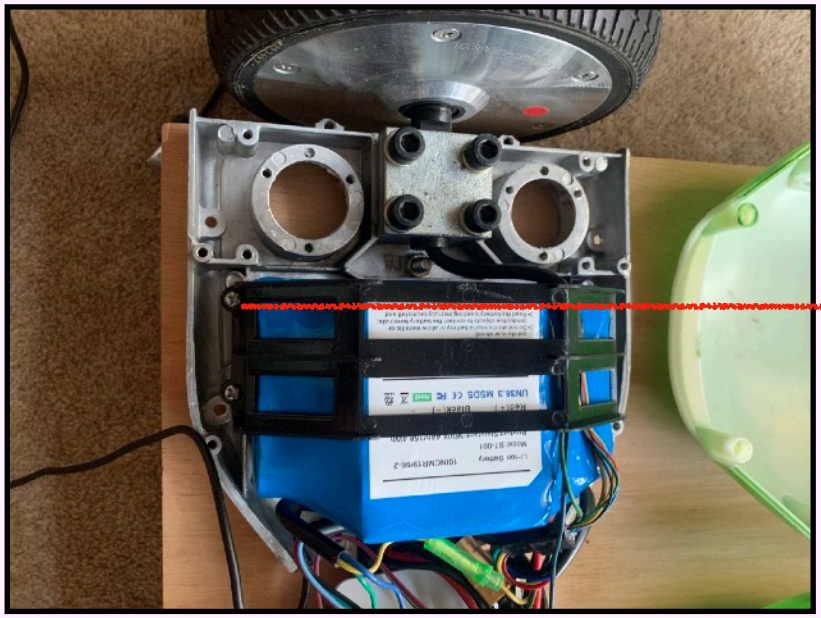


Figure 11: The battery can be removed easily now that it is exposed.

To ensure a safe disassembly and prevent electric shocks, we need to remove the battery as soon as possible. So the next step was to remove the battery holder and unplug the battery.

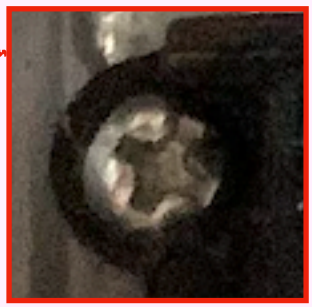


Figure 12: Combination Screw

DISASSEMBLY

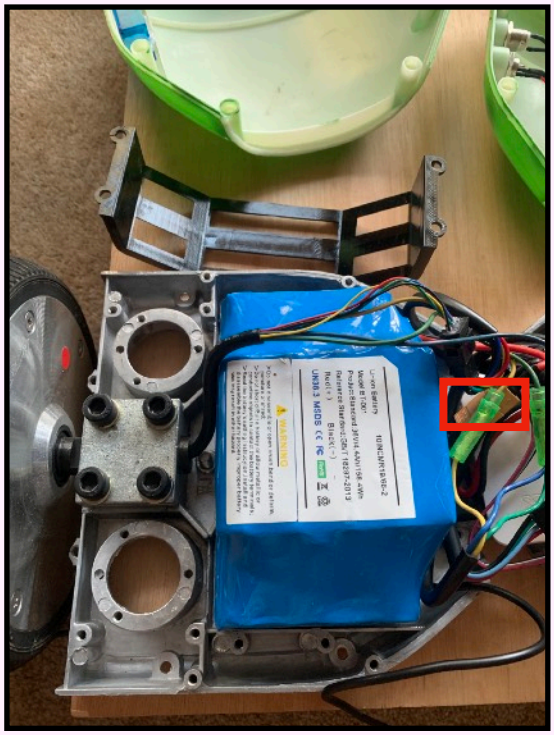


Figure 13: Since the battery holder is removed, the power cables are easy to access and unplug.

