

Reverse Engineering

Team 9



Objective

The objective of this report is to thoroughly analyze the disassembly and reverse engineering of iRobot's Roomba 670 robotic vacuum cleaner. Through this process, we aim to document the physical characteristics of this application, including its assembly process, key components, control systems, and electronic architecture. The report also gives insight into the cost structure by way of a bill of materials with component weight. In addition, a performance evaluation was conducted before and after the teardown, and the reassembly process was documented to assess how well the Roomba performed after reassembly. This research aims to give a comprehensive understanding of the Roomba design, assembly, and functionality as well as its cost margins.

System Description

A Roomba is a robotic vacuum cleaner that comes equipped with several systems and features that helps it to clean floors. Roombas in general use a 3-stage cleaning system including a spinning side sweeper, counter-rotating brushes and a vacuum chamber. All together these clean dirt, dust, larger debris, and pet hair. The Roomba has two main wheels, as well as an optical caster wheel that helps the robot to navigate and clean in neat rows. The Roomba that was reverse engineered for this project is an iRobot Roomba 670. This specific model does not have a mapping navigation system, and instead uses physical landmarks and walls to identify its location. Roombas are self-charging and return to the charging stations at the end of its cleaning cycle, the battery typically lasts for 90 minutes without having to be charged. There are charging lights that pulses red while charging, and then turns a solid green to indicate when it is fully charged. Roombas can communicate with the user through flashing lights, beeping and an automated voice. Additionally the iRobot Roomba 670 can connect to a 2.4GHz network to access Wi-Fi.

Patent Search Results

IRobot holds over **30 U.S patents** specifically for Roomba technology

- Patents cover topics relating to autonomous navigation, cleaning mechanisms, and docking systems
- The basic patent is 6,883,201

Source: <https://patents.justia.com/assignee/irobot-corporation>

Operating Features

The specific operating features of the iRobot Roomba 670 can be seen detailed in Figure 1 and 2, graphics taken from the Roomba user guide.

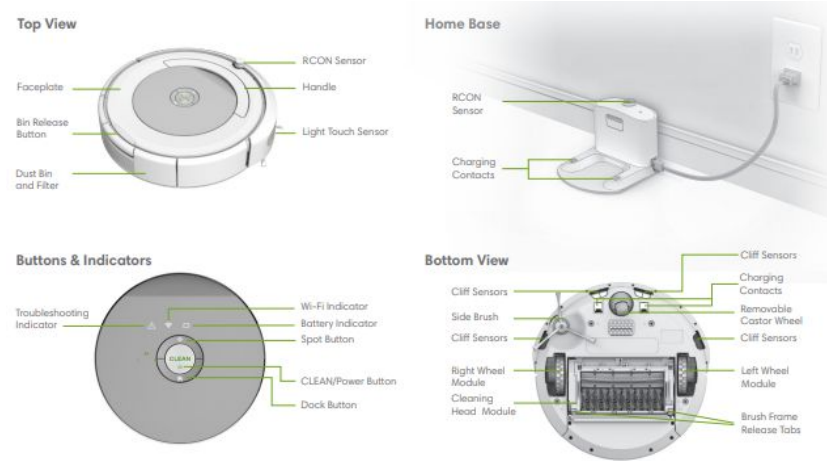
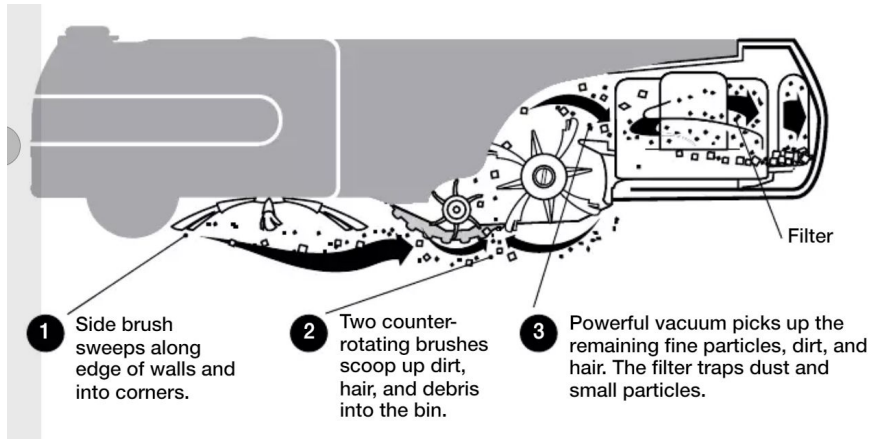


Figure 1&2. Graphic detailing the operating features on an iRobot Roomba 670

Background

The robotic vacuum market earned 4.5 billion USD in 2023. IRobot is responsible for over 40% of this market share. This market continues to grow at an expected rate of 7.1% per year as the global demand for smart home products increases. Technological advancements and innovations continue to revolutionize the robotic vacuum space with improved navigation systems, enhanced battery life, and greater compatibility with smart home ecosystems like Amazon Alexa and Google Home.

Although iRobot remains a leader in the robotic vacuum market, iRobot faces many competing companies particularly from Asia. Key competitors in the robotic vacuum market include brands like Roborock, Ecovacs, and SharkNinja. These companies offer different features at varying prices and are slowly taking market share from IRobot.

The market for robotic vacuum cleaners is largely driven by North America and Europe, which account for more than 60% of total global sales. Though Asian markets account for a large percentage of sales as well. The Asian robotic vacuum market is expected to surpass the western market by 2030 as more Asian consumers incorporate smart technologies into their lives.

