2023

ONLINE CHALLENGES

VRC High School - Reverse Engineering

Disassembly and Analysis of iRobot Roomba 565

Team 832A
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1.0 Summary Report

iRobot Roombas are one of if not the most iconic robot vacuums ever with over 40 million sales worldwide. It is common to find one navigating through the maze of objects on the floor of any house. The Model 565 first released 12 years ago and is now obsolete in design. With little usage in the future, it is perfect for the online challenge. That is why it has found itself in the hands of a group of curious teenagers trying to disassemble it to find out how it works and how to improve its efficiency.

When taking the iRobot apart, it was clear that the robot consisted of many mechanical parts and sensors. These sensors range from simple bump sensors to complex infrared cliff sensors. The bump sensor allows the robot to know when it has touched any obstacles such as a wall or a piece of furniture. The cliff sensors prevent the robot from dropping by using the infrared rays that bounce off the floor. There are many more sensors that help the robot navigate and they all function together with the motorized wheels and cleaning modules to guide the robot for efficient cleaning.

Even with all the mechanical components operating in pristine condition, the iRobot is still dysfunctional without a motherboard. The motherboard works in an electronic device as the brain does in a human body. It houses the most important electrical components of the electronic device and the core processing units. The motherboard in the iRobot is very similar to other motherboards, on which many electronic components can be found such as capacitors, resistors, inductors, etc. Because the motherboard is the main controlling unit of the iRobot, special chips and ports are integrated to allow it to control motors and receive output from sensors.

Although the chips and electronics are hard to identify due to the minuscule labels on them, it is not very challenging to research each chip once the model is identified. These chips work with the data from sensors to command motors on how to move the robot around obstacles on a floor while operating the cleaning modules at the same time. Since each chip series is different, each has its own environment of small resistors, voltage regulators, and capacitors. This shows how many small bits of seemingly useless electronics can create the substantial result of a fully functioning robot.

Our team has learned the inner workings of the iRobot Roomba 565 through this disassembly process. Not only have we learned about the function of each mechanical and electronic part from extensive research, but we have also developed the skills of presenting and an understanding the algorithms robots run through visual charts. iRobot's hardware design is not very complicated. Most of the cleaning task depends on the programmed route. It reminds us that when we focus on building complicated robots in the VEX Robotics competition; we should not forget that good software programming can also significantly and economically improve the performance.

Word Count: 498

2.0 Research Process Action Plan Design

This chart is used to give our team guidance on how to disassemble and analyze its components while making sure everyone does the most they can do.

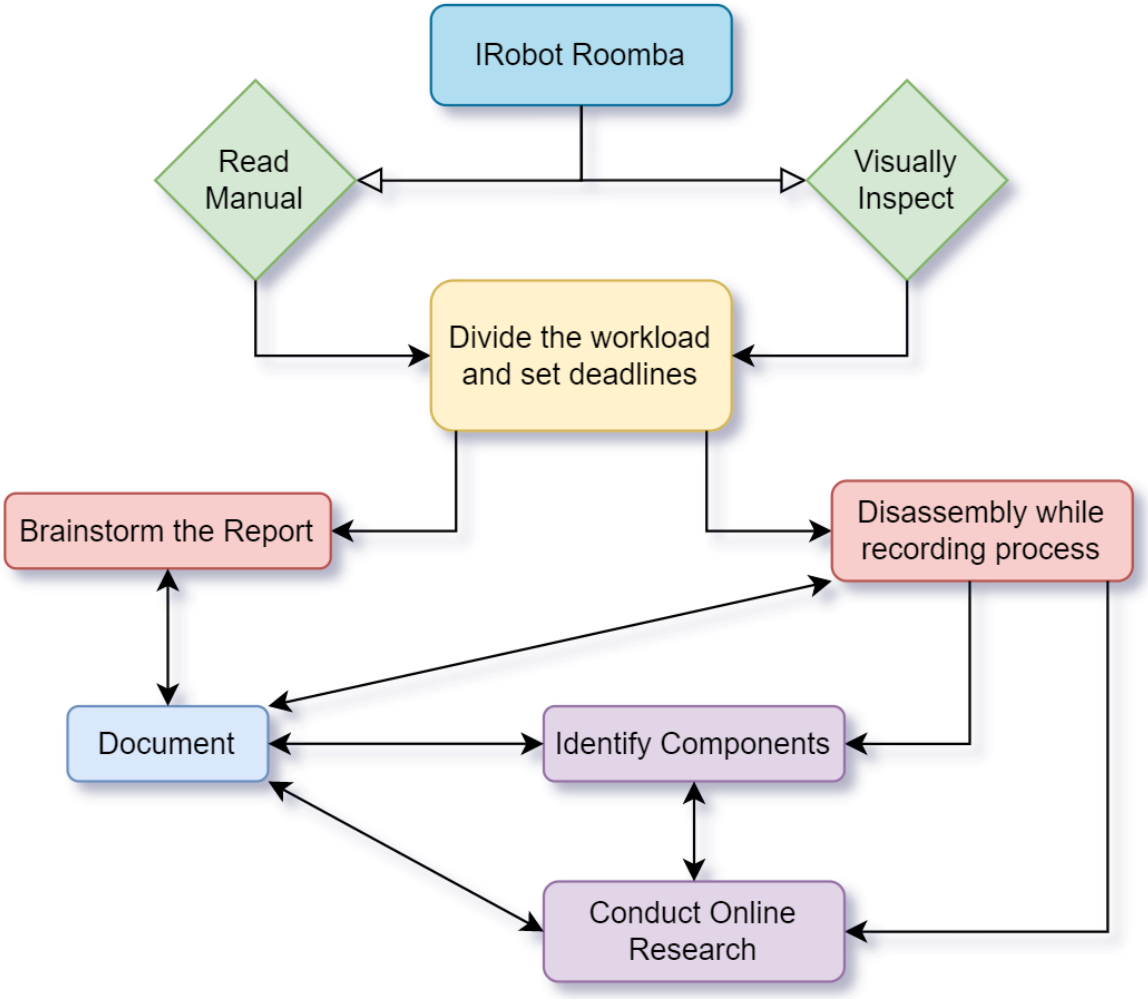


Figure 2.1: Reverse Engineering Action Plan

3.0 Architecture Diagram

This diagram shows how different parts interact with each other to create a successful system. We used this diagram to help identify and understand components in the iRobot Roomba.

