REVENG Report

Item: Speaker
Client: Lucky Wu's Handymen

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Contents

Technical Summary

This report outlines both a product teardown and redesign solution for the UE Roll 2 Speaker. The teardown involves an analysis of the materials used to create the product as well as their manufacturing processes. CES Edupack was used to conduct an Eco Audit to assess environmental impact. The total embodied energy was estimated to 81.4 MJ and the Carbon footprint was 6.8 kg.

The redesign proposal suggests new material and manufacturing process that could be used to make the product for suitable for the Client 'Lucky Wu's Handymen'. The aim was to make the product cheaper to increase profit margins. The changes suggested were to replace the casing material with PVC and reduce the number of mechanical fasteners.

Introduction

The aim of this report is to analyse the materials and manufacturing processes used to create the UE Roll 2 Bluetooth speaker. This will be achieved by doing background research, then conducting a full disassembly of the item. The individual components and sub-assemblies will be analysed individually, using their physical characteristics to determine the materials they were made from and the manufacturing processes that were likely used to create them. An Eco Audit and bill of materials will be created using CES Edupack to analyse the environmental impact of the product.

The final aim of this report is to propose a redesign of the product for the client, Lucky Wu's Handyman. The client's focus is increasing profit margins, so the redesign should allow the product to be made in a cheaper way whilst keeping its functionality so it can still be marketed at the same price. Using the information gathered from the product, changes to both the materials and manufacturing processes will be suggested to meet the client's criteria.

Background

Product Information

Product type: Bluetooth Portable Speaker. Figures 1, 2 & 3 show the product from 3 angles.
How the product functions: The speaker is charged via the charging port and switched on/paired with a device with light-up buttons integrated into the lower casing. The upper casing has + and – signs woven into the mesh that are connected to pressure-sensitive pads inside the device that change the volume when pressed. The circuitry inside processes information received from the buttons are Bluetooth connection. There is one speaker in the centre of the device that takes the current through a coil interacting with a magnetic field to vibrate a diaphragm.
Product name/model: UE Roll 2
Product features: The speaker is fully waterproof (IPX7 certification means it can be fully submerged in water for 30 minutes). [1] It is also portable (size/shape, mass, and bungee cord make it easy to transport), made to used outside, and can be easily cleaned.
Electrical Input: Micro-USB charging (5V at 2A, so power rating is 10W)
Retail Price: £80.00
Mass: 330g
Dimensions: Disk-shape with 13.5cm diameter and maximum height of 4cm.
Manufacturer: Ultimate Ears, Logitech
Country of Manufacture: China

Figure 1 - back

Figure 2 - side

Figure 3 – front

Benchmarking

Research into materials and manufacturing processes used the create similar products will inform the product analysis and help guide the redesign proposal. In general, a Bluetooth speaker can be broken down into 5 parts:

1. Casing. Higher-end products may use wood or metal for the aesthetics, but most casing will be made from a polymer or polymer blend. These are useful because they are electrically insulating, unreactive, and can be easily dyed to a desired colour. The most common polymers used to make casings are ABS, PA, PC and PPE. [2]
2. Circuitry. Most small electric products have PCBs made from a fibre reinforced epoxy resin with copper foil. [3]
3. Speaker component. This includes a few complex elements, but one of the main aspects that can change sound quality is the material used the make the diagram, which can be plastic, paper, aluminium or aramid fibre. The material most often chosen for cheaper products is plastic. [4]
4. Fasteners. A combination of mechanical fasteners, snap fits and glue adhesives are usually used to stick the casing together and hold internal components in place. Circuitry is soldered together. [5] [6]
5. Battery. For rechargeable devices, a lithium battery is often used. [5] [6]

Case study: The Mini Ipx4 Waterproof Wireless Shower Sucker Bluetooth Speaker

Manufactured at the Shenzhen Xiankeliang Technology Co factory, this product costs just $1.59 a piece when manufactured in bulk. [7]. Figure 4 shows the product.

The assembly process [8] :

- The Silicon casing is injection moulded.
- Most sub-assemblies (PCBs and speaker component) are shipped in from other suppliers.
- All soldering is done by hand.
- The internal components are screwed together by hand.
- The battery is stuck to the housing using a foam sticker.
- The casing is glued together using a hot glue gun.