Components

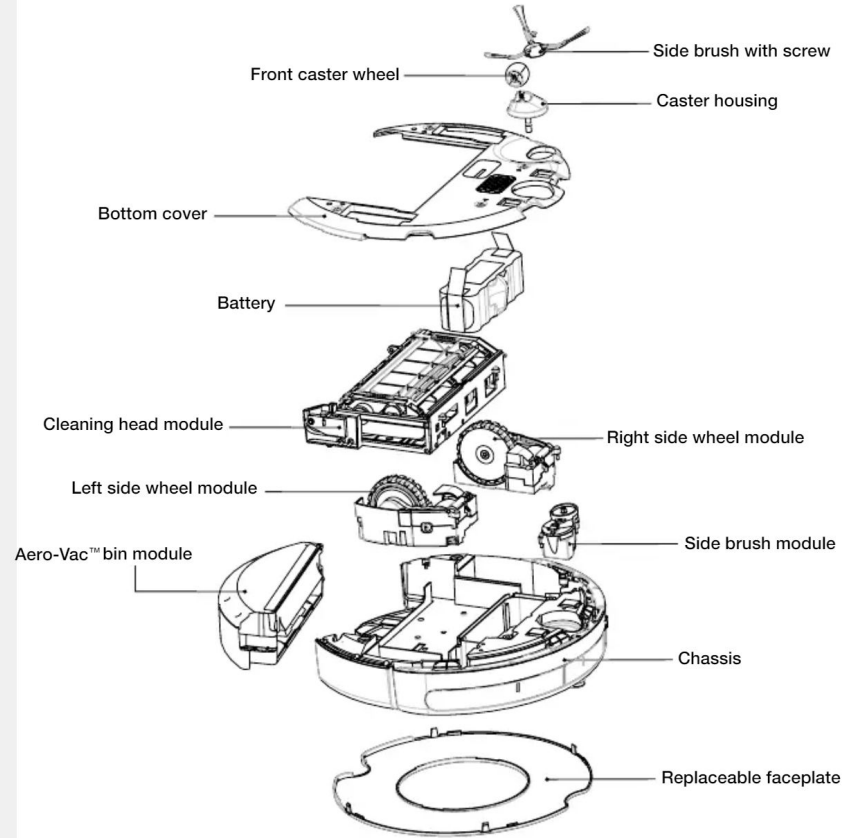


Figure 3: Roomba 670 Components

Procedure For Disassembly

1.) Remove Side Brush

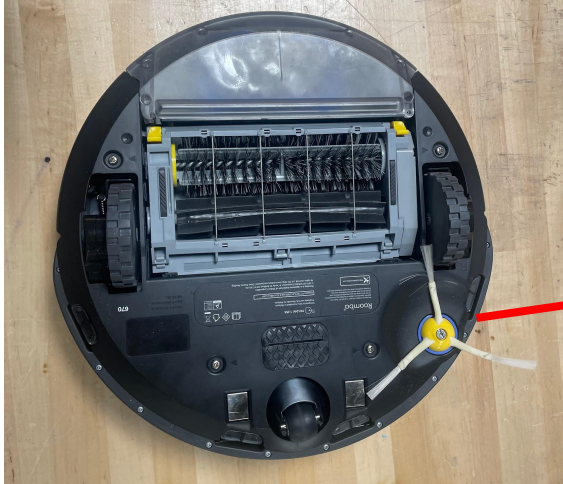


Figure 4. Top Down View of Assembled Vacuum Bottom

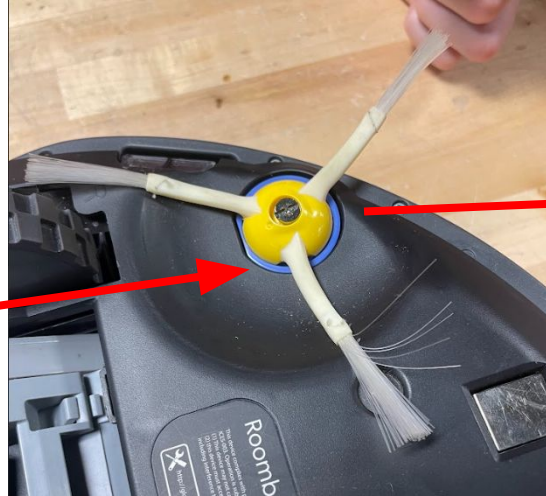


Figure 5. Side Brush With Screw



Figure 6. Unscrewed Side Brush

2.) Remove Bottom Cover and Side Brush Module



Figure 7. Bottom Cover



Figure 8. Side Brush Casing

2.) Remove Bottom Cover and Side Brush Module Contd.

