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Reverse Engineering: Bluetooth Speaker

Purpose: To discover the inner workings of a speaker, including an in depth analysis of the different parts which includes functionality, materials, manufacturing, and structure and use this information to discover wear and parts that could potentially lead to product failure.

Hypothesis: When the speaker is disassembled after an analysis of the products, the connection points at the ends of the wires will be the weakest parts and have the highest potential to lead to a product failure.

Data/Analysis:

Functional Analysis

The plastic housing holds together all of the parts. The wires are placed intricately through each hole and connects directly where it needs to. In order to translate an electric current into sound, every speaker contains an electromagnet, which is a metal coil that creates a magnetic field when an electric current passes through it. When the direction of the current within the coil is reversed, the poles of the magnet are flipped. The electromagnet is placed in front of a normal magnet, the electromagnet being able to move slightly but the normal magnet is fixed into position. As the flow of the current throughout the coils are changed and the poles of the magnet are continuously flipped, the electromagnet will be attracted to and repelled from the normal magnet, causing rapid vibrations. The electromagnet is attached to a cone made of paper, plastic, and rubber which amplifies these vibrations, sending sound waves out into the air creating the music we hear from the speaker.

A Light Emitting Diode is a way of converting electrical energy into light. It contains a semiconductor, which has a varying ability to conduct electrical currents, and a voltage is applied to it. Electrons are affected and start moving and vibrating rapidly. They then enter electron "holes" in the surface of the semiconductor and begin to produce a light. Each LED can only produce one color. For color changing LEDs, like ours, each LED has three individual LEDs: one blue, one red, and one green. Shining these colors at the same time will emit a totally different color. Green and blue will produce cyan, red and green will produce yellow, and red and blue will emit magenta.

Electronic circuits are composed of wires and many other components including light bulbs, transistors, computer chips, and motors. Wires connect the components and are made up of metals called conductors that have a low resistance to current. Copper etchings into the plastic carry electricity to every component of the circuit board.

Structural Analysis

The frame of the color blast speaker is composed of 2 primary plastic structures [forward shell = (1), backward shell = (2)]which hold together the remaining parts of the speaker which are held by a set of 4 screws. They are also linked together on the back by a foam pad [foam pad = (3)] which is glued on to the bottom of the two plastic pieces(1)(2). The front portion is composed of a semi translucent plastic [semi translucent plastic= (4)] and is held by prongs which attach to the forward facing plastic structure(1) behind the semi translucent plastic (4) is the tricolor LEDs and LED circuit board [tricolor LEDs and LED circuit board = (5)] which are attached together through soldering and and then screwed together with the front facing plastic shell(1) using 4 screws, with the bottom of the board with the adm ribbon wire connector positioned downward toward the foam(3) where the slit for the wire [adm ribbon wire = (6)] to go through the plastic(2) is. Beneath the led board is the speaker [speaker = (7)] which goes through the forward facing plastic shell (1) from outside of it and behind the led board(5), and is attached to the forward plastic shell (1) with a metal support structure [metal support structure = (8)] which is then glued and goes through a hole cut into the shell(3). Wires[wire blue = (9), wire green = (10)] attached by sodder to the speaker(7) provide an electrical connection to the main

circuit board[main circuit board = (12)] and is pointed downward toward the thin slit the ribbon wire(6) goes through. The back of the speaker(7) encompassed by another layer of plastic [internal square shaped plastic piece that is hollow and has indented corners = (13)] that is within the two outer shells(1)(2). This plastic layer(13) is tightly fitted with an internal ridge on the inner side of the forward facing shell(1) which then fits inside a small gap in the interior plastic layer(13). After the interior cup like piece of plastic(13) is fitted into place it is then fully attached to the forward shell through 4 screws(1). The interior cup(13) has a built in slit to allow the wires(9)(10) soldered on to the speaker(7) to get through. These wires are then attached to the central circuit board(12) using solder. The ribbon wire(6) is attached using a clip similar to as the led board(5), to the central circuit board(12). The circuit board(12) is attached to the backward shell(2) using grooves between two pylons which tightly hold the circuit board into place, it is also slotted into the backward facing plastic shell(2) using holes to allow for a micro usb charging port, auxiliary cord port, an on/off switch and brightness button (is pressed between the backward outer shell). The central circuit board(12) is then attached to the battery[battery = (14)] by a set of black and red cables[set of black and red cables = (15)]. The battery is then fit between the circuit board (12) and interior wall of the backward shell and glued in to placed. When all pieces are attached together two outer shells(1)(2) should be able to close like a clam with the central circuit board(12) and battery (14)fitting snugly beneath the interior shell(13) around the speaker(7).