Figure 4

The reason why this product is so cheap to manufacture is a combination of cheap labour costs and high production rate.

Teardown

Figure 5 shows the stages of sub-assembly as the product is taken apart.

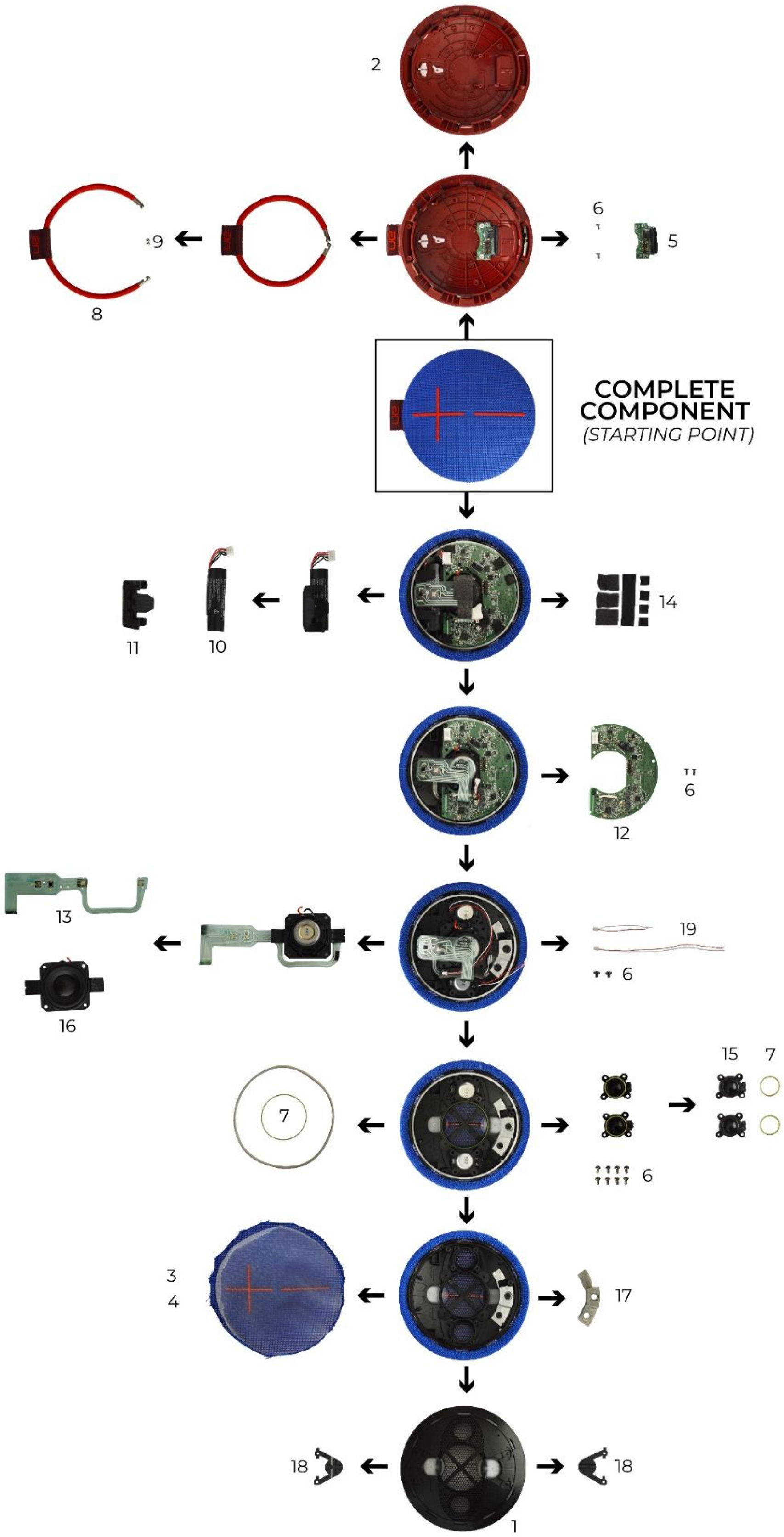


Figure 5

Bill of Materials

Table 1 shows the critical components, only including components that make up above 0.5% of embodied energy. For the full BOM, see Appendix A. The confidence level refers to how accurate the material and manufacturing process selected is. A confidence level of 1 is certain and 3 is an informed, but perhaps inaccurate guess.