3 Gear Gear Train



Figure 9. Side Brush Gear Train



Figure 10. Side Brush Motor

3.) Disassemble Aero-Vac Bin Module



Fan

Latching door with
a release
mechanism for
trash disposal

Figure 11. Dust bin with
blue dust filter removed



Blue dust filter

Figure 12. Dust bin with
blue dust filter

3.) Disassemble Aero-Vac Bin Module Contd



Figure 13. Aero-Vac Fan Housing

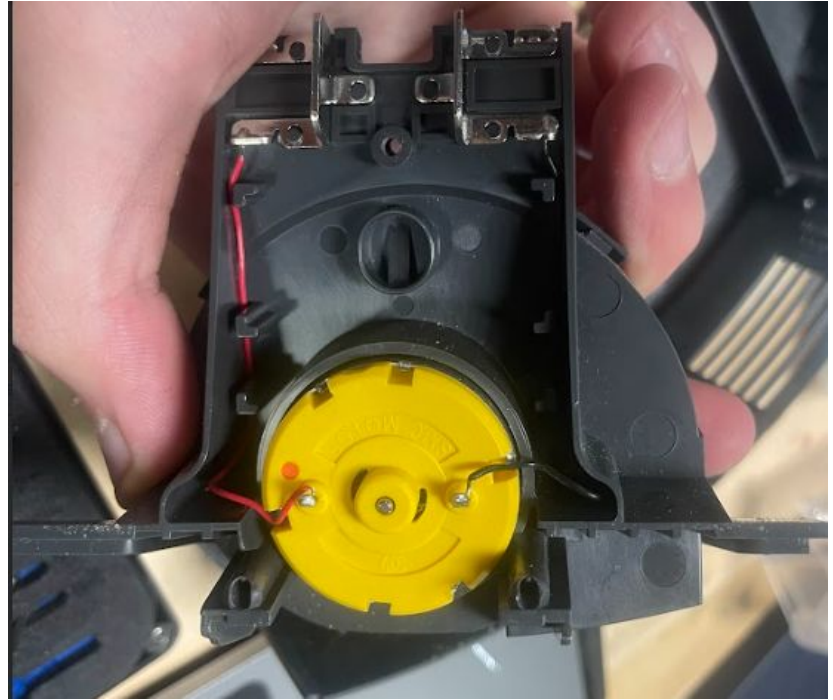


Figure 14. Aero-Vac Motor

4.) Disassemble Brush Assembly (Cleaning Head Module)



Figure 15. Brush Assembly (Top view)

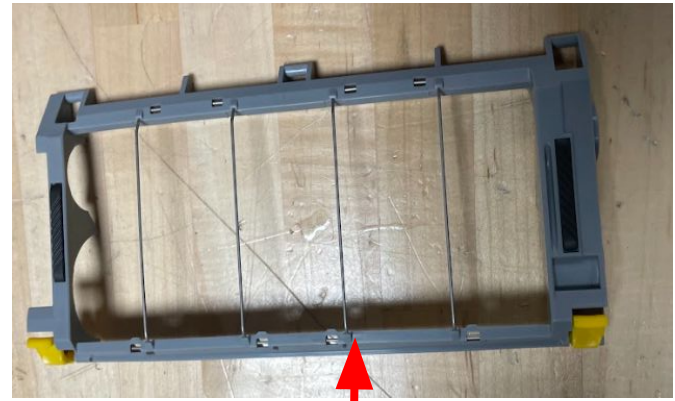
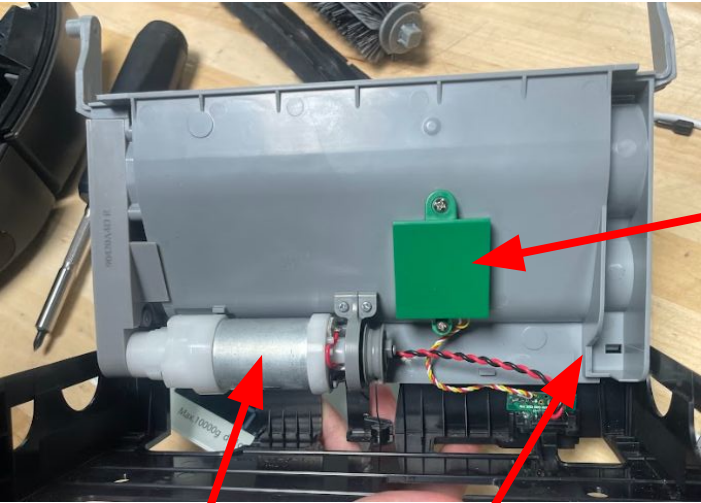


Figure 17. Detachable Cage

Figure 16. Two Brushes



4.) Disassemble Brush Assembly (Cleaning Head Module) Contd.



Motor

PCB
Housing

Figure 18. Brush
Assembly (Bottom View)

Pressure
Sensor

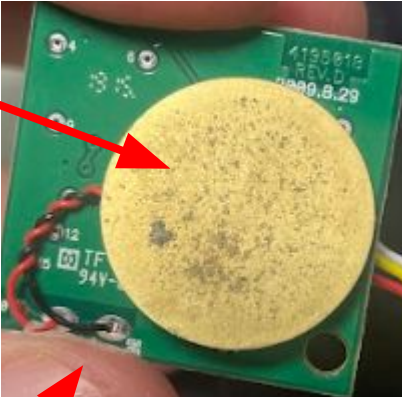
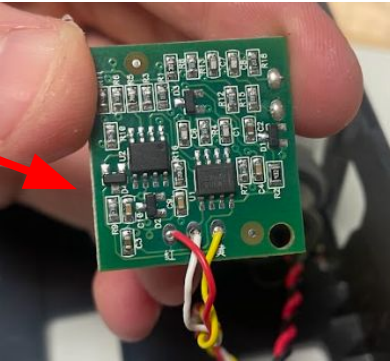
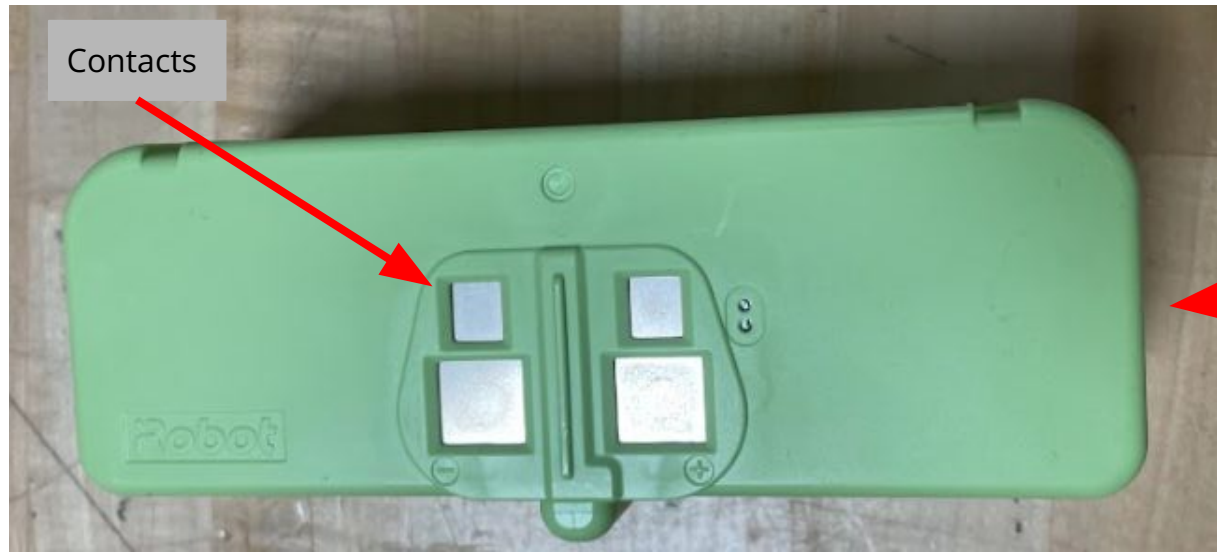