Material Analysis

- **Plastic:** The material used to hold the speaker, circuits, LEDs, and battery in place is a cheap plastic. The cheap plastic saves money for the manufacturer, allowing them to mass produce these speakers. These speakers are discounted when sold in bulk, and they able to have custom logos printed on them, making them the perfect gift for companies to give their employees. Plastic is also easily molded, making it easy to form complex shapes that interlock with precision. Despite its cheapness, plastic is also sturdy when cool, making it a good choice for a cheaper, but sturdy, product. In this product, plastic is

also used to hold the metal mesh, helping add a layer of protection to the speaker's internal components.

- **Foam:** There is a small piece of foam on the bottom of the two halves of the plastic casing. Together, with glue, this foam serves as a hinge when the speaker is disassembled. The use of foam prevents the speaker from both scratching the surface and sliding around easily.
- **Glue:** Glue is used for a variety of reasons, but it is mainly used as an inexpensive and easy way to hold two objects together or in place. In this speaker, glue is used frequently to hold objects in place so they don't slide around.
- **Aluminium:** Aluminium is used to form the metal mesh on the outside of the speaker. It protects the speaker, but it also affects the sound created. Aluminium is cheap and easily molded, making it a good choice for this product as it is mass produced. It is also sturdy, allowing for protection of the speaker. Aluminium also makes up the screws in this speaker, again because it is a strong, but inexpensive, metal.
- **Copper:** Copper is used in this product for all of the wires, because copper is a very good conductor and relatively inexpensive. The only conductor that is better is silver, which is much more expensive.
- **Rubber:** The wires are covered in rubber as to protect the metal underneath from touching other metals and exchanging electrons in an unwanted fashion.
- **LEDs:** Leds are made up of a variety of materials, including various semiconductors which allow for the creation of different colors. The use of LEDs here makes it so the speaker can light up while music is playing, allowing for added aesthetic.
- **Lithium Ion Battery (LIB):** There are various types of LIBs, all used for different purposes. The one in this speaker is likely lower end, shorter lived, and safer, because it is used in a mass distributed speaker, but it does allow for recharging and wireless connection.
- **Speaker:**
    - **Aluminum:** The frame of the speaker is made from aluminum because it is a cheap but sturdy material, and it doesn't interfere with the sound too much.

    - **Permanent Magnet:** This magnet is made from iron oxide, strontium, and a ceramic binder. These three materials allow for a strong, yet cheap, magnet that produces sound easily.
    - **Treated Paper:** There are various parts made with this treated paper, mostly because it is good with sound and it is sturdy but cheap. The spider and cone are two parts made from this paper.
    - **Copper:** The voice coil in the speaker is wrapped with copper to create a magnetic field. Copper is used because it is a very good conductor and isn't as expensive as silver, which is the only conductor that is better.
    - **Plastic:** There is some framing and structure that is made from plastic, as well as the bobbin that is wrapped in copper that makes up the voice coil. Plastic is used due to its inexpensiveness and non-conductivity.
    - **Glue:** Glue is used to hold everything together in the speaker because creates a strong bond while keeping costs down.
- **Circuit Board:**
    - **Reinforced Phenolic Resin:** This makes up the base of the circuit board due to its strong nature and cheap price compared to fiberglass, which is used in higher end products
    - **Copper:** Both sides of the circuit board are coated with copper, allowing for conductivity all across the board.
    - **Tin-Lead:** The copper is coated with a thin layer of a tin-lead alloy to prevent oxidation of the copper.

Manufacturing Analysis

Plastic Housing:

Plastic injection molding uses a mold or die made from aluminum or steel to form the object. The mold is placed into a plastic injection molding machine. This machine heats up raw plastic pellets until molten. The thermoforming plastic resin is then injected under great pressure into the empty cavity of a mold tool. The machine then opens up to eject the finished product.