Table 1

Part No.	Part Name	Material	Confidence Level	Total Mass /kg	Embodied Energy /MJ	C02 Footprint /kg
1	Upper Casing	Polycarbonate (PC)	3	0.049	5.2	0.23
2	Lower Casing	Polycarbonate (PC)	3	0.066	7	0.31
3 + 4	Mesh	Nylon	2	0.0071	1.014	0.0497
5	Charging Port	Printed Circuit Board Subsystem	2	0.005	0.65	0.049
6	Screw (x14)	Low Carbon Steel	1	0.007	0.22	0.016
7	Washer (x4)	Rubber (SBR)	2	0.001	0.11	0.0022
8	Bungee Cord	Nylon	2	0.01	1.4	0.07
10	Battery	Li-Ion (Rechargeable)	1	0.042	38	4.3
12	Circuit	Printed Circuit Board Subsystem	1	0.028	3.6	0.27
15	Button	Low Carbon Steel	2	0.024	0.74	0.056
16	Speaker	Transformer Component	2	0.064	5.5	0.41
17	Holder	Stainless Steel	1	0.02	1.5	0.11

The components that make up for most of the embodied energy are the casings, circuitry, battery and the speaker.

Table 2 shows estimated values calculated using CES Edupack. When conducting the Eco Audit, transportation was simplified into 2 stages: ocean freight and last mile transport. The product life is assumed to be 3 years, as the product warranty covers 2 years [1]. A speaker is used about 100 days a year with the average time spent charging per day as half an hour.

Table 2

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	65.8	80.8	5.91	86.9
Manufacture	2.94	3.6	0.22	3.2
Transport	1.29	1.6	0.0931	1.4
Use	11.3	13.9	0.57	8.4
Disposal	0.0791	0.1	0.00554	0.1
Total (for first life)	**81.4**	**100**	**6.8**	**100**
End of life potential	0		0	

Materials & Manufacturing Process

Table 3 shows the details of the manufacturing processes used to create the critical components.

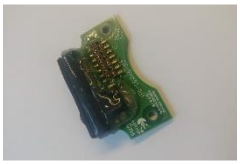
Table 3

Part No.	Part Name	Component details and manufacturing processes
1	Upper Casing	The polycarbonate casing is injection moulded, as injection pin marks can be seen. It was likely moulded at 280-320 degrees Celsius [9] . There has been no finishing method applied as the surface is not visible. The grill pattern may have been made separately through sheet polymer cutting.
2	Lower Casing	The polycarbonate was likely over moulded with a rubber or silicon layer, to create a softer and more flexible surface to make it easier to press the button integrated into the design. There are ribs on the harder inner surface to increase strength without adding too much weight. There are a few stickers sealing up small holes around the sides, perhaps made during the moulding process.
3 + 4	Mesh	The mesh layers are made from blue, red and transparent synthetic fibres that were coloured and woven together. These fibres are most likely to be nylon as it is strong and resists abrasion. It is warmed up and drawn into threads. The surface mesh is thick and serves an aesthetic purpose, whilst the lower mesh is much finer and tightly woven to help repel water droplets.
5	Charging Port	This small PCB was created using the typical method. Glass fibres were dipped or sprayed with epoxy resin to create a rigid plate. The shape is cut, and screw holes drilled using a CNC machine. The copper pattern may have been created using an additive or subtractive process. [3]
6	Screw (x14)	As with most small mechanical fasteners, these screws were made from a magnetic low Carbon Steel. The Primary manufacturing process is extrusion, with the screw head shape and threads created using a machining process.
7	Washer (x4)	The circular washers create a watertight seal. The long and thin shape with uniform cross-section suggests that the rubber was extruded and cut into strips so the ends could be sealed together.
8	Bungee Cord	The thick cord is made from durable synthetic fibres that have been dyed and woven. To make the design consistent, the same fibres are used as the surface mesh.
10	Battery	The battery was wrapped individually and likely to be made by an independent supplier.
12	Circuit	The larger PCB will have been made in the same way as the charging port
15	Button	The primary material is low carbon steel, but it has been over moulded with plastic, as the interface between the 2 materials is very strong.
16	Speaker	Estimated to be made from similar materials as a transformer component. Likely includes drawn wires, a permanent magnet and a waterproof polymer diaphragm
17	Holder	The material used is not magnetic, so it is likely to be stainless steel. It was created using a die casting process, as die pin marks can be seen, indicating where it was pushed out of the mould.

