VIQRC Middle School Reverse Engineering Online Challenge

Disassembling and Analyzing a
Portable Media Speaker MD-96

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Summary

We have hit the nail, hit the bullseye on the head. With the vigorous development of technology, we have entered an era in which we live in a variety of electronic 3C products, including, mobile phones, computers, home appliances, and electric vehicles. The foundation of all this technological development is based on deep cultivation in various fields. Our team members collected machines that were visible in their daily life but were no longer in use. We found: a PS3, a vacuum cleaner, a portable speaker, a screen monitor, and a large battery.

Most of our teammates were on the same page and we wanted to disassemble the portable speaker because music is everywhere in our lives. Whether on computers, mobile phones, cars, or movie theaters, music is an indispensable part of our lives. When the portable speaker appeared in front of us, we were excited and couldn't wait. We wanted to learn more about the technical principles of how music archives are transmitted, the principle of speakers, etc.

The Portable Media Speaker MD-96 is made out of an antenna, 2 speakers, a lithium-ion battery, 2 circuit boards, an IR receiver, a 7-segment display, and a variable resistor. This machine flows like a river where each part contributes to something big. Starting at the very top of the river where inputs like SD, USB, and FM. Then it would flow down the river to the main circuit board where it gets transferred into analog signals where it would travel to the amplifier downstream and flow downstream to the speakers where they create the music you hear.

The important thing is that we are a team that is highly curious about machines. In addition to studying the machines, we learned how the 7-segment display uses an optical illusion called the persistence of vision to show many numbers at once even though it only displays one at a time. How the speaker vibrates and makes sounds, and how the buttons can change the volume of the sound. We did further experiments on these questions. We also wanted to know how the IR receiver works. When we tried to do a test on the IR receiver, we used a remote controller, breadboard, and IR receiver. The LED should light up when we click a button on the remote, but it doesn’t. This showed that the IR receiver was broken. We also had a test on the variable resistor. It could adjust the brightness of an LED light proving that it was still functioning.

Even though we had many troubles over the weeks, we learned to climb over troubling times and think on the bright side. We have learned a lot from this project. We learned what it’s like to have better team chemistry and how to work efficiently together. It has strengthened our friendship with each other. It has also taught us to be creative, make friends, problem-solve, and think outside of the box.

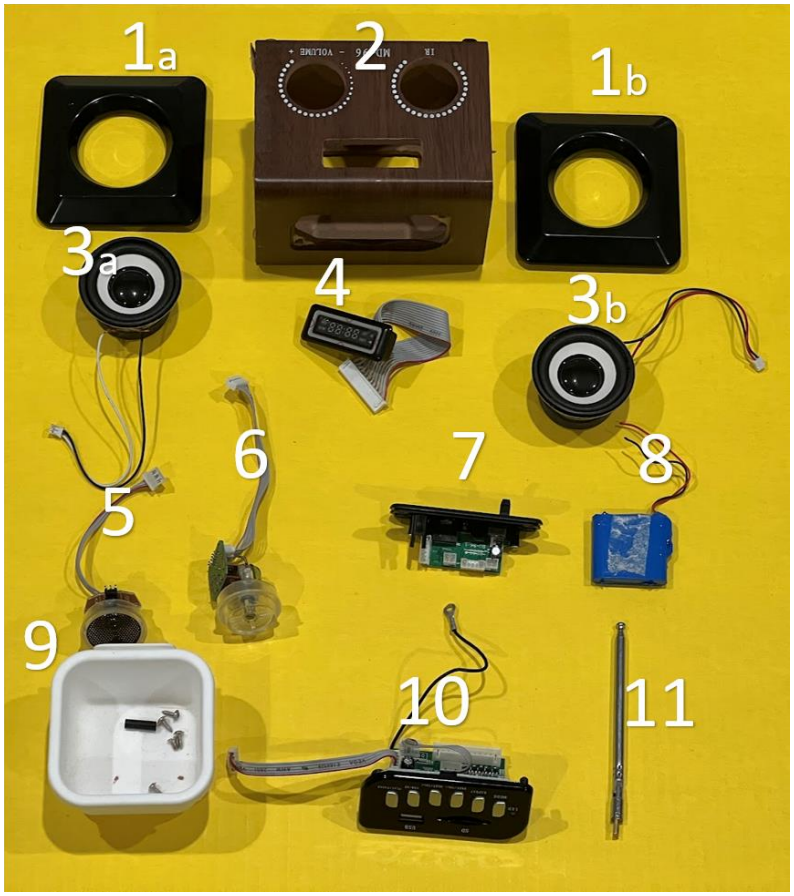
Word count: 490

Introduction

Over the centuries with strenuous effort, effervescent humanity managed to grasp and take hold of the sounds around us. That was what we thought when we saw this out-of-the-world invention, the Portable Media Speaker MD-96. It was a bright shooting star out of the dark night sky, a shiny fish in the aquamarine and vast ocean. Once we laid eyes on it, we couldn't take them off. It was full of mysteries for us to unlock and take hold of. Conundrums such as how does the speaker make sound? How does a rechargeable battery know when it's full? Why can we just turn a knob and the sound would become louder or softer? Why was this piece here? What is the use of the constituent? Whenever we think of one we snatch it up and research it. This is why we chose the Portable Media Speaker MD-96 over all the other electronics such as the PS3, monitor, battery, and Dyson vacuum because it was full of mysteries for us to unlock and it helped us view and investigate the past, present, and future of the technology around us.

Our Team

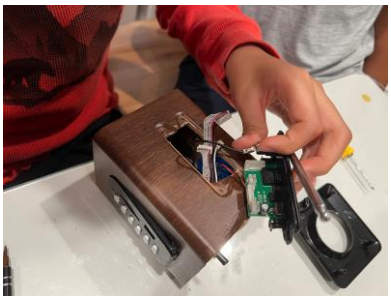
Parts list



1a 1b	2	3a 3b	4	5	6
casing/frame		Speakers	Multiple 7-segment Display	IR Receiver	Variable Resistor
7	8	9	10	11	
Module 2	Li-ion battery	Screws	Module 1 (Main)	Antenna	

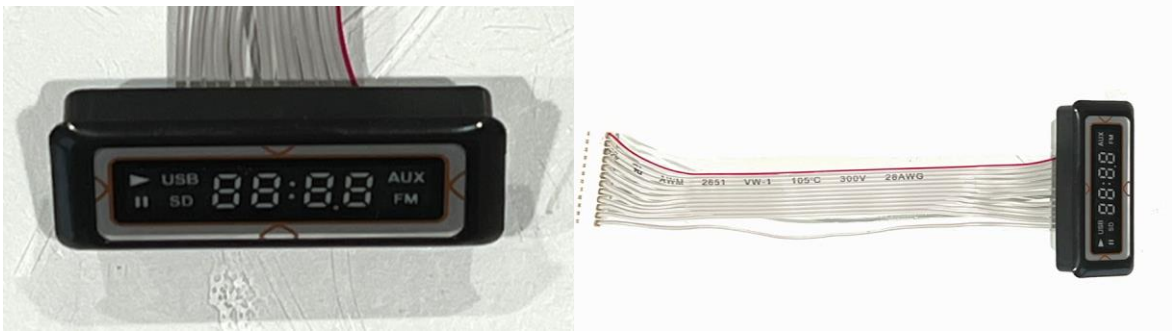
Disassembly Procedure

	First, we took off the tape connecting 1b and 2 to reveal what was underneath the speaker. This was a dead end because there wasn't anything else That was connected here so we had to move on.
	We then took off part 6 since it was another place we could look forward to, it held buttons that seemed to connect to everything so we decided to go for that and take it out.
	After unscrewing part 2, we decided to take a look inside to see if it connected to anything and to take it apart for a further understanding of our machine so we decided to lift it up.
	We found out that almost everything was wired up onto the circuit board which means we hit the main circuit board. This also means that we could find out how to take out all the other components since it also leads to the inside of the casing.

