Amazon Echo Dot Disassembly

Reverse Engineering Challenge

Mechanical Mayhem 538K

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1 Introduction

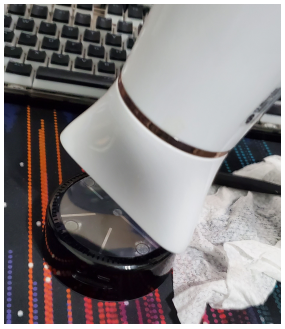
The 2nd Generation Echo Dot is the second iteration of the Echo Dot line. It's a small, puck sized smart speaker with Amazon's smart assistant, Alexa, built in. The puck has a micro USB port for power as well as a 3.5 mm auxiliary port. The Echo Dot offers both this auxiliary port and Bluetooth as alternatives to its internal speaker. It is primarily voice operated and the built-in assistant is activated by the trigger word – Alexa. Its capabilities include, but are not limited to: music, weather, jokes, games, news, and even simple conversations.

We chose this speaker to analyze because we were intrigued the way it condenses almost all of the incredible functionality offered by the full size Echo into a much, much smaller package. We were interested in discovering how the small puck is so compact, and seeing how we can apply that knowledge to our own robot. Like the device, our team plans to have a lot of capability in a small amount of space, so we looked to the device to make our own robot more dense and space efficient.

2 Disassembly

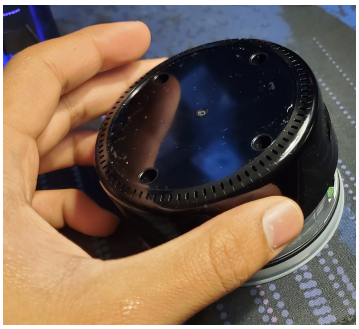
1. **Pry off the rubber pad**
   Use a pry tool or a sharp edge to take off the rubber pad on the bottom.

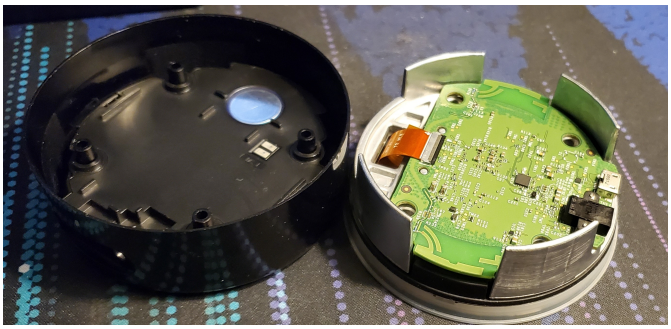
2. **Remove the plastic protective pad**
   Remove the plastic pad by heating up the glue using a hair drier on low and prying it off with a sharp edge or pry tool.



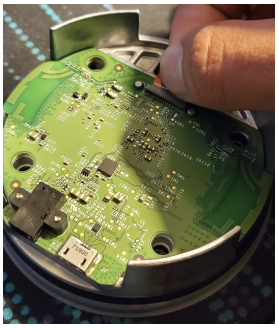
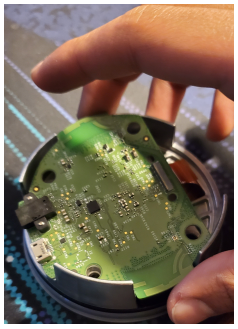
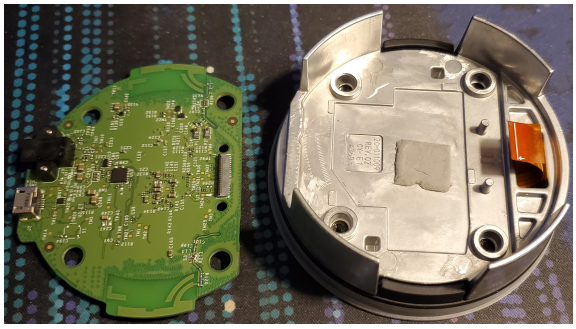
3. **Unscrew the Base**
   Using a T8 screwdriver bit, remove the four exposed screws.

