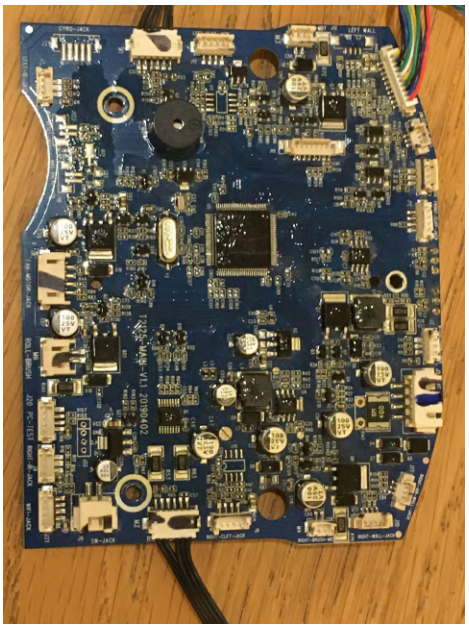
VIQC Middle School - Reverse Engineering Online Challenge

Disassembling A Robotic Vacuum Cleaner - Eufy 30C



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1.0 Summary Report

The Eufy Robovac was a cheap alternative to having local cleaning services come to your house. This fully automated robot is a revolutionary design as it is efficient and convenient. With Eufy already being a proficient company, the robot was well advertised and different models emerged. Different models incorporated different mechanisms and hence, it improved efficiency significantly. Being able to connect with softwares including Amazon Alexa, we took the machine for granted and never realised the complexity of the robot. Hence, we decided to take apart the Eufy vacuum cleaner as we wanted to explore its unique mechanisms.

The machine has a system to allow for dirt to be gathered and stored. The circuit board is attached to two side brushes and a roller brush which gather and push dust into the robot respectively. This is then suctioned into the robot, through a vacuum, and enters the dirt chamber. This dirt chamber can be easily taken apart from the robot, so dirt can easily be thrown away.

The machine is controlled by one main circuit board or motherboard. This is linked to all of the machine's technologies, including motors which allow the robot to move, brushes to spin and sensors which detect objects in front of the robot. This motherboard contains many capacitors and resistors which regulate the current in the circuit board.

Aside from previous knowledge, we had to research about different components and how they worked with each other to create a working robot. Research was not only essential to understand how the robot worked, but it was also necessary to re-assemble the robot after examining it. Key practical skills such as improvisation were needed. For example a regular screwdriver wouldn't fit into tapered holes containing screws that needed to be disassembled. Hence, we had to improvise and use a thin screwdriver with a specialised attachment so that these screws could be taken out. This process of disassembling the robot allowed us to fully appreciate the complexity of everyday technology, which we had previously taken for granted.

2.0 External Anatomy

Figure 1.1 Top View

Figure 1.2 Back View

Figure 1.3 Front View

Figure 1.4 Bottom View

Figure 1.5 Dust compartment

Figure 1.6 Product Label

3.0 Tools and Safety

Figure 2.1 Flat headed Screwdriver

Figure 2.2 Phillips Head Screwdriver

Figure 2.3 Thin Phillips Screwdrivers

Figure 2.4 Tapered Screwdriver and attachments

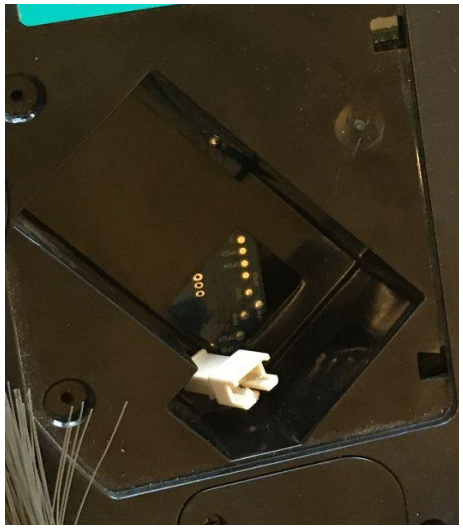


Figure 2.5 Battery taken out

Figure 2.6 Safety Goggles

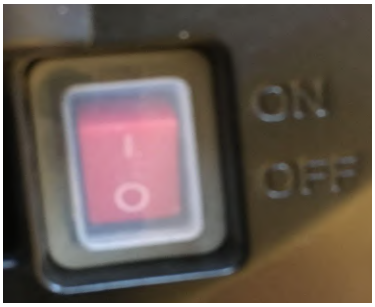


Figure 2.7 Power turned off

4.0 Disassembly Process

Step 1: Wear safety equipment such as safety goggles and gloves to ensure the safety of the team member.

Step 2: Turn off the power switch (see figure 2.7) and take out the battery (see figure 2.5).

Step 3: Press down on the blue plastic at the back of the cleaner and remove the dust compartment (figure 1.5).

Step 4: Turn the robot upside down and pull out the two side brushes. Then take out the blue cover of the roller brush, before pulling out the roller brush itself (figure 3.1).