	We decided to take out the circuit board for a better understanding of the inside so we took off all the wires that were connected to the circuit board and took it off. The speaker (guessing that it connects to the circuit board) fell off.
	We then took out a blue cuboid inside and found that the blue cuboid was a battery. We think it is a lithium-ion battery because we could recharge the speaker.
	We then took out all the components inside just to find out that there was something else that we didn't disconnect. We found out it was another circuit board and took it out too.
	Finally, we took out the two round cylinder-shaped objects from the two holes and we were done with our disassembly.
	In the end, the parts we have look like this from a birds-eye view. We have the speakers, the casing, some screws, a battery, and an antenna as we know for now.

Parts Research Findings

Multiple 7-segment Display

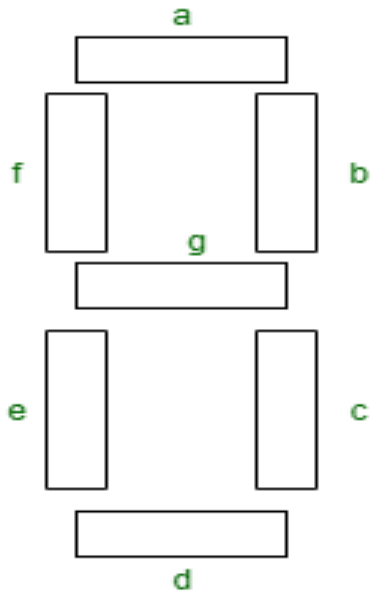


This multiple 7-segment LED display has four digits,
decimal points, and USB, SD, AUX, and FM signs.

The basic 7-segment LED Display is made out of LED and 7 of them are needed to form any number. There is occasionally a dp or decimal point in between them. It uses binary code to put them to work. 1 is equal to light and 0 is equal to no light. We use LEDs because they can come in any shape, they could be any size, and they could come in any color. There is also a common cathode and anode. The cathode is on the bottom and is negative. The anode is usually on top and is positive. It either uses TTL 7447 or CMOS 4511 as the circuit board to control them sending out signals to light them up.

number	A	B	C	D	E	F	G
1	0	1	1	0	0	0	0
2	1	1	0	1	1	0	1
3	1	1	1	1	0	0	1
4	0	1	1	0	0	1	1
5	1	0	1	1	0	1	1
6	1	0	1	1	1	1	1
7	1	1	1	0	0	0	0
8	1	1	1	1	1	1	1
9	1	1	1	0	0	1	1

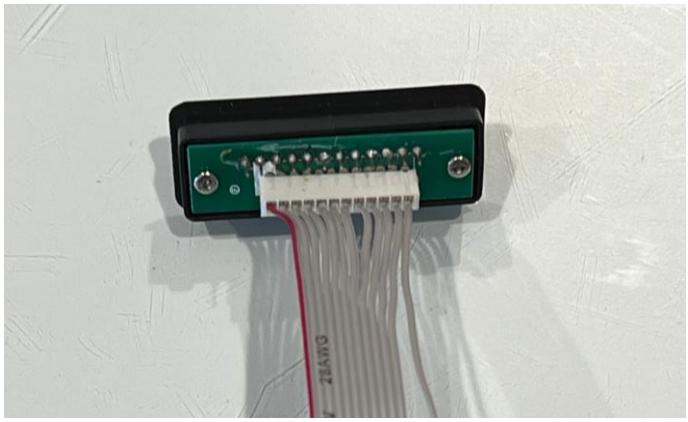
Key: 1=light 0=close



We tried to find out whether the LED lights on the panel showed specific numbers and labels. At first, we tried to search for the spec with the part number, but we couldn't find the spec.

So we tried to search it another way starting with one 7-segment display, there are 7 pins in a group, and a common cathode/anode is needed. The total number of pins for a single 7-segment display is 8 (7+1). When we have a 2-digit 7-segment display, we need to add another common cathode/anode to control instructions for selection. The total pins for a 2-digit 7-segment display is 9 (7+2(common cathode/anode)). Other marks on the panel (||, ►, ∶, USB, SD, AUX, FM), also belong to a group (7 items). According to the above, this display has a 4-digit 7-segment display and 1 group for the signs (||, ►, ∶, USB, SD, AUX, FM). There will be a total of 5 groups on the panel. The total number of pins we calculate for this display is 12 (7+5) and it matches the number of PINs on this display.

The machine first selects which group to activate one of the 5 pins, then selects which symbol/line (of the seven segments) in the group we want to activate one or multiple of the 7 pins. This is why we see 12 pins on the panel.

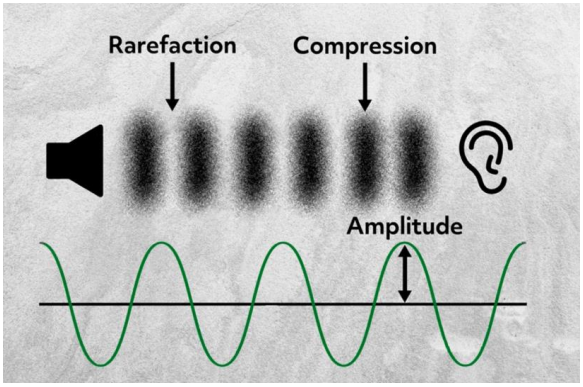


D1	D2	D3	D4	D5
Digit 1	Digit 2	Digit 3	Digit 4	Signs (FM, AUX, SM, USB…)

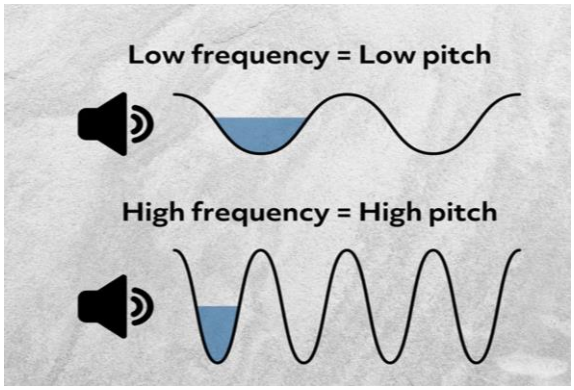
Can it display 4 digits at once? The answer is no, it cannot, it uses an optical illusion called persistence of vision which happens when something shines so fast that your eyes think it is not in motion because eyes use chemical and electrical cells which cause them not to react as fast as the ear. The eye processes stuff 0.1 -0.4 seconds, so if you see another picture 0.09 seconds or below, the eye thinks it is a picture or one motion. So for all of them to appear simultaneously, every digit has to appear 0.02 seconds or lower.