Joining Methods

Table 4 shows the 3 types of joining methods that were identified.

Table 4

Join type	Picture	Purpose/Details
Melting		To seal the two halves of the casing together with the mesh layers folded in between, it looks like the casing material itself was melted. Some of the fibres are stuck in the melted interface. This process was used in conjunction with snap fits at regular increments around the inside circumference of the speaker.
Mechanical fasteners	 	Mechanical fasteners include the screws and bungee cord fastener. These components add weight, increase manufacturing complexity, and are likely to have been attached by hand.
Silicon		The clear sealant around the charging port keeps it watertight and holds the component onto the casing. It was dripped onto the component as a liquid to fill all the gaps before hardening.

Re-Design Proposal

Design Objectives

- Decrease cost of component whilst keeping functionality, as the client wants to maximise profit.
- USP of the speaker should be maintained so it is marketable. The speaker must still be waterproof and portable, so basic shape will remain the same.
- Increase sustainability. Ideally, the new design will have a lower embodied energy and C02 footprint.

The redesign will be achieved by taking out unnecessary components, changing the materials used to make components and rethinking the manufacturing methods.

Re-Design

2 changes are proposed to achieve redesign objectives:

1. Change the material used to make the casing.
2. Reduce the use of mechanical fasteners.

Change 1 – Casing

A different polymer should be chosen that is cheaper, more environmentally friendly and still has the correct level of impact resistance, so the speaker is still portable and durable. Only plastic is being considered as it the most used subset of materials for cheap casings. Selection of a new casing material was done using level 1 polymers in CES Edupack. 3 factors were considered before creating an Ashby plot:

1. Cost. All polymers above the price of Polycarbonate (£1.79/ kg) were filtered out.
2. Density. To maintain the same feeling and quality of the product, the density of the material should stay within a similar range to that of Polycarbonate. All polymers below 1150 kg/m^3 were filtered out.
3. Environmental Impact. All materials that cannot be recycled were filtered out. Polymers with an embodied energy above 100 MJ/Kg were filtered out.

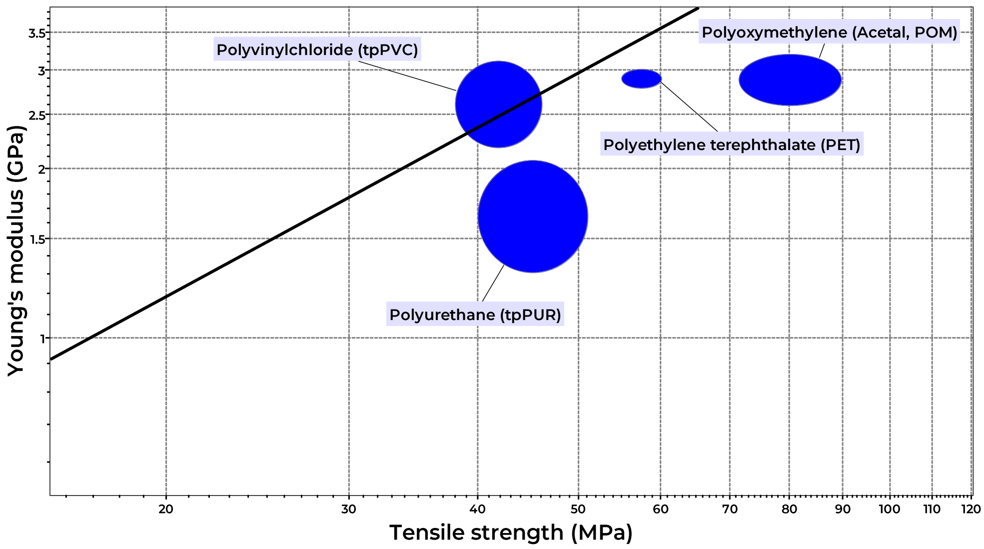


Figure 6

In figure 6, tensile strength and young's modulus are maximised, with PVC having the optimal properties. In having a high Young's Modulus, if it is dropped on the floor, it will be able to absorb a lot of energy before fracturing. This means the speaker will remain portable. Table 5 shows the material properties of both PVC and PC for direct comparison.