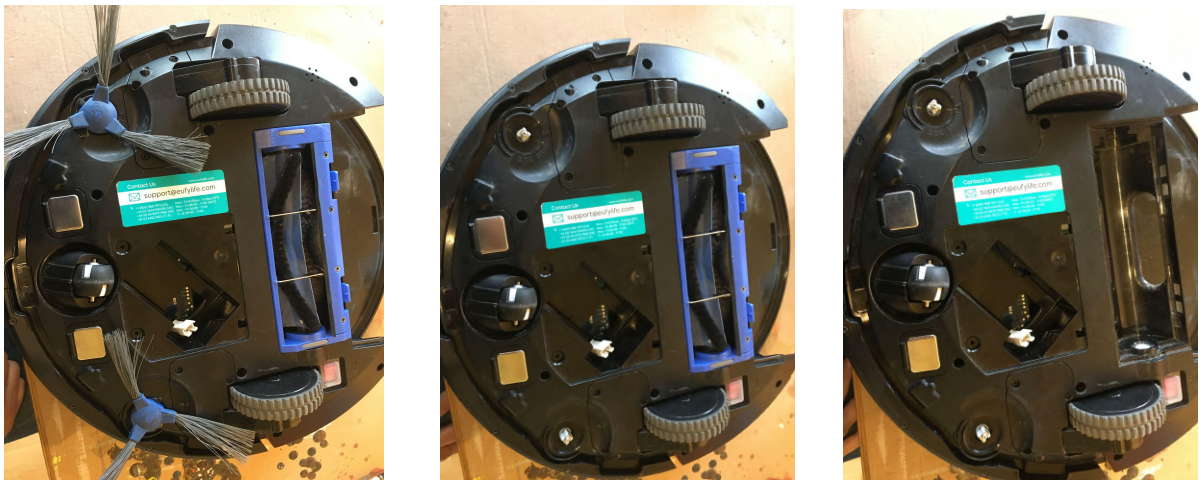


Figure 3.1 Removing The brushes

Step 5: Unscrew the two rear wheels using a phillips head screwdriver. Then pull the wheels into the centre of the robot and lift them out. Then pull out the front wheel.

Figure 3.2 Removing the wheels

Step 6: Unscrew the front bumper and pull the entire bumper out.

Figure 3.3 Removing the front bumper

Step 7: Using the tapered screwdriver with a phillips head attachment (figure 2.4), unscrew the 8 screws located in the deep holes. Then locate the 2 small screws in the roller brush compartment.

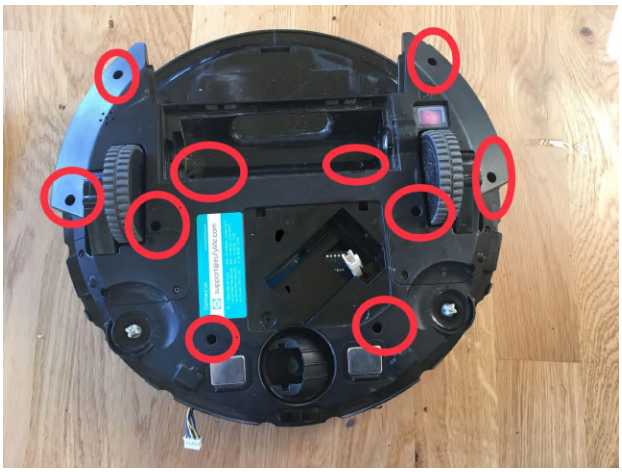


Figure 3.4 Location of screws

Step 8: Prise open the lid of the robot using the flat headed screwdriver (figure 2.1). Then remove the power connector, attached to the lid, from the motherboard. There should now be 2 parts: the electronic and internal structures and the lid.

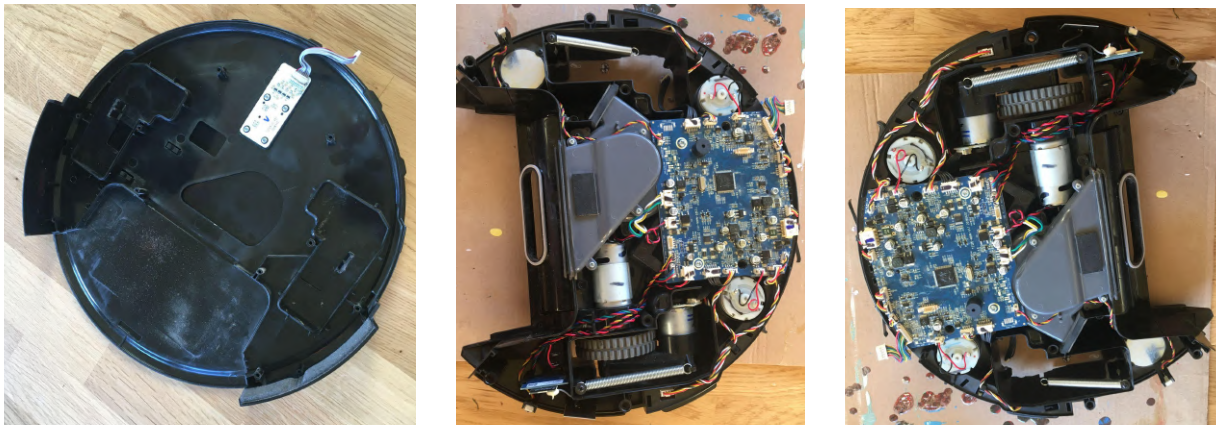


Figure 3.5 The lid and internal structures

Step 9: Gently, pull out all of the wires from the connectors on the motherboard. Then unscrew the metallic screws using a thin phillips head screwdriver, before carefully removing the motherboard, making sure not to touch any capacitors.

