Reverse Engineering Online Challenge

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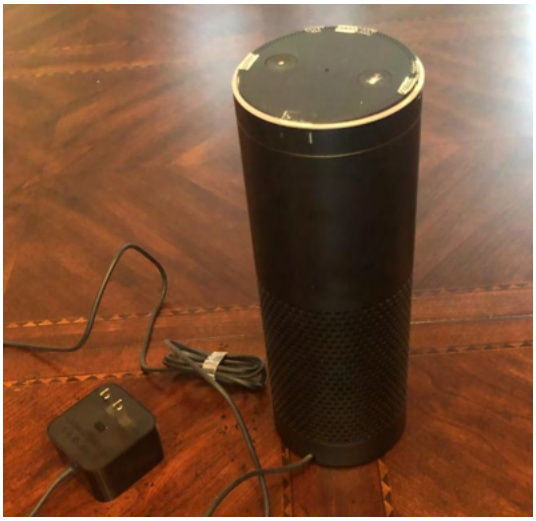

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Introduction

What is the Amazon Echo (1st Generation)?

The Amazon Echo 1st Generation is the first of 4 models of the Echo, also known as Alexa. It is a smart speaker device which operates on voice commands. Though it is listening all the time, it only activates when someone says the word “alexa”, at which point they can give it a command. The Amazon Echo is most commonly used for playing music and getting information such as the weather, the news, and sports scores. However, this does not limit its capabilities, as it can also converse and play games with humans, tell jokes, and connect via Bluetooth to nearby devices.

Why did we choose an Amazon Echo (1st Generation)?

The 1st Generation Amazon Echo is only (insert size dimensions), but can provide information from all over the internet with just a simple voice command. It’s vast capabilities were intriguing to our team, and thus we decided to explore how it all worked. We were interested in finding out exactly what components were used in an Amazon Echo which gave it full access to the web, allowed it to perform numerous tasks at the same time, and also allowed it to constantly listen for identifiable sounds. We were also fascinated by the sound quality of it’s speaker, and wanted to find out more about how it created those loud but accurate sounds.

Disassembly Process

Steps:

Step 1: Unplugged the Amazon Echo and found a clear area to work on (Figure 1.1). Obtained tools such as a screwdriver and pliers (Figure 1.2).

Figure 1.1: Amazon Echo in clear workspace

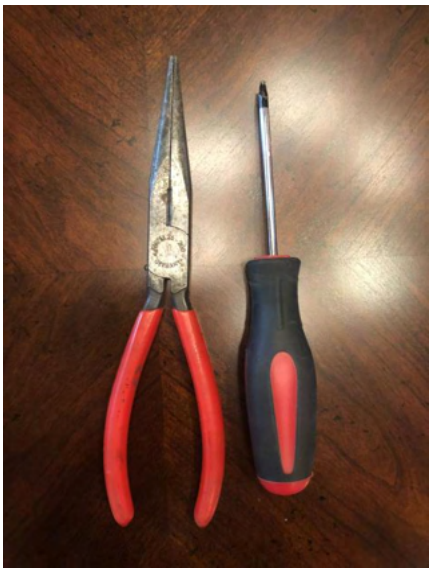


Figure 1.2: Tools required to disassemble Amazon Echo.

Step 2: Turned the Amazon Echo upside down and removed the rubber base using pliers (Figure 1.3). Then unscrewed 4 long screws, detached 3 wires, and removed the power board (Figure 1.4).

Figure 1.3: Upside down Amazon Echo with rubber base removed.

Figure 1.4: Amazon Echo with 4 long screws removed, and power board being removed.

Step 3: Removed the speaker cover (Figure 1.5), and unraveled the fabric sheet (Figure 1.6).

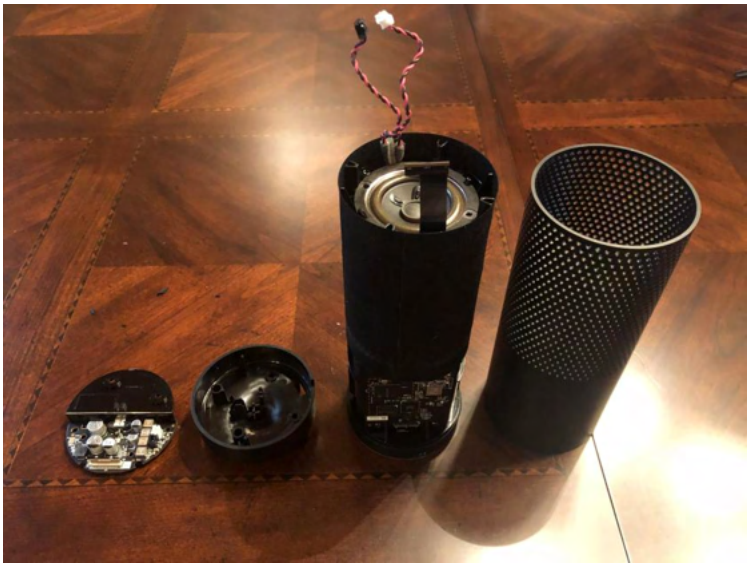


Figure 1.5: Amazon Echo with power board and outer casing removed.

Figure 1.6: Amazon Echo with fabric sheet removed.

Step 4: Removed 4 more long screws, and then pulled out the woofer (a loudspeaker designed to reproduce low frequencies) (Figure 1.7) and the tweeter (a loudspeaker designed to reproduce high frequencies) (Figure 1.8).

Figure 1.7: Amazon Echo with woofer removed.

Figure 1.8: Amazon Echo with tweeter removed.

Step 5: Removed 5 short screws and detached 2 wires, in order to separate the system board from the Amazon Echo frame (Figures 1.9 and 1.10).

Figure 1.9: Amazon Echo with system board.

Figure 1.10: Amazon Echo frame with system board detached.

Step 6: Pulled off the volume ring (Figure 1.11) and separated it into 3 layers (Figure 1.12): The top, the control board, and the bottom.

Figure 1.11: Amazon Echo with volume ring removed.

Figure 1.12: Volume ring separated into 3 layers.

Amazon Echo Components Analysis

Major Components:

- Power Board: The power board is responsible for providing power to the entire Amazon Echo. The power cord is attached to the power board, which is located near the base of the Echo. The power board provides the system board, control board, tweeter, and woofer with the right amount of power in order for each component to function.