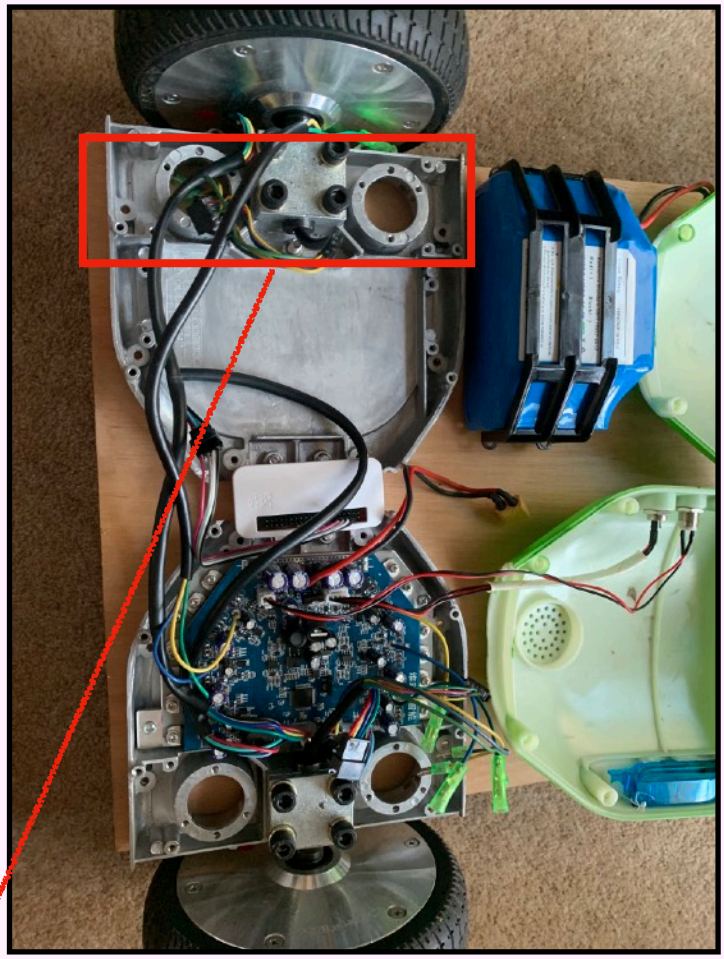


Figure 14: Now we are able to remove the battery entirely and ensure that our disassembly will be safe.

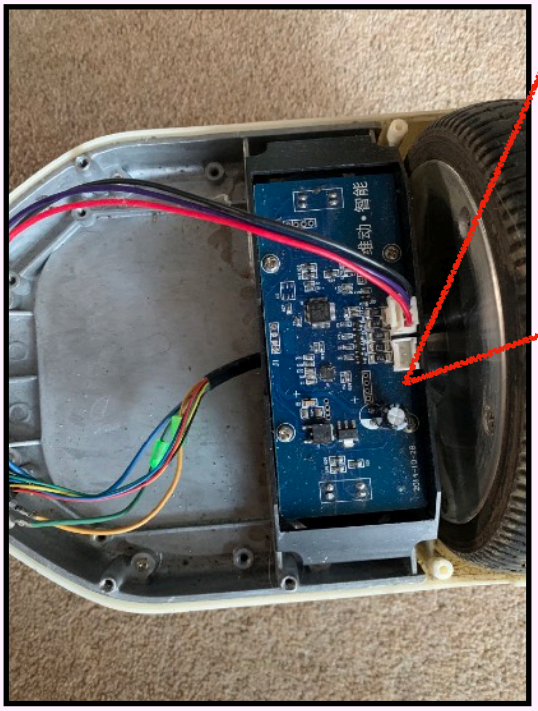


Figure 15: Unmodified Hoverboard (battery side circuitry)

Figure 16: The IR sensor which can be seen on the opposite side when disassembled.

If we compare our modified Hoverboard to a commercially available one, we can see that some components are missing.
This subcomponent includes infrared sensors and this part is present on the left and right side of the hoverboard.