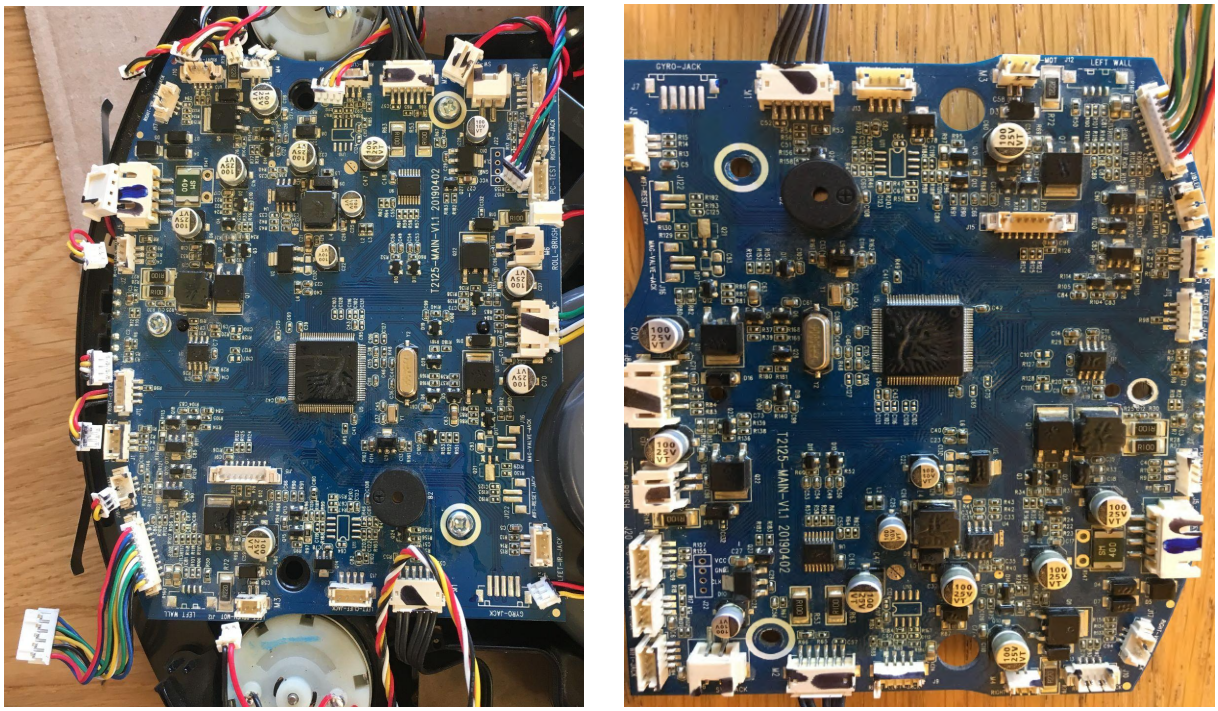


Figure 3.6 Removing the motherboard

Step 10: Gently pull out the front sensor board being careful of the wires attached to it. Make sure that the sensors on the side aren't damaged or bent.

Figure 3.7 Removing the Front Sensor Board

Step 11: Unscrew the corner brush motors using the tapered screwdriver with a phillips head attachment. Then gently pull it out from the main body. Turn the motor over and unscrew the small metallic screws to reveal the gear compartment.

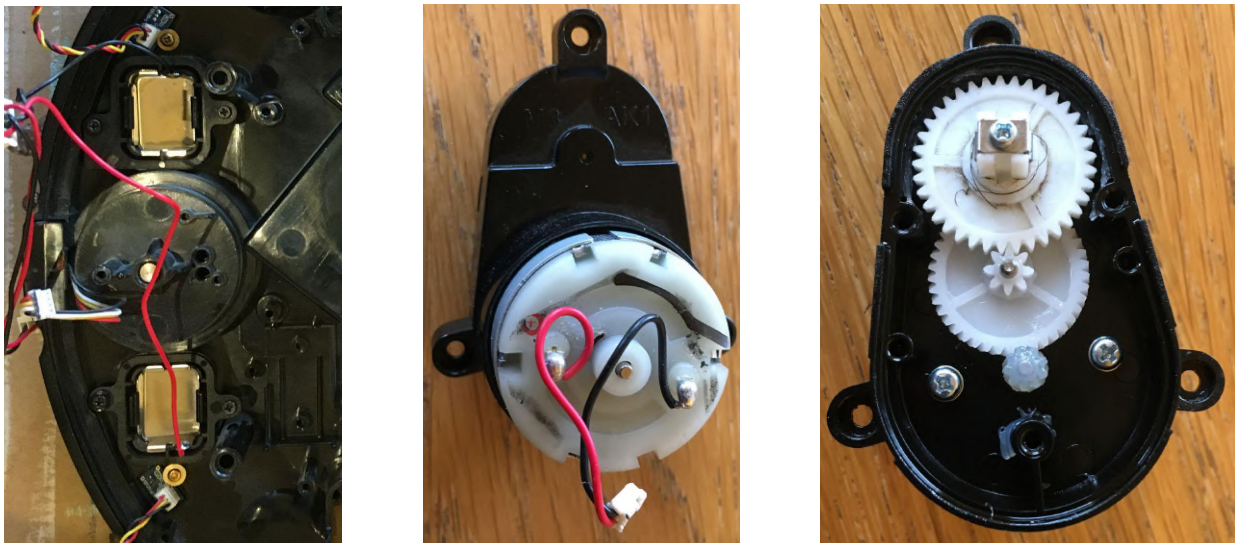


Figure 3.8 Removing and unscrewing the corner brush motor

Step 12: Unscrew the vacuum assembly using a phillips head screwdriver and then gently pull it out. After this, unscrew the man brush motor, located next to the vacuum assembly.

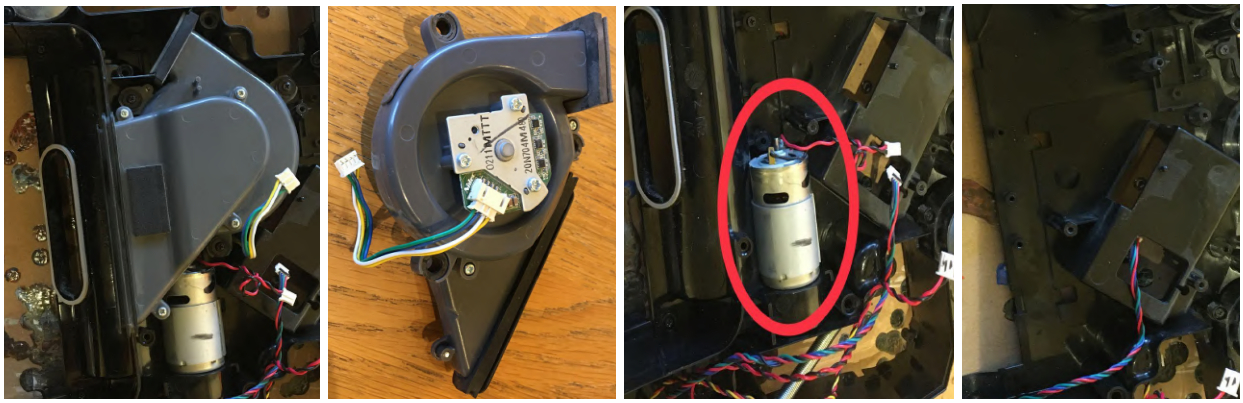


Figure 3.9 Removing the vacuum assembly and unscrewing the main brush motor

Step 13: Pull out the brush motor with the vacuum chamber entrance.