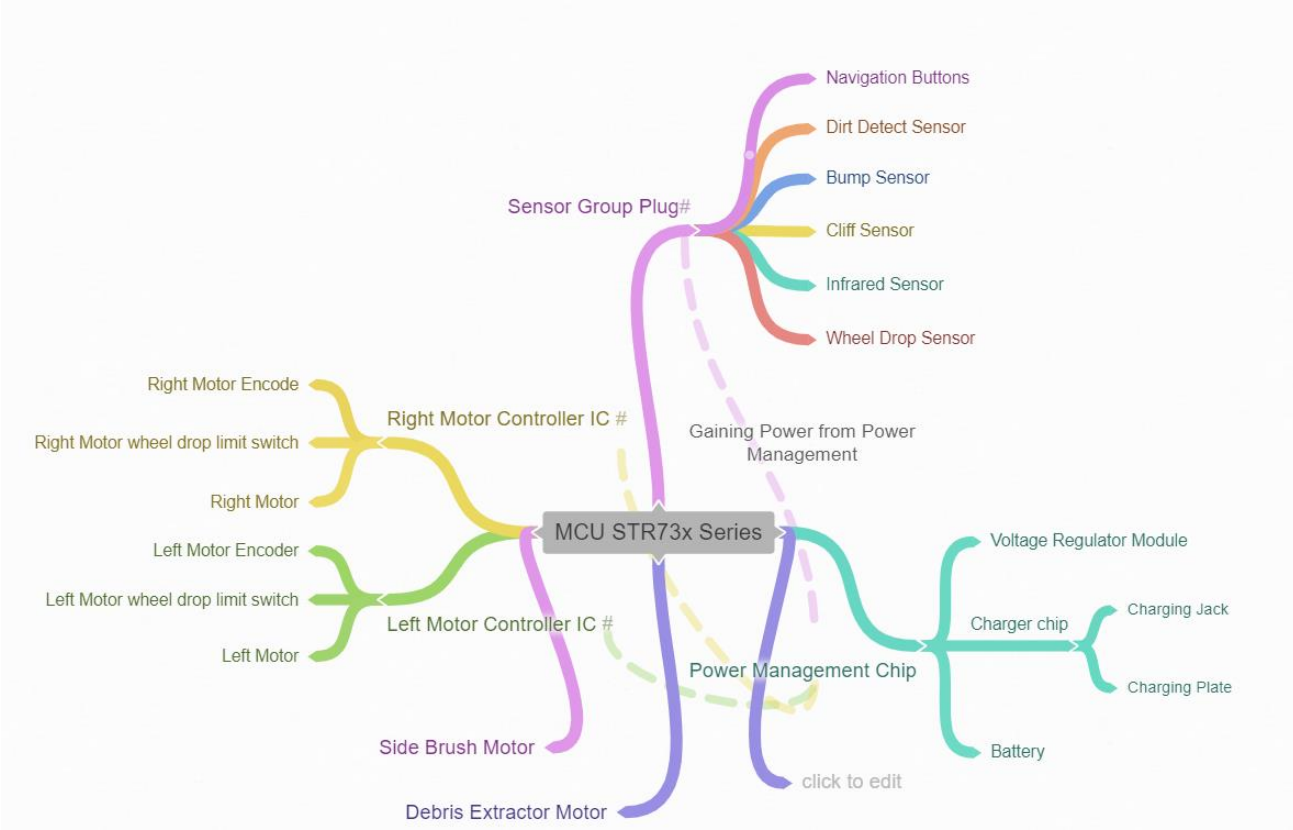


Figure 3.1: Architecture Diagram of iRobot Roomba 565

4.0 External anatomy of the iRobot Roomba

Figure 4.1: Top View

Figure 4.2: Bottom View

Figure 4.3: Front Side View

Figure 4.4: Back Side View

Figure 4.5: Left Side View

Figure 4.6: Right Side View

Figure 4.7: Product Info View

4.1 The Top View of the iRobot Roomba

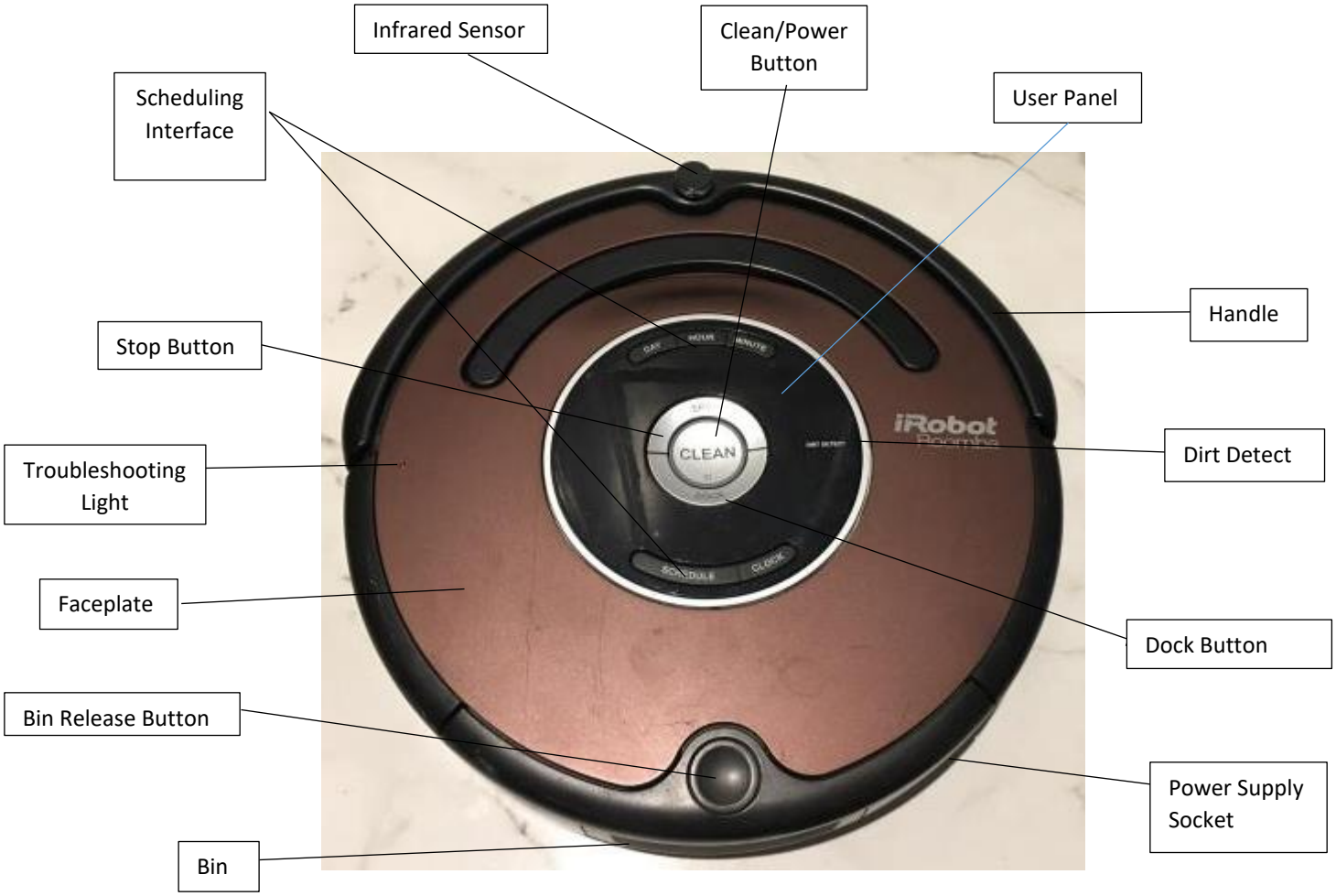


Figure 4.8: The Top View of the iRobot Roomba

4.2 The Bottom View of the iRobot Roomba

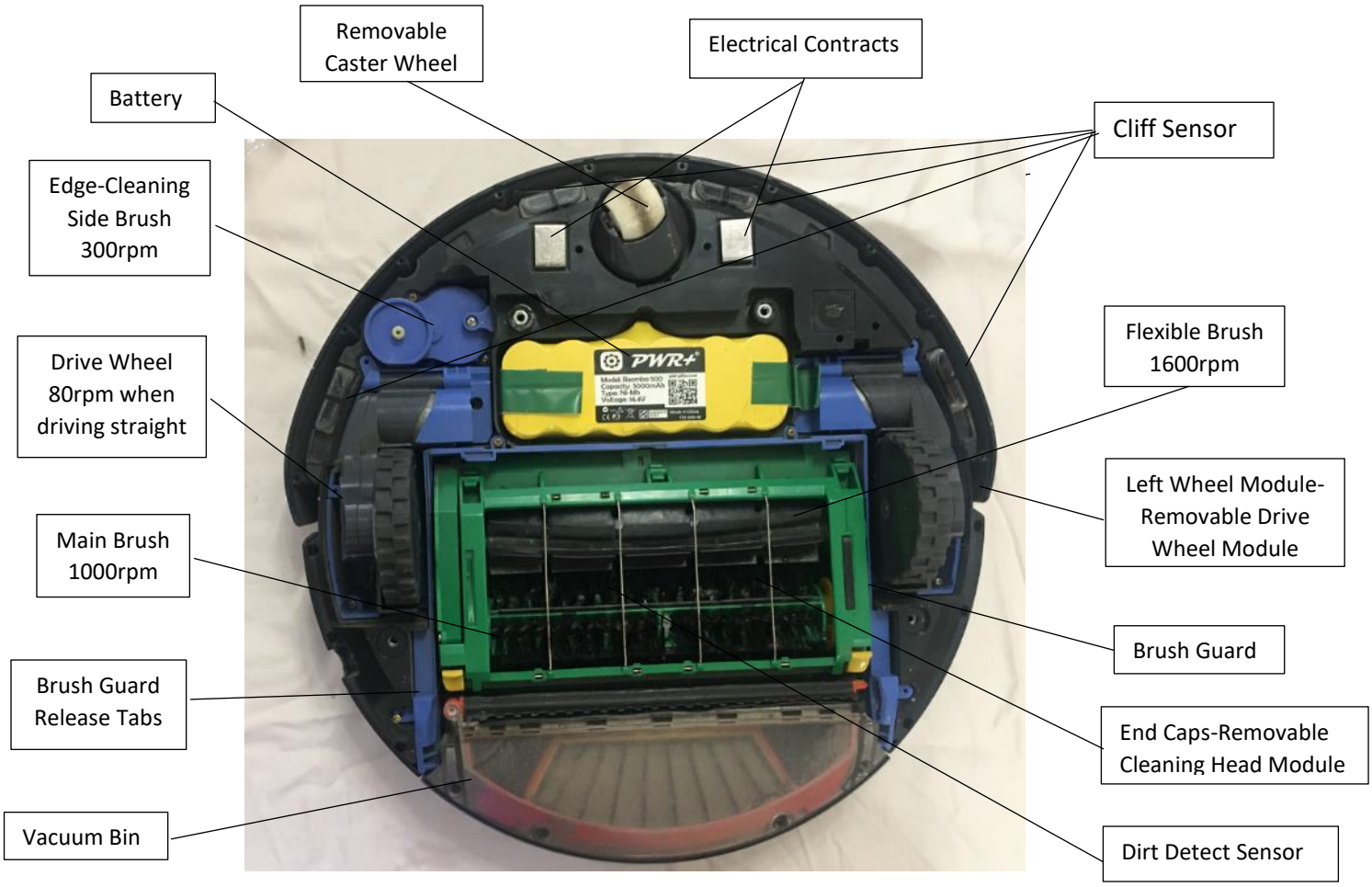


Figure 4.9: The Bottom View of the iRobot Roomba (Cover removed)

5.0 Disassembly Process

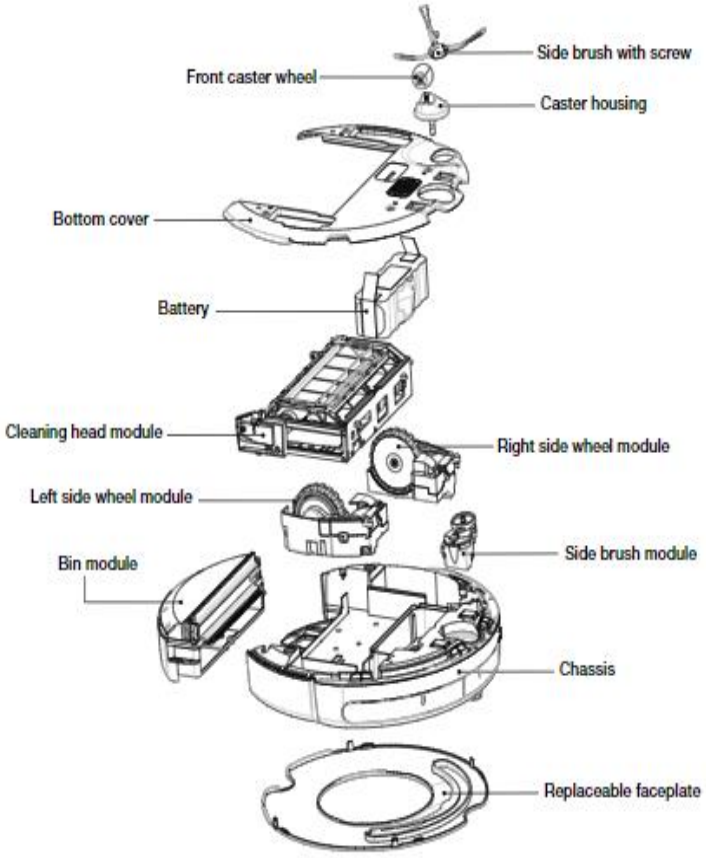


Figure 5.1: Anatomy of Roomba 565

Tools Lists:

- Safety Glasses
- Screwdrivers
- Small Torx Screwdrivers
- Tweezers

Figure 5.2 All components of Roomba

Step1: Wear safety equipment such as safety goggles and gloves to ensure the safety of team members.