Speakers

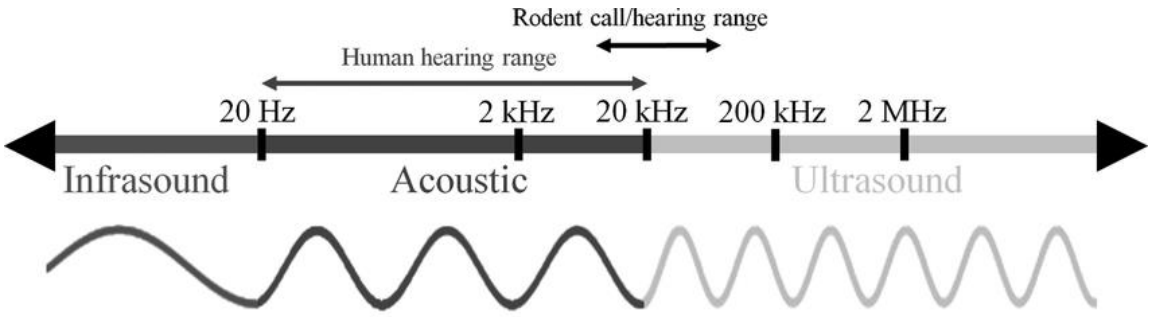
The speaker is an output hardware device that connects to the amplifier to generate sound. The speakers are built left and right to make a stereophonic sound. The speakers are connected to the amplifier by cables/wires that connect to the DAC that translates the digital signals into analog. Speakers comprise two main things, a natural magnet and an electromagnet (voice coil). When positive and negative analog signals go through the wires, the voice coil attracts and repulses because it acts like an electromagnet. The voice coil's attraction/repulse moves the cone in and out. The movement of the cone rams in air molecules is like a domino effect. This wave reaches the ear and your brain interprets it as sound. It also does the same when the cone repulses. When Analog signals go in the copper wires, it creates magnetic pulses. It moves the natural magnet which is connected to the cone. The cone moves back and forth creating sound waves. To create sound, when the cone moves forward, it creates a high-pressure area called compression and when it moves backward, it creates a low-pressure area called rarefaction. The faster the cone moves back and forth, the more compressed the compression areas are, and the higher the sound, the same for the opposite. This is measured in hertz, the higher the hertz, the more compression areas fit in a second. For example, 500 hertz means that 500 compression areas fit in a second.



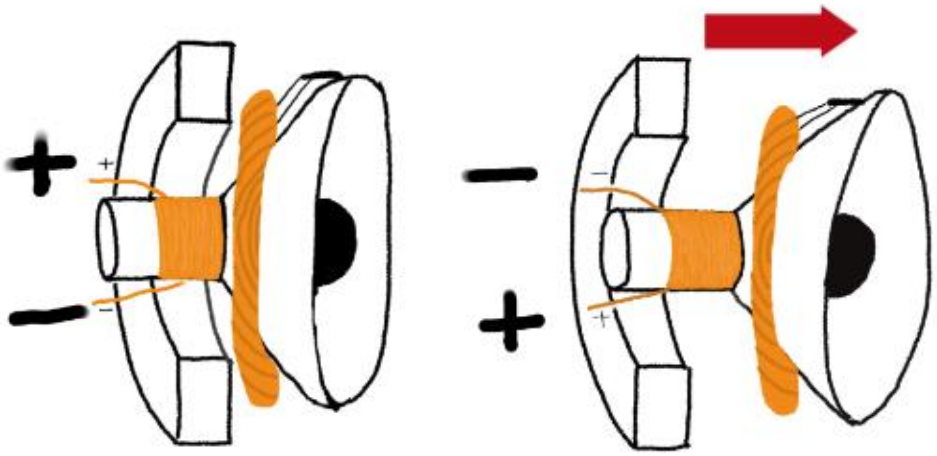
The sound wave from the speaker



Different frequencies result in different hertz



Human hearing range(speakers can go from 20 Hz to 20,000 Hz)



The faster the cone moves back and forth, the higher the pitch(in hertz), and the slower the cone moves back and forth, the lower the pitch(in hertz). The higher the peaks of the sound waves make the sound even louder and the lower the sound waves are, the quieter the sound. The loudness of sound is measured in decibels(dB). 120 dB would hurt your ears and possibly cause hearing loss.

Casing/frame

The casing or frame has 2 uses, to safeguard all important and expensive parts such as the battery, the main circuit board, and other circuit boards. The other use is to hold the speakers left and right to make a stereophonic sound. The material of the casing also affects the speakers, the material has to be heavy/dense, rigid, and non-resonant which means that if you hit it, it won't make a loud sound like a tuning fork. Wood is one of the best solutions except that it is not as heavy. This is one of the reasons why they might have used wood as the case. The casing is also a closed and sealed case, meaning the sound quality won't be as good because the base won't be as low and heavy. The casing also blocks the echoing, making the sound cleaner.

What is the circuit board?

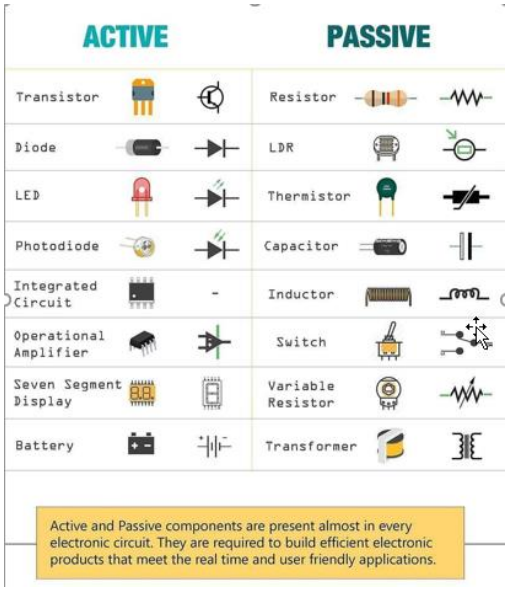
This circuit is comprised of three major components:

1. A conductive "path," such as wire, or printed etches on a circuit board.
2. A "source" of electrical power, such as a battery or household wall outlet, and,
3. A "load" that needs electrical power to operate, such as a lamp.

Two optional components can be included in an electrical circuit. These are control devices and protective devices. Control and protective devices, however, are not required for a circuit to function. They are optional.

Circuits are made up of two distinct elements:

- Active elements are defined as the sources of electrical energy.
- Passive elements carry or use electrical energy for some specific reason.

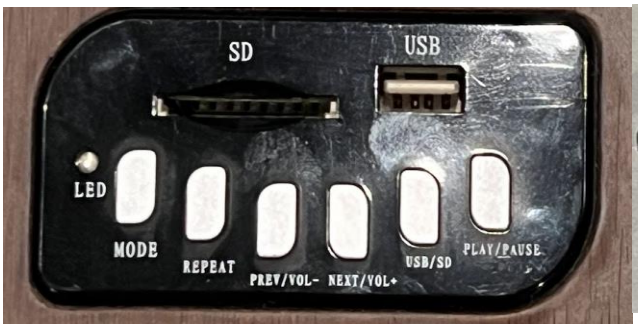


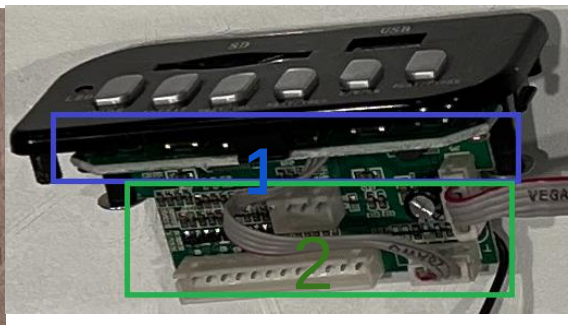
Resistors, capacitors, and inductors make up the passive elements in circuits. Each is used alone or in conjunction with the others to achieve the desired circuit functions. For example, a circuit that switches on an air conditioner when the temperature is too high would contain the following components:

- A source of electrical energy.
- A protective device that senses current flow on the circuit, the circuit breaker in the panel box
- A control device that redirects the current, the switch in the thermostat.
- A passive element, such as an air conditioner cools the space down until the circuit opens shutting the air conditioner off.