Figure 3.10 The disassembled brush motor and vacuum chamber entrance

5.0 Analysis Process

During the entire disassembly process, we were handling components whose function we were unsure about. In order to efficiently research and analyse the entire parts list, we identified 2 main regions of the robot. These were the main body where many systems were integrated and most non-electronic parts were found such as a gear. We decided to research and analyse the aspects of the main body, which much of our disassembly process included. However, we already had met many of these parts previously, so we had some knowledge. In comparison, we had to extensively research the motherboard, our second main region of the robot, where there were multiple components that we didn't know about. Later, having researched about the motherboard and how it functions the robot, we understood a lot more about this core part, but there were still unidentified components. Not only were there unidentified components in the motherboard, but there were also some in the main body. Our findings and research are presented below, organised into the two main regions we decided to explore.

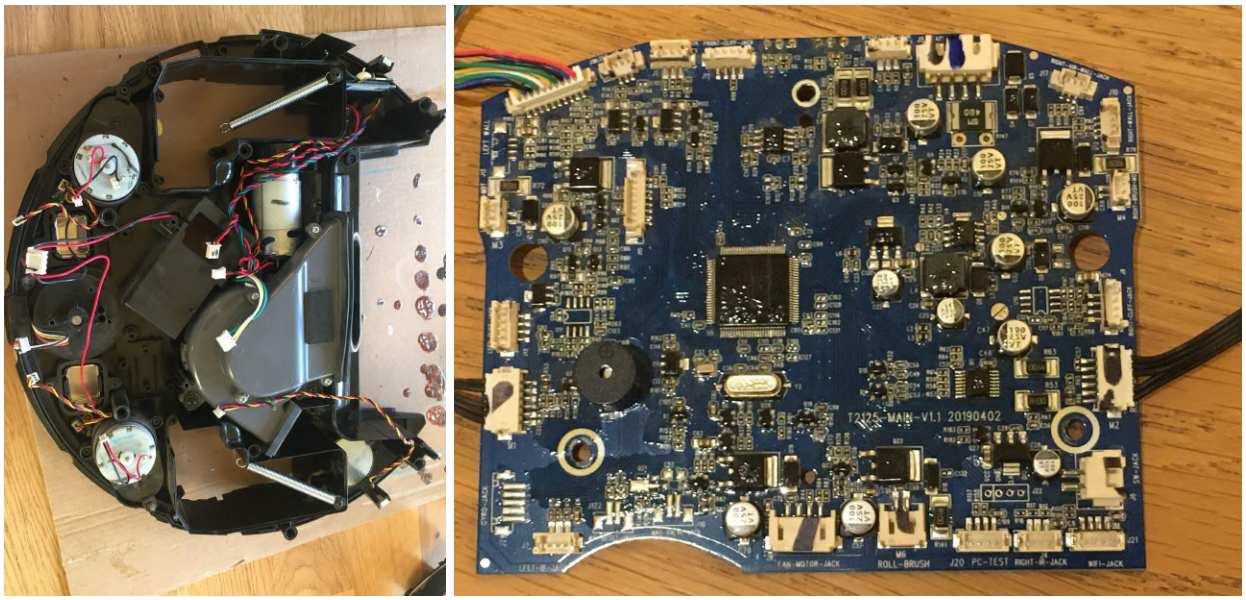


Figure 4.1 The two main regions of the robot

5.1 The Motherboard

During the disassembly process, one of the most fascinating elements of the robot was the motherboard. A motherboard is the main printed circuit board of a product, which often contains the most important and delicate aspects of the product. It is usually also connected to other subsystems and smaller circuits that the product encases. Due to the large number of components on the motherboard, we found it difficult to pinpoint the specialised function of each individual component, inside its internal system. For example, there were a large number of resistors so it was impractical to try to understand the role that each played, but instead we generalised the function of it.

