Open Playback Recorder
DESIGN RATIONALE

Introduction

The Open Playback Recorder is an open-source device that can record three lists of voice messages that its user can playback via the trigger of an accessible button connected through a 3.5 mm mono jack. It aims to assist users with communication difficulties by giving them alternative methods to engage in conversation. This device has functionality similar to AbleNet's Big Mack or Step by Step.

Research

Commercial Products

Big Mack

The Big Mack is an audio recording and playback device that costs between $150 and $200. It can record a message with a maximum length of two minutes via the trigger of a record button. The stored message can then be played back after the trigger of a large accessible button. It has adjustable volume and is battery powered by a 9V battery.

Message from AbleNet (ablenetinc.com)

Message storage procedure (From AbleNet):

1. Ensure you've properly installed a 9V Alkaline battery into your device
2. Turn the device on
3. Press and hold the Record Switch until the LED lights up solid Red, then release the switch
4. Press and hold down the main switch top of your device. You will see the LED flashes Red when recording.
5. Speak your message into the communication device, then release the switch top to complete the recording
6. When finished, press the Record Switch one time to exit record mode

Button size: ~12 cm diameter

Little Mack: Little Mack = ~6 cm

Big Step by Step

Costing between around $220, the Big Step by Step is a similar product to the Big Mack with two additional features. This device can record a sequential list of messages with a maximum total length of four minutes. Each message in the list is played one by one for each press of the playback button. The second feature included is a 3-level switch where each level stores a unique list of messages.

BIG Step-by-Step (ablenetinc.com)

Message Recording Procedure (From AbleNet)

1. Add one alkaline 9-volt battery to device (battery not included).
2. Turn device on.
3. Select desired level.
4. Press and hold record button until recording indicator light turns on.
5. Press and hold colored switch top. Begin speaking into microphone after you hear beep.
6. When done recording message, release colored switch top.
7. Repeat steps 5 and 6 to record additional messages.
8. Press the record button to turn the recording indicator light off.
9. Optional: Select a different recording level to record a second and third set of messages.
10. Adjust volume as needed.
11. Your device is ready to use.

Little Mack Options

Both styles of the Big Mack are also offered in smaller sizes for a similar cost.

https://www.spectronics.com.au/product/littlemack-communicator-enhanced

https://www.spectronics.com.au/product/little-step-by-step-communicator-with-levels-enhanced

Pet Training Button

There are a series of audio playback buttons designed for the use of trained pets. They are inexpensive, costing between $10 to $40 with the drawback of back functionality. They can record and store a single message with a maximum length of 10 to 30 seconds. Stored messages are played back via the trigger of a small button and has no volume control.

Neutral Record Talking Button : Amazon.ca: Office Products

DIY Projects

Project	Demonstrates	Link
Arduino Spy Bug	• Using Micro SD Modules with Arduino • Using microphone • Saving WAV files onto a micro-SD card	Make Your Own Spy Bug (Arduino Voice Recorder) : 5 Steps (with Pictures) - Instructables
Arduino Spy Bug Remix	• Similar Project • Different micro controller	Simple Arduino Voice Recorder for Spy Bug Voice Recording (circuitdigest.com)
Arduino Audio Player	• Audio Amp • Playing WAV files	Audio Player Using Arduino With Micro SD Card : 7 Steps (with Pictures) - Instructables

Arduino Mp3 Player	• Similar project to Arduino Audio Player	Arduino Mp3 Player : 5 Steps - Instructables
SD Card Experiments	• Using SD card modules with Arduino • Applications of SD cards	SD Card Experiments with Arduino | DroneBot Workshop

Requirements

Goals

G01	Record and store a message with a minimum allowable record time of 4 minutes
G02	Play stored message after trigger of an accessible button
G03	Adjustable playback volume with maximum level loud enough to be heard within a room

Functional Requirements

F01	Total print time under 24 hours
F02	Battery powered with easily obtainable batteries
F03	Ability to be trigger by an external switch via a 3.5 mm mono cable