Step 2: Unscrew the screws in the bottom side of the robot. Then, remove the bottom layer to reveal the robot's inside components.

Figure 5.3: The robot with its outer components taken off

Step 3: Remove robot's wheels, batteries, vacuum, and dust bin and disassemble the components separately by unscrewing any screws holding it together.

Figure 5.4: Parts located in the bottom side of the robot

Step 4: Remove the robot's top cover along with the handle and the plastic sheet beneath it. This will reveal the motherboard.

Figure 5.5: Taking off the robot's top layer, revealing the motherboard

Step 5: Unscrew all screws that are securing the motherboard to the robot and unplug any external cables connected to the motherboard to take it off.

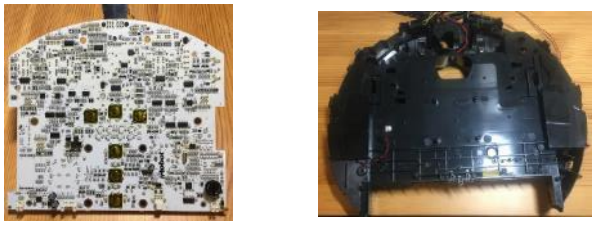


Figure 5.6: The robot's motherboard

Step 6: Remove the contact detection hardware from the front of the robot to reveal the base structure of the robot

Figure 5.7: The robot's collision detection

Step7: Disassemble the robot's charger by unscrewing any screws on the outside layer. This should reveal the motherboard within.

Figure 5.8: The robot's charger

6.0 Analysis Process

By researching what components look like on a Printed Circuit Board, we can identify what role each physical component has to allow the iRobot Roomba to navigate around its surroundings and clean the floor.

6.1 Motherboard

Table of components and Quantity

Components	Quantity	%	PCB Thermal Analysis (Low to high: Red highest)
Capacitors	12	2.19%	
Diode	16	2.91%	
Integrated Circuit	21	3.83%	
Inductor	1	0.18%	
LED	36	6.56%	
MOSFET	67	12.20%	
Port	12	2.19%	
Resistors	356	64.85%	
Transistor	27	4.92%	
Unidentified	1	0.18%	

These numbers are approximations, no abnormal temperature.