5.1.1 Labelled Diagram of the Motherboard

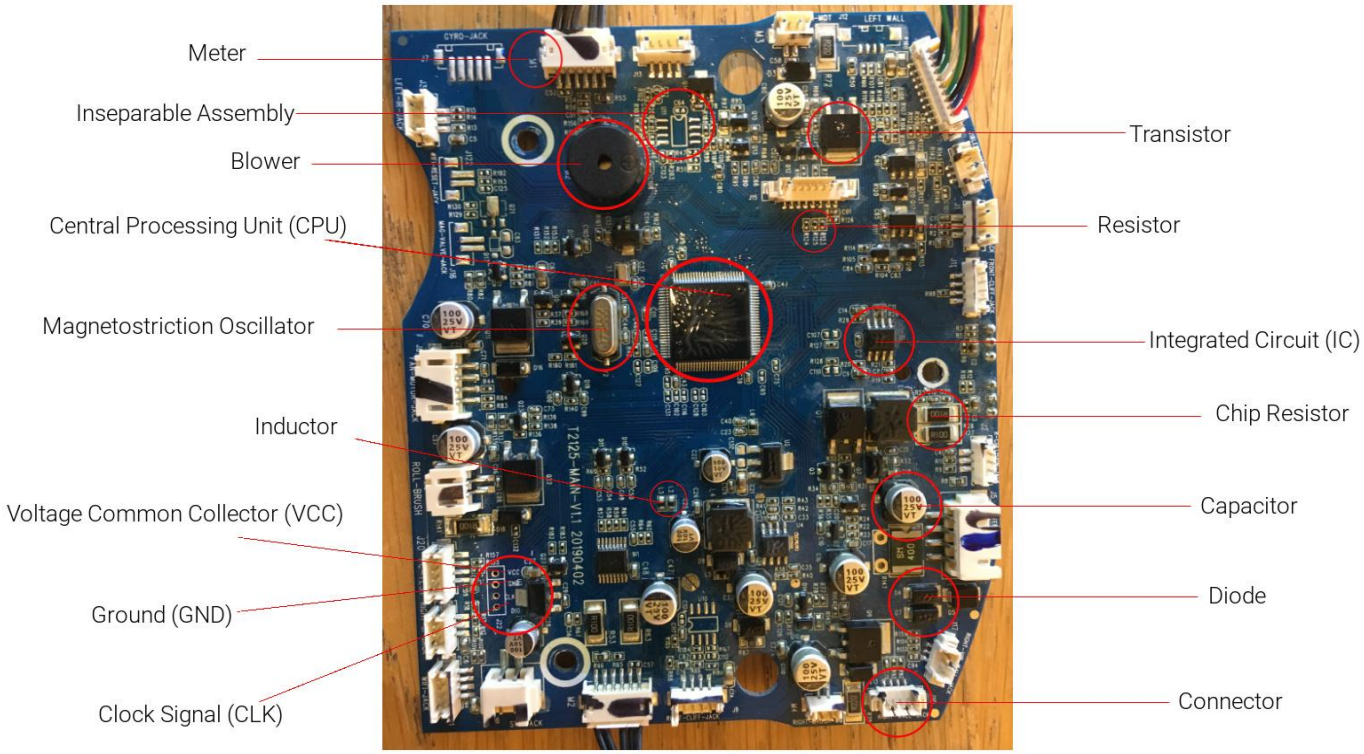
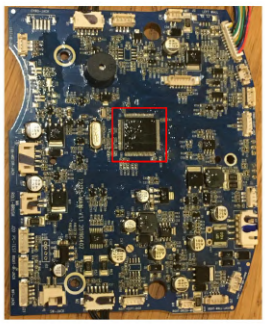
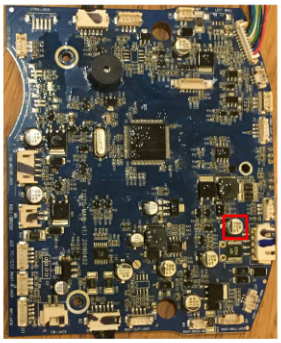
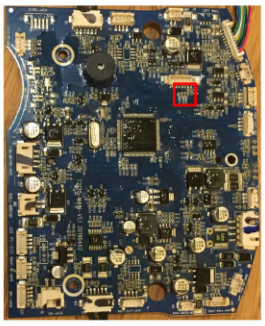
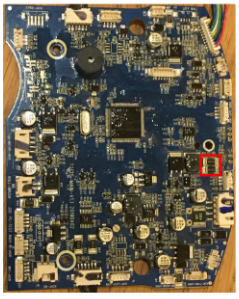
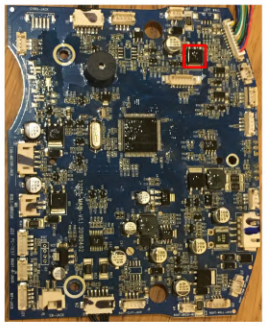
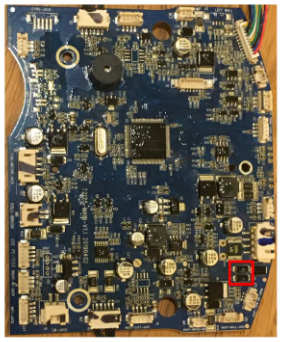
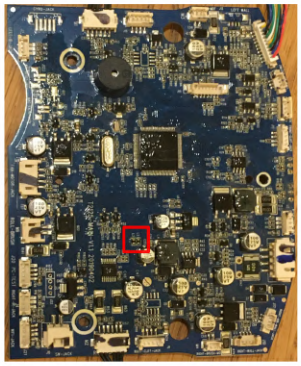
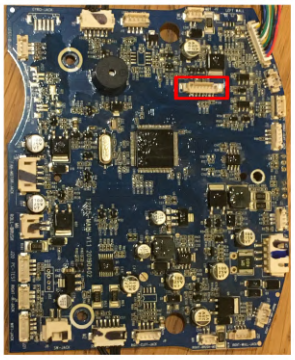
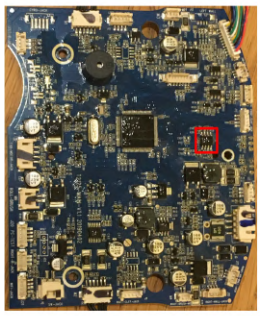
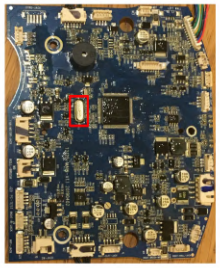
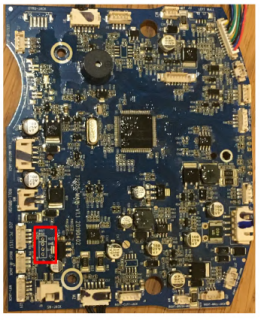
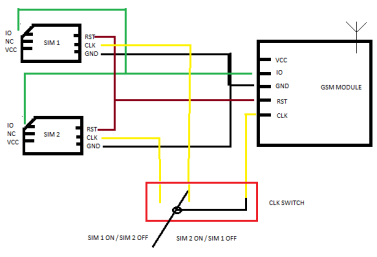
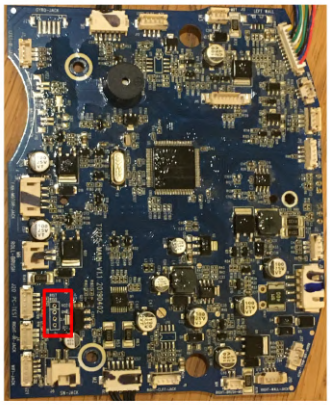