Module 1

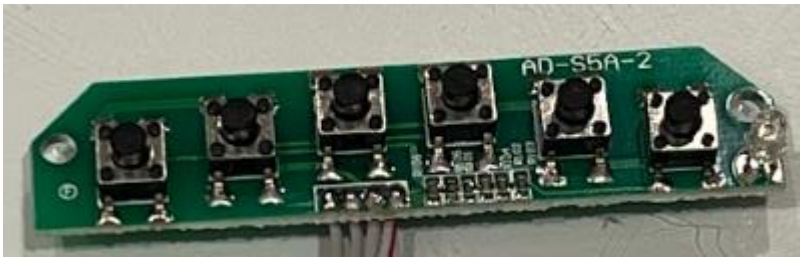
This is the main module of this Portable Media Speaker MD-96. It includes all the input and output functions connected to this module.





1	2
Button board	Main circuit board

Button board



There are some input buttons and an output LED on it.

In this case, there are 6 buttons for the six inputs and an LED to signal if it is on or off. The six buttons represent the mode, repeat, prev/vol-, next/vol+,usd/sd, and play/pause. Those buttons are press buttons; their use is to connect and disconnect a path in an electrical circuit board. On the other side, there are wires connected to the main circuit board to process the information.

Button

Buttons connect to the circuit board through two or more metal contacts on the underside. When the button is pressed, these contacts meet corresponding pads or traces on the circuit board, closing it temporarily. This closure is detected by electronics, signaling the input. The connection is made and broken as the button is pressed and released.

Those buttons have different functions:

- Mode:
  This Portable Media Speaker MD-96 selects different input sources - FM, aux, and USB/SD. When the "mode" is clicked. It sends the signal to the circuit board and the board processes this signal and switches to different input sources.
- Repeat:
  This Portable Media Speaker MD-96 can repeat an audio file when the "repeat" is clicked.
- NEXT VOL+/-:
  When the "NEXT VOL+" is clicked, the volume is implemented through a variable resistor. When you adjust the volume, it changes the resistance of the signals in the circuit affecting the amplification level.
- USB/SD:
  When the "USB/SD" is clicked under USB/SD mode, It sends the signal to the circuit board and the board processes this signal and switches to USB or SD for media input.
- Play/pause:
  This Portable Media Speaker MD-96 has a pausing and playing capability which once clicked. It sends a signal to the circuit board. The board processes this signal and activates a control mechanism that interrupts the flow of electrical current to the parts responsible for playing the sound. This pauses the playback of audio signals.

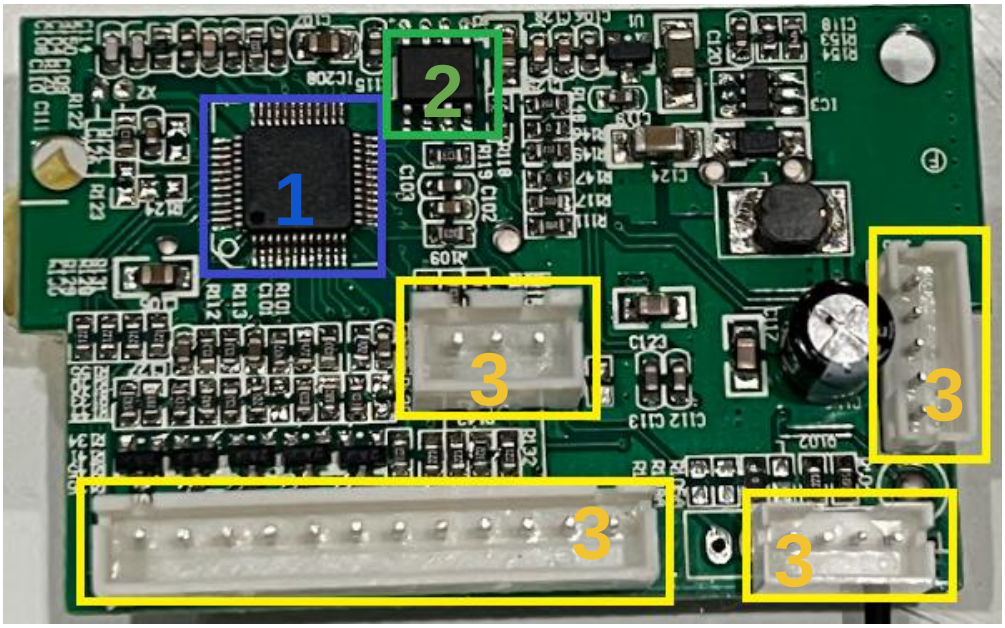
LED light

The tall cylinders in a straight line are LED lights that work by passing an electrical current through a semiconductor material, making electrons release energy in the form of photons which produce light. The LED has two leads, anodes (positive), and cathodes (negative). These leads are soldered onto the corresponding pads or traces on the board.

The LED light is an output that tells when the Portable Media Speaker MD-96 is on or off. If it is on, the LED will light. If it's off, the light will not shine.

Main Circuit Board -front

This circuit board is the main input and output and acts like a motherboard for the Portable Media Speaker MD-96.



1	2	3
CKE003 Chip	Atmlh910 Eeprom	sockets

CKE003 Chip

A CKE003 chip is an mp3 decoder IC. This IC is the main processor of this Media player. It is designed to read audio files from an SD/flash drive and decode audio files to digital signals. This IC creates analog signals by DAC (Digital to Analog Converter). This IC also can control a 7-segment display. But, because we can't find any specs for this, this is all we can write.

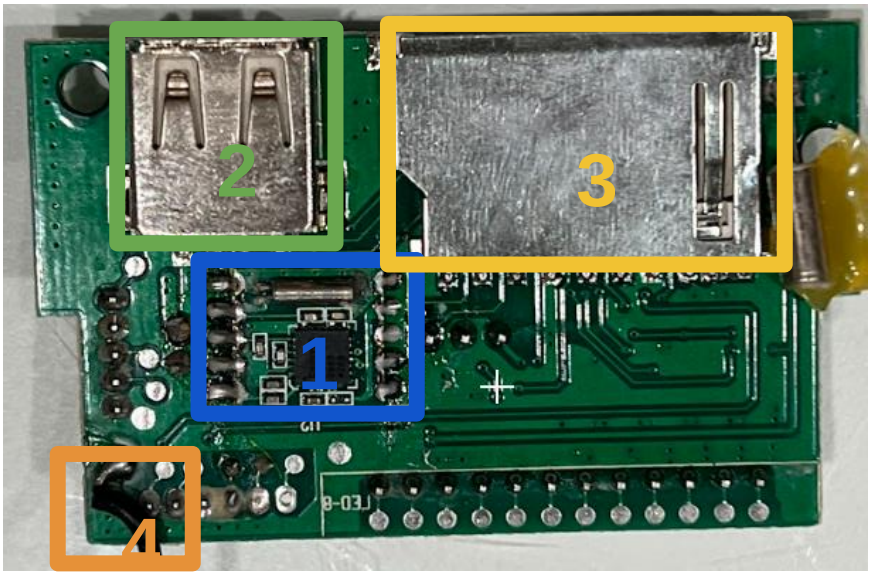
Atmlh910 Eeprom

An EEPROM(electrically erasable programmable read-only memory) is a memory chip that can have code added and erased using pulses. The EEPROM is a flash drive and is much harder to change or erase and can't store as much information. Right now, we don't use them because flash drives are more efficient and cheaper too. It is used to store all the main codes for the Portable Media Speaker MD-96.