Metal Grill:

Formed from aluminum wires and weaved together to form a grill. The grill is then wrapped over the plastic housing to cover the front of the speaker.

Two way speaker:

- The permanent magnet is constructed by mixing iron oxide with strontium and then milling the compound into a very fine powder. The powder is mixed with a ceramic binder and then closed in a metal die. The die is then placed in furnace and sintered to bond the mixture together.
- The frame is constructed from an aluminum or steel sheet. The sheet arrives at the plant preformed. It is then placed on a conveyor belt and transported to a cutting machine that used a hydraulic press to cut holes in the sheet to allow free air movement from the cone. The sheet is then formed by a hydraulic press that forces the sheet into a die of the desired shape. Mounting holes are then drilled at their proper locations.
- The cone, surround, and spider are individually formed out of composite paper and then glued together as an assembly.
- The voice coil is built by winding many turns of very fine insulated copper wire on a plastic bobbin. The bobbin and voice coil assembly is glued to the dust cap of the cone assembly.
- The frame, soft iron core, and permanent magnet are bolted together as an assembly.
- The cone assembly is then attached to the frame assembly by first manually gluing the spider to the base of the frame and then gluing the surround to the top of the frame.

Joining methods:

Most of the speakers components are held together by either glue or a few different screws.

LEDs:

First and foremost, the semiconductor material must be made. This is called the semiconductor wafer. The semiconductor material is “grown” in a high temperature, high

pressure chamber. Elements such as gallium, arsenic, and/or phosphor are purified and mixed together in the chamber, which then liquefies into a concentrated solution. Once the elements are mixed, a rod is placed in the solution and slowly pulled out. The solution crystallizes on the end of the rod as it is pulled out, creating a long, cylindrical crystal ingot.

This material is then sliced into semiconductor wafers and essentially sanded down, much like you would sand down a table, until the surface is smooth. Then, it is dipped into a solution of various solvents for a rigorous cleaning to rid it of any dirt, dust or organic material.

In the next step of the process, additional layers of semiconductor material are added to the wafer. This is one way to add impurities, or dopents.

Next, metal contacts are defined on the semiconductor. This is determined in the design stage and takes into account whether the diode will be used individually or with others.

Lastly, diodes are mounted onto the appropriate package, wires are attached and then everything is encased in plastic.

Circuit Board:

Woven glass fiber is cured, cut and stacked in layers. The substrate material is also bonded to copper foil. Holes are then drilled in designated locations. The panel is electroplated with copper. The copper foil is then stripped away using an acid spray. Contact fingers are added and the panel goes through another round of plating. Plating is done with three metals: first tin-lead, next nickel, than gold. Finally, all the necessary components are mounted and soldered to the boards.

Lithium Ion Battery:

First, an electrolyte is made from a mixture of pastes. This electrolyte is then fed to coating machines which then coat the anode and cathode metals. The foam separator is then stacked between the anode and cathode. After this, the stack is inserted into a cell which is then filled with electrolyte to soak the separator, anode, and cathode. Conducting plates are added after this. The final step is the addition of any other safety features like insulators and seals.

Conclusion:

Our proposed hypothesis ended up being somewhat true. The connection of the wires to the circuit board and the speaker was indeed the weakest part; the majority of the wires ended up breaking off from their original connections, but this would not be an issue for the actual functionality. The wires only broke when they were moved around from the movements caused when the speaker was disassembled. In the speaker's normal uses, the wires won't move around, as they will be on the inside of the speaker where no one can touch them unless they decide to take the speaker apart.

After the rest of our in depth analysis of the manufacturing, function, structure, and materials, we couldn't find any other parts that seemed like they would fail. This is for a couple reasons. The first of those is that it is hard to see if there is any physical wear because the product is newer and isn't very scratched or worn down. That is also partly due to the lack of lots of moving parts, so there is nothing really that will wear down any parts that we can see. The other reason we couldn't find anything was because the other wear could be in the electronics. None of us are electrical engineers, so we wouldn't know what to look for, aside from the obvious, and couldn't determine where the wear was on any of the electronic components. All of this information led us to believe the product did not have any apparent parts that would lead to a product failure.

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