4. **Pull off the speaker and plastic housing**
   Carefully separate the two pieces, exposing the lid and internals of the echo dot.

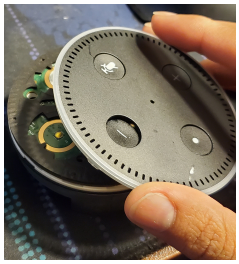




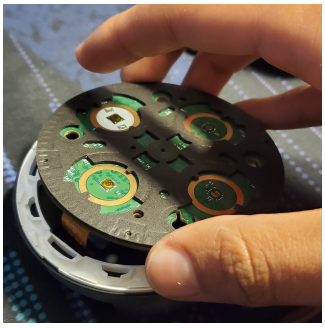
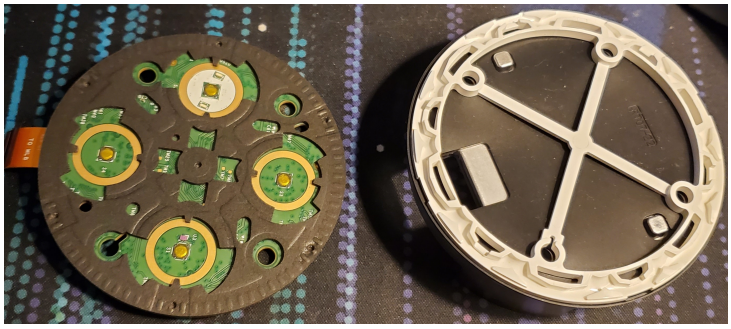
5. **Remove the main PCB**
   Carefully remove the wire connecting the PCB to the lid by pulling the locking mechanism upwards and pulling on red tab on the wire. Then carefully lift out the PCB.

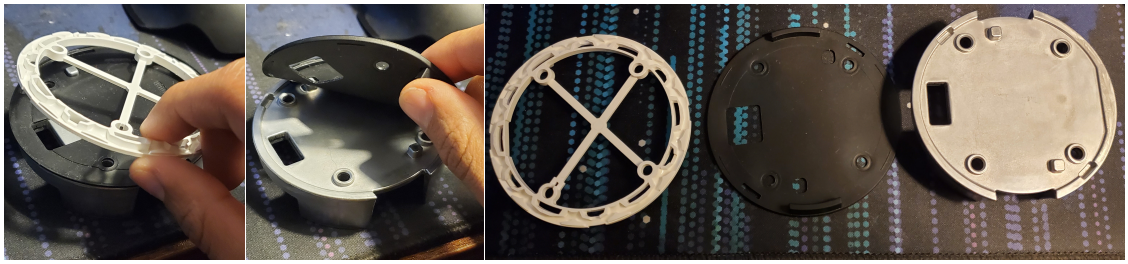
6. **Remove the top cover**
   Turn over the top section and remove the lid, taking care that none of the loose components inside fall out.

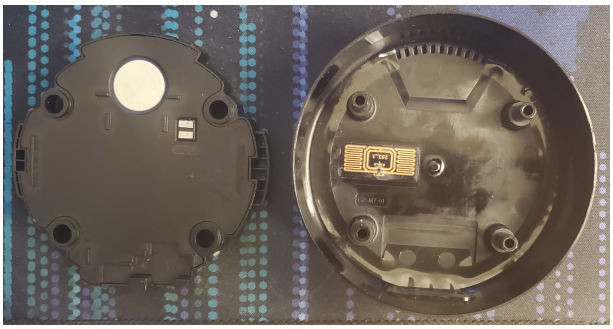

7. **Remove microphone PCB**
   Carefully remove the microphone PCB.

8. **Separate the top housing components**
   With all the electronic components removed, the white bracket and rubber pad separate from the metal piece easily.