Table 5

Material Property	Value for PC	Value for PVC
Cost (£/kg)	1.79 – 2.49	1.32 – 1.46
Density (Kg/m^3)	1190 - 1210	1290 - 1460
Recycling number	7	3
Embodied Energy (MJ/kg)	100 - 111	61.8 – 68.2
Tensile Strength	62.7 – 72.4	38 - 46
Young's Modulus	2.24 – 2.52	2.19 – 3.11

Although PVC does not have the same mechanical properties as PC, it is an acceptable substitute, considering the client's needs. It can be injection moulded at 180-210 degrees Celsius [9], significantly lower than PC, meaning that the injection moulding process will use less energy. However, PVC gives off toxic gas during the moulding process so sufficient ventilation must be considered when designing new injection moulding machinery [11].

Change 2 – Mechanical Fasteners

10 of the screws should be replaced with snap fits/interference fits. The only screws that should be kept are the 4 holding electric circuits in place. This modification will reduce use of additional small parts, embodied energy and carbon footprint, although it will make a minimal change an individual product. However, considering this is a mass-produced product, small changes can make a significant impact on these values. The use of snap-fits will also mean that the manufacturing process will be easier to automate, making it both quicker and cheaper, due to the reduced labour costs.

A disadvantage of using snap fits is that serviceability is not possible. This would not pose too much of a problem as this product is not designed to be disassembled and reassembled, considering it is meant to be waterproof.

Comparing Original and Redesign

Table 6 shows the sustainability metrics for the redesigned product, and figures 8 and 7 show a comparison with the original. The EoL potential for the redesign is no better than the original, as realistically, plastic casings are likely to put in landfill no matter what plastic they are made from.

Table 6

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Material	60.7	80.1	5.65	86.9
Manufacture	2.43	3.2	0.183	2.8
Transport	1.27	1.7	0.0917	1.4
Use	11.3	14.9	0.57	8.8
Disposal	0.0781	0.1	0.00547	0.1
Total (for first life)	**75.8**	**100**	**6.5**	**100**
End of life potential	0		0	

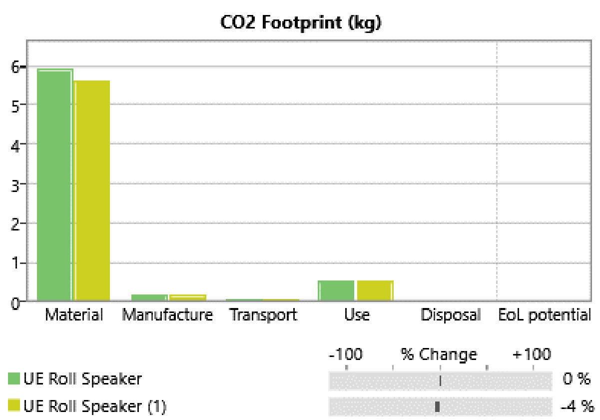


Figure 8

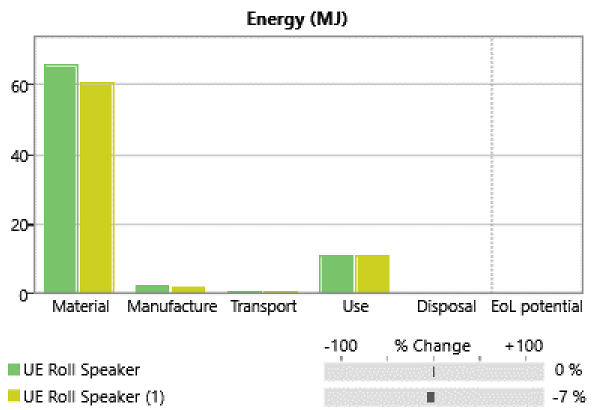


Figure 7

Conclusion

The proposed redesign fits the client's criteria, meaning that the product can be sold at the same price with a lower manufacturing cost, therefore increasing profits. The redesign also has a lower embodied energy and carbon footprint, which is another feature to make the product desirable to eco-conscious consumers.