Figure
19&20.
Top and
Bottom
View of
PCB



Contacts



5.) Main Chassis (Battery)

Figure 21. Lithium Battery (Top View) with contacts



Figure 22. Lithium Battery (Bottom View)

6.) Disassemble Wheel Assembly

Figure 23. Wheel Assembly - Case Removed

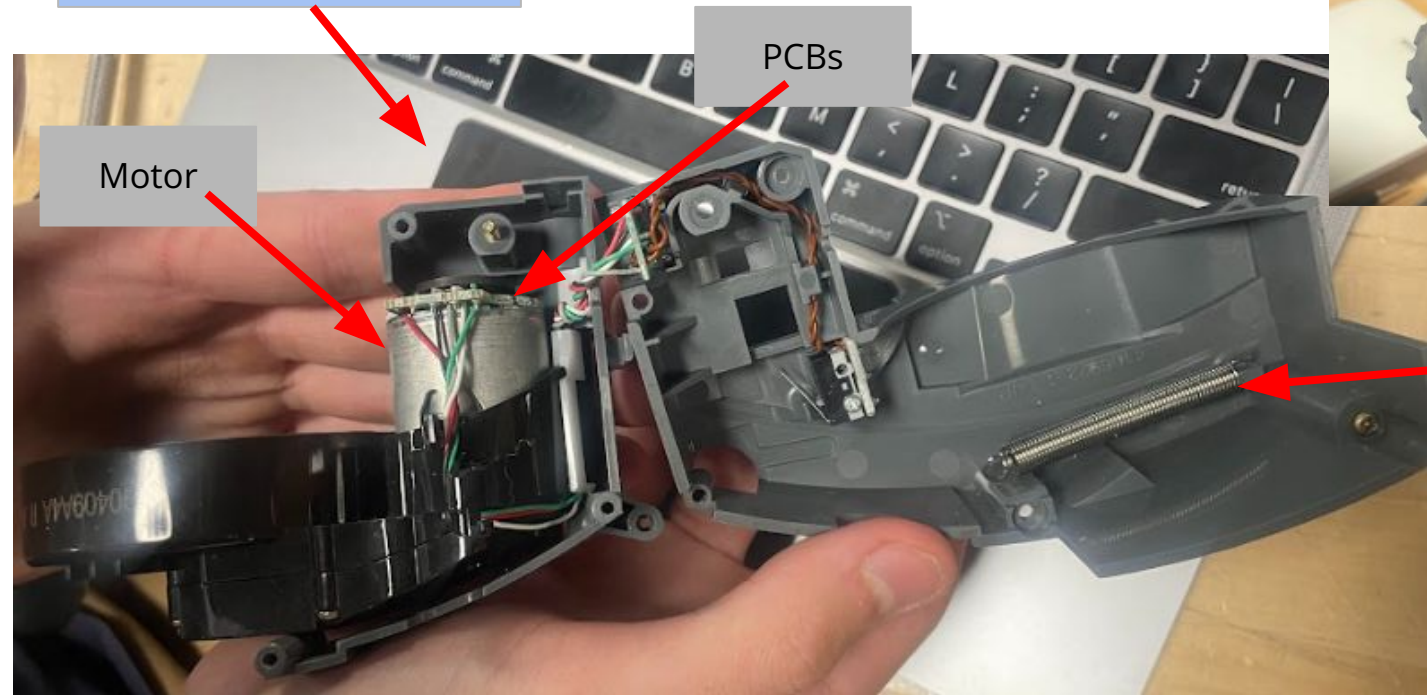
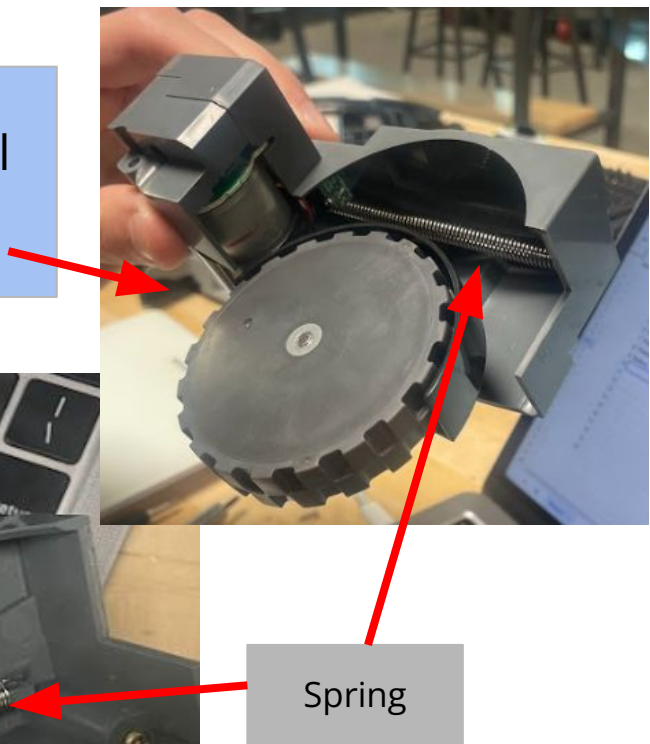