Sockets

The sockets on Circuit Board 1 are used for connecting to other components or modules (7-segment display, IR receiver, Circuit Board 2, and button board) by wiring cables.

Main Circuit Board -back end



1	2	3	4
CL5757P FM Radio Module	USB socket	SD socket	Black wire

CL5757P FM Radio Module

Single-chip FM Stereo Radio with fully integrated digital low-IF selectivity and demodulation. The radio can tune to worldwide FM bands 70 to 108 MHz meaning a million cycles per second.

A CL5767P chip is an FM stereo radio IC that is designed to process and receive FM. Frequency modulation. These ICs are often used in portable radios, car stereos, and home audio systems.

USB socket

USB connectors connect through soldered connections. The USB connector has metal pins that pass through corresponding holes on the circuit board. These pins are then soldered to the copper traces on the board, making a secure connection.

SD socket

Secure Digital, more often abbreviated as SD connectors also connect to a circuit board through soldered connections. The SD card slot has metal contacts that align with pads on the circuit board. These contacts are soldered to the board, making the transfer of data easier between the SD and circuit board.

Users can insert a flash drive with audio files (like MP3, WAV) into a USB socket or an SD card with audio files (like MP3, WAV) into an SD socket and the Portable Media Speaker MD-96 reads the audio file and using the inside components, it sends out the signals as sound through the speakers.

Module 2

Outside

1	2	3	4
On/Off switch	DC5V	Line in	Antenna

On/Off switch

In every electronic device, for it to function, the electricity must travel in a loop. When the switch is turned on, the switch completes the circuit and when the switch is off, it cuts off the circuit, which doesn't allow the electricity to go in a loop causing it to turn off.

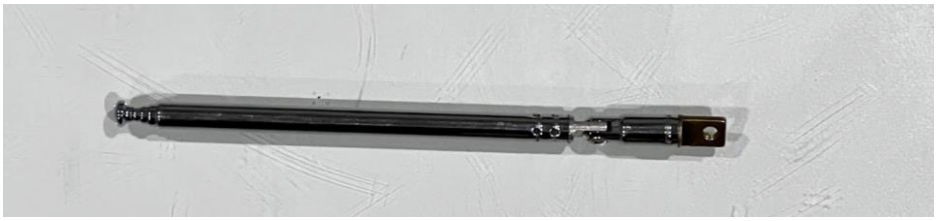
DC5V

These two circular ports are called DCV5. It is called this because it means the device requires 5 volts to operate. This is supplied by an external plug or device if the wire is circular and fits into the port.

Line in

On the boarding platform, there is a circular port for an external device to be plugged into. This would be used for recording audio from the MP3 player or transferring audio from an external device. This allows us to store audio content.

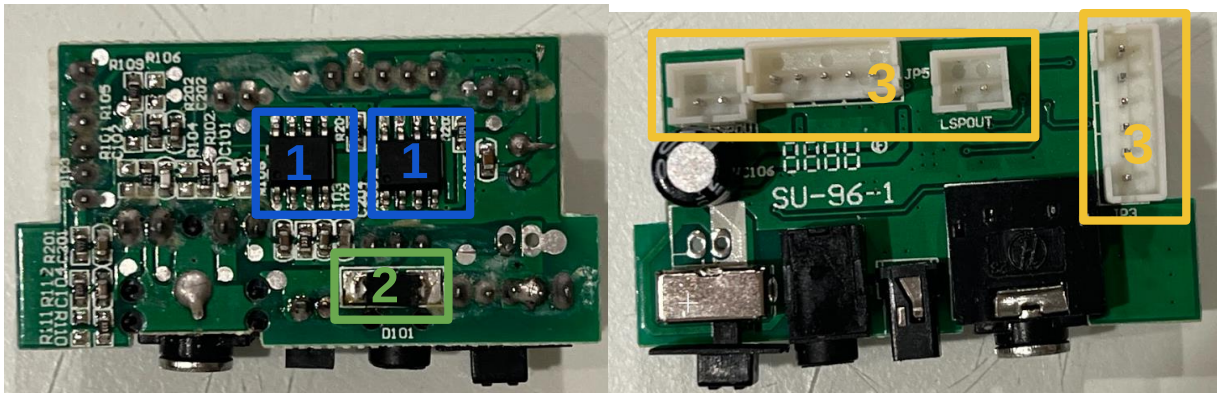
Antenna



Antennas convert voltage from a transmitter into a radio signal. They also pick radio signals out of the air to convert them into a voltage. Antennas are important on radios as they maintain a stable and reliable radio connection. The antenna at the transmitter generates a radio wave. A radio wave is a magnetic field at a right angle next to an electric field. The material is copper or aluminum because they have the best conductivity. The antenna is on the radio because it is good at maintaining a stable and reliable radio connection.

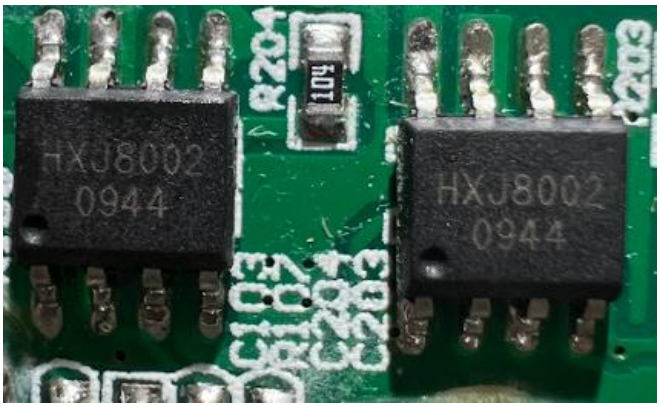
Circuit Board 2

This module does all the things that are power-related: the power supply and amplifier.

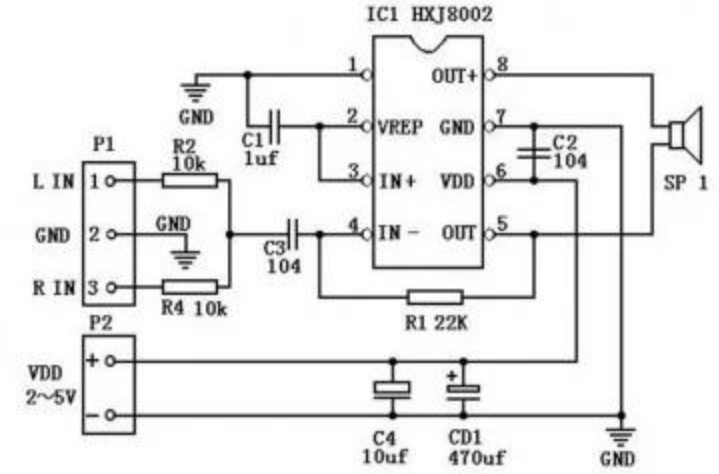


1	2	3
HXJ8002 chip	SS14 Schottky diode	sockets

HXJ8002 Chip



The HXJ8002 chip is a single channel 3W, BTL(bridge-tied load) audio power amplifier. It can operate at 5V and 3 amps load. It is specially designed for providing high-power, high-fidelity audio output. It saves board space and works under low voltage. It does not require coupling capacitors or buffers.