References

[1] "Roll 2," [Online]. Available: https://www.ultimateears.com/en-us/wireless-speakers/roll-2.html.

[2] "A GUIDE TO THE PLASTICS USED FOR ELECTRONIC ENCLOSURES," okw, [Online]. Available: https://www.okw.co.uk/en/technical_data/enclosures_plastics_guide.html.

[3] "Printed Circuit Board," madehow, [Online]. Available: http://www.madehow.com/Volume-2/Printed-Circuit-Board.html#:~:text=Raw%20Materials,used%20in%20household%20electrical%20devices..

[4] "HOW DO MATERIALS MAKE A DIFFERENCE IN SPEAKER CONSTRUCTION?," audioengineusa, [Online]. Available: https://audioengineusa.com/explore/materials-speaker-construction/.

[5] "#48 JBL Charge 3 Bluetooth speaker teardown," khronscave, [Online]. Available: https://khronscave.blogspot.com/2019/09/48-jbl-charge-3-bluetooth-speaker.html.

[6] "Teardown: AmazonBasics Nano Bluetooth Speaker," digikey, [Online]. Available: https://www.digikey.com/en/maker/projects/teardown-amazonbasics-nano-bluetooth-speaker/2bfdb4782316469d879230455df9db4b.

[7] "Promotional Mini Ipx4 Waterproof Wireless Shower Sucker Bluetooth Speaker Bts06," eptusbchina, [Online]. Available: https://eptusbchina.en.made-in-china.com/product/voxnNQpHssRT/China-Promotional-Mini-Ipx4-Waterproof-Wireless-Shower-Sucker-Bluetooth-Speaker-Bts06.html.

[8] D. N. O'Connor, "Bluetooth Speaker Factory (12)," Tech Asia, 14 February 2017. [Online]. Available: https://www.youtube.com/watch?v=XOIsalHHg_M.

[9] "Injection molding temperature," EcoMoulding, [Online]. Available: https://www.injectionmould.org/2019/04/10/injection-molding-temperature/.

[10] "Everything You Need To Know About PVC Plastic," creativemechanisms, [Online]. Available: https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-pvc-plastic.

[11] "#138 PET Plastic," 25 January 2013. [Online]. Available: https://www.misumi-techcentral.com/tt/en/mold/2013/01/138-pet-plastic.html#:~:text=PET%20is%20the%20abbreviation%20for,this%20plastic%20is%20its%20fluidity..

[12] A. B. Varotsis, "Injection molding SPI surface finishes," [Online]. Available: https://www.3dhubs.com/knowledge-base/injection-molding-spi-surface-finishes/.

Figures 1, 2, 3 and are my own

All other graphs and material data was obtained from CES Edupack.

Appendices

Appendix A

Table 7 shows the complete bill of materials.

Table 7

Part No.	Part Name	No. of units	Material	Mass per unit /kg	Embodied Energy /MJ	C02 Footprint /kg
1	Upper Casing	1	Polycarbonate (PC)	0.049	5.2	0.23
2	Lower Casing	1	Polycarbonate (PC)	0.066	7	0.31
3	Surface mesh	1	Nylon	0.007	1	0.049
4	Lower mesh	1	Nylon	0.0001	0.014	0.0007
5	Charging Port	1	Integrated Circuit	0.005	0.65	0.049
6	Screw	14	Low Carbon Steel	0.0005	0.22	0.016
7	Washer	4	Rubber (SBR)	0.00025	0.11	0.0022
8	Bungee Cord	1	Nylon	0.01	1.4	0.07
9	Bungee Fastener	1	Low Carbon Steel	0.0001	0.0031	0.00023
10	Battery	1	Li-Ion Rechargeable	0.042	38	4.3
11	Battery Holder	1	Polycarbonate (PC)	0.006	0.63	0.029
12	Circuit	1	Integrated Circuit	0.028	3.6	0.27
13	Flex Circuit	1	PEEK	0.001	0.3	0.017
14	Foam Sticker	11	Flexible Polymer Foam (MD)	0.0001	0.099	0.0035
15	Button	2	Low Carbon Steel		0.74	0.056
16	Speaker	1	Transformer component	0.064	5.5	0.41
17	Holder	1	Stainless Steel	0.02	1.5	0.11
18	Button Pads	2	Polycarbonate (PC)	0.0005	0.11	0.0048
19	Wire	2	Cable Component	0.0001	0.018	0.0014

Appendix B

Figure 9 shows only the individual components that make up the product, without stages of sub-assemblies.