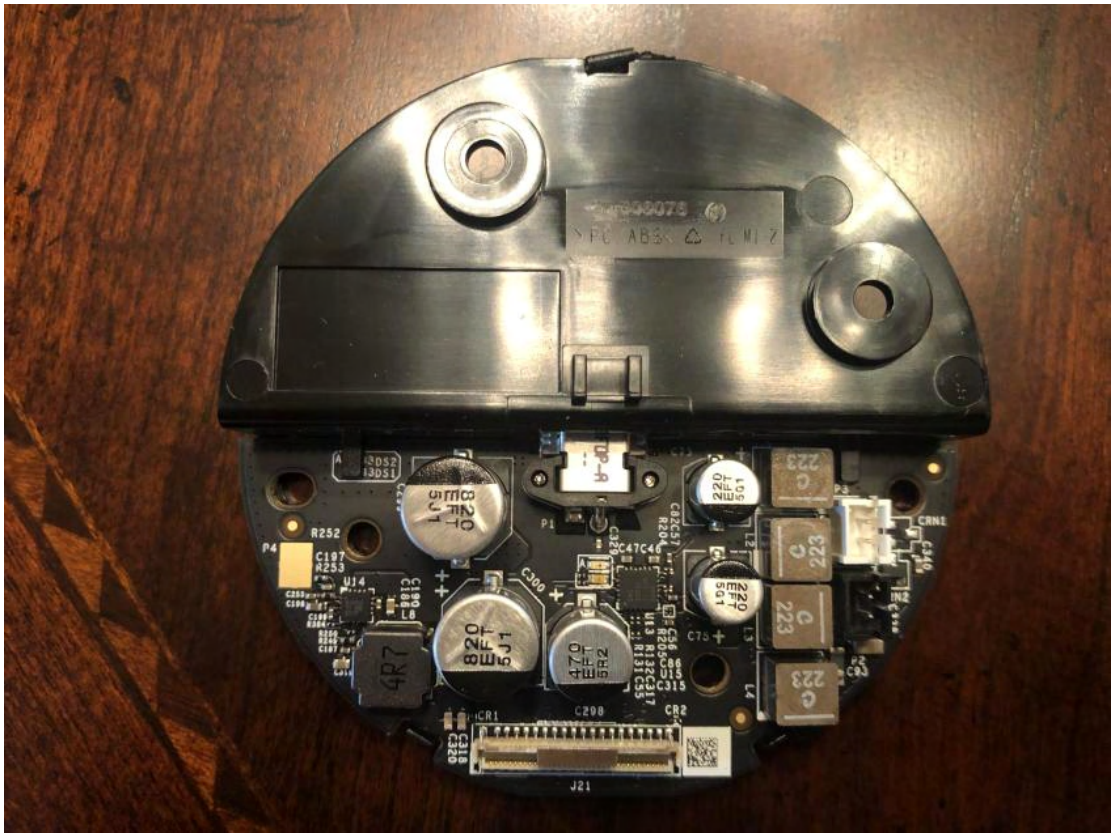


Figure 2.1: Power Board

Figure 2.2: Power Board (Back Side)

- Control Board: The control board is responsible for several essential functions in the Amazon Echo. It's primarily responsible for receiving input from the user and processing that information, which it then sends to the system board. It receives input through the buttons on the top of the Echo, the potentiometer on the top of the Echo, and also from a microphone. The control board also has LEDs surrounding the board, which light up to create a light ring when the user says the word "alexa".

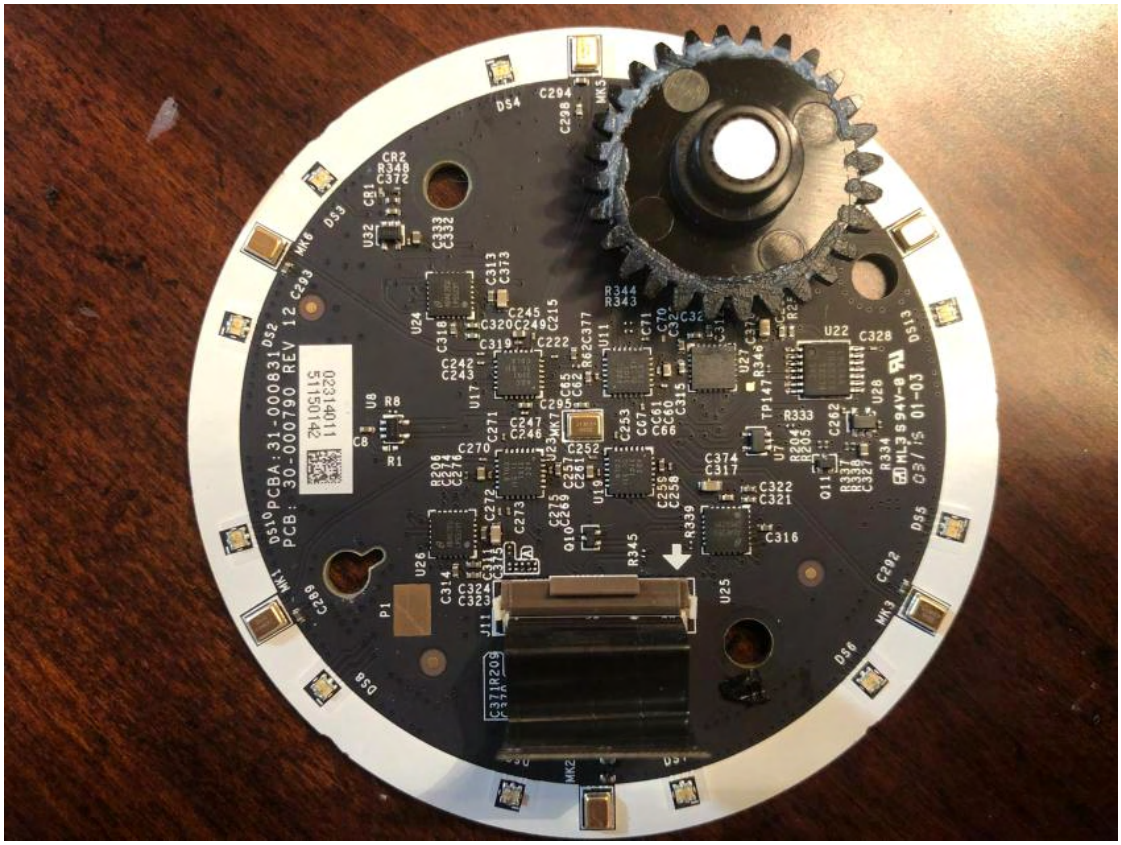


Figure 2.3: Control Board

Figure 2.4: Control Board (Back Side)

- System Board: The system board is the main brain of the Amazon Echo, and is responsible for almost everything else. Some of its key functions include connecting with the tweeter and woofer, and transferring information to them as to what to say. It also allows the Echo to connect to wifi networks, and communicate as a bluetooth device. Lastly, it contains an integrated memory chip, which allows it to store 4 GB of long term memory, and 512 KB of short term memory.