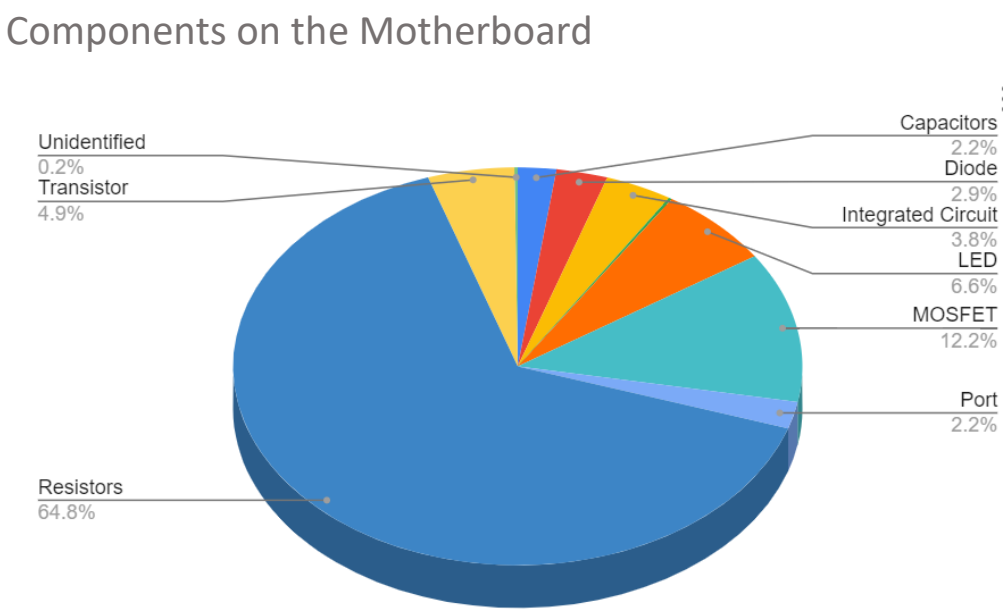


Figure 6.1: Pie chart for the components on the motherboard

6.1.1 Motherboard: Labelled images of circuit board (Front View)

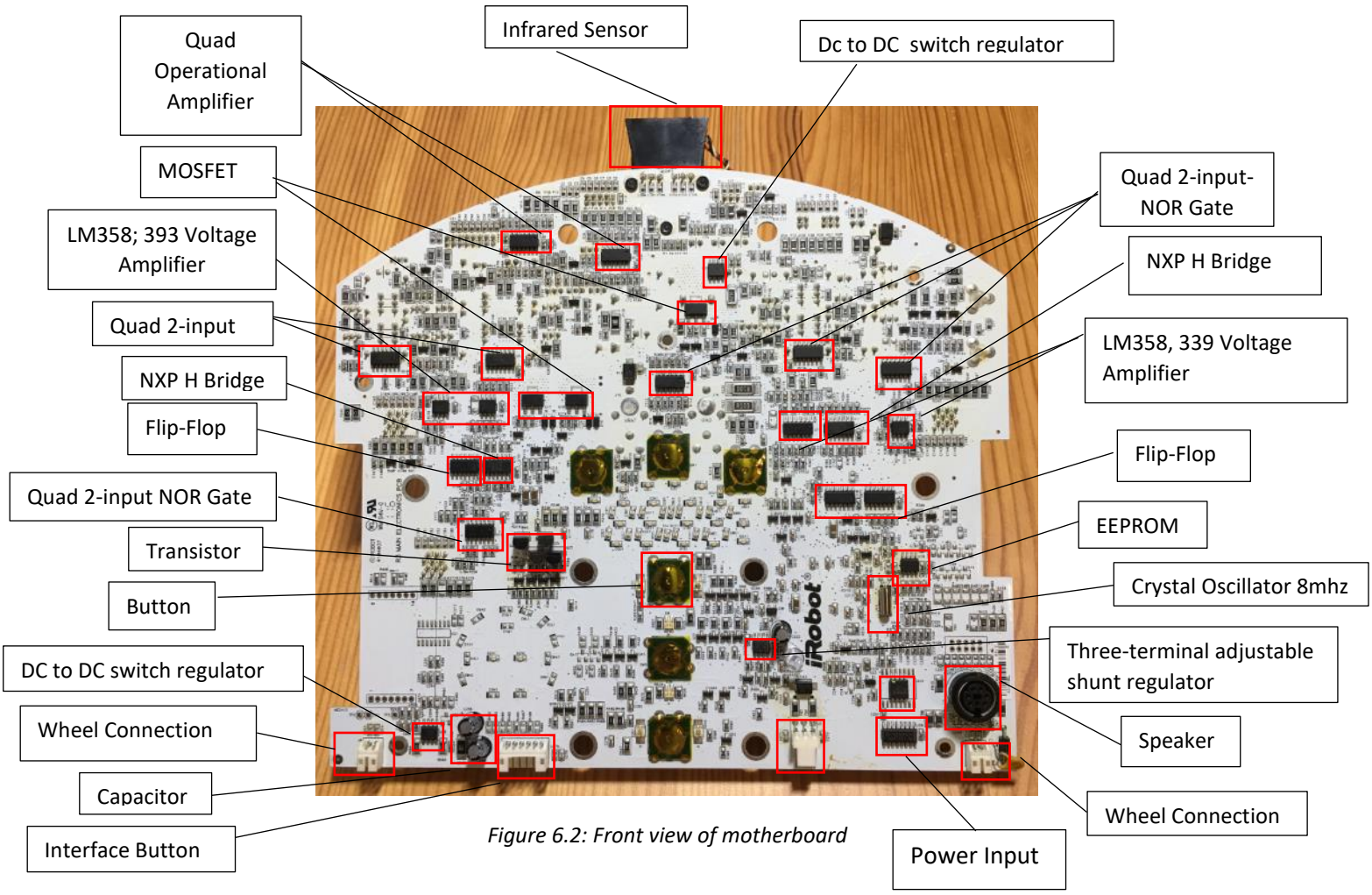


Figure 6.2: Front view of motherboard

6.1.2 Motherboard: Labelled images of circuit board (Back View)

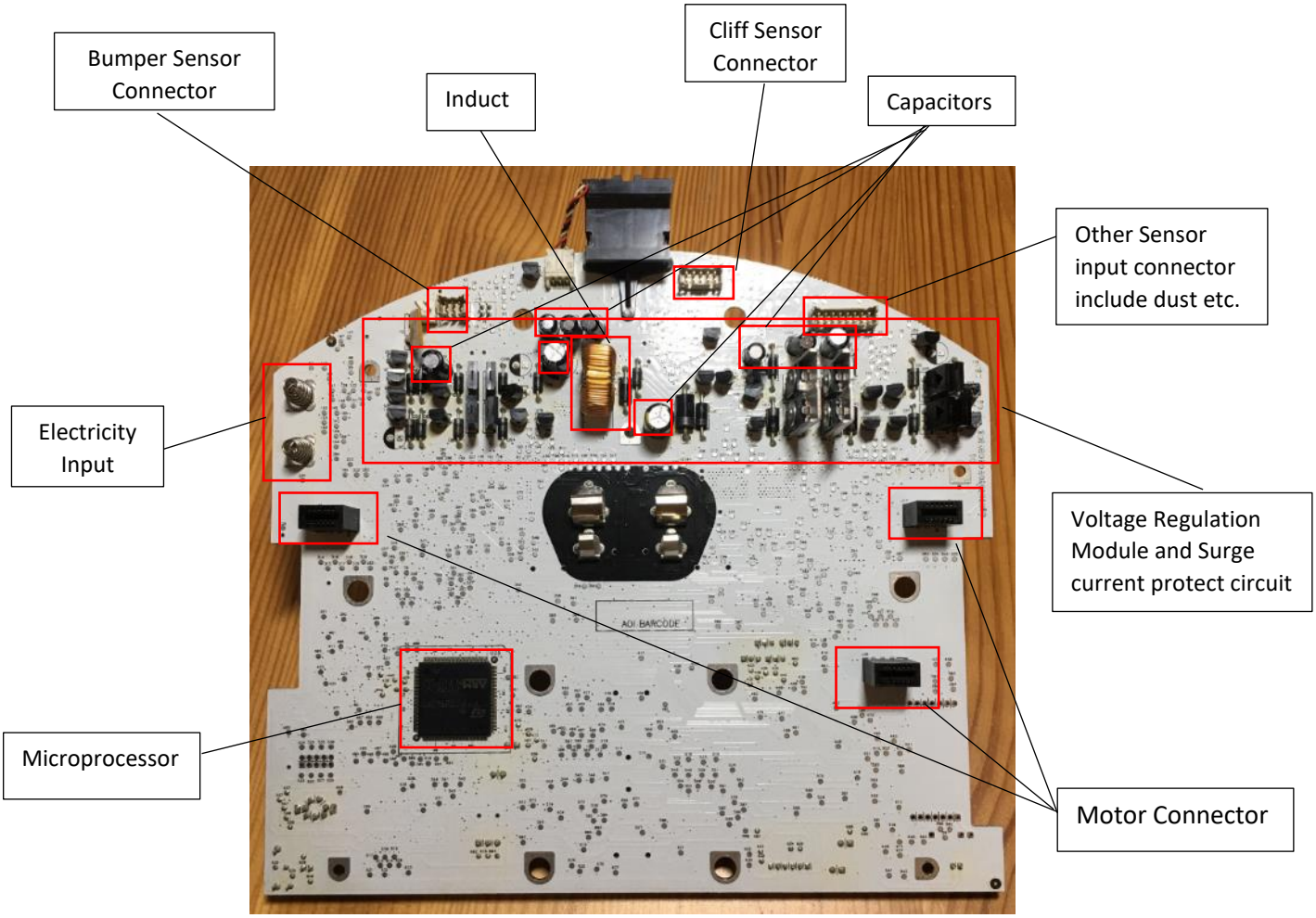
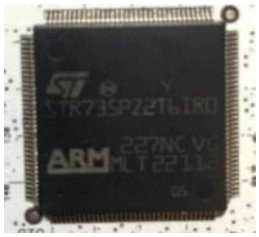
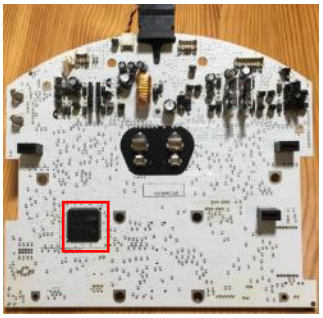
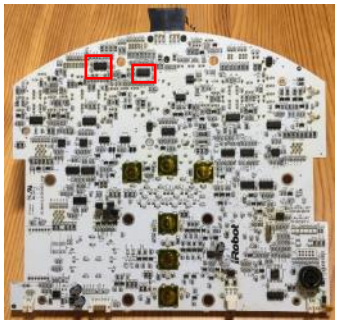
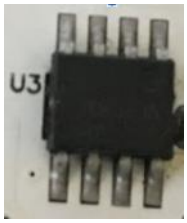
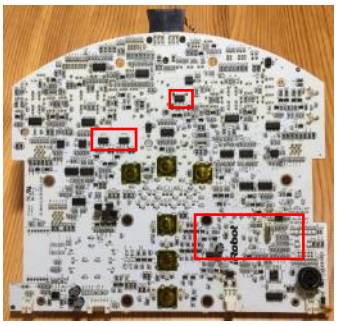
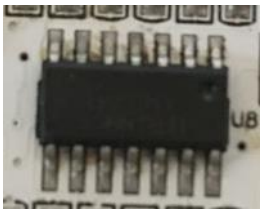
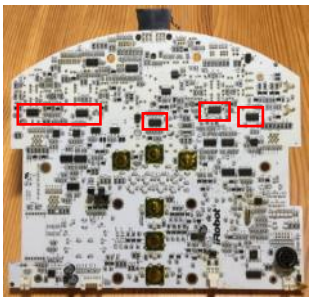
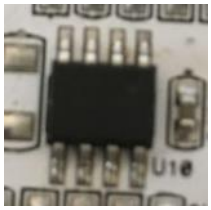
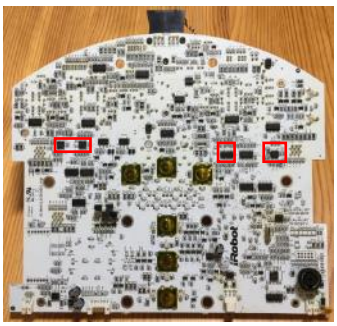
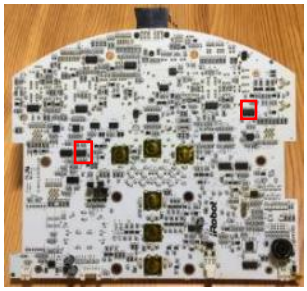
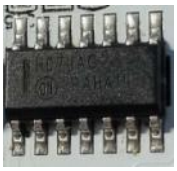
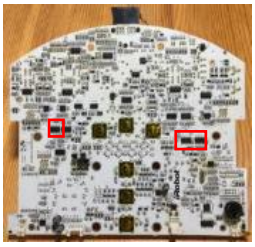
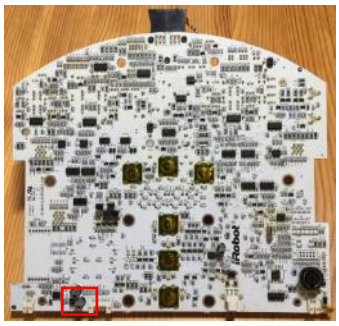
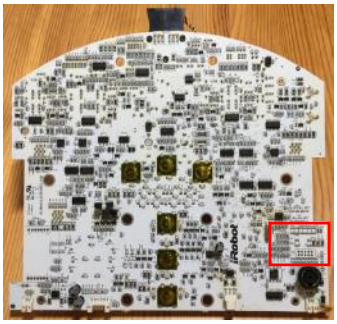
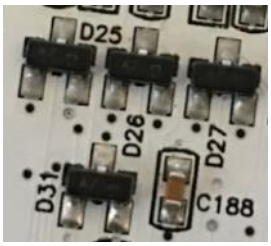
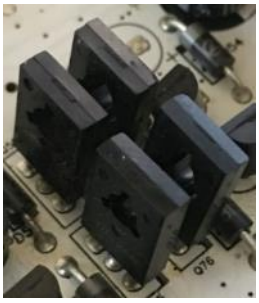
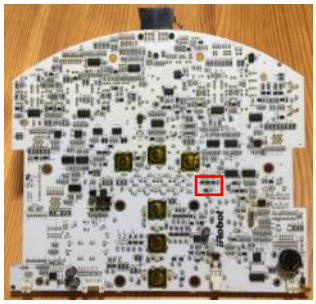
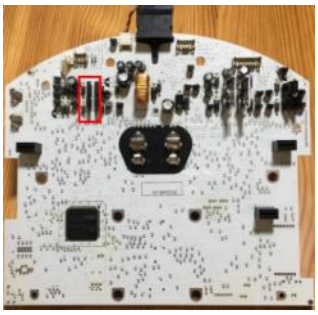
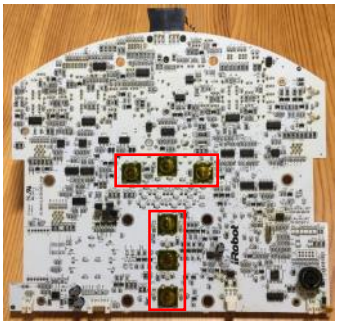


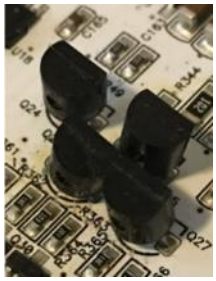
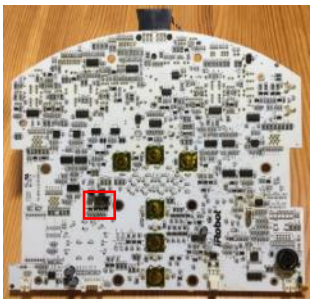
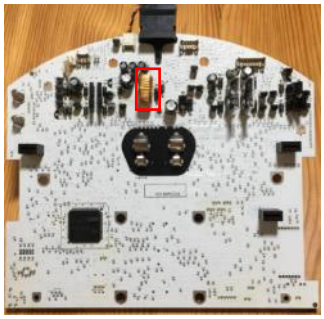
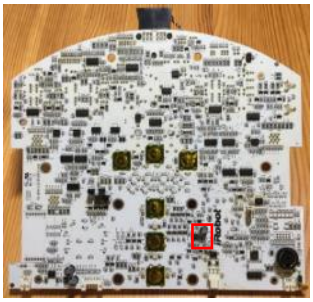
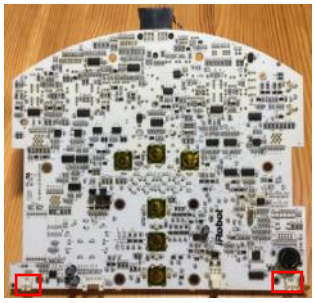
Figure 6.3: The Back view of motherboard