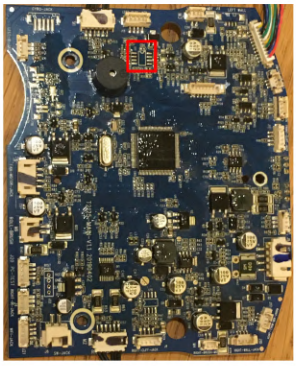
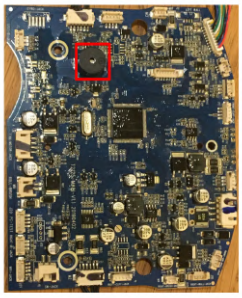
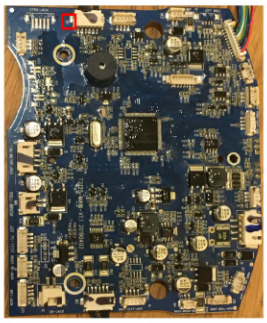
Figure 4.2 Labelled diagram of the motherboard

5.1.2 Analysis of the components

Part and Description	Function	Location
Central Processing Unit (CPU) The central processing unit is the main processing unit which is essentially the brain of the robot. It uses input, store data, and output data.	The function of the PCB is to 'synchronise' all the different internal systems in the vacuum cleaner to work together, enabling the product to function. Hence, this is one of the most important components in the entire robotic vacuum cleaner.	
Capacitors A capacitor is an electronic component that stores electrical energy in an electric field producing a potential difference across its plates. It states the potential charge it can hold on the top for safety regulations.	There are three main functions of a capacitor, the first being charging and discharging, helping it to act like a power source. The second main function of a capacitor is to maintain the voltage at the same level. The final function of a capacitor is to remove noise made by the circuit.	
Resistors A resistor is a passive electronic component which gives resistance against the flow of electric current. They are fundamental to nearly every circuit, and hence are one of the most common components on the motherboard.	The function of a resistor is to limit or regulate the flow of an electric current. They do this by converting excess electricity into thermal energy. This is necessary so components don't receive too much electricity which could lead to undesired outcomes.	
Chip Resistors Chip resistors are a type of resistor also known as a SMD resistor. They differ from standard resistors as they are manufactured using metal oxides or metal films and are protected using robust coatings.	Chip resistors have the exact same function as normal resistors(see box above) which is to oppose the flow of electrical current in a circuit. However they are surface mounted and hence don't have leads or a colour coding system.	

Transistors Transistors are another type of resistor. It is a miniature semi-conductor. They work together with the other types of resistors to maintain and regulate the flow of electricity to each and every electronic component.	The function of a transistor is to regulate and control current and voltage flow in addition to amplifying and generating these electrical signals. It acts like a switch or gate for this, meaning it either lets the flow of electricity move freely or stop completely.	
Diodes Diodes are another type of electronic component found commonly in circuits working to regulate current and in particular the direction of flow. They are most commonly made from silicon and germanium. There are different types of diodes each with specific applications.	Diodes are used to protect circuits by limiting voltage. It acts like a one-way switch for current, as it allows current to flow easily in one direction but restricts it from flowing the opposite direction.	
Inductor An inductor can be defined as an electronic component which is used in most circuits to store magnetic energy when electric current flows through it. It is measured in inductance which is the ratio of the voltage to the rate of change of current.	Sometimes electricity supplied by the main power stops for a moment. Normally the device would shut down for a split second. The role of the inductor is to keep the robot operating and current flowing without a supply of electricity. This allows the device to keep working for a short time even when there is no electricity.	
Connector Connectors are a main part of the motherboard as they are each important to allow the robot's systems to work together.	A connector contains multiple metal legs which connect to the wire. This links the motherboard to other subsystems in the main body of the vacuum cleaner. However it can also link to other smaller circuit boards including the main power source.	

Integrated Circuit (IC) An integrated circuit is a semiconductor wafer in which it contains a circuit with many resistors, capacitors and other electronic components inside. Hence, it is 'integrated'.	The function of an IC also known as a chip is to perform high - level tasks including signal - processing and amplification. It is a key part of this motherboard as it is extremely important for components on the motherboard to work together.	
Magnetostriction Oscillator A magnetostriction oscillator is an electric oscillator in which the frequency is controlled by the mechanical vibrations induced in a body by magnetostriction.	The function of a magnetostriction oscillator is to convert electromagnetic energy into other forms of energy, in particular mechanical energy and vice versa.	
Voltage Common Collector (VCC) & Ground (GND) The voltage common collector is the power input of the device with a higher voltage in comparison to ground (GND).	These two components work together and are usually places where the measurement of voltage is taken. The VCC may be positive or negative in respect to the GND, where the GND usually has a voltage of 0.	
Clock Signal (CLK) The clock signal is a component which works together with all the other components on the motherboard and is essential for the robot to function, with all its sub-systems working in unison. Here is an example of how it functions with the VCC and GND in an example circuit (see left).	The function of the clock signal is to synchronise every element of the robot so that it can work together. It oscillates from a high to a low state to coordinate actions of the entire circuit. 	

Inseparable Assembly In the motherboard there were many inseparable assemblies which is a mini assembly where there are many components inside. Due to the nature of the component it was difficult to identify their functions.	Despite it being difficult to identify the functions of the assemblies, we could make some guesses. In general, inseparable assemblies allow you to manage multi-component systems easily as a single component. We thought that this could be used to reduce the number of small parts in the motherboard.	
Blower The blower is an integral part of the circuit and we believe that it's used to stop the motherboard from overheating, in particular the CPU; hence its proximity to the CPU.	The main function of the blower is to act as part of a blower motor circuit in which the components in this subsystem work together to control the blower's speed so it can maintain the heat and it itself doesn't overheat.	
Meter This is another component which is part of the internal motherboard system of regulating, measuring and controlling current and voltage. It works together with other components in its sub-system inside the motherboard.	The function of a meter is to measure current and voltage in a circuit without changing the value of either of these two variables.	