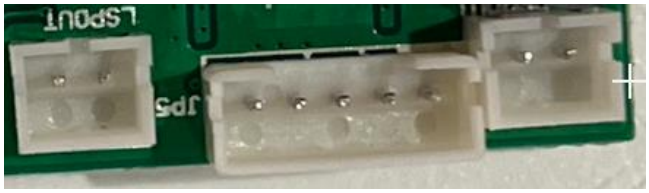
HXJ8002 layout diagram

There are two HXJ8002 on Circuit Board 2 and each HXJ8002 chip is used for one side speaker and 2 chips can make a stereophonic sound.

SS14 Schottky diode

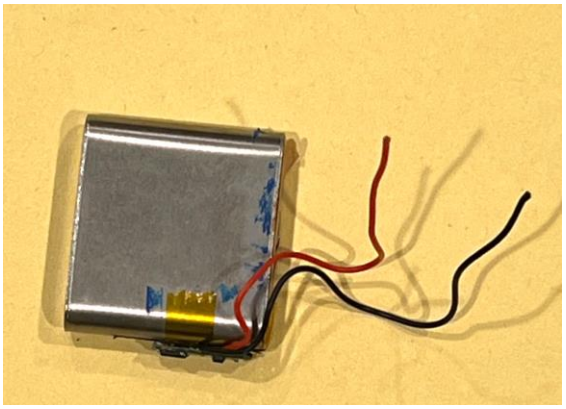
It is a semiconductor diode formed by the junction of a semiconductor with a metal. It has a low forward voltage drop and a very fast switching action. The main function of the SS14 Schottky diode is to protect the circuit in case someone accidentally connects the power to the socket backward.

Sockets



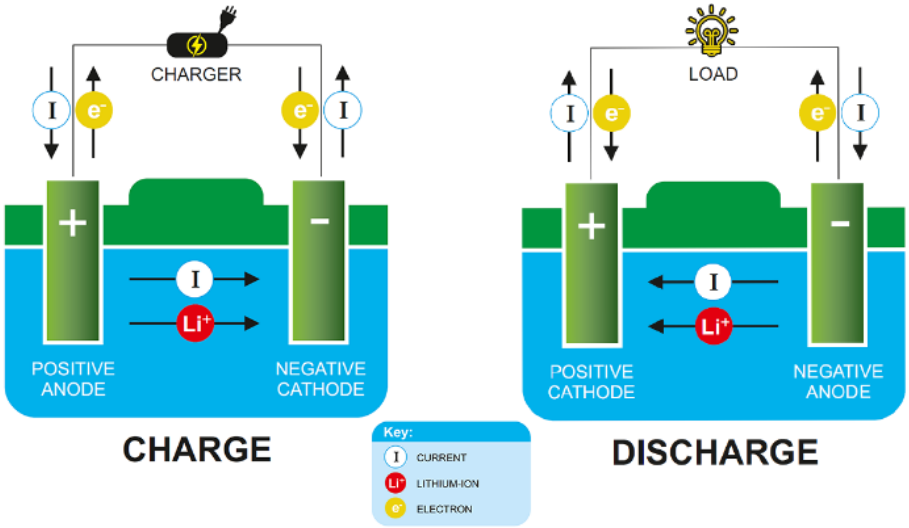
The sockets on Circuit Board 2 are used for connecting to other components or modules (Variable Resistor, 2 speakers, Circuit Board 1) by wiring cables.

Li-ion(Lithium-ion) battery



A battery is made up of anode, cathode, separator, electrolyte, and two positive/negative current collectors. The lithium is stored in the anode and cathode. When the battery is discharging and providing an electric current, the anode releases lithium ions to the cathode, generating a flow of electrons. When plugging in the device, the complete opposite happens and lithium ions are released from the cathode to the anode. Materials like germanium, silicon, and antimony react with Lithium ions to form alloys. To fully recharge the battery, it needs 5 volts of direct current. The output ranges from 4.2V when completely charged to 3.7V. The lithium battery was chosen for the radio because it has the lowest density and it also has the greatest electrochemical potential.

When the battery charges, lithium ions (positive) go through the thin porous membrane into the other side while the electrodes from the wire you plug it in go to the anode which is how the battery charges up itself. When you waste the battery, because the electrode is still in the cathode and the elements aren't to balance out, the protons go back to the cathode through the membrane to join with their original electron.



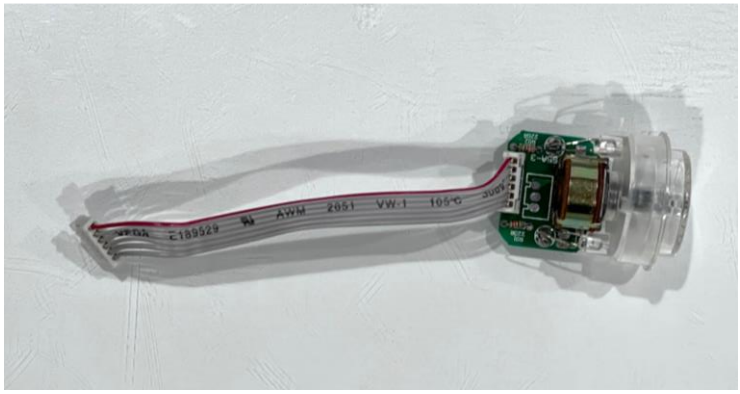
Battery Management System

The battery management system on this battery uses a 9205 battery management IC which supplies a Voltage of 4.25 to 6.5 V and a charge Current of 0.05 to 0.9 A. Lithium-ion batteries can be very hazardous if not designed and manufactured correctly. The reason behind this is that lithium-ion batteries contain very flammable electrolytes. Lithium-ion batteries can explode and can also go up in flames. A battery management system is an electronic system that manages a rechargeable battery. It manages the battery in many ways. It stops the battery from operating in a dangerous operation area. Not only does it monitor the state of the battery, but it also controls and balances it. It will tell the battery to stop charging when it reaches 100% and if it is anything lower, it will tell the battery to charge. The battery management system transfers the energy from one cell to another to balance the cells. This guarantees that they will all run at the same voltage. Without battery management systems, lithium-ion batteries would be very dangerous. Lithium-ion batteries rely a lot on a battery management system, and lithium-ion batteries would have no use without a battery management system.