Figure 24. Wheel Assembly



7.) Remove Front Shield

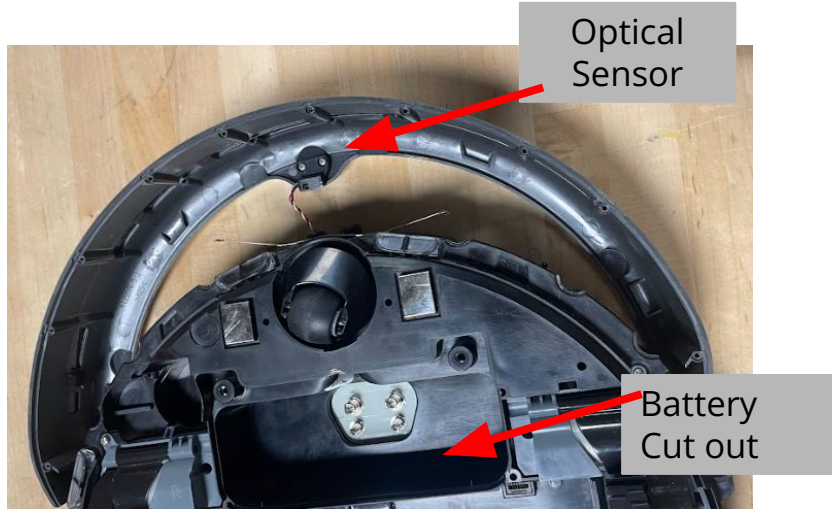


Figure 25. Front Bumper

10 Screw Holes



Figure 26. Front Bumper Screw Portion

7.) Remove Front Shield Contd.

Rubber
Bumpers

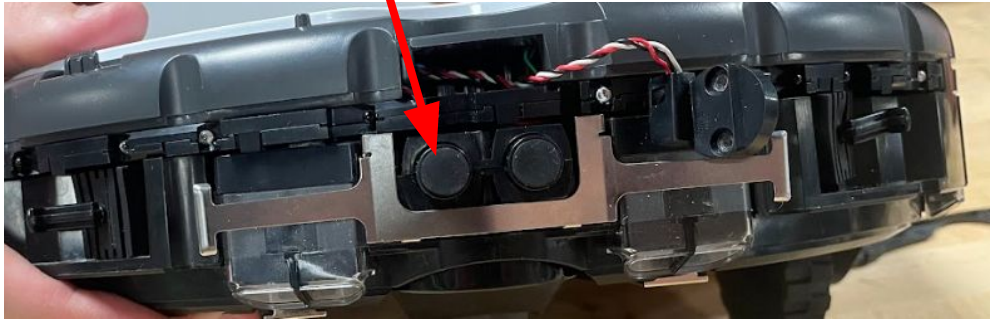


Figure 27. Exposed
Front Bumper



Figure 28. Bumper
Switch

8.) Disassemble Detachable Caster Wheel



Figure 29. Caster Wheel

9.) Disassemble Top of Roomba



Figure 30.
Detachable
White Top



Figure 31. Grey
Shield With Handle

9.) Disassemble Top of Roomba Contd.