DISASSEMBLY

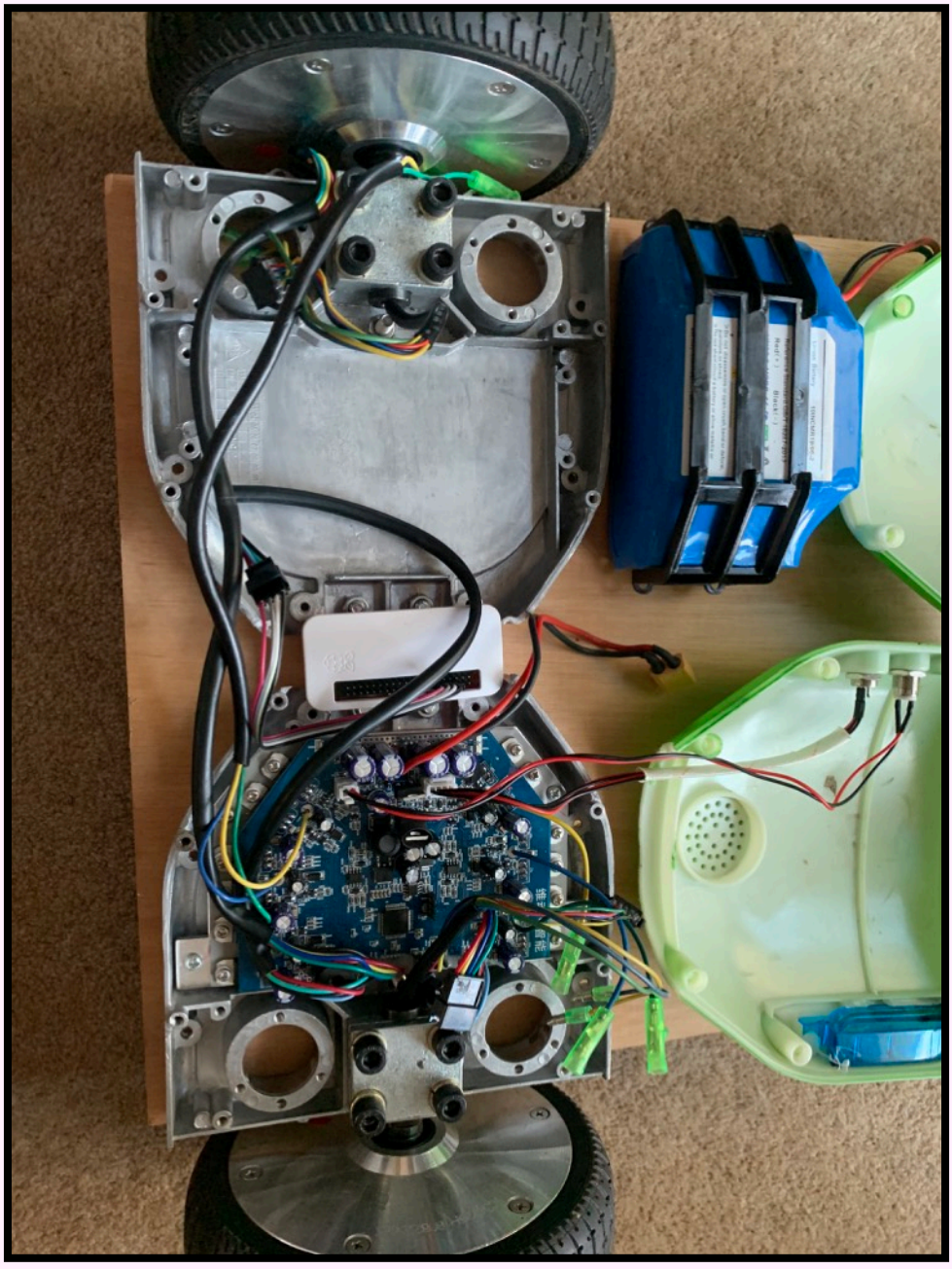


Figure 17: Disconnecting as many wires as possible to give a clearer view of the control board.

DISASSEMBLY

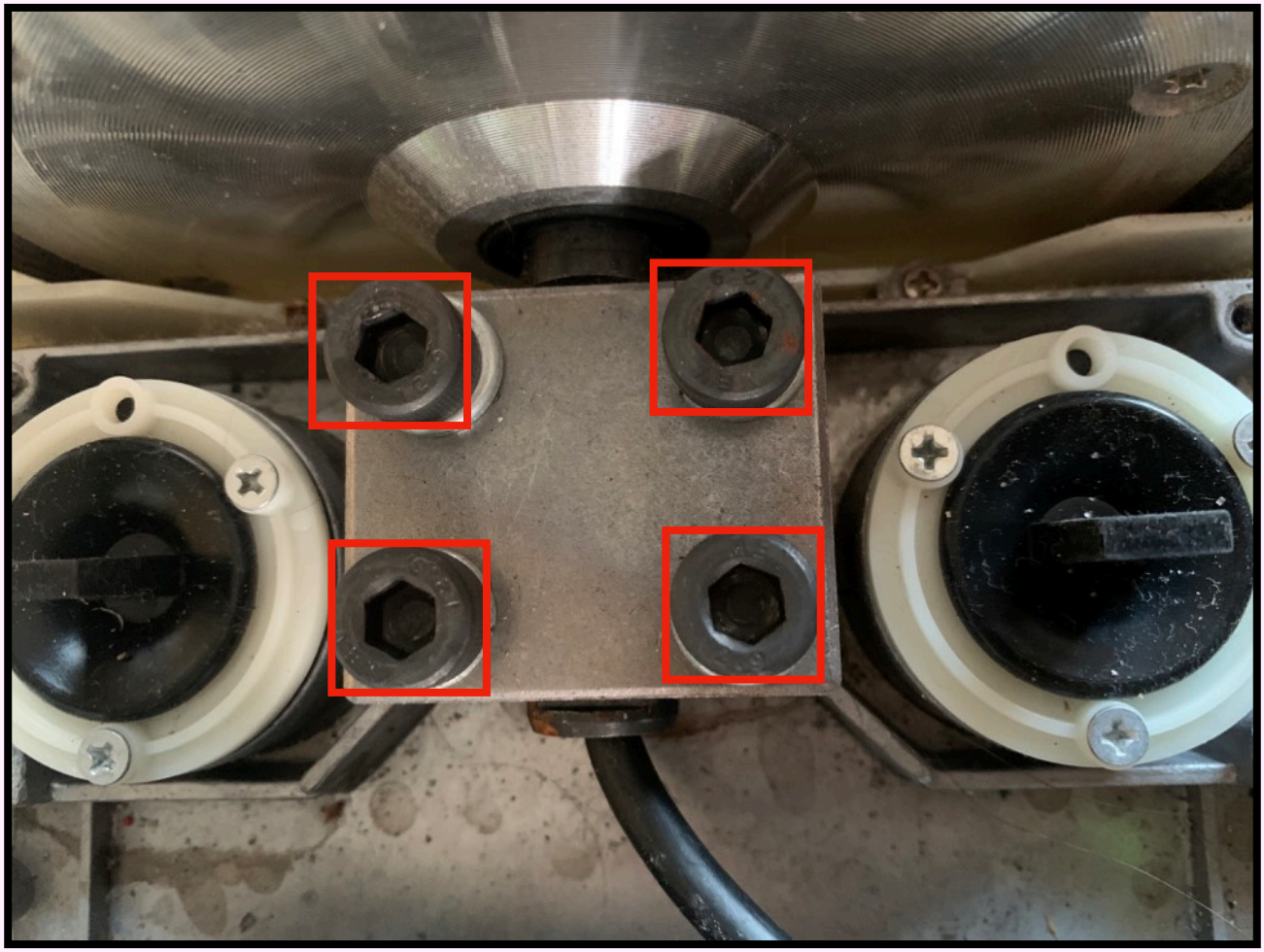


Figure 18: To remove the wheel, the axle enclosure must be removed by removing the 4 highlighted hex drive bolts.