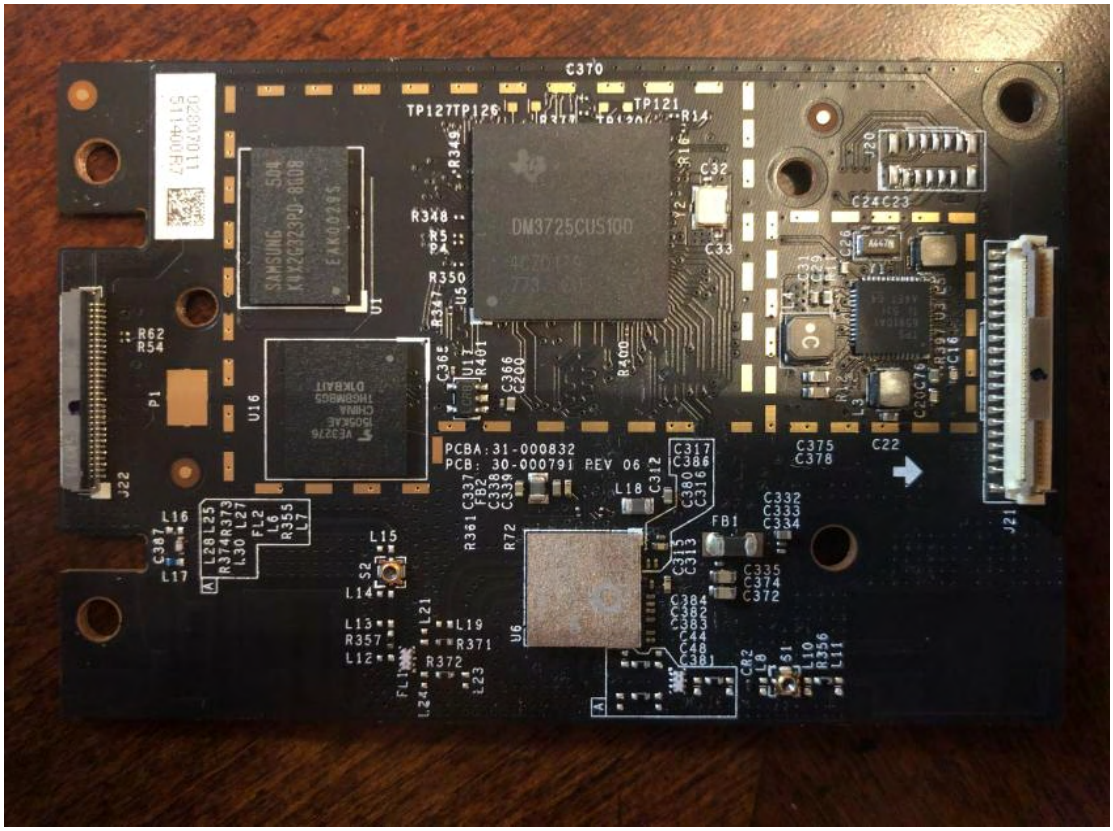


Figure 2.5: System Board

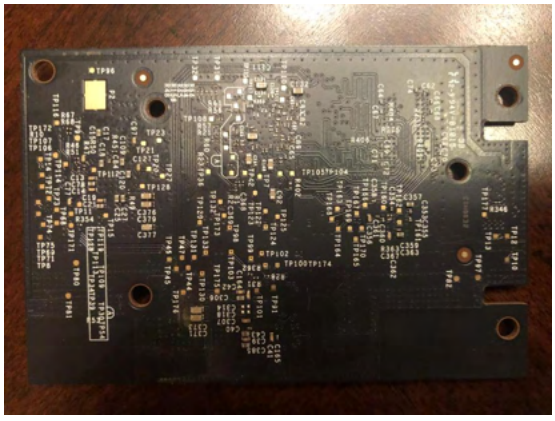


Figure 2.6: System Board (Back Side)

- Tweeter: The tweeter is part of the speaker system in the Amazon Echo. It's purpose is to produce high frequency sounds in order to increase the variety of sounds that can be played by the Echo. It connects only with the power board, which provides it with the correct amount of current to produce the accurate sound.

Figure 2.7: Tweeter

- Woofer: The woofer is also part of the speaker system in the Amazon Echo. It's purpose is to produce low frequency sounds in order to improve the overall speaker quality, and also to amplify the sound so the Echo can play sounds at a higher volume. The woofer also only connects to the power board, from where it gets the optimal current to produce the correct sound.