Figure 32.
Button Ring



Figure 33. Bottom
View of Button
Housing Cap



Figure 34. Light
Cut Out Sheet

10.) Access PCB



Figure 35.
Motherboard PCB
Plastic Shield

Speaker

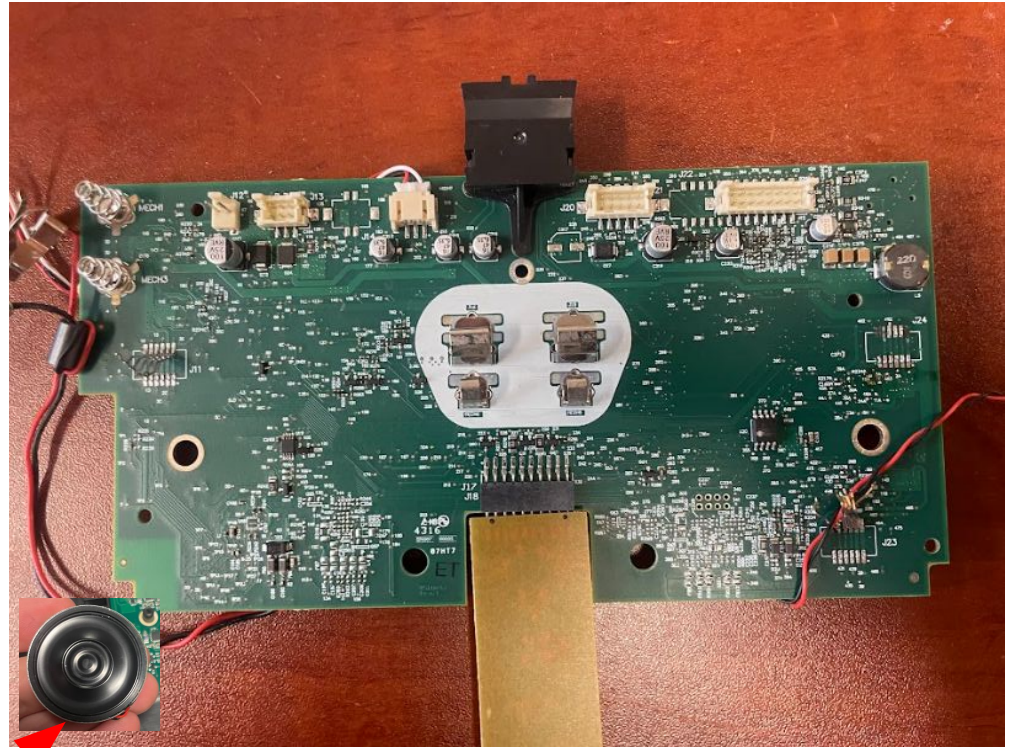


Figure 36.
Motherboard PCB
Bottom View

Motherboard PCB

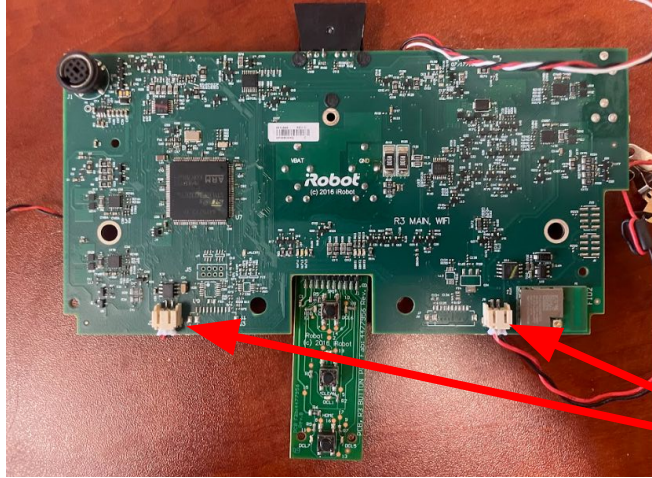


Figure 37.
Motherboard PCB
Top View

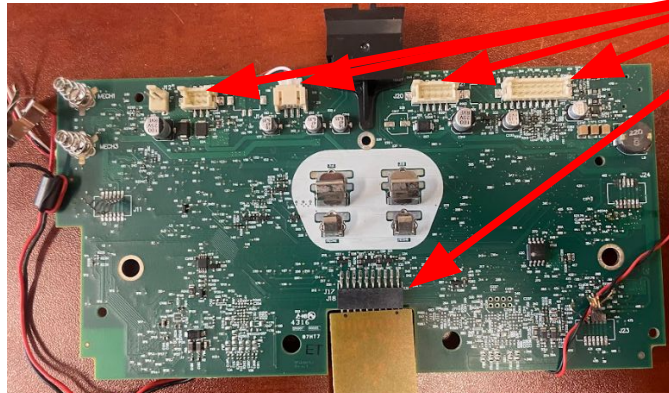


Figure 38.
Motherboard PCB
Bottom View

Connector

- 345 Resistors
- 265 Capacitors
- 28 Diodes
- 65 Transistors
- 20 IC's
- 14 Fuses
- 5 Inductors