DISASSEMBLY

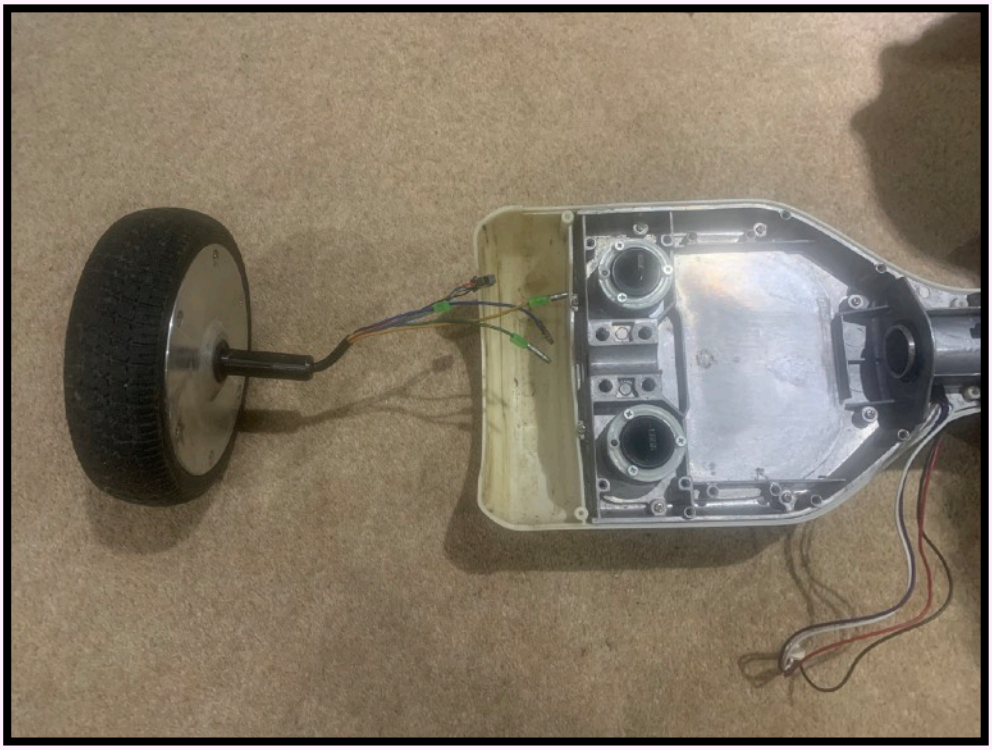


Figure 19: Once the wheel is removed from the assembly, we can see that there is no motor present on the hoverboard. This led us to wonder if the motors may be present inside of the wheels.

(N.B. This wheel is from the unmodified hoverboard as we did not want to damage the wheel from the modified one but both should have similar properties as they are all sourced from the same provider).

Figure 20: The wheel on its own

DISASSEMBLY

SAFETY: To remove the tyre, a lot of force is used, therefore we recommend that appendages like fingers are kept away from the tools which are used to prop open the wheel.

Figure 21: Using a thick metal screwdriver, we were able to pry open gaps between the tyre and the frame to insert Alan keys into the gaps along the whole circumference of the rim. In this way, we managed to take off the tyre.

DISASSEMBLY

The eight highlighted screws were then removed to open the wheel compartment.

Figure 22: Tyre separated from the rim.