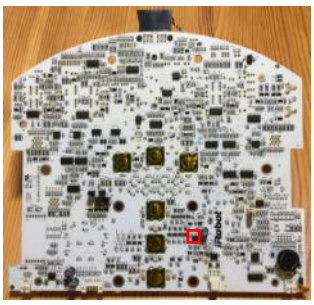
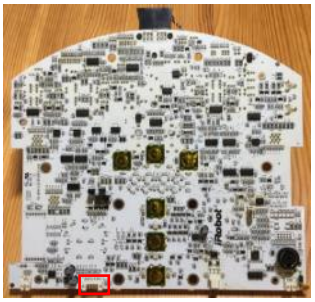
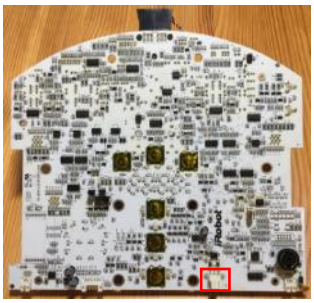
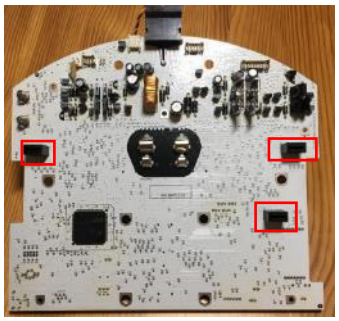
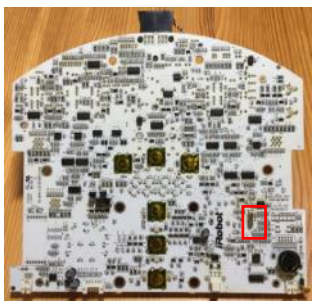
6.1.3 Motherboard Components Analysis

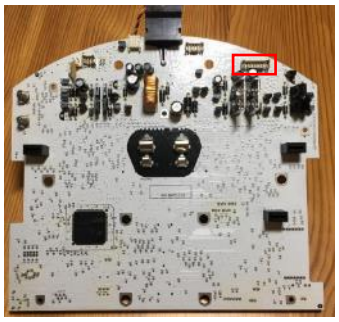
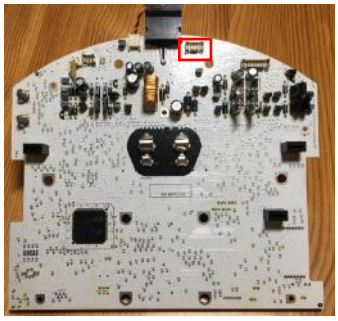
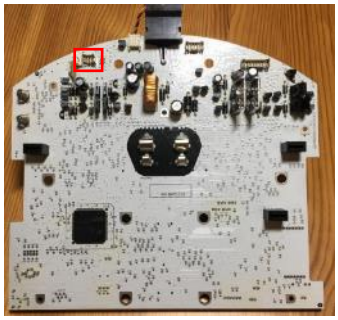
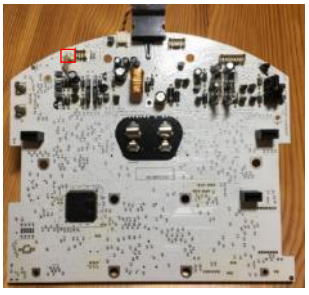
Part and Description	Image	Location
Microprocessor **ARM** **STR735PZ2T6IRO** The ARM is a microprocessor that processes information for the IRobot. It is also the central unit of the Roomba's system and it helps perform logic operations. Datasheet 1		
Quad Operational Amplifier **UTC NMC7 LM324L** This component consists of four independent high gain internal frequency amplifiers. The purpose of the UTC LM324L is to amplify or buffer raw sensor input signals when they reach the Roomba's system. Datasheet 2		
DC to DC Switch Regulator **UTC NMBR MC34063AL** This component is used to convert input DC voltage to the desired DC voltage. This is used to regulate the power received while at the charging station as well as throughout movement. Datasheet 3		
MOSFET **ZXMP6A17** This component is made for high-efficiency power management applications, including the Roomba. The ZXMP6A17 can be used for motor control, power management functions, and uninterrupted power supply. This component controls the power throughout the IRobot. Datasheet 4		

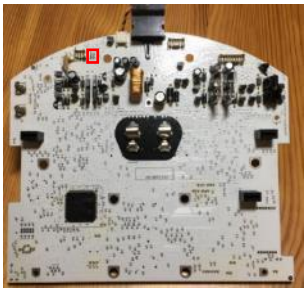
Part and Description	Image	Location
Quad 2-input NOR Gate **NXP 74HC02D** The 74HC02D enables the use of current-limiting resistors to control inputs in voltages. This allows the Roomba's resistors to function properly. Datasheet 5		
LM358; 393 Voltage Amplifier **UTV NKCA LM393L** This component consists of 2 independent voltage comparators and is designed to specifically operate from a single power supply to a wide voltage range. Datasheet 6		
NXP H Bridge DC Motor Driver **74HO14D LOK3R202 UXG1050F** This integrated circuit controls the low-voltage DC motors found in the Roomba.		
Dual D Flip-Flop **HC74AG PAHA14** The Flip Flop is used as a CMOS Gate which means that it starts digital circuits just like the ones found on the motherboard of the Roomba.		
Capacitor Capacitors are responsible for smoothing out the Electricity input. Since power outlets cannot always have a consistent flow of electricity, Capacitors store energy when there is too much energy and release the energy into the system when there is not enough.		

Part and Description	Image	Location
Resistor Resistors are passive two-terminal electric components. Resistors are used to reduce current flow, adjust signal levels, divide voltages, and terminate transmission lines. Resistors are vital in Roomba's as they manage voltage levels. When there are voltage spikes, components that are sensitive to heat, for example a LED will be damaged. Resistors essentially prevent too much voltage.		
MOSFET (general) The metal-oxide-semiconductor field-effect transistor (MOSFET) is one of the most common types of transistors today. Its primary use is to control conductivity and how much electric flow occurs. This ensures that there is electric flow in the Roomba when needed.	 	 
Button For a touch-user interface like that on the Roomba-500, buttons are needed for the user to interact with the robot. The buttons are beneath pieces of plastic that create a more user-friendly interface.		

Part and Description	Image	Location
Transistor Transistors are commonly found in microprocessors, but they can also be found in a circuit. When they are found like this, their main purpose is to ensure the circuit is on when the current is flowing and switch off when it is not.		
Inductor Electricity flow from a power outlet will never output power constantly as it is supposed to. Power outlets will occasionally stop outputting power completely for a split second, and usually, the device shuts off for a split second. However, Inductors keep the current flowing for a short time even when there is no input electricity. This allows the device to keep running for a short time even when there is no input electricity		
LED Light Bulb: A light-emitting diode (LED) is often used as an indicator. In the case of the Roomba, its purpose is to shine a light located in the front of the Roomba to indicate the Roomba's charge level.		
Wheel Connection Ports The Roomba is mounted with 2 powered wheels that allow it to move and clean the floor. These 2 wheels are powered by these plugs on the motherboard which tell the wheels what direction to move in and how fast it needs to move.		

Part and Description	Image	Location
Three-terminal adjustable shunt regulator TL431C TL431C offers better stability, lower temperature drifts, and lower reference currents and for improving system accuracy.		
Interface Button Connector This connects the navigation buttons with the motherboard which allows the robot to act accordingly.		
Charging Jack As a secondary way of charging the Roomba, it uses the traditional way of plugging a charger into the robot to charge. The charging jack is connected to this port through a wire.	 	
Motor Connector These 3 Motor Connectors connect to two drive wheel and the motor spinning the brush. Motor Connectors combine power with a brake, and are used for controlling the power from the circuits so the robot is able to stop, and move at varying speeds.		
Crystal Oscillator 8mhz This crystal oscillator is used to connect the remote control to the robot for it to be controlled remotely. The oscillator will generate a constant frequency signal so that the remote control can control the robot.		

Part and Description	Image	Location
Sensor Port As a robot navigating its way through a room or house, it needs to have sensors telling the robot where it is and what obstacles it is encountering. This port is the port where all sensors combine to feed information to the robot about its surroundings.		
Cliff Sensor Connector This connects the 4 Cliff sensors on the robot which allows the robot to know whether or not the robot is close to an edge or not.		
Bumper Sensor Connector This connector connects the Bump sensor with the motherboard, which allows the robot to realize whether it has hit something or not.		
Charging Port The primary way of charging the Roomba is by putting it on its charging dock. This charging dock has 2 pieces of metal that contact another 2 pieces of metal on the robot. An electrical charge is transferred between the two metals and then the electricity is carried through a wire to then be connected to this port.		

Part and Description	Image	Location
Front Caster Wheel Connector This connects the front faster wheel to the motherboard to allow the robot to know which direction it is heading.	 	

6.2 Charger & Virtual Wall Barrier

Table of components and Quantity

Components	Quantity	%	PCB Thermal Analysis (Low to high: Red highest)
Capacitors	3	5.17%	
Diode	2	3.45%	
Integrated Circuit	2	3.45%	
LED	4	6.90%	
MOSFET	11	18.97%	
Resistors	33	56.90%	
Transistor	3	5.17%	

Note: These numbers are approximations, no abnormal temperature.

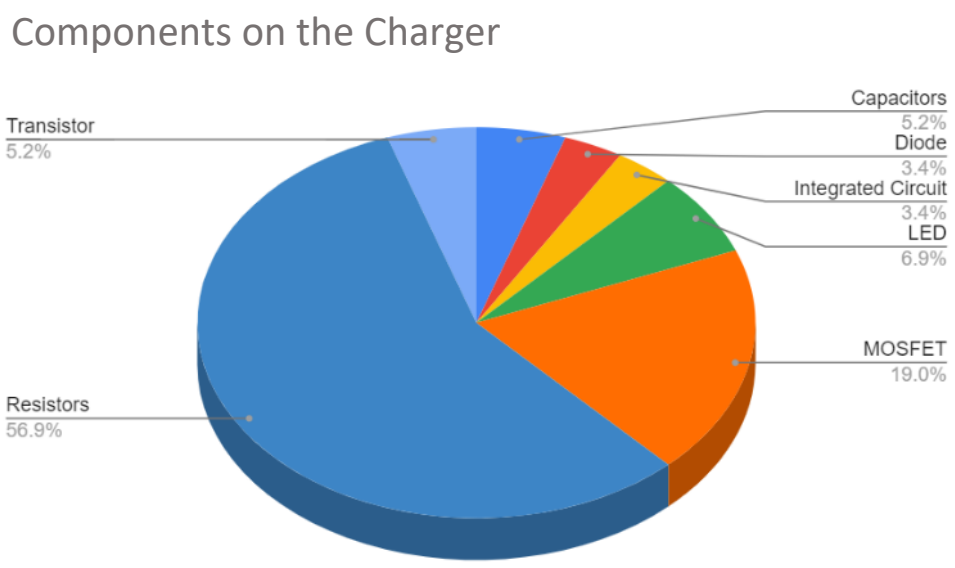


Figure 6.4: Pie chart for the components on Charger's circuit

6.2.1 View of Charger & Virtual Wall Barrier

The compact Home Base (Figure 5.5) is used as a dock for the robot. Once the robot is done cleaning or if it is low on battery it will use infrared signals to locate the home base and rest above it to charge. A green light on the top of the home base indicates the robot's charge level.