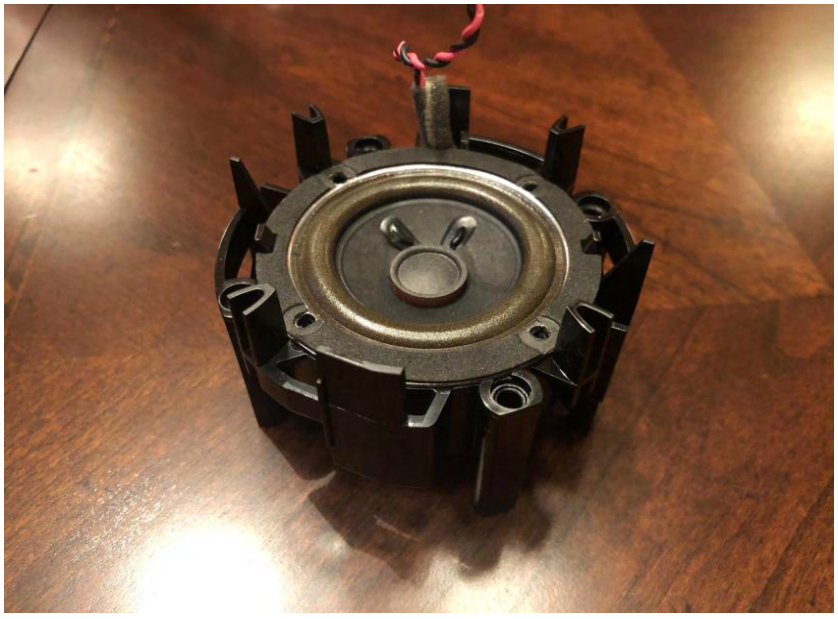
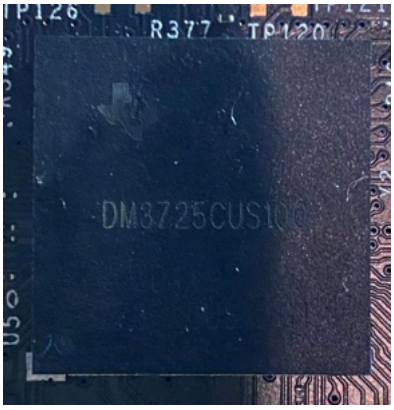
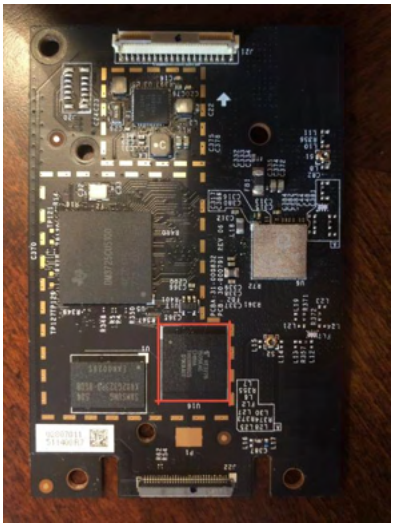
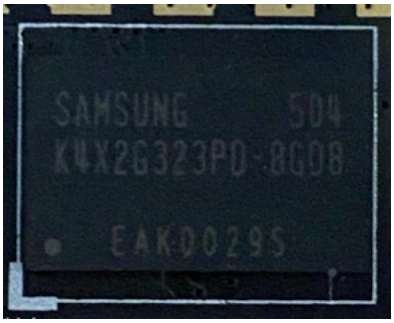
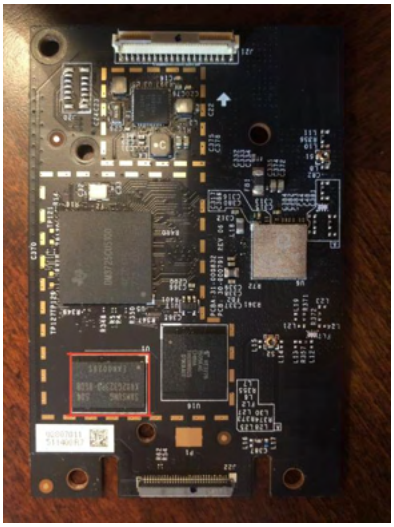
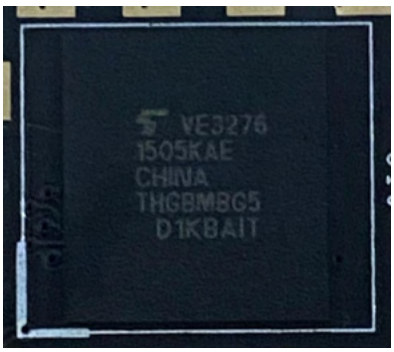
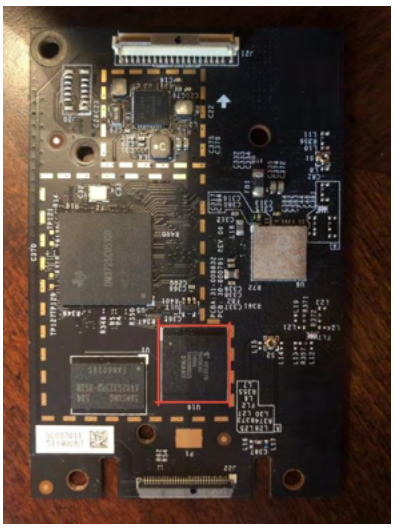
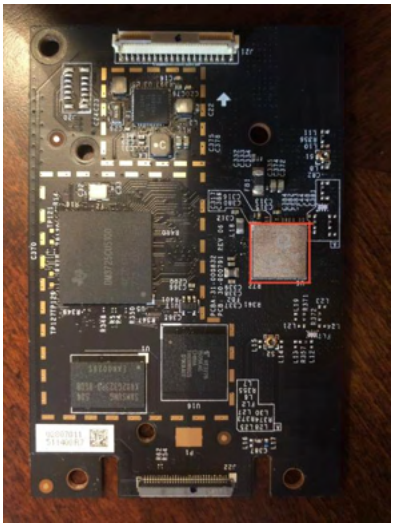
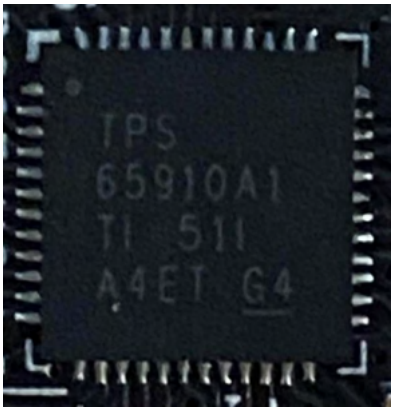
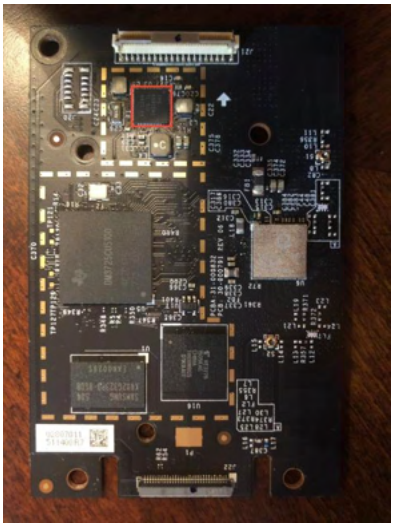
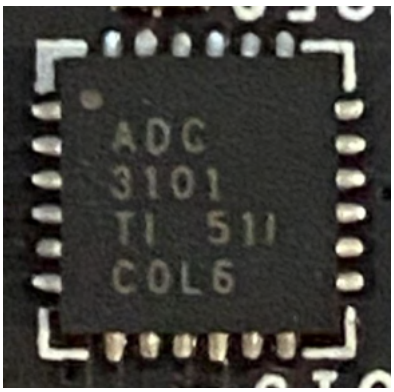
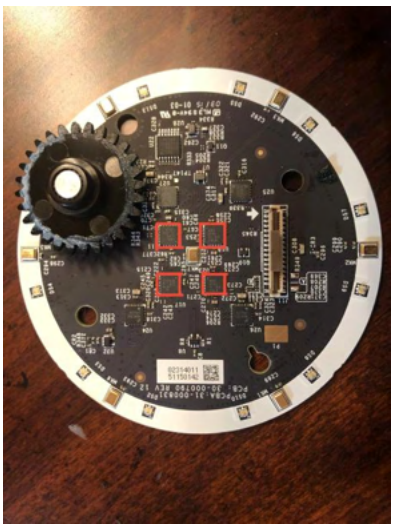
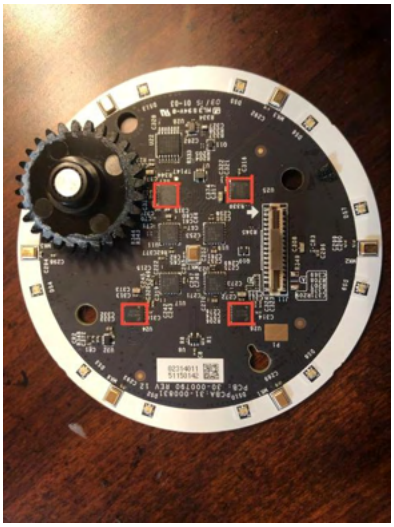
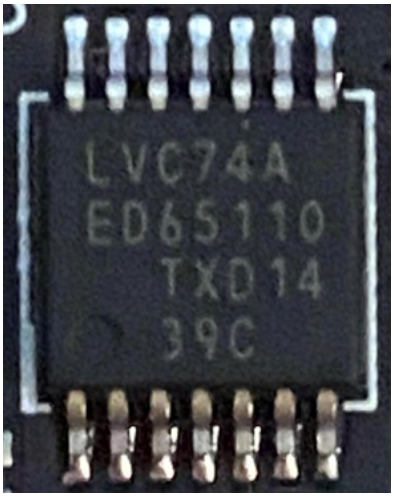
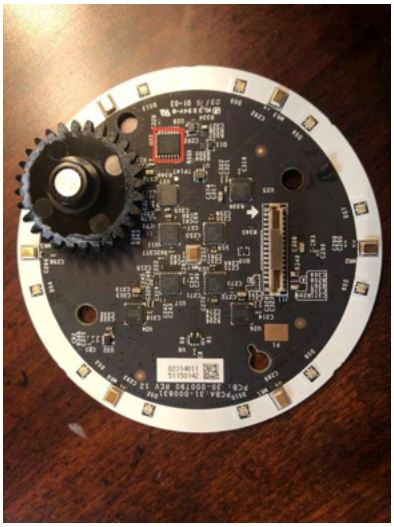