DISASSEMBLY

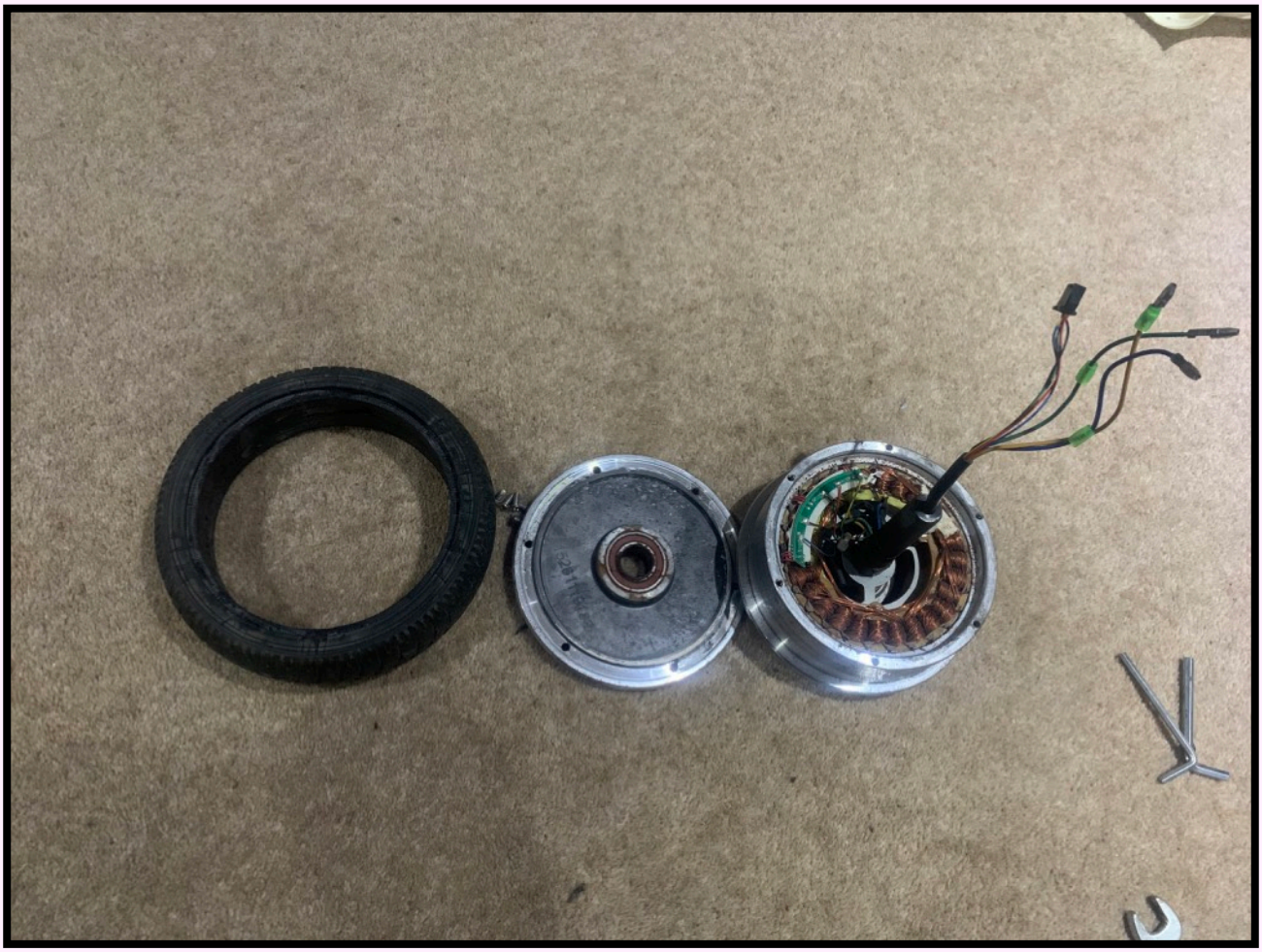


Figure 23: The three components of the wheel separated.

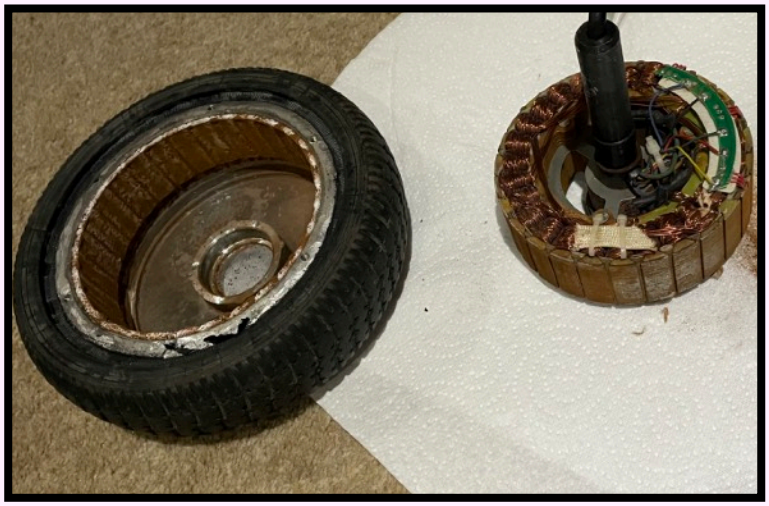


Figure 24: The motor separated from the rim.

We managed to go one step further and pull out the motor from the wheel itself. This step was crucial for us to truly understand the structure of a hoverboard wheel and how it spins.

With that, our dismantling process was complete.