The auto virtual wall barriers (Figure 5.6) use infrared signals to create an invisible line which the robot can see. When the device is turned on, the robot will not cross the invisible line.

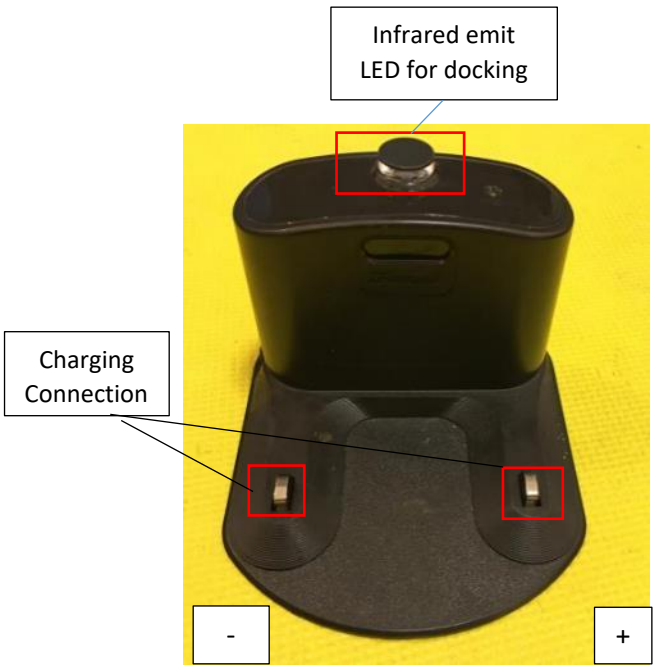


Figure 6.5: Compact Home

Figure 6.6: Auto virtual wall

6.2.2 Labelled images Charger (Front & Back View)

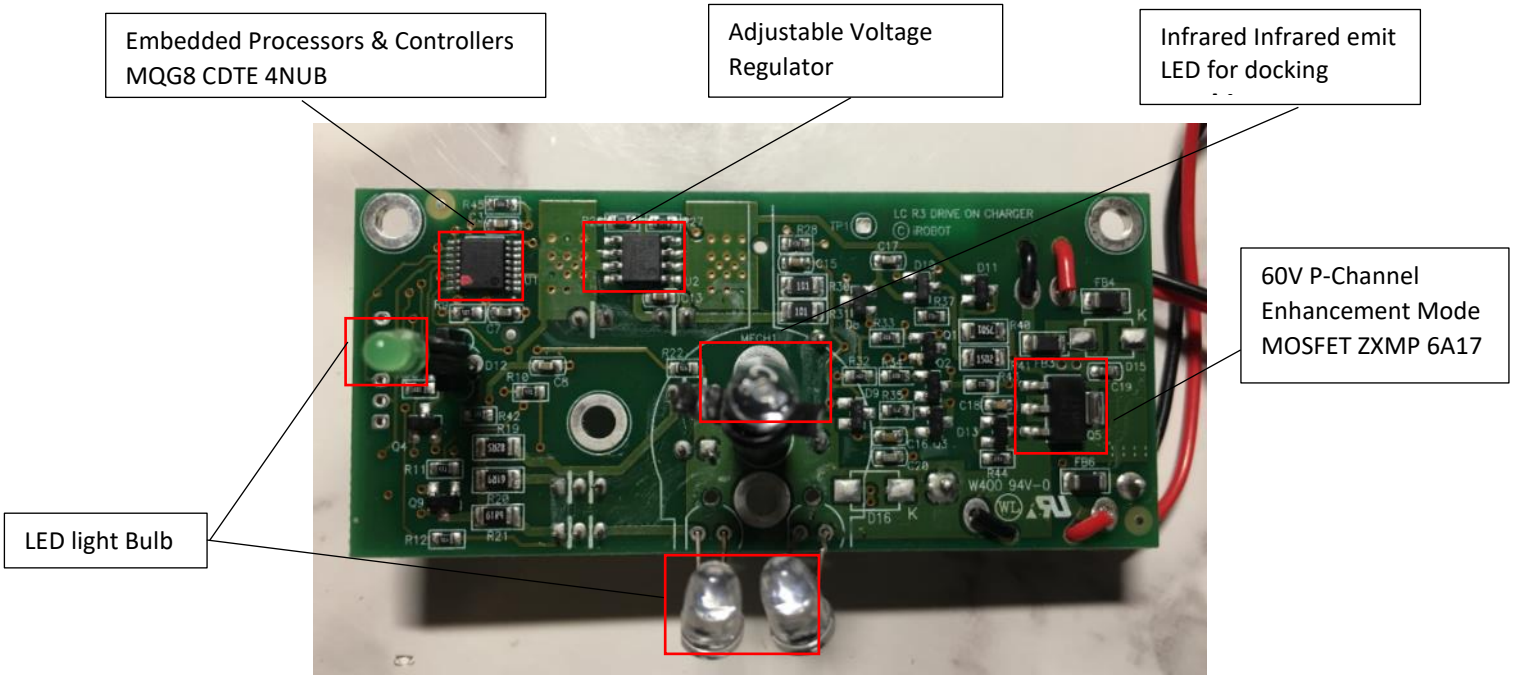


Figure 6.7: The front view of Charger motherboard

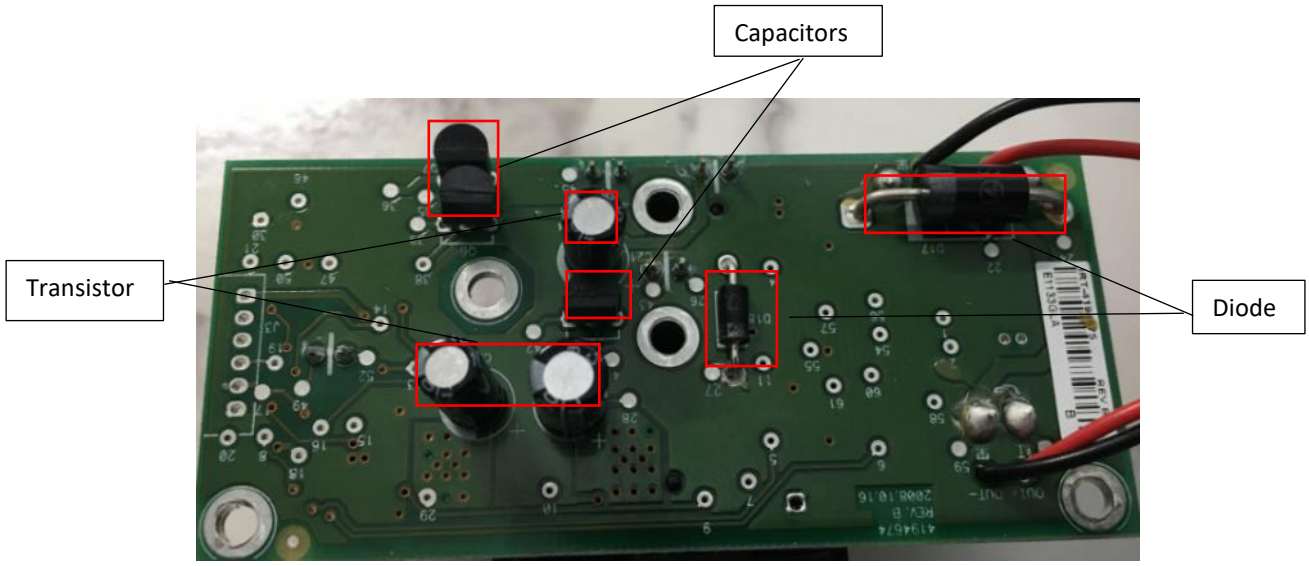
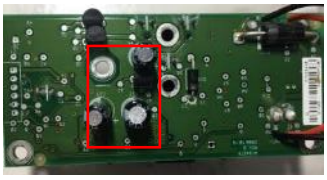


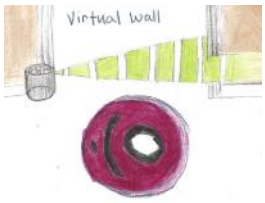
Figure 6.8: The Back view of Charger mother board

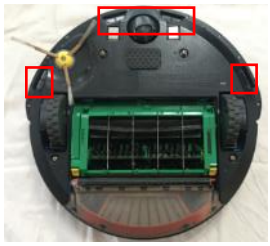
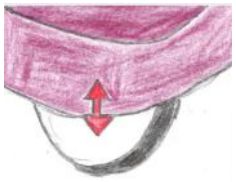
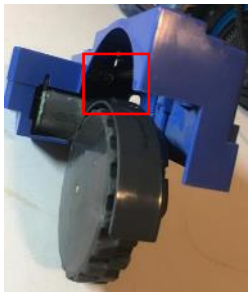
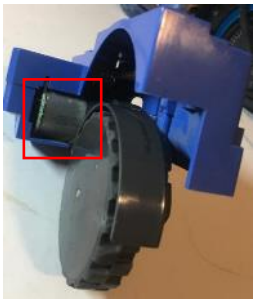
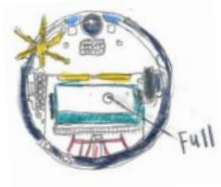
6.2.3 Charger Components Analysis