Figure 2.8: Woofer

Integrated Chips:

Part and Description	Picture	Location
Digital Media Processor - DM3725CUS100 The media processor processes incoming data in real-time in order for the Amazon Echo to operate smoothly and be able to receive all incoming requests. Datasheet		
BGA Processor - K4X2G323PD-8GD8 The processor interprets data and performs basic operations. It also controls how quickly the Amazon Echo is able to receive and execute commands. Datasheet		

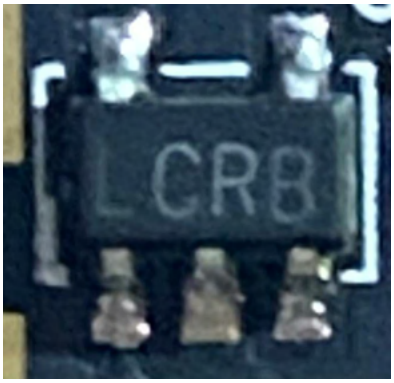
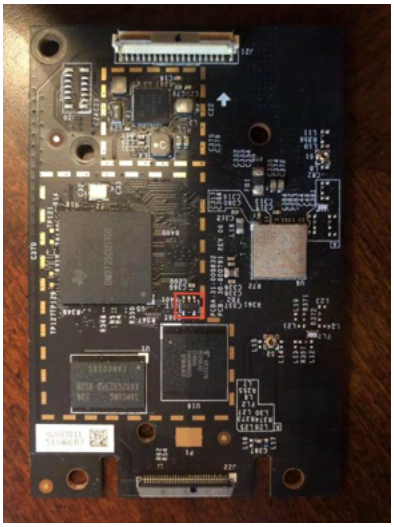
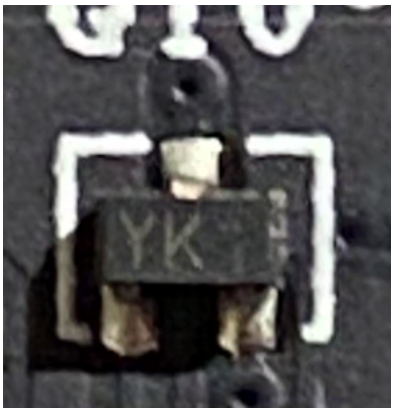
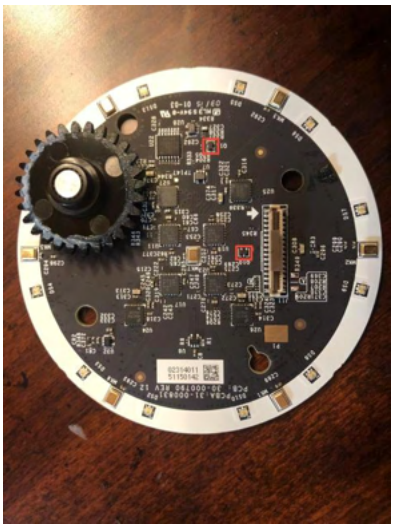
Toshiba THGBMBG5D1KBAIL The chip is an embedded Multimedia-Card, which consists of the flash memory, the flash memory controller, and the multimedia card. It is used to temporarily store up to 4 GB of data, and can also retain the data while the Echo is plugged out (no power). Datasheet		
WLAN + Bluetooth Module QCA6234X-AM2D The chip allows the Amazon Echo to communicate wirelessly through bluetooth with other devices. It also allows the Echo to connect to Wi-Fi networks, as well as transmit and receive radio frequencies. Datasheet		
Power Management Unit - TPS65910A The chip helps regulate the amount of power coming into the system board from the power board in the Amazon Echo. It is also able to control how much power each part of the system board receives. Datasheet		

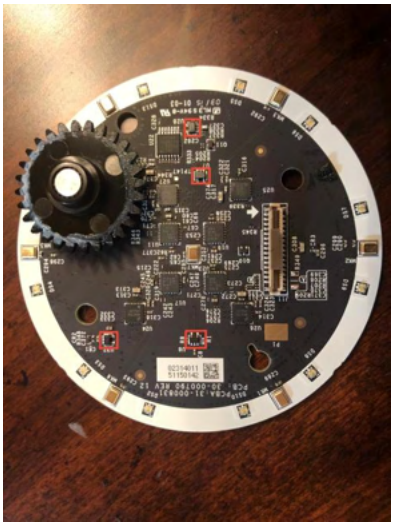
Analog to Digital Converter - ADC31JB68 The 4 chips take in data from the 7 microphones on the control board. They then convert the analog signals to digital signals, which can then be transferred to the system board where they can be processed. Datasheet		
LP55231 - LED Driver The 4 chips are used to control the LED lights on the control system. When lit up, the LED lights from a light ring, consisting of mostly dark blue and a small portion of turquoise. Datasheet		
D type flip-flop - LVC74A Based on the position of the chip, we can infer that it is used to receive data from the potentiometer located near it. The potentiometer transfers information about its angle, which is then used to control the LED lights on the control board and the volume of the Amazon Echo. Datasheet		