COMPONENT ANALYSIS

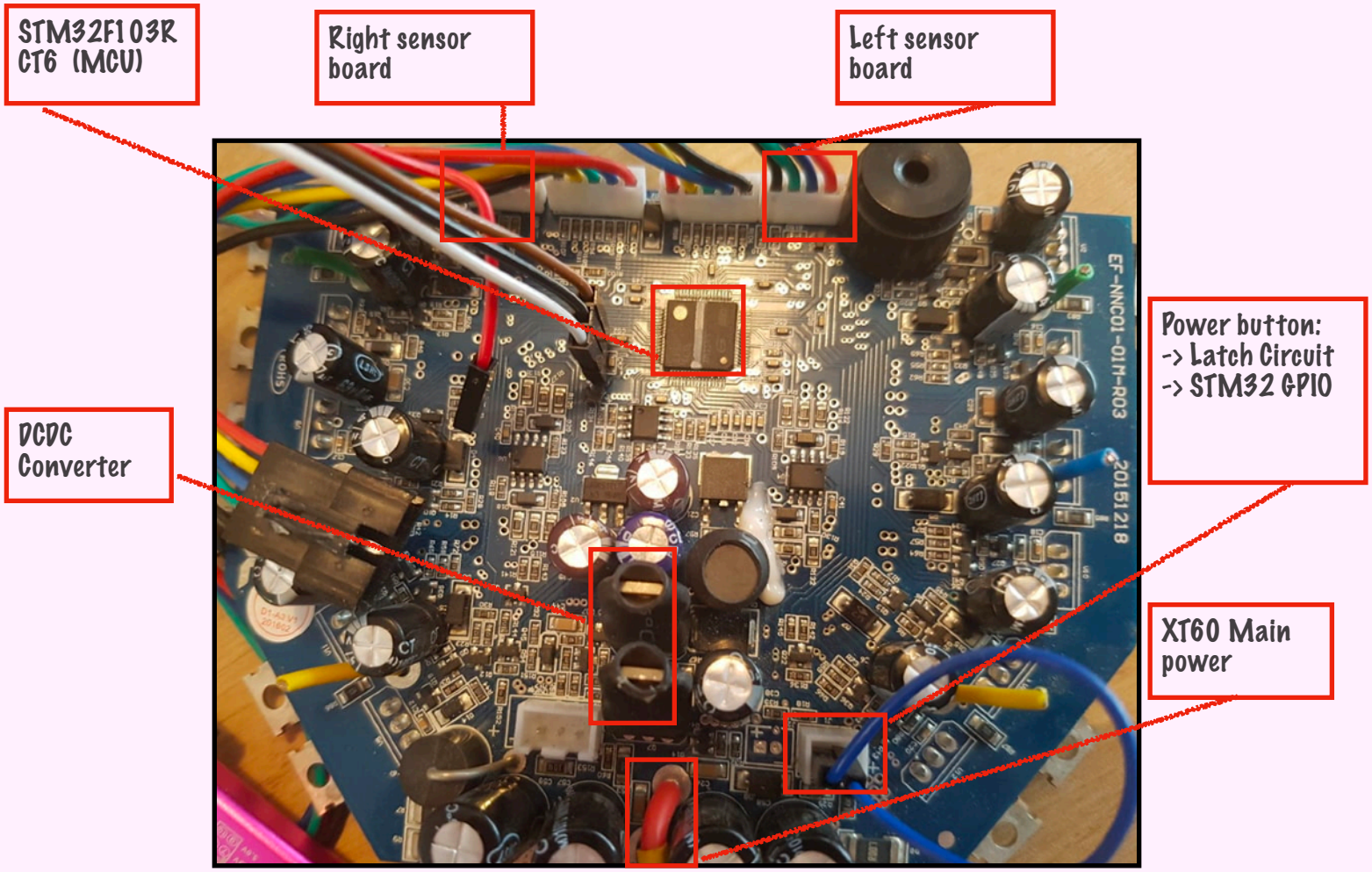


Figure 25: The motherboard (this s a picture from “https://github.com/lucysrausch/hoverboard-firmware-hack/issues/96" as we were unable to get a clear picture of our board).