IR Receiver (Infrared Receiver) with LED

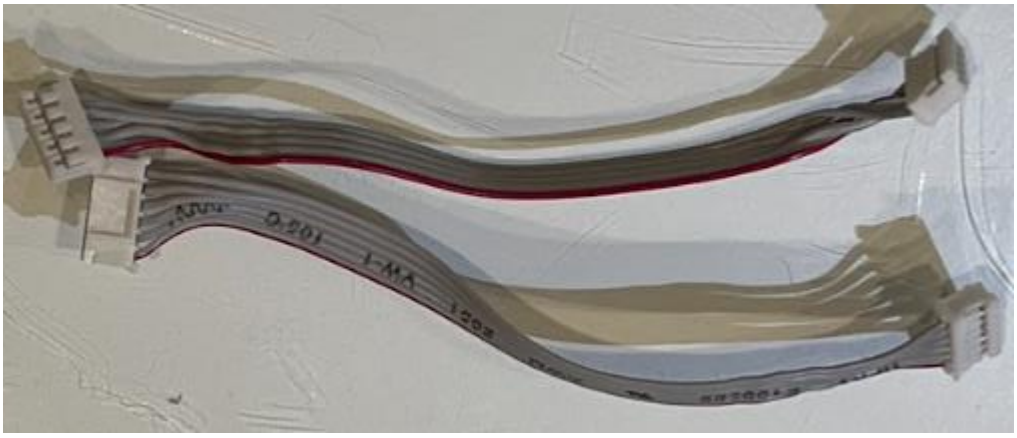
An Infrared Receiver is the hardware that can pick up infrared signals. It is also responsible for detecting and decoding signals. Ir Receivers need to be where you desire because they require line-of-sight transmission. The material would most likely be silicon because it transmits IR, but not visible light. The IR receiver is on the radio because of its ability to receive data signals and suppress all other sources of noise.

Variable Resistor with LED



Variable resistors adjust the value of current or voltage. The resistance of variable resistors can be set to a certain value. It allows you to change the voltage by changing the resistance and keeping the current constant. The variable resistor material can be a metal sheet, metal wire, carbon film, or conductive liquid. The variable resistor is on the radio because of its ability to adjust both the value of a current and voltage.

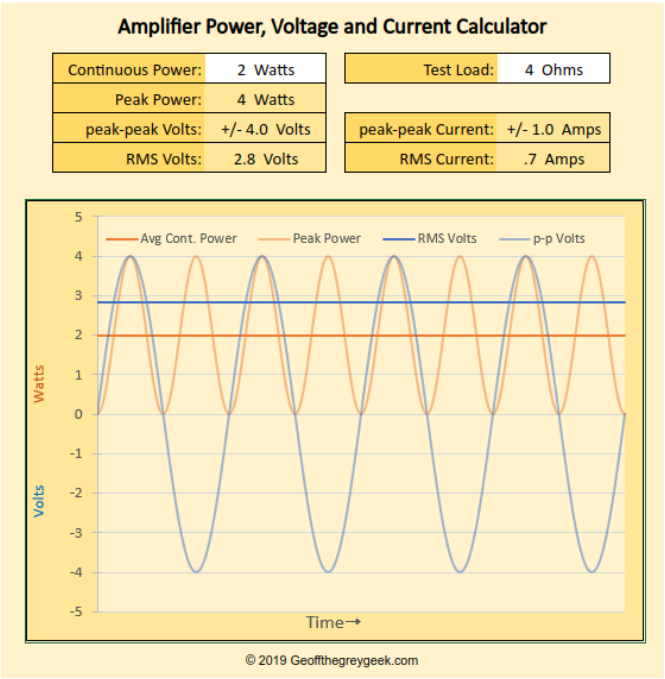
Wiring



The wiring on this Portable Media Speaker MD-96 involves connecting various components to a circuit board. Components like the battery, display, buttons, audio jack, antenna, and battery. The wiring ensures that these elements are interconnected. This is made through soldered joints or connectors, allowing electrical signals to flow.

Deeper analysis

Speaker

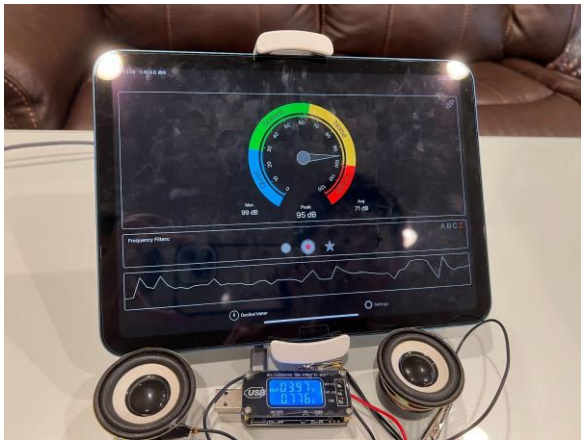


Our research on how many volts

To conduct this experiment, we first need to know how many volts we could put into the speaker with a speaker voltage calculator entering the number of watts and ohms on the speaker. We are going to do an experiment where we see how many decibels each volt we add on.

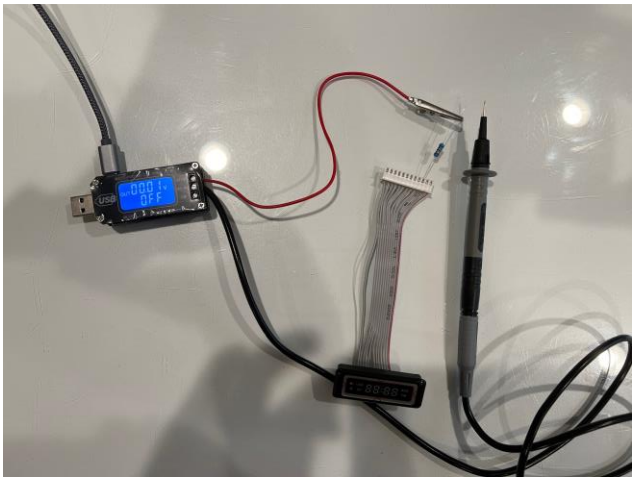
Material	Steps
Alligator clip wires Crimp-On Wire Connectors Electrical tape USB regulator module power supply	Connect wires to the two speakers Connect them with more wires Connect the wires to the power supply

The more volts we give to the speakers, the louder the sound and the higher the decibel number. We put the microphone right next to (in-between) the two speakers giving it a higher decibel, equivalent to putting it next to your ear.

	
1. With 1 volt, the decibel number was 66	2. With 2 volts, the decibel number was 76
	
3. With 3 volts, the decibel number was 82	4. With 4 volts, the decibel number was 95

We learned that the higher the voltage you give the speakers, the louder the sound with an average of 7.25 decibels higher by each volt. The higher the pitch, the more times the speaker has to move back and forth.

7-segment display

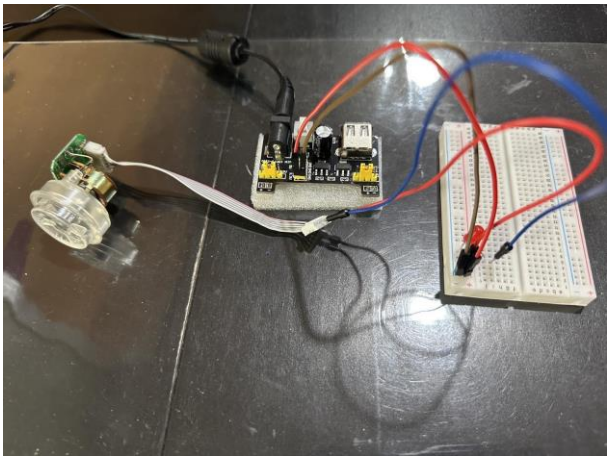


We want to find out if our 7-segment Display uses a common cathode(ground) or a common anode, and what pin connects to which LED and number. If we want to test which pin is which, we would first have to solve for the common anode or cathode. To test that we would have to connect one of the wires onto pins 1 and 12 with the side with the red wire 1. To test if it had a common cathode, we would need to connect the black wire(ground) to 1 and the red wire(voltage) to 12 to see if it lights, if so, the 7-segment display has a common cathode, if not it has a common anode. In our case, it didn't light so ours has a common anode but to double-check, we swapped the wires and it lighted. So now we know that our 7-segment LED display uses a common anode. Curiously, when we tested it our first digit on the display lit up so are pins 1-5 digits one through five? Well, in theory, it should be, our display is just formatted like that. The first five pins are for the digits and the rest are the 7 segments A-G, but we would have to test it out.