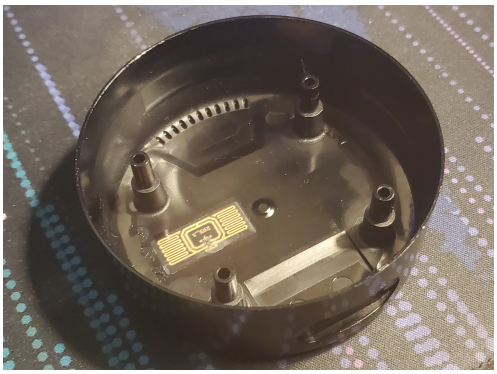
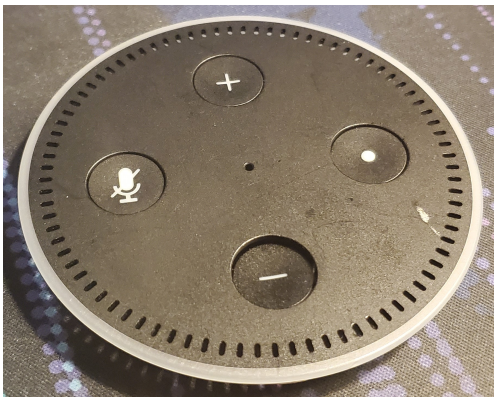
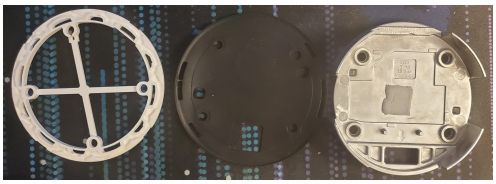


9. **Remove the speaker** Use a pry tool to pull the speaker out from the bottom of the plastic housing. Prying the corners will be most effective.



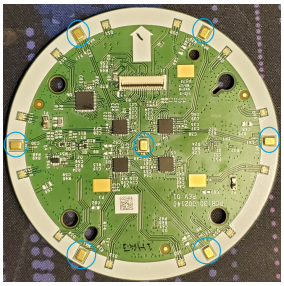
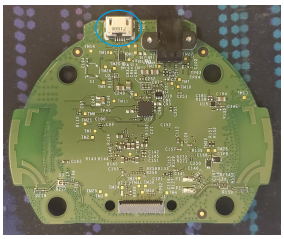
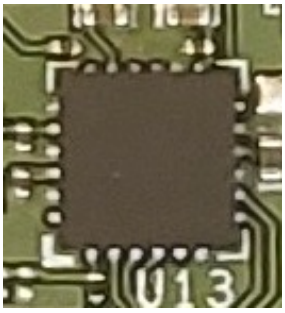
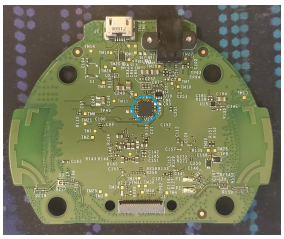
3 Components

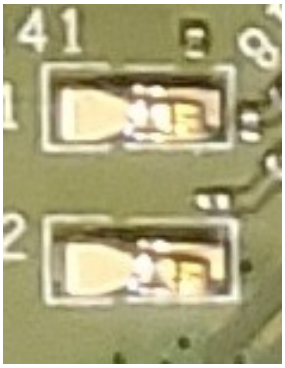
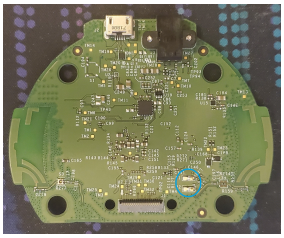
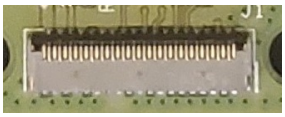
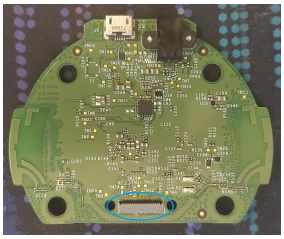
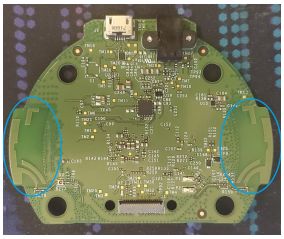
3.1 Structural Components