Part and Description	Image	Location
Transistor Refer to "5.1.3 Motherboard Components Analysis: Transistor"		
Capacitors Refer to "5.1.3 Motherboard Components Analysis: Capacitors"		
Diode A diode is a one- way switch for current, which is always a semiconductor device. The function of the diode is to allow current to flow easily in one direction while making it hard in the other.		
Embedded Processors & Controllers -micro-controller chip MQG8 CDTE 4NUB The MC9S08QG8 is 8-bit microcontroller units. It includes the enhanced HCS08 core and are available with a variety of modules, memory sizes, memory types, and package type. Its function is to control the amount of electricity going through the charger. Datasheet 7		
LED Refer to "5.1.3 Motherboard Components Analysis: LED Light Bulb"	 	

Part and Description	Image	Location
Adjustable Voltage Regulator **UTC OATJ LM317LG** This is a monolithic integrated circuit and it is an adjustable 3−terminal positive voltage regulator capable of supplying in excess of 1.5 A over an output voltage range of 1.2 V to 37 V. This regulator requires two external resistors to set the output voltage with internal thermal overload protection, internal short circuit current limiting and output transistor safe area compensation. Datasheet 8		
MOSFET **ZXMP 6A17** **60V P-Channel Enhancement** This Mosfet combines the benefits of low on-resistance with fast switching speed. This makes them ideal for high efficiency, low voltage, power management applications. Datasheet 9		

6.3 Sensor

Part and Description	How it works	Image	Location
Infrared Sensor for avoiding object The Infrared Sensor is an omnidirectional sensor that is used to sense both the location of the charging port and the laser walls. The laser walls are components that send signals to the infrared sensor and tell the Roomba to stop at a certain line.		 	 
Infrared emit LED for Docking Docking sensor emits infrared signal which allows Roomba follow the signal and Dock itself to the charger.	 		
Infrared emit LED for Virtual Wall When paired with 2 of these LEDs, they will make an invisible line that the Roomba will not cross; this helps to contain the robot in a particular area.			
Bump sensor and spring The bump sensor is a component that can sense contact. It contains springs that hold the bumper in place until impact.			

Part and Description	How it works	Image	Location
Cliff Sensor The cliff sensors are IR sensors that look for a bounce in infrared rays. The cliff sensors allow the Roomba to sense when it is near a ledge like stairs and tells the Roomba to turn around to avoid falling.		 	
Wheel Drop Sensors (Limit switch) This sensor is to help lower the chances of the robot falling down a ledge. When the wheel is full extended, the motherboard will stop the robot from moving any further.			
Hall Effect Encoder The Hall Effect Encoder measures how much rotations the wheel has turned. It is designed to be extremely robust as there are many dirty objects that it will encounter when navigating along the floor.			
Piezoelectric/Dirt Detect Sensors The dirt detect sensor is used to detect the concentration of dirt in an area. This allows the Roomba to know what parts of the house are harder to clean than others.			

6.4 Wheel Module

The iRobot Roomba Model 565 uses various sensors to navigate its way through a uses 2 wheel module to move the robot; a flow chart will show what the processes the wheel goes through to control the power output to the wheels.

Figure 6.9: Top View

Figure 6.10: Bottom View

Figure 6.11: Left Side View

Figure 6.12: Right Side View & Gear Ratio

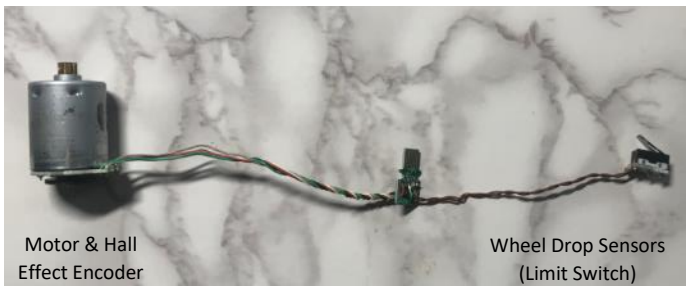


Figure 6.13: Wheel Electrical Subassembly

6.4.1 Wheel Electrical Subassembly Flow Chart

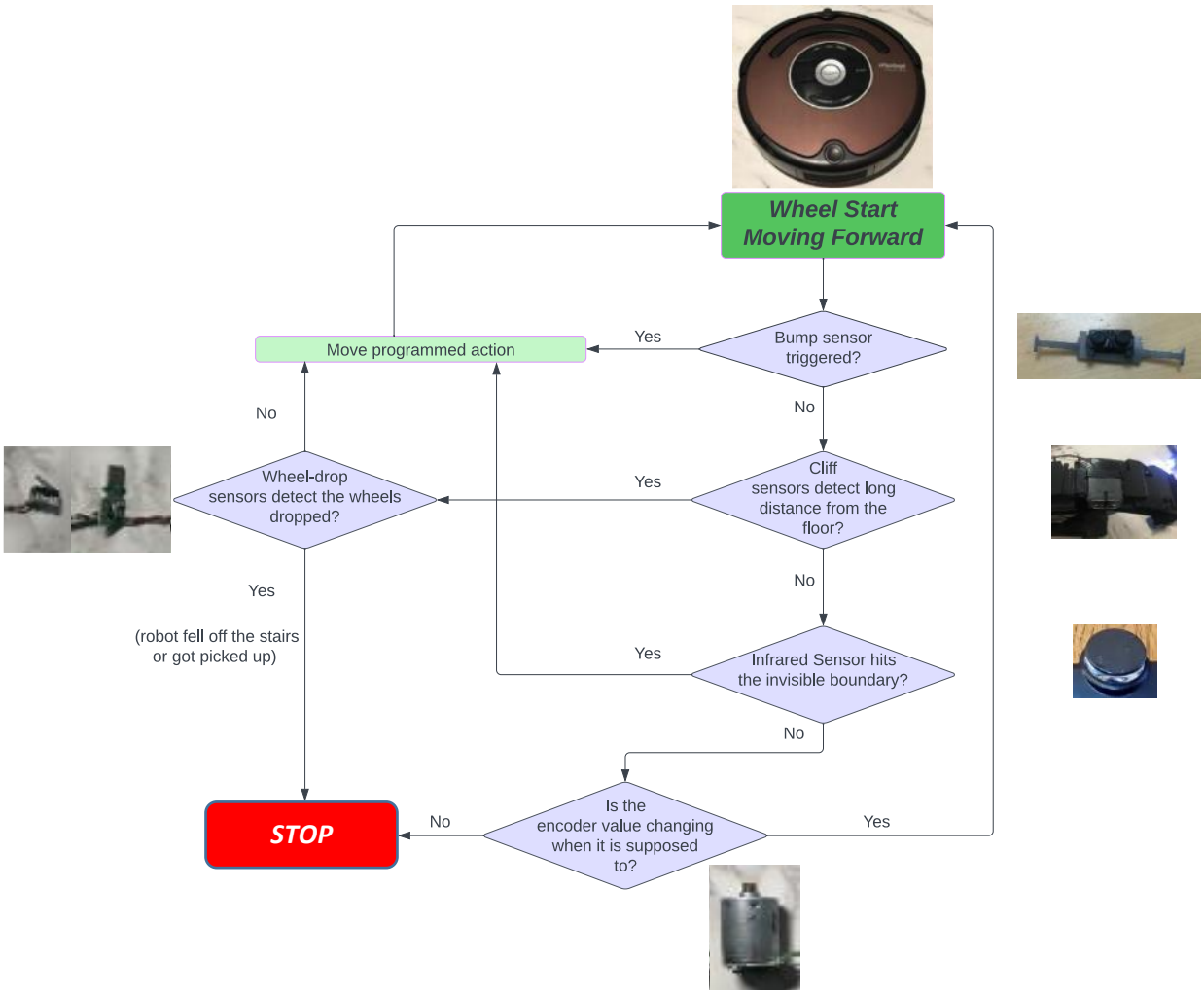
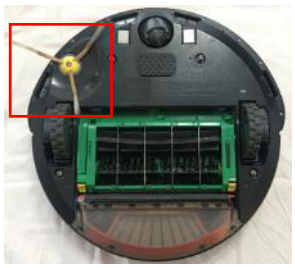
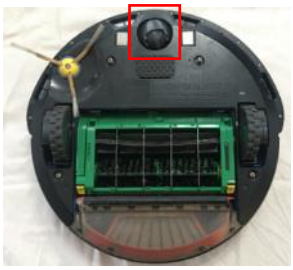
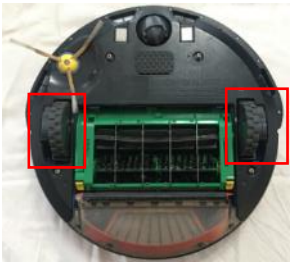
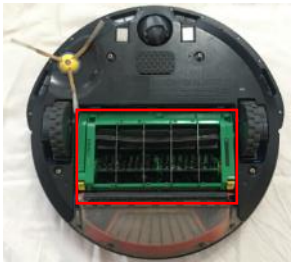
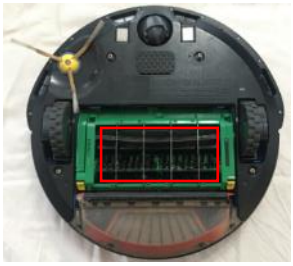
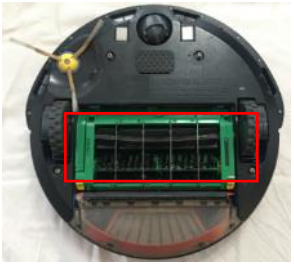
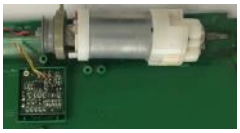
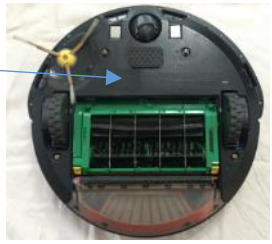
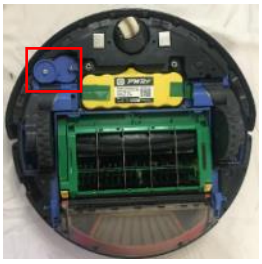


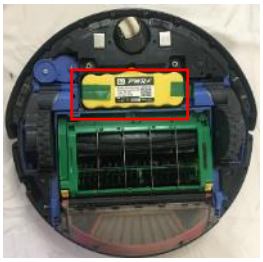
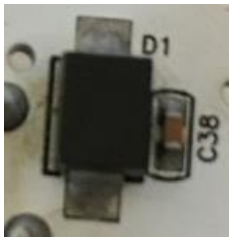
Figure 6.14 the flow chart of Wheel Electrical Subassembly

6.5 Other Components

Part and Description	Image	Location
Dust Bin This component is where all of the dirt and dust gets pushed to. The dust bin is released by pressing the button on top and pulling outwards. The dust bin allows the Roomba to run for long durations of time without needing to be emptied.		
Top Cover Plate The Top Cover Plate's main purpose is to protect the insides of the Roomba from any hazardous objects that may fall or rest on top of the robot. However, it also serves to keep the aesthetics of the robot more pleasing to look at.		
Motherboard As a Roomba that needs intelligence to know where it is located and what its surroundings are, the motherboard serves as a place where most of the electronic components go.		
Side Brush The side brush gets debris from near the walls and spins them into the Roomba's main brush bits located in the middle of the underside.		