Top Buttons PCB

- 7 Resistors
- 3 Buttons

Buttons

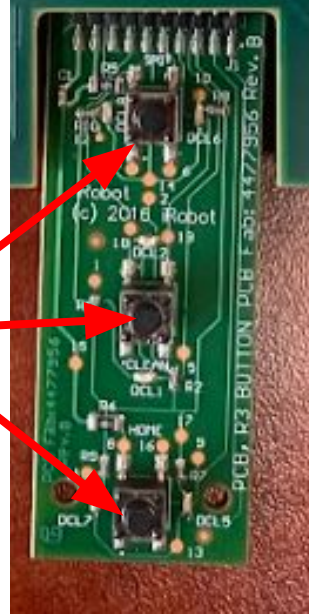


Figure 39. Top Buttons Top View



Figure 40. Top Buttons Bottom View

Figure 41. System Block Diagram

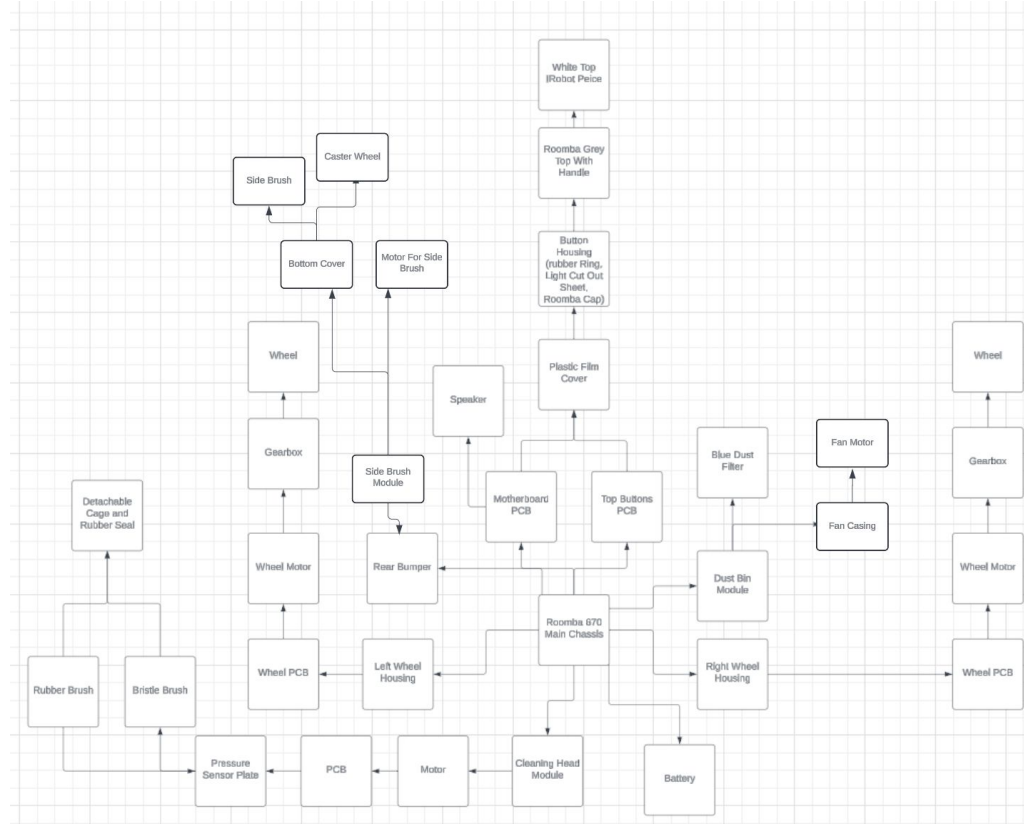
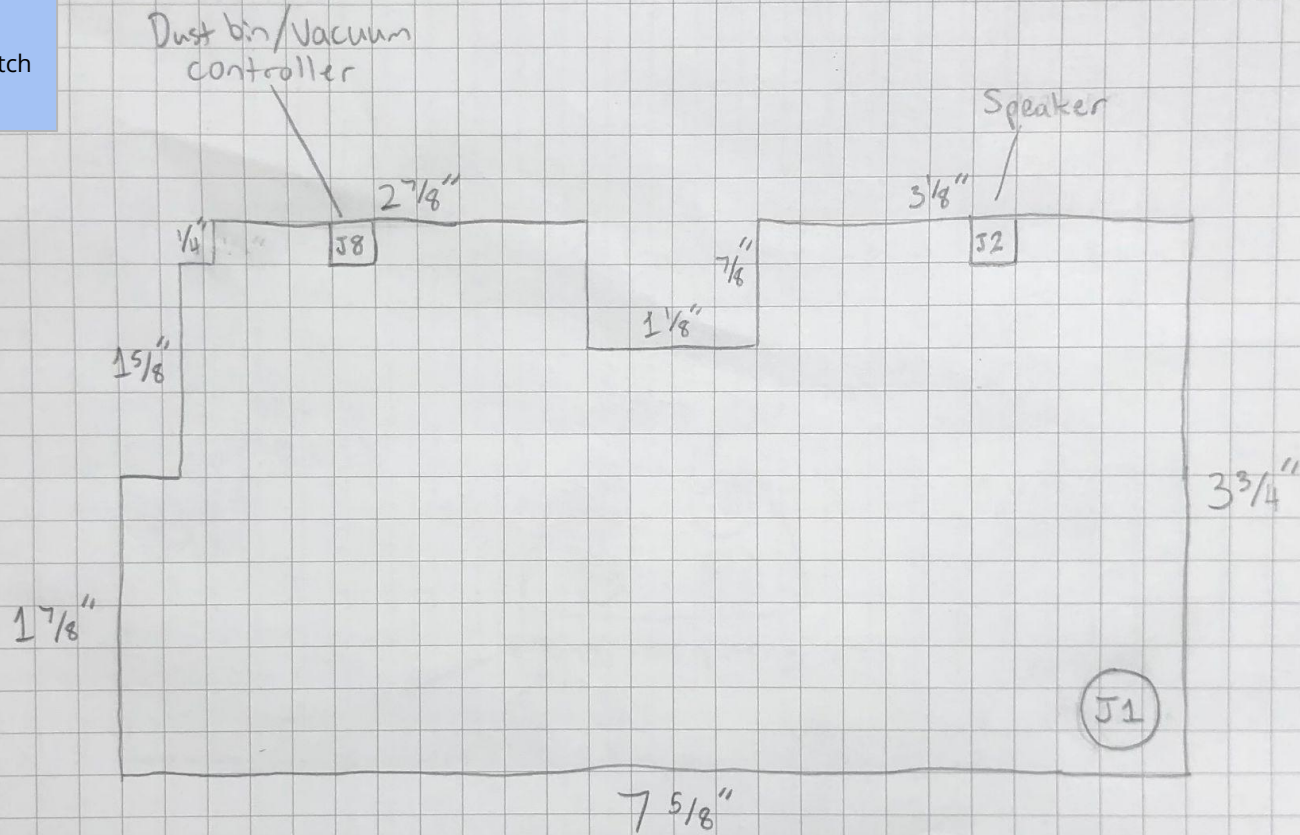