DAC 32031 - Digital to Analog Converter The chip takes a digital signal and converts it to an analog signal, which is then sent to the speakers. Datasheet not found		

Transistors:

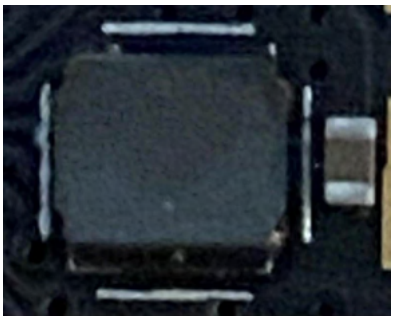
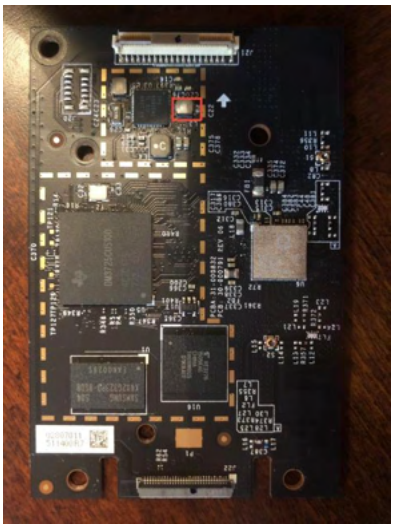
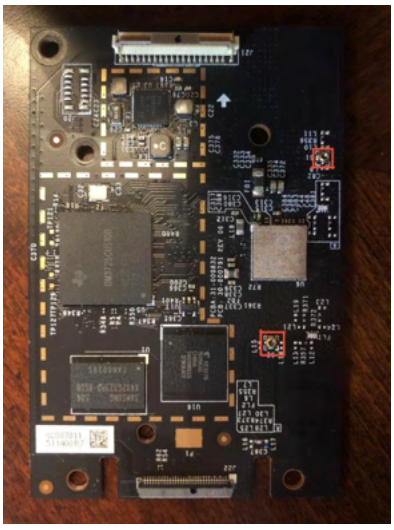
A transistor is a semiconductor which regulates current or voltage from one point to another. It can be used to amplify the current provided, or to completely switch its directed path.

Type	Image	Location
LCRB Transistor The transistor is probably being used to regulate how much power the components in the system board are receiving. Since this is the only transistor on the system board, we can infer that it is also switching the current pathways when needed.		
YK Transistor 2 YK transistors are located on the control board. Based on the first transistor's location, we can infer that it controlled the amount of power going into and coming out of the ribbon cable, which is placed right next to it. Based on the second transistor's location, we can infer that it controlled the amount of power going into the potentiometer.		

UY4Z0 Transistor There are 4 UY4Z0 transistors on the control board. Since there are 4 of this type of transistor, and there are 12 LEDs, we can infer that each transistor controls the amount of power that 3 of the LEDs receive.		
M24 Transistor Based on the location of this transistor, we can infer that it was used to control the amount of power coming and going through the 2 wires connecting right next to it. The wires connected to the woofer and the tweeter, meaning that the transistor would control how much power each of those devices receive.		

Inductors:

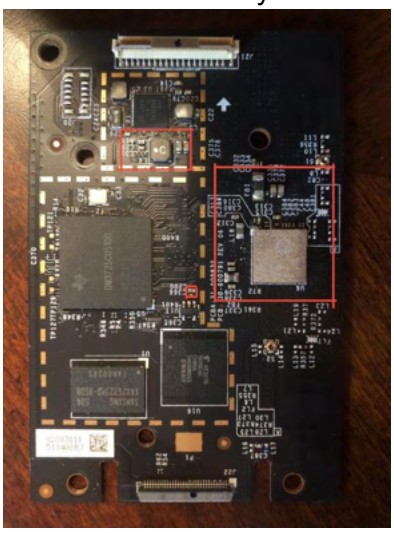
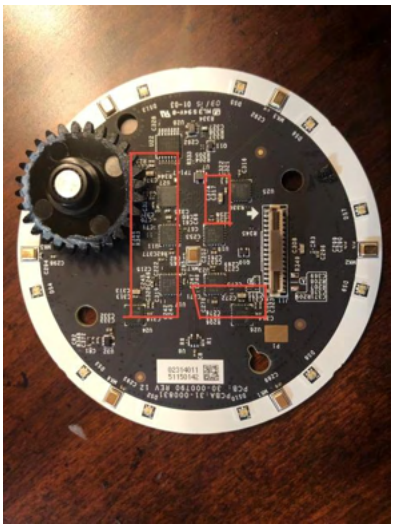
An inductor is an energy storage device which consists of an insulated wire warped into a coil. The inductor stores energy in a magnetic field when current is passing through, and then provides power for the seconds in between where the current stops flowing.

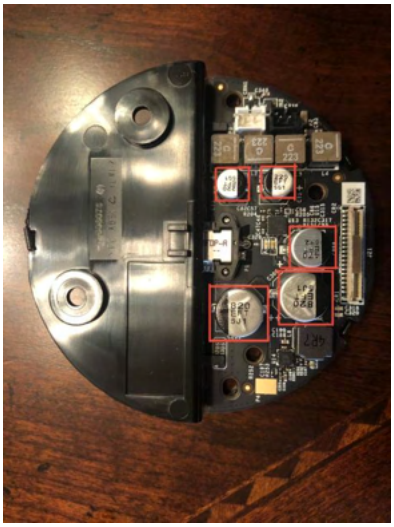
Type	Image	Location
Unidentified Inductor Based on its position, we can infer that it is being used to provide power to the system board. When current is flowing normally, the power will come from the ribbon cable and into the power board. But when it stops for a few seconds, the inductor will take its place and provide power for a short period of time.		
Unidentified Inductor There are 2 of this kind of inductor on the system board. Since there are no other inductors on the system board (except for the one above) we can infer that these just keep the entire board with current flowing, even when the power is out for a short while.		

Unidentified Inductor Based on its position, we can infer that the inductor provides energy to the power board when the Amazon Echo is plugged out for a few seconds. It is located right next to the port where the power gets plugged in, meaning that it would be able to provide power to all the areas around there.		