5.1.3 Distribution of components in the Motherboard

NB: The data represented below are approximations

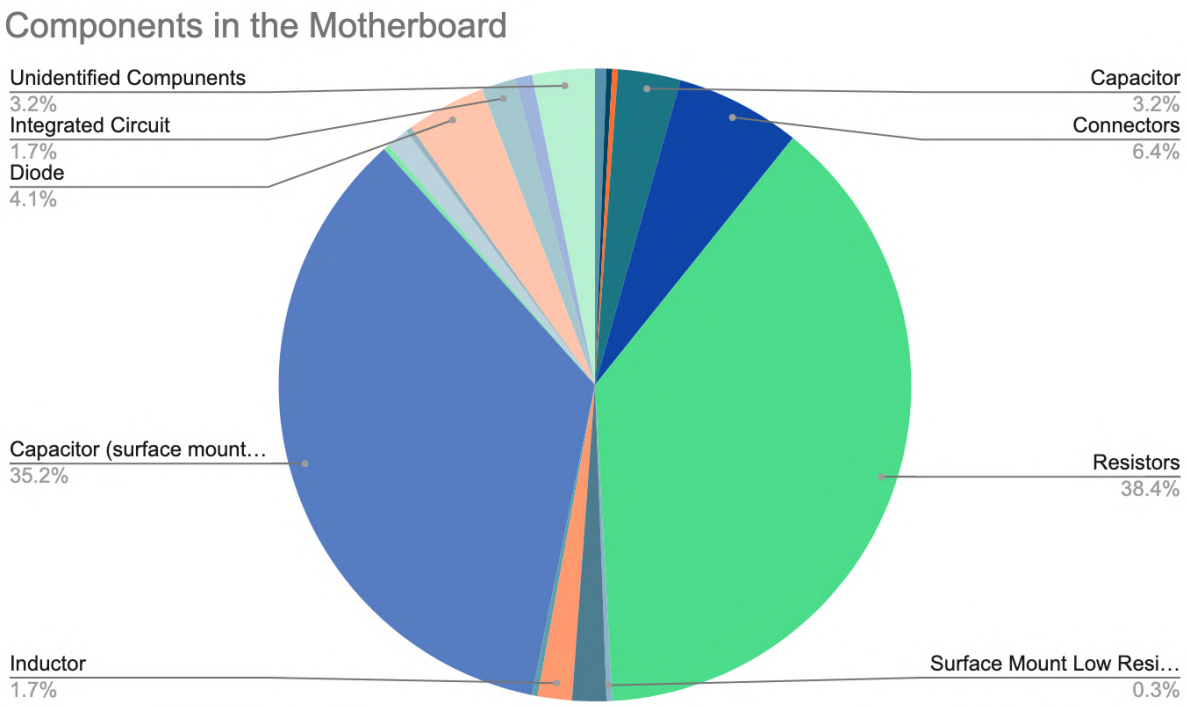
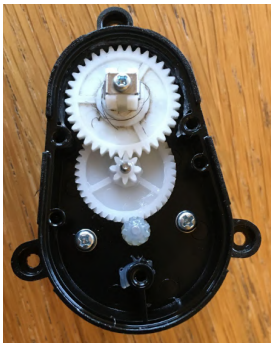


Figure 5.1 Pie Chart of components in the Motherboard

5.2 The Main Body

During the disassembly process we identified two main elements of the robot; the motherboard and the main body. The main body was interesting to disassemble because we could easily identify many of the parts. Furthermore, we developed our understanding of how the components worked together in different subsystems inside the main body. We encountered new parts including sensor board assemblies whilst getting a feeling of satisfaction that we managed to disassemble the main body fully. Despite there being aspects we didn't fully understand at first, researching into the parts improved our understanding on how the robot functions together. For example we understood the path that dirt would take from being swept into the internal systems of the vacuum (by the brushes), to the detachable dust compartment. Hence, having finished the main body disassembly we were able to fully explain how the vacuum cleaner functioned.

5.2.1 Components Analysis

Part and Description	Function	Location
Gear A gear is a component which rotates with teeth cut into the part which locks together with other teeth. When the gear spins, it causes the teeth to spin and any other teeth of other gears it is interlocked with.	Gears are essential to any machine, irrespective of its size. They are used in different ratios to increase the speed of objects spinning such as metal shafts attached or increase torque to provide resistance to perform a stabilising function.	
Motor An electric motor is a component found commonly in circuits and machine interiors. Inside the vacuum cleaner there were many different motors to allow systems to function together. For example the brush motor's role is to spin the shaft which the brush is attached to enabling dust to be swept towards the machine.	The function of a motor is to convert electrical energy into mechanical energy. It does this as when an electric current is passed through a loop a magnetic field exerts torque on the loop which in turn rotates the shaft. This is very useful in motion to occur inside the machine, especially in a vacuum cleaner and the rotation of brushes, making motors key to sub-systems in the interior of the robot.	
Vacuum Chamber and Suction The vacuum chamber was a specific assembly found inside the main body of the cleaner, essential for it to function. Inside the chamber it contains a suction which means dirt accumulated is 'wafted' through the chamber by a fan or suction into the exterior dust compartment (shown in figure 1.5). This makes it essential so the robot's systems can function together and clean.	The purpose of the vacuum chamber is to lock in place with the brush motors which rotate pushing dirt into the entrance of the vacuum chamber. Then the fan or suction mechanism (which we couldn't identify as it was an inseparable assembly), would then cause the dirt to act like a current and would move into the dirt chamber.	

Wheels Inside the robot we found two different types of wheels. They both had different grips and rolled at different speeds. One could rotate on different axes which enables the robot to turn(top right) and the other wheel has more grip (bottom right) which enables for motion in a straight line. The addition of a turning wheel is a special modification made to the Eufy 30C as it doesn't have a motor but is essential to the robot. However the larger wheels (bottom right) have a motor attached so it can only spin along one axis.	The function of each wheel is slightly different but they are used to provide grip, allow the robot to move, and make sure the robot can turn. The wheel which is smaller (top left) is used for turning and less for stability as it can spin in different directions. This is essential as it works together with the robot's navigation and sensing systems. The other wheel has more grip, preventing the vacuum cleaner from 'slipping'. Hence, it is essential in the navigation of the vacuum cleaner, as it is the fundamental part enabling the machine to move.	 