We learned that our 7-segment display uses a common anode where you give the voltage to digits 1-5 and ground to A -G (6-12) pins. Another thing we learned is that the display uses persistence of vision because we can't make the display show 4 different numbers at once.

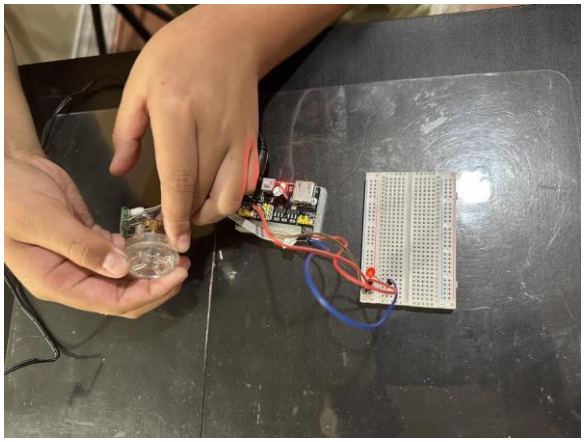
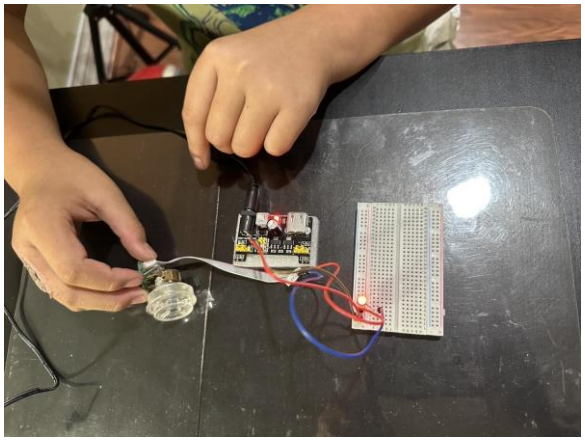
	
1. According to our theory, if we connect our voltage to pin 3, and pin 12, A on number 3 would light	2. If we tried pin 11 it would be B on the number
	
3. If we tried pin 9 it would be D on number 3	

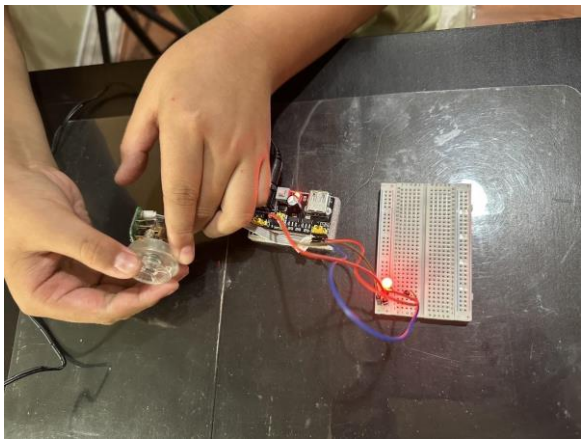
Variable Resistor



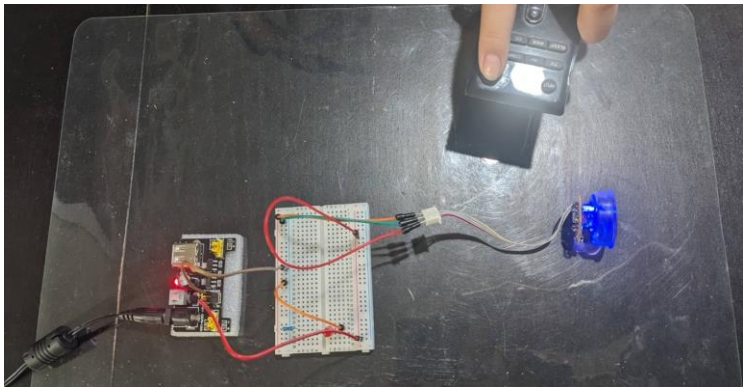
We wanted to find out if a variable resistor could adjust other things besides volume. We decided to test to see if it could change the brightness of a small lightbulb. We connected it to the wiring board and we connected the wiring board to more circuits.

We learned that their receiver could not only change how loud the speakers were, but it could also adjust the brightness of a light.

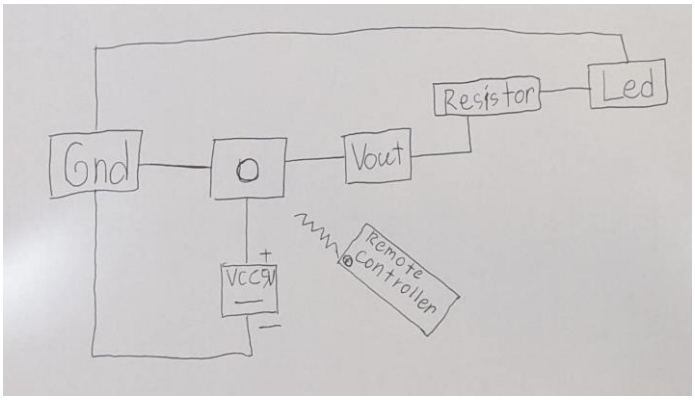
	
1. If we turn to the left, it becomes dimmer and this is the dimmest it can become.	2. When we turn it on, this is the original brightness

	
3. When we turn to the right, it becomes brighter and this is the brightest it can be	

IR Receiver



We wanted to find out if an IR receiver could get signals from remotes. We also wanted to see if it could make an LED light up. We connected the IR receiver to multiple wires which connected to the breadboard. The components we used were an IR receiver, remote controller, breadboard, and a circuit board that contains 5 volts of power supply.



Block diagram

The Vcc has 5 voltages of power supply. There is also ground which makes it so that it goes in a loop. The VCC power goes through the IR receiver to make it work. Then we also clicked a button on the remote controller to make the IR receiver send a signal from Vout. Then it goes to the resistor. Eventually, it will end up with an LED lighting up.

1. The red wire is the Vcc wire 5V
2. The orange wire is the Vout wire
3. The green wires are both ground wires
   (The three wires that we are talking about are connected to the IR receiver.)

Sadly, the LED didn't light up because the IR receiver was defective.

Conclusion

In conclusion, we learned many things like time management, team chemistry, research, and how to do experiments. We worked as a team to find out what each piece was, how it worked, and what purpose it had on the Portable Media Speaker MD-96. We did many experiments on a few pieces from the Portable Media Speaker MD-96. We did a test on the IR receiver, 7-segment display, speaker, and variable resistor. We did all our research promptly and we used the right information for each thing. We were patient while doing reverse engineering and we were patient even if it didn't work after multiple attempts. We learned to take apart things strategically and carefully. That allowed us to separate every single piece without breaking anything that wasn't already broken. This provided a very fun and educational experience for all of us. We were satisfied with what we did and all our accomplishments along the way. All of these lessons connect to us because they show all of the lessons we learned on our journey to finishing reverse engineering. Another reason why all these lessons can connect to us is because these lessons give all of us new skills and new knowledge.

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