Capacitors:

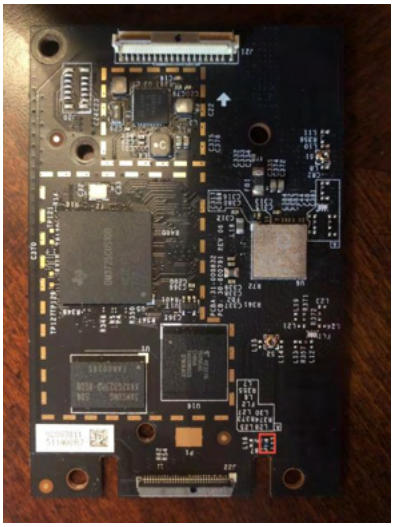
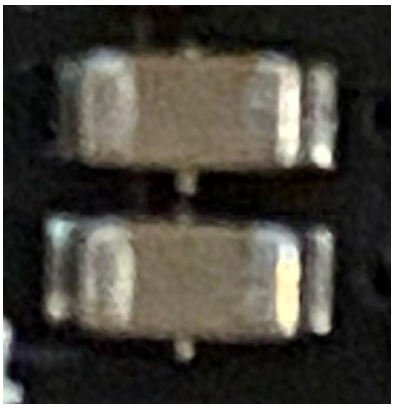
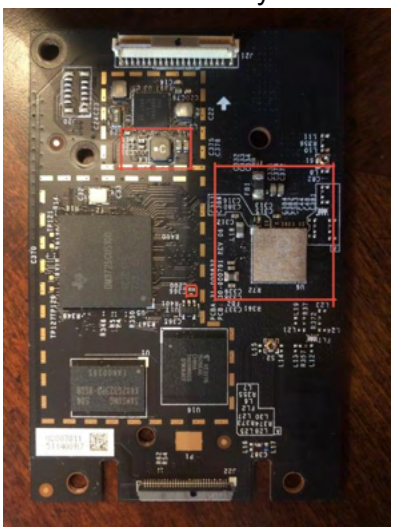
A capacitor is an electrical storage device which stores energy in an electric field. It consists of 2 conductors kept close to each other, but insulated from one another. Capacitors help stabilize the flow of energy in the circuit, by providing energy where it is needed.

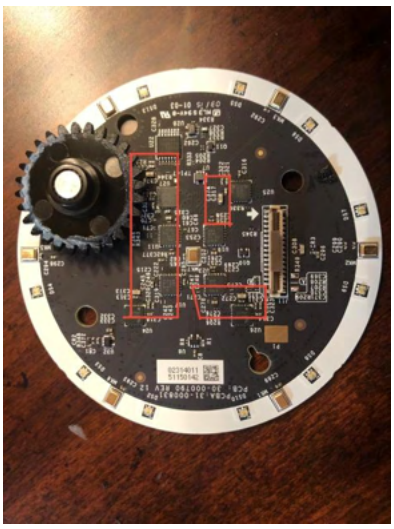
Type	Image	Location
SMD Capacitor There are many SMD Capacitors on the system board, control board, and power board of the Amazon Echo. They all help regulate the current on each board, and make sure it is always running smoothly.		Note: There were too many SMD Capacitors to mark each one individually.  

		
Cylindrical Capacitor There are 5 cylindrical capacitors located on the power board of the Amazon Echo. Each one stores a large amount of current in order to keep the entire Echo functional even when the power board is receiving chaotic amounts of current.		

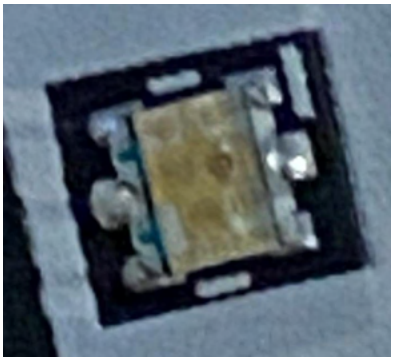
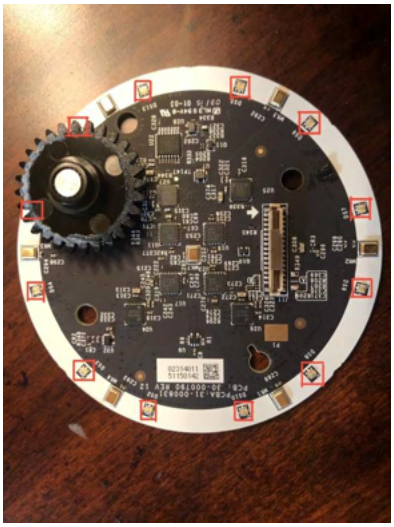
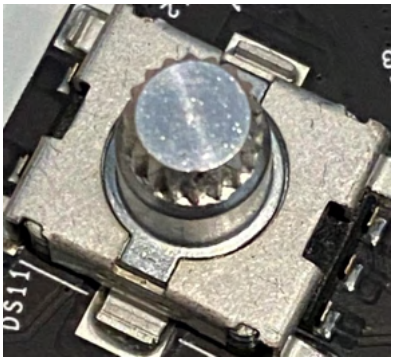
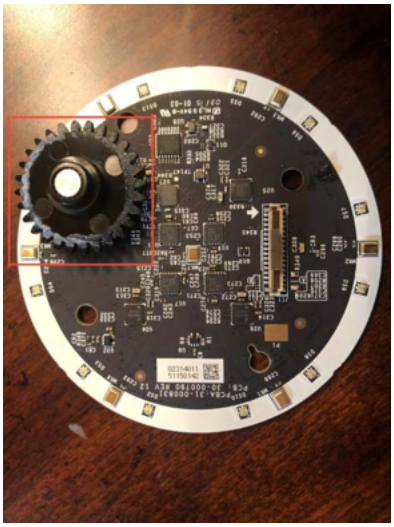
Resistors:

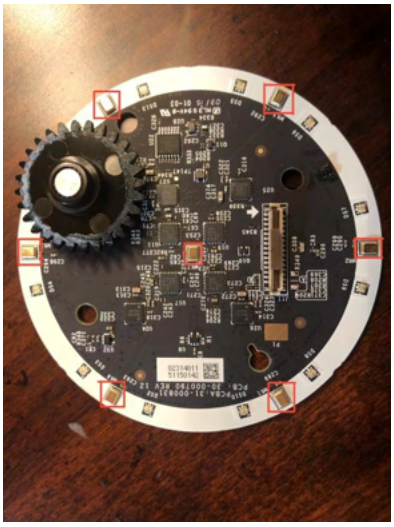
A resistor is a device which implements an electrical resistance between 2 points where current is flowing. This is useful as it can regulate the amount of current flowing into an area to make sure a component doesn't receive too much power.