5.2.2 Systems in the Main Body

When we were disassembling the vacuum cleaner, our understanding of how different components functioned in unison developed. We were able to identify three main subsystems inside the robot, allowing the Eufy 30C to function efficiently. These were the sensory system, the navigation system and the cleaning system. The sensory system works with the navigation system and detects if any obstacle is in the vacuum cleaner's path. If so, it would transmit a signal to the navigation system which would then turn away accordingly. This stops collision with other objects. The system also detects signals sent out by the charging base which it then interprets and the navigation system receives instructions upon the relative position of the charging base from the machine. The navigation system is responsible for the movement of the robot and at the end of a cleaning session it would be able to navigate the machine back to its charging base quickly and successfully, guided by the sensory system. The cleaning system is the most important system and relies on the other two functioning. The cleaning system would gather dust and dirt from the floor, before processing it into its internal components which in turn make sure the dirt finishes in the dust compartment, which the owner can empty after a cleaning session. Having understood the basic principles of each system, we tried identifying, researching and understanding the roles of the different components in each system and how they work to perform the function of the system.

5.2.3 The Sensory System

The sensory system was the most delicate system when we disassembled the vacuum cleaner. This is because it had multiple different electrical and physical components, which were a lot smaller than the components in other systems. We found out that the sensory system consisted of one major assembly. This was the front sensor board assembly (see fig 5.2). It had wires leading out of smaller integrated circuits which contained sensors. This would send signals via the wires to the motherboard and CPU where it would be processed. Having processed this information the cleaner would either turn randomly clockwise from an angle of roughly between 45 degrees and 90 degrees. However, in some cases which we have tested the robot would continue to go forwards and its front 'collision' bumper would collide with the obstacle before the machine turns. We were unsure as to why this occurred, but we thought that it was due to a fault where the vacuum cleaner wasn't suddenly able to detect obstacles in its path. Another function of the sensory system is being able to successfully detect and interpret signals sent by the charging base. We knew that the charging base sent out signals as when the robot was instructed to return to the charging base it was unable to when the charging base was powered off. As a result, we knew the robot's navigation system didn't map and remember every step it had taken but instead used sensors and signals to determine its relative position. This struck us as remarkably similar to what we want our coding in VEX IQ to resemble as we wanted to be able to rely on more precise sensors and constantly mapping our robot's position, instead of using an exact measurement method, which means there is a smaller margin of error.

Fig 5.2 The front sensor board assembly

5.2.4 The Navigation system

The navigation system is closely linked to the sensory system and works together. Hence, it was quite difficult to identify which system some components' roles are part of and its functions. The main role of the navigation system is to successfully enable the vacuum cleaner to move. This happens as the motor spins as it is connected to the motherboard. Along the motor shaft is the larger wheel with grip on it which then spins forward enabling the machine to move forwards. It can also turn, if there is an obstacle ahead of it. It does this by using the smaller turning wheel and rotating about one larger wheel. After this it can continue to move forwards again. It also is guided by the sensory system to return to the charging base where the wheels can lock the machine in place. The navigation system works with electrical components as well, especially receiving signals from the CPU about how much to turn and/or move.

5.2.5 The Cleaning System

The most important system in the entire vacuum cleaner is the cleaning process. It begins by gathering dirt from the floor into the main body of the robot. This is done by the two spinning side brushes which are individually attached to a motor. The spinning motion turns dust and dirt towards the interior of the vacuum cleaner by forcing it under the vacuum cleaner. Here, there is the roller brush, which is enclosed inside its case, pushing it inside the vacuum cleaner itself by spinning the dust and dirt. The roller brush is attached to the brush motor which enables it to spin the dirt. Once the dirt is inside the Eufy 30C it enters a vacuum chamber which contains a suction or a fan which wafts the dirt into the dust compartment where it can be removed. This process is the main purpose of the vacuum cleaner, and the other two systems help to enable this to be the most efficient as possible.

5.3 Conclusion

Overall, the entire reverse engineering experience has been a significant achievement for us. While going through the stages of dismantling, understanding, researching and learning our knowledge has improved of how every-day items function. It has also made us understand that we shouldn't take things for granted as often objects are more complex than they seem. We learnt transferable skills from the reverse engineering process such as perseverance and effective group - research which we can use in our actual VEX Robot. As for programming which we both value greatly, the experience of understanding how the machine works has felt truly rewarding; similar to that of using logic to understand complex lines of code. This satisfaction gained made every stage of this project enjoyable and productive.

Having disassembled the entire vacuum cleaner, we felt a feeling of satisfaction. After taking the robot apart, we used our knowledge to correctly re-assemble it and the vacuum cleaner functioned as usual, which made us feel proud.

NB: Every photo taken and displayed is original and taken by Team 599X.

6.0 References

Much of the online challenge would have been unable to be factually correct without the research from the websites listed below. These were great resources into developing insights and knowledge upon topics involved in this project.

- https://electronics.stackexchange.com/questions/25308/what-do-the-pcb-markings-mean
- https://eepower.com/resistor-guide/resistor-fundamentals/what-is-a-resistor/#
- https://byjus.com/physics/uses-of-inductor/
- https://www.merriam-webster.com/dictionary/magnetostriction%20oscillator
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- https://en.wikipedia.org/wiki/Electric_motor#:~:text=An%20electric%20motor%20is%20an,applied%20on%20the%20motor's%20shaft.
- https://openstax.org/books/physics/pages/20-2-motors-generators-and-transformers#:~:text=Motors%20consist%20of%20loops%20of,mechanical%20work%20in%20the%20process.
- https://www.britannica.com/technology/diode