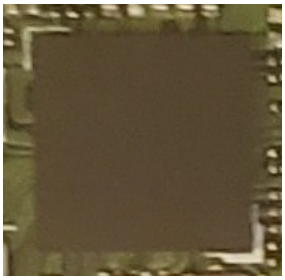
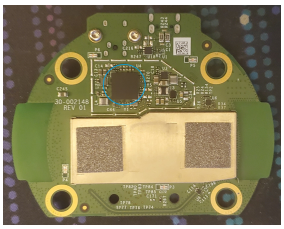
Plastic Housing The plastic housing contains all the internal components including a small antenna at the bottom. It also has cutouts for the micro USB port and 3.5mm auxiliary port on the main logic board. There are four protruding posts to receive the screws that hold the Echo Dot together.	
Lid The lid keeps of all the internal components inside the plastic housing and also includes four buttons. They are plastic circles with small bumps on the bottoms to interact with the small buttons on the microphone board. the buttons actuate by flexing strips of plastic that are attached to the rest of the lid.	
Other Structural Components The metal housing protects the main logic board and speaker. The rubber pad and plastic holder protect the microphone PCB. The rubber padding both on top of the PCB and under the plastic piece helps soften small shocks, especially button presses which directly interact with the microphone PCB.	

3.2 Electrical Components

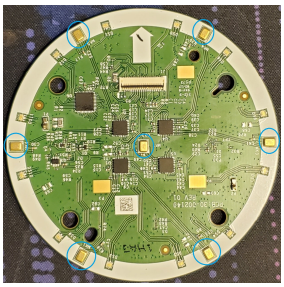
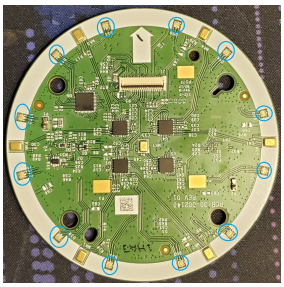
3.2.1 Main Logic Board

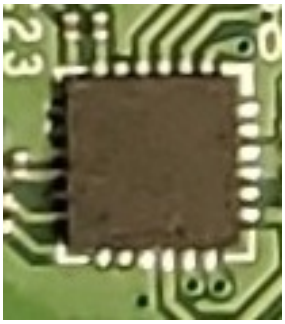
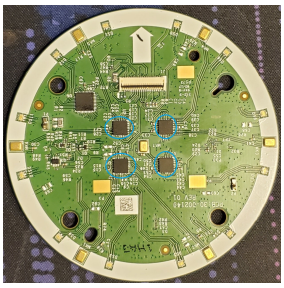
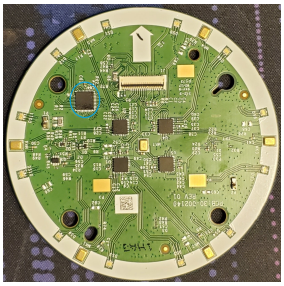
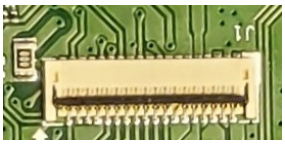
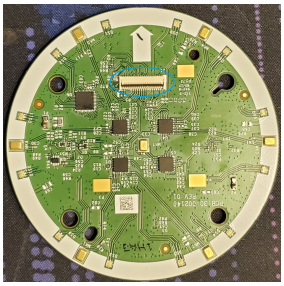
3.5mm Auxiliary port The there is an auxiliary port on the board so that, rather than using the onboard speakers, external speakers or headphones can be used. It routes the analog signal directly from the digital to analog converter (DAC).		
Micro USB port The micro USB port is used for power input. Although the data pins are still present, there is no official use case for them. However, some users have been able to access the firmware with the data pins.		
Digital to Analog Converter (DAC) The DAC is used for both the speaker and any potential external speakers or headphones. The chip converts the digital audio files or stream (like music sent to the device over Bluetooth) to the internal or external speakers.		