Part and Description	Image	Location
Front Caster Module The Front Caster Module allows the robot to more easily as just having 2 wheels will not allow the robot to be well-balanced. This module can freely move in all 360 degrees.		
Wheel Modules The Wheel Modules are mechanical devices that allow the robot to navigate its way around a room or house. They are equipped with a small suspension system to make sure the wheels keep constant contact with the ground to prevent wheel slippage. The speed of the wheels are 80 rpm, this make sure that the robot can drive straight and also navigate through the house easily.		
The Extractor Frame The extractor frame is a component that uses wires to prevent large debris from entering the Roomba. The frame is important in holding up the debris extractors.		
Debris Extractor The debris extractors are a component that attach inside of the extractor frame. The debris extractor has 2 brushes. One brush is used to agitate and loosen dirt inside of carpets while the other brush spins the opposite way and guides debris into the dustbin.		

Part and Description	Image	Location
Gearbox The gearbox connects the two rollers together allowing it to be powered by one motor. The gearbox is designed so that the rollers spin in opposite directions.		
Vacuum bin The Vacuum bin is to collect the objects or dust that the robot has managed to pick up while cleaning.		
Extractor motor This motor is used to spin the debris extractor so that the robot can pink up dirt and dust while spinning the debris extractor at 1000 rpm for the main brush and 1600 rpm for the flexible brush		
Bottom Plate The bottom plate is screwed in place to protect other small and delicate components. The bottom plate is made to be durable and to withstand possible impact.		
Sweeper Brush Motor The sweeper brush motor is a 2006 model. This motor is what allows the side brush to spin. The side brush is directly connected to the motor. The motor will spin the sweeper brush at 300 rpm so that the dust can be swept away when it reaches the sweeper brush		

Part and Description	Image	Location
Lithium Ion Battery The lithium Ion battery is the main power source for the entire Roomba. It has a capacity of 3000mAh and has 14.4V. The battery is a Ni-Mh battery and is rechargeable. Capacity: 3000mAh Type: Ni-Mh Voltage: 14.4V		
Interface Button This module is connected to a port on the motherboard through a wire and detects whether or not the bottom 2 buttons of the interface have been pressed.		
Integrated Circuit **PJ1119CE** We could not find the product number of this Integrated Circuit.		

Note: All photos were original from Team 832A.

7.0 Control Flow Chart

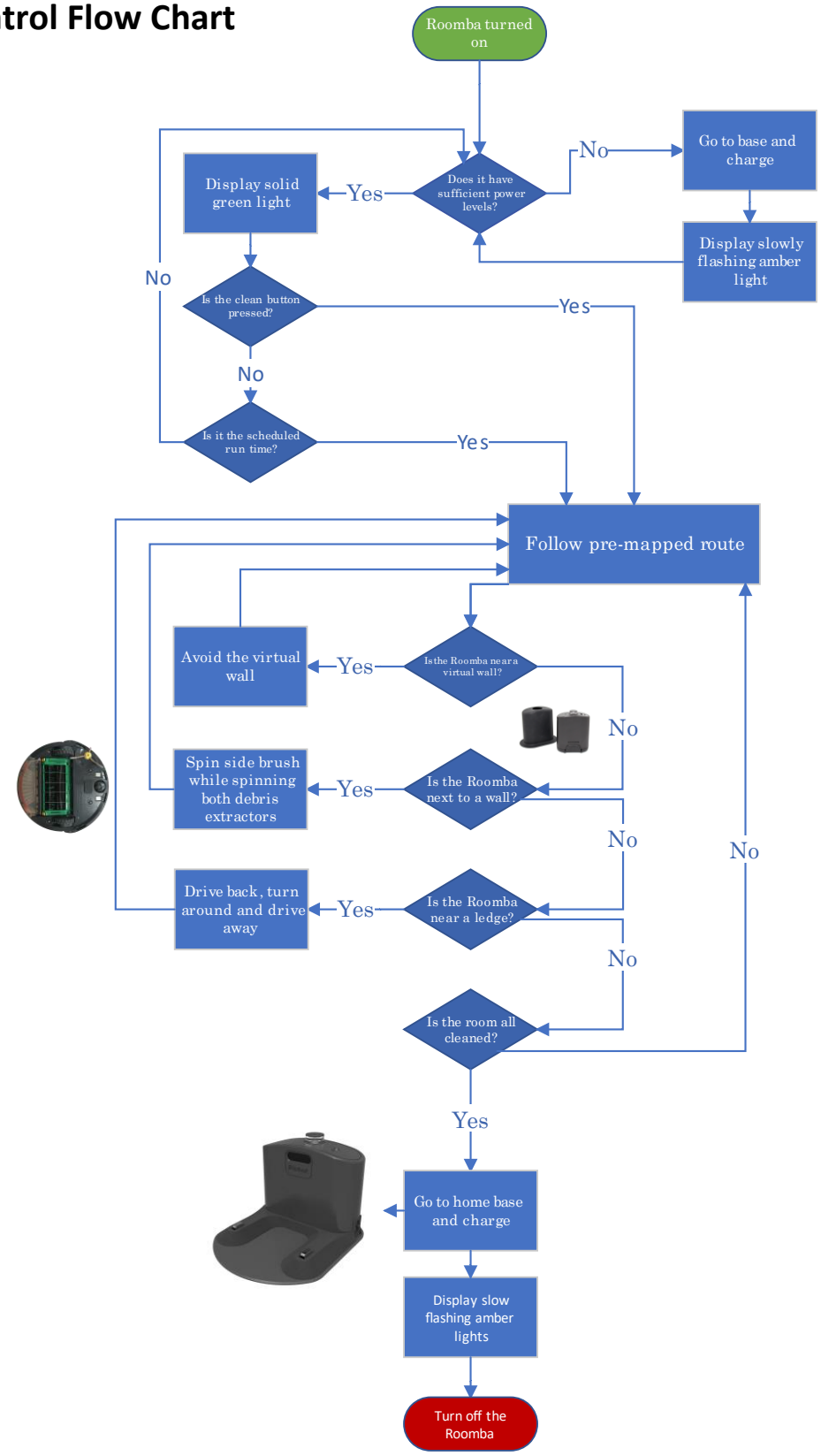


Figure 7.1: Control Flow Chart of iRobot Roomba 565

8.0 References

Figure 4.1 : Anatomy of Roomba

https://manualzz.com/manual/iRobot/Roomba%2B565

Datasheet 1: Microprocessor

https://www.jotrin.com/product/parts/STR735PZ2T6IRO

Datasheet 2: Quad Operational Amplifier

https://www.ti.com/lit/ds/symlink/lm324.pdf?ts=1672687399424&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FLM324%253Futm_source%253Dgoogle%2526utm_medium%253Dcpc%2526utm_campaign%253Dti-null-null-xref-cpc-pf-google-wwe%2526utm_content%253Dxref%2526ds_k%253D%257B_dssearchterm%257D%2526DCM%253Dyes%2526%2526utm_source%253Dgoogle%2526utm_medium%253Dcpc%2526utm_campaign%253D%2526utm_content%253D%2526ds_k%253Dlm324%2526DCM%253Dyes%2526gclid%253DCj0KCQiAnsqdBhCGARIsAAyjYjSnt95l5jNcWTYiBPLxFE9g7UCLQ-1GI8r1f8nd4Ou8NFNom9_hCpEaAtiHEALw_wcB%2526gclsrc%253Daw.ds

Datasheet 3: DC to DC Switch Regulator

https://www.ti.com/product/MC34063A?utm_source=google&utm_medium=cpc&utm_campaign=app-null-null-GPN_EN-cpc-pf-google-wwe&utm_content=MC34063A&ds_k=MC34063A&DCM=yes&&utm_source=google&utm_medium=cpc&utm_campaign=&utm_content=&ds_k=mc34063a&DCM=yes&gclid=CjwKCAiAwc-dBhA7EiwAxPRylIPvTis9dMi3hXxSQLvZWnp8c4J6LR3229gxlnKVvDtc2-_rFBt_yxoCd_kQAvD_BwE&gclsrc=aw.ds#description

Datasheet 4: MOSFET

https://pdf1.alldatasheet.com/datasheet-pdf/view/103307/ZETEX/ZXMP6A17GTA.html

Datasheet 5: Quad 2-input NOR Gate

https://assets.nexperia.com/documents/data-sheet/74HC_HCT02.pdf

Datasheet 6: Voltage Amplifier

https://datasheet.lcsc.com/lcsc/1811081221_UTC-Unisonic-Tech-LM393L-D08-T_C71104.pdf

Datasheet 7: Embedded Processors & Controllers -micro-controller chip

https://www.alldatasheet.com/view.jsp?Searchword=MQG8CDTE
https://www.apogeeweb.net/productdetail/freescale-semiconductor-inc-nxp-semiconductors-mqg8cdte-4kr56vqb

Datasheet 8: Adjustable Voltage Regulator

https://www.alldatasheet.com/view.jsp?Searchword=LM317LG&sField=2

Datasheet 9: MOSFET

https://datasheet.octopart.com/ZXMP6A17GTA-Diodes-Inc.-datasheet-5334178.pdf