COMPONENT ANALYSIS

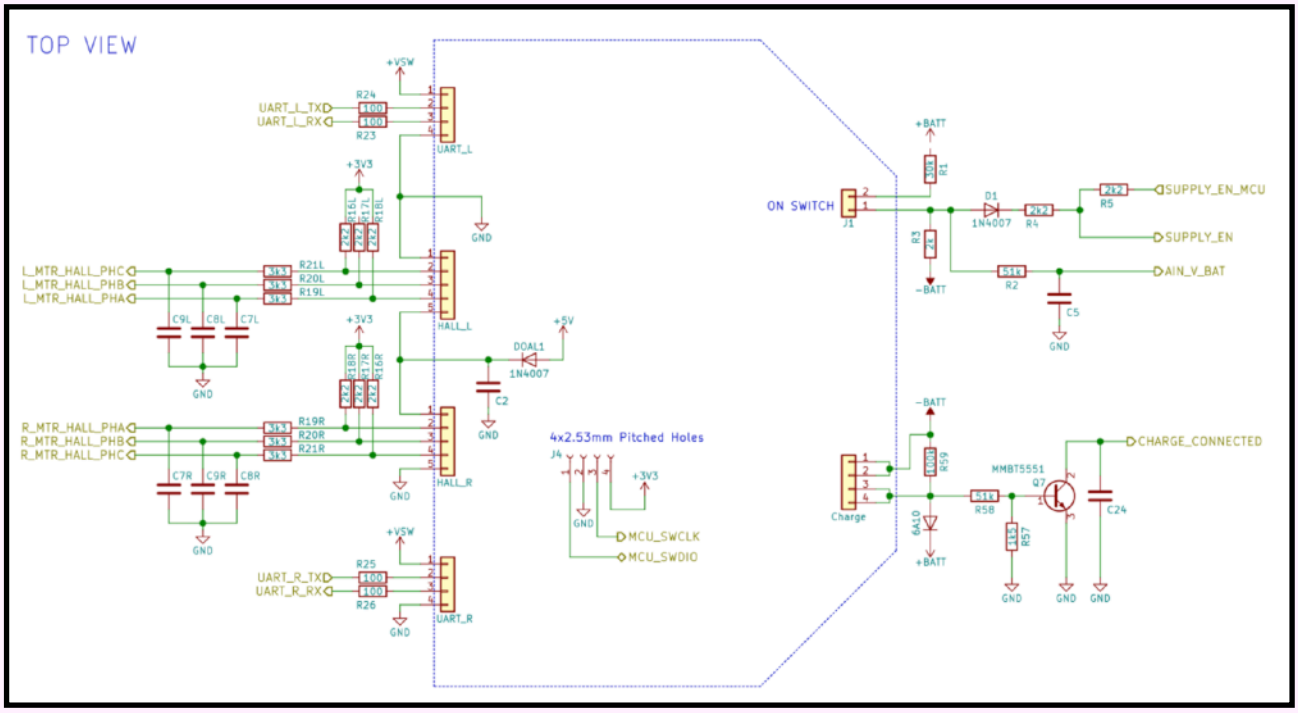
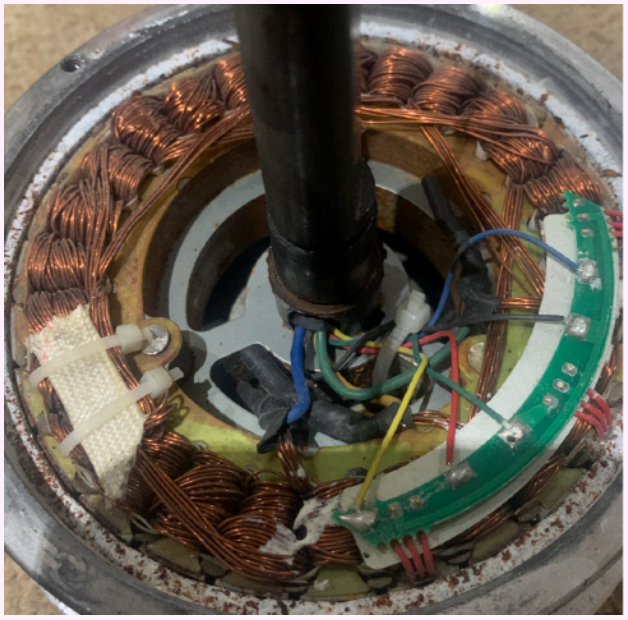
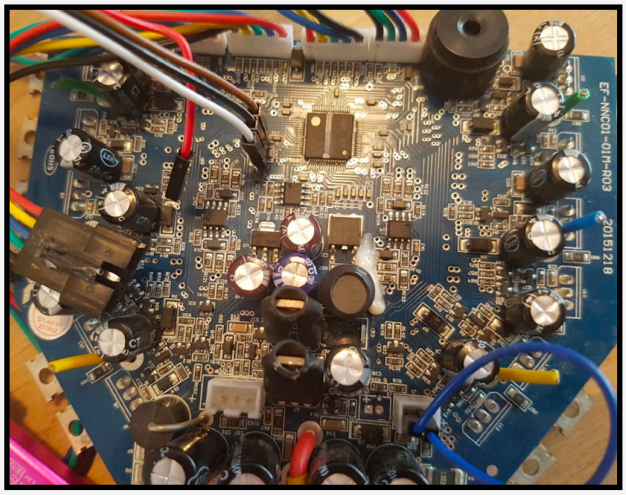


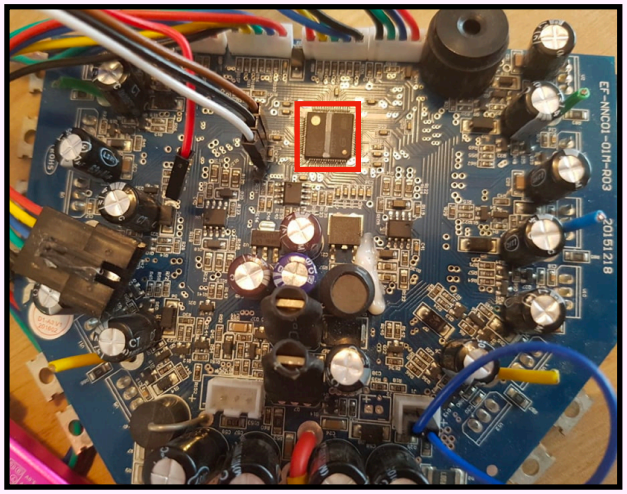
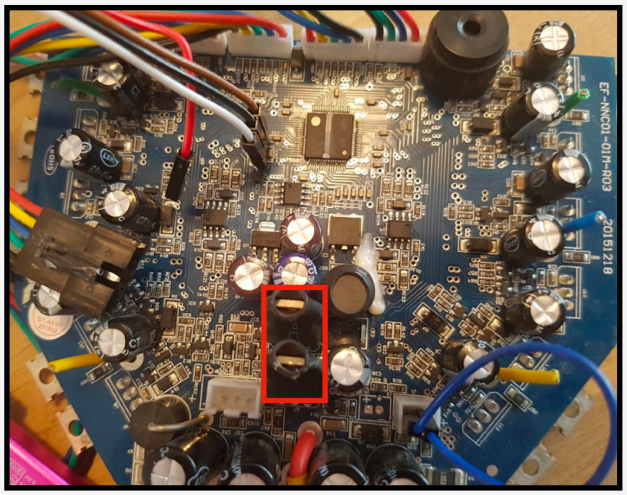
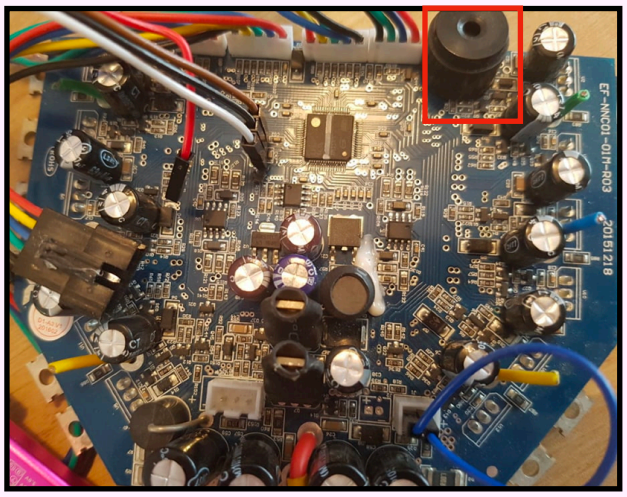
Figure 26: Motherboard circuit diagram (courtesy of https://beta.ivc.no/wiki/index.php/File:Hoverboard_main_schematic.png)