Figure 42. PCB
Assembly Top Sketch



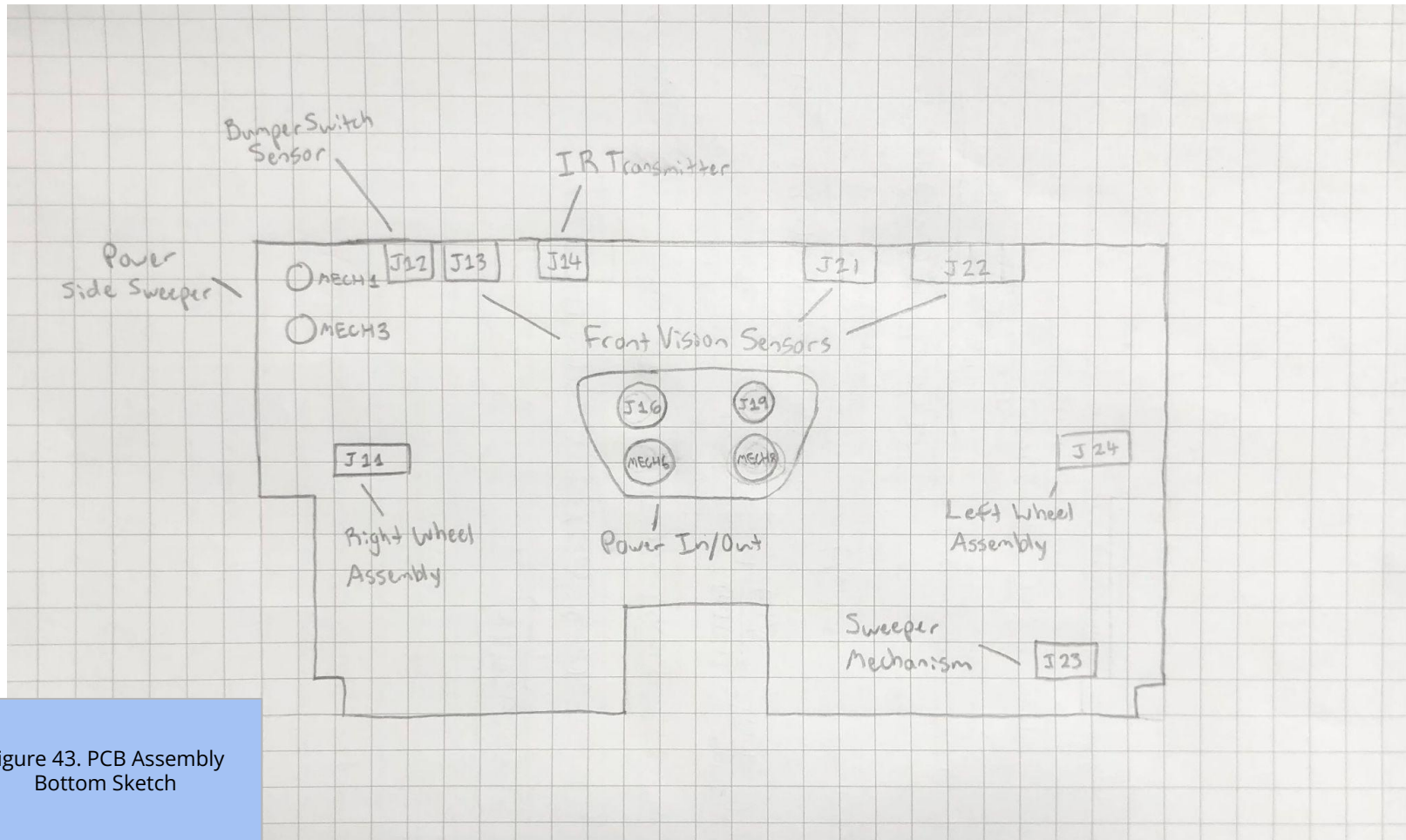


Figure 43. PCB Assembly
Bottom Sketch

ABS Plastic Cost

- Q1 2024: \$1796/Metric Ton
 - <https://www.chemanalyst.com/Pricing-data/acrylonitrile-butadiene-styrene-19>
- 1000000 g/MT
 - $1796/1000000 = \$0.001796/\text{g}$
- +20% for manufacturing and injection molding costs
 - $.001796 * 1.2 = \$0.0021552/\text{g}$

BOM

Item Number	Item Name	Qty	Weight (g)	Unit Cost (USD)	Ext Cost
1	Bottom Cover	1	123	0.2650896	0.2650896
2	Side Sweeper Housing and gear Train	1	17	0.0366384	0.0366384
3	Side Sweeper	1	6	0.0129312	0.0129312
4	Side Sweeper Motor	1		2.85	2.85
5	Gray brush assembly top	1	96	0.2068992	0.2068992
6	Brush Assembly Cage	1	29	0.0625008	0.0625008
7	Brush 1	1	53	0.1142256	0.1142256
8	Brush 2	1	40	0.086208	0.086208
9	Black brush assembly chassie	1	66	0.1422432	0.1422432
10	Brush Assembly motor	1		2.85	2.85
12	Pressure Sensor	1		9	9
13	Battery	1		40	40
14	Rubber Seal	1	4	0.0086208	0.0086208
15	Entire Dust Collector Assembly	1	227	0.4892304	0.4892304
16	Dust Collector Motor			2.85	0
17	Wheel Casing/Assembly	2	145	0.312504	0.625008
18	Wheel Casing Motor	2		2.85	5.7
19	Front shield bracket	1	13	0.0280176	0.0280176
20	Front Wheel Mechanism	1	10	0.021552	0.021552

BOM

20	Front Wheel Mechanism	1	10	0.021552	0.021552
21	Front Bumper	1	99	0.2133648	0.2133648
22	Optical Sensor Transmittor Lense	1	4	0.0086208	0.0086208
23	Optical Sensor Transmittor	1		1.05	1.05
24	Optical Sensor Reciever	12		2.1	25.2
25	Top White Cover	1	81	0.1745712	0.1745712
26	Gray Top with Handle	1	249	0.5366448	0.5366448
27	Plastic Ring	1	13	0.0280176	0.0280176
28	Plastic Cap	1	32	0.0689664	0.0689664
29	Indicator Light Film	1	0	0	0
30	Button Mechanism	1	36	0.0775872	0.0775872
31	PCB Shield	1	4	0.0086208	0.0086208
32	Speaker Housing	1	8	0.0172416	0.0172416
33	Speaker	1		1.83	1.83
34	Roomba Casing	1	452	0.9741504	0.9741504
35	Motherboard PCB	1		16	16
Total Cost					108.6869504

https://docs.google.com/spreadsheets/d/1fW1fvsYSVm9aI7dLSB-UOHx0KW0q2w09k01B_LXVN3o/edit?gid=0#gid=0

Margin Mark Up

Total Cost to Manufacture
\$108.69

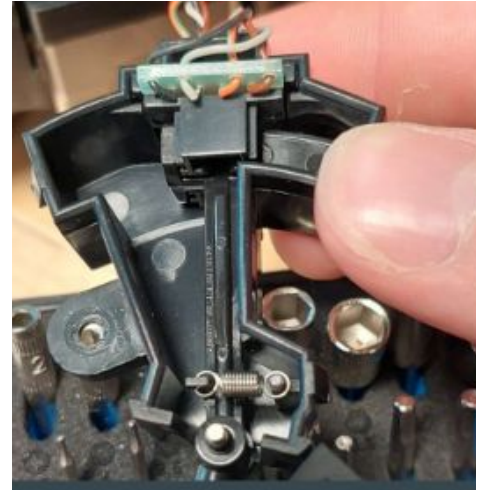
Retail Price as of Jan 2024
\$199.99

Margin in USD
\$91.3

Percentage Mark Up
45.65%

Notes About Reassembly Process

- Initially reassembled with leftover screws, had to determine their correct placement.
- Faced challenges removing the motherboard PCB and top handle.
- Took time to understand the operation of the bumper switch sensor



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