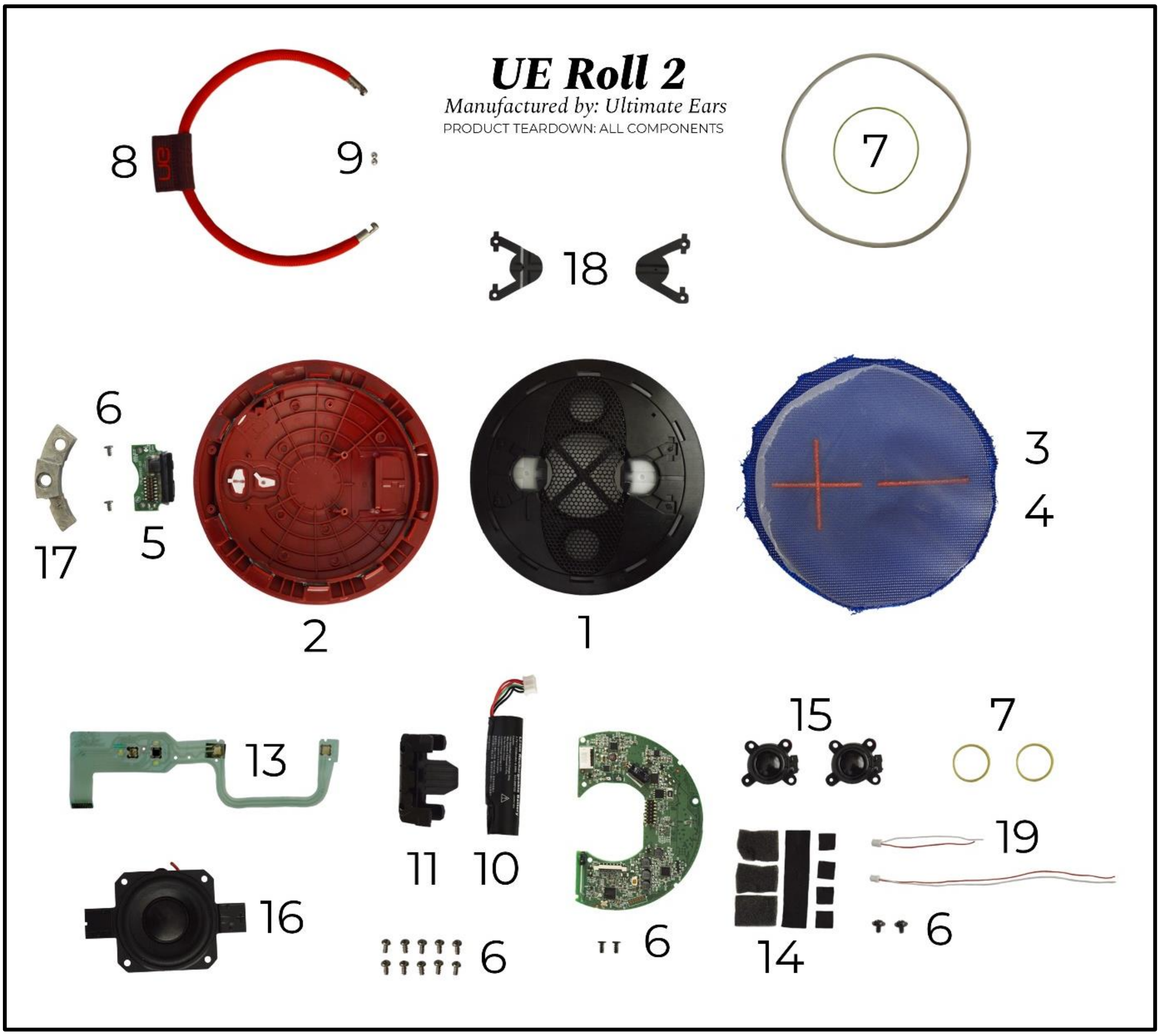


Figure 9