PARTS LIST

Part and Description	Image
Battery: -> This is a 36 Volt Lithium Ion battery with 4.4 Ah of battery life. This battery is where all the electricity needed for the Hoverboard to run is stored and also provides a compact method to do so.	
Sensory Circuit Board: -> This part contain many micro components which help the hoverboard to function. One of its main functions is to detect whether or not someone is standing on top of the board. It utilises infra-red sensors to do so. When pressure is applied at the top, two small plastic prongs are lowered into the gaps between the IR sensors which breaks a light gate and signals to the board that someone is on it and triggers the accelerometer. This sensor takes readings of the boards position and angle to make the motors spin the correct amount to keep you upright.	

Part and Description	Image
Infra-red sensor (See sensory circuit board for description)	
The wheels: -> The wheels are arguably the most interesting part of our project as they have many different sub components. The wheels are made of a rubber tyre on the outside to provide suspension when on the board and have a solid steel frame on the inside to maintain their integrity as this is where all the force is applied.	
The Motor: -> Our hoverboard uses a brushless DC Motor. Being this, it is able to stay inside the wheel unlike normal motors and cleverly utilises the space wasted on the inside of the wheel whilst helping to improve its structural integrity. There are several strong magnets on the outer rim of the wheel which make the copper coil spin and create movement.	

Part and Description	Image
Gyro meter: -> Inside the wheels there are sensors called pyrometers which track how fast the object is moving and also any angular changes which also aid in keeping the rider upright.	
Cover plates with ball bearings: -> The cover plates help to enclose and protect the copper coils and improve structural integrity of the wheel. However, they also have ball bearings which helps reduce friction on the axles and take stress off the motors which makes the board more efficient.	
The motherboard: ->The motherboard is where all the magic happens. It collates all readings and signals from the sensors and translates them into output signals for the motors. It also deals with power management.	

Part and Description	Image
STM32F103RCT6: -> The MCU is the most important part of the motherboard which is where all the processing takes place. It is an integrated circuit which is also a system semiconductor with a CPU that is able to control the whole electronic device one its own.	
DCDC converter: -> This is a very important part of the circuit as it helps to lower the voltage levels from the battery. It takes in a high voltage and gives out a lower one so that smaller components can handle it. Otherwise, they would overheat and cause damage. This may be why many hoverboards caught fire (due to faulty DCDC converters).	
Piezo Buzzer: -> This component makes sounds to alert users of low battery or to signal when it is on or off.	

FINAL LEARNINGS

From this project, we were able to identify many possible causes of error that eventually led to the hoverboards catching on fire.

Firstly, a lack of strict laws in other countries may lead to poor batteries being manufactured. Lithium ions batteries must be certified by organisations like the Federal Communications Commission ("FCC" mark) or the European conformity ("CE" mark). Poorly manufactured batteries may have small pieces of metal inside the battery that may come into contact with other parts of it leading to a short circuit and causing excessive heating and eventually fire.

Furthermore, the chargers that some hoverboards ship with are mostly specific to that type of battery. Switching out cables may overload the batteries too and cause it to overheat.

However, there are also some very ingenious implementation of engineering in hoverboards like the brushless DC motors which are integrated into the wheels themselves. Solutions like these are able to create a more space efficient way of spinning a wheel unlike traditional spinning wheels.

Moreover, the intertwined nature of the components beckon our curiosity and teaches us lessons of how each component must not only function well on its own, but must also be able to work with other components to make a finished product overall.

In conclusion, this project has taught us many crucial lessons outside of the competition perimeter and has given us an opportunity to dive deep into the realm of real-world engineering!

CITATIONS

https://www.cnet.com/tech/computing/why-are-hoverboards-exploding-and-catching-fire/

https://community.simplefoc.com/t/hoverboard-main-board-with-simplefoc/2610/4

https://github.com/lucysrausch/hoverboard-firmware-hack/issues/96

https://beta.ivc.no/wiki/index.php/File:Hoverboard_main_schematic.png