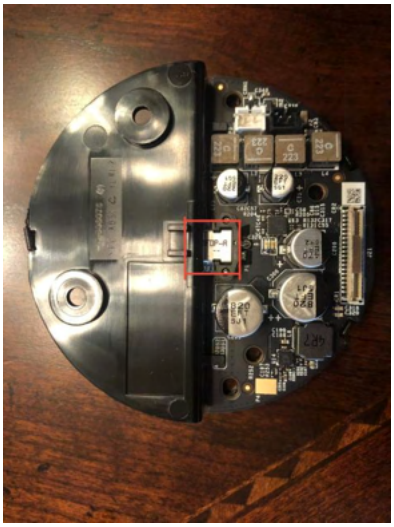
2200 Ohm Resistor Based on its location, we can infer that it helps regulate the amount of power coming from the ribbon cable located near it. The ribbon cable attaches the system board to the power board, meaning that the resistor is controlling how much power enters the system board.		
SMD Resistor There are many SMD Resistors throughout the system board, control board, and power board of the Amazon Echo. Together, they make sure that each component receives the correct amount of current so it is able to function optimally and not malfunction or overheat.		Note: There were too many SMD Capacitors to mark each one individually. 

Other Components:

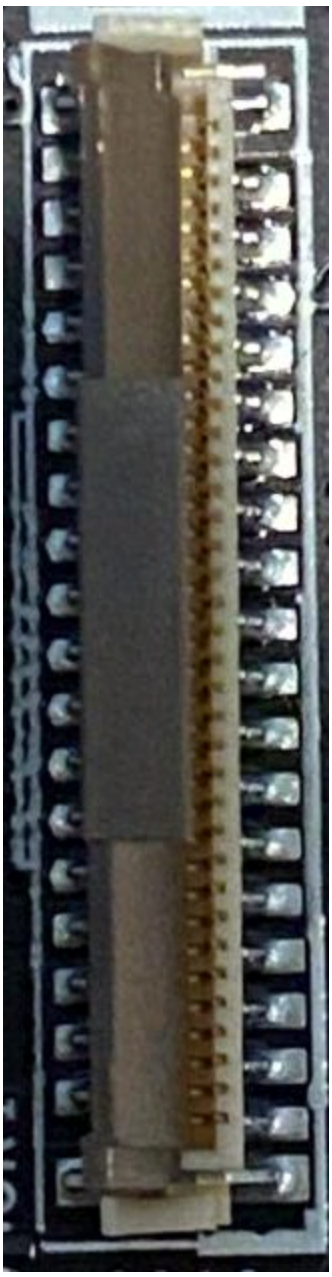
Component	Image	Location
LED There are 12 LEDs located on the control board of the Amazon Echo. When lit up, they form a light ring which activates when the user says “alexa”. The LEDs are controlled by 4 LP55231 chips, all of which are also located on the control board. The chips can change whether the LED is on or off, and also what color the LED is.		
Potentiometer There is a potentiometer located on the control board of the Amazon Echo. The potentiometer is connected to a gear, which spins when the volume ring is turned. This sends data to the system board of the Echo, and tells exactly how many degrees it has been turned. Based on that information, the system board can process the data and increase the speaker volume of the Echo.		

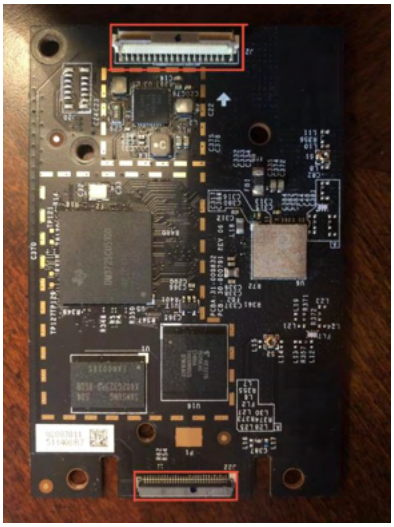
Microphone There are 7 microphones located on the control board of the Echo. The microphones take voice commands from the user as analog signals. A chip then converts the analog signals to digital signals, which can then be processed by the system board. After being processed, the new digital signal is converted back into an analog signal, which is then transferred to the tweeter and woofer to produce the correct sound.		
Button There are 2 buttons located at the very top of the Echo. One is the mute button, while the other is the activate button. When the mute button is pressed, the LEDs turn red, and the microphones stop listening for commands. When the activate button is pressed, the LEDs turn blue and the Echo starts listening for a voice command without the use of the word “alexa”.		

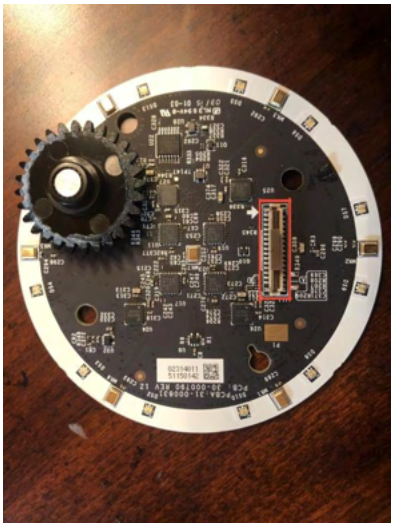
Power Cable The Amazon Echo power cable is a 21 Watt AC Adapter. It can take an input voltage of 100-240 Volts, while outputting 15 Volts. The power cable connects directly to the power board on the Echo, from where the entire Amazon Echo is able to receive electricity.		
Power Cable Connector The power cable connector is located at the side of the power board. It is surrounded by capacitors, transistors, resistors, and inductors in order to maintain the correct flow of energy throughout the entire system.		

Ribbon Wire Connector

There are a total of 4 ribbon wire connectors on the Amazon Echo. One of them is on the power board, from which a ribbon wire is attached and connected to another ribbon wire connector on the system board. There is also a ribbon wire connector on the control board, from which another ribbon wire is attached and connected to a ribbon wire connector on the system board.







Final Summary Report

Completely disassembling the Amazon Echo and thoroughly understanding every tiny component inside has been by far the greatest learning experience our team has gone through. It never would've occurred to me that there are countless different types of parts to build a device like this. Every part inside the Echo, no matter how small, plays a significant role in helping it operate properly.

While working on this project, we learned about all the different pieces which together make up the Amazon Echo. We studied each piece carefully to find out exactly how it is made, and how it is able to do what it was designed to. We studied exactly what purpose the piece fulfills, and also what greater functionality it is adding to in the overall Echo.

Once we had identified each piece, and had learned each of their functionalities, we were finally able to completely understand how the Amazon Echo worked. The system board, control board, and power board all worked together to make a functioning device. Each and every integrated chip provided the Echo with an essential feature, such as Bluetooth and Wifi connections, flash-memory, processors, LED controllers, analog to digital signal converters, etc. Every single capacitor, resistor, transistor, and inductor worked together to maintain a smooth current throughout the entire system.

What I found to be most interesting in this project was the Amazon Echo speaker. In order to produce a sound of the right volume, but also the exact pitch, the Echo contained both a tweeter and a woofer. It was discoveries like these, in which our team got to explore the exotic components, that really made this project worthwhile, and taught us skills we will never forget.

Citations

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