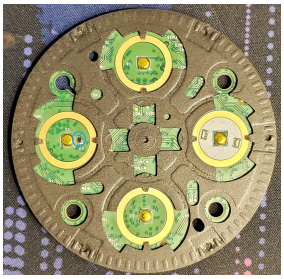
Pogo Pins to speaker The pins connect the speakers to the main logic board. This arrangement is preferable to discrete wires because it is far smaller, more durable, and easier to service. Because the speaker only needs two pins, the relatively large pogo pins made sense.		
Ribbon Cable connector This connector is a PCB transition header. It's the receptacle for the ribbon cable that connects the main logic board to the microphone pcb. It takes 37 pins, although 9 remain unused.		
Antenna The antenna uses a PCB antenna design rather than a chip antenna design, allowing for reduced cost and larger range. The antennae themselves appear on the sides of the PCB. They are used for Wi-Fi and Bluetooth signals. They appear on both sides of the device and use large amounts of space on the PCB, allowing for a long-range antenna with robust shielding against RF interference.		

Power Management System The specifications for this chip are unknown because the Echo Dot 2nd Gen is not patented, but similar chips serve as power management system chips. This is used to regulate the power the board gets from the micro USB port to ensure a stable input.		

3.2.2 Microphone PCB

Microphones (7) There are seven microphones in total. Six microphones are evenly dispersed around the perimeter of the board while the seventh is in the center. The microphones are used to listen for voice commands. The large number of microphones improves performance at range, allows for effectively omni-directional listening, and is very helpful for data preprocessing, including cleaning up unwanted noise like music or conversation in the background.		
RGB LEDs (12) Around each microphone, except for the center microphone, there are two LEDs. These are used as indicators for: the volume level, alarms, device listening status, and much more.		

Analog to Digital Converter (4) The Analog To Digital Converters (ADC) are used to convert the analog signal the microphone provides into a digital signal the processing chips can use. Because there are so many microphones, four ADCs are required to convert all the data collected by the microphones. Each ADC can handle two microphone, so one of the ADCs has an unused channel.		
Micro controller/LED driver (?) There is unmarked chip that appears to be either a micro controller or an LED driver. It's difficult to tell because of the lack of markings or patent documentation, but the position suggests that it is the LED driver for the indicator LEDs on the board.		
Ribbon Cable connector This connector is a PCB transition header. It's the receptacle for the ribbon cable that connects the main logic board to the microphone PCB.		
Buttons There are four buttons on the back side of the PCB. They are dome tactile buttons and interact by the four buttons on the cover. They serve as inputs for the device and can increase and decrease the volume, mute the volume, or trigger the device to listen for commands.		

LEDs Next to the mute button, there is a pair of LEDs. They serve, along with the LEDs on the perimeter of the other side of the board, to indicate if the device is muted or not. The LEDs turn red, making the button above glow red, when it's muted. Otherwise, they're never illuminated.		
Light sensor The light sensor is right next to the action button. It detects the level of light in the room and changes the brightness of the LEDs accordingly.		

4 Conclusion

Throughout this project, we learned how to properly disassemble an electronic device and analyze it's components. We greatly improved our understanding of how commercial electronic devices are designed and organized, especially the PCB design component. Identifying each component also improved our skills in research and using documentation. It was also beneficial to see how to efficiently use a small amount of space, which we applied to the design of our robot. Although much of the Echo Dot's compactness can be attributed to the use of custom-designed PCBs and chips, there are still concepts transferable to robot design. The PCBs are thoughtfully shaped and arranged to make maximum use of the horizontal space, since the Echo Dot was most fundamentally constrained in that direction. For instance, the ribbon pin connectors are intentionally oriented and positioned slightly differently on the main PCB and the microphone PCB to efficiently route the cable while maximizing usable space on the microphone PCB. We were able to apply these insights to our robot design by considering both vertical and horizontal space when designing subsystems so that multiple can share what would have been only enough space for one.

5 Sources

1. All About Circuits
2. Predictable Designs