Non-functional Requirement

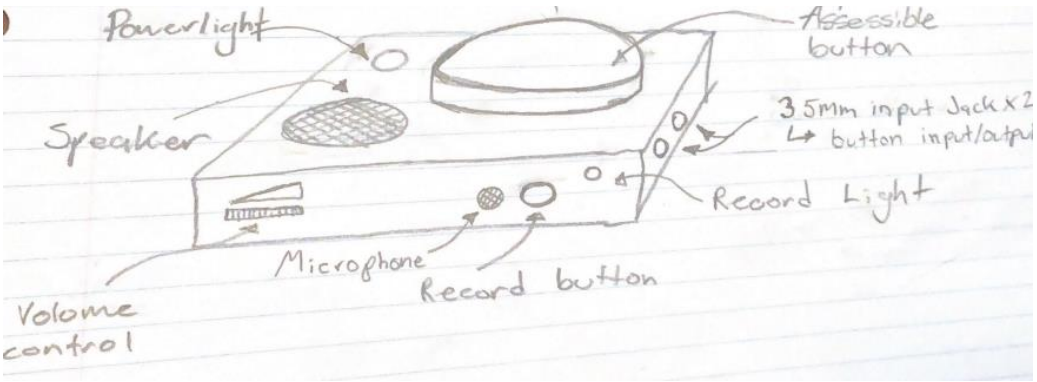
NF01	Exchangeable button cap designs for different needs of the user.
NF02	Capable of interconnecting additional Open Playback Buttons
NF03	Easy access to batteries for exchanging them.
NF04	Must be easily cleaned

Constraints

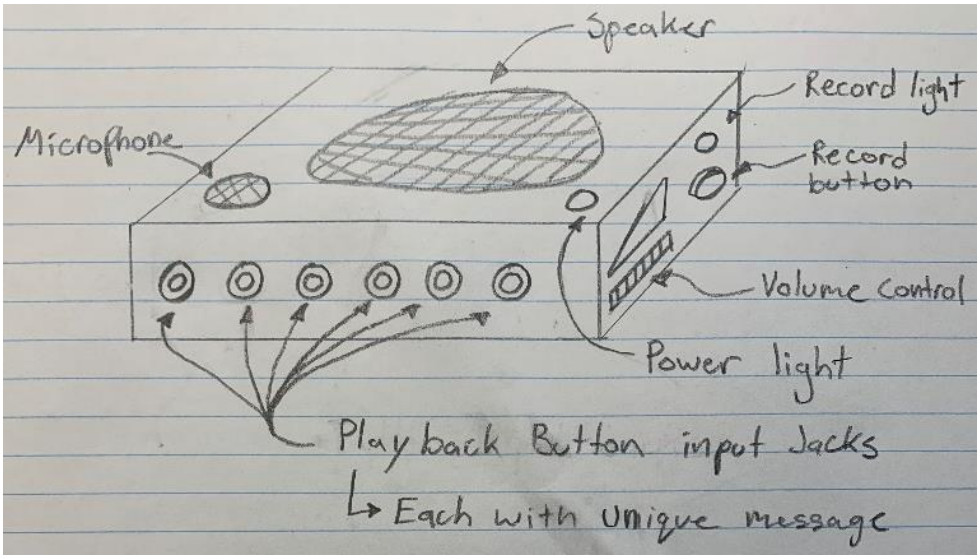
C01	Capable of being constructed using basic maker tools.

Ideation

Idea #1: Basic concept with necessary components.



Idea #2: Modular design utilizing external switches.



Instead of fitting all the electronics inside a large button, another idea could be to have a single unit to handle message recording and playback. An array of external buttons could then be plugged into one or many of the 3.5 mm input jacks. Each button would control its own message or sequential list of messages. This would allow for more space to fit larger speakers and electronics. The large assessable button would become its own device to be designed.

Conceptual Design

Options for Audio Recording and Playback

Option 1: Use of Voice Record and Playback Module

System	Possible Product	Notes:	Cost
Voice Record and Playback	SEN0197 DFRobot | Development Boards, Kits, Programmers | DigiKey	SEN0197 • 10s Record time • Connects easily with Arduino	~$10
	NC-ISD1620B Nuvoton Technology Corporation | Development Boards, Kits, Programmers | DigiKey	NC-ISD1620B • Single message • 6.6s to 40s record time	~$10
	107020007 Seeed Technology Co., Ltd | Development Boards, Kits, Programmers | DigiKey	Grove – Recorder V2.) • Volume control • 8Ω/2W Speaker • 8s to 20s record time	~$10
Overall Notes	These modules are simple and easy to use while remaining inexpensive but may be to limiting functionally. As part of the requirements for this project, 4 minutes of record time is needed but these modules are intended for much shorter recordings.		**Total** ~$30

Option 2: Use of Micro SD Storage

System	Component	Possible Product	Notes:	Cost
Controller	Arduino Micro	A000053 Arduino | Development Boards, Kits, Programmers | DigiKey	Cheaper options?	~$25
Audio Playback	Audio Amplifier Module	2130 Adafruit | Mouser Canada	Pam8302A: • Mono sound • Shut off capabilities	~$6
	Speaker	3351 Adafruit | Mouser Canada	3W 4 Ohm, 2.8" x 1.2" • Easy to mount • Recommended for Pam8302A or MAX98357A	~$6
	Potentiometer: Volume Control	3395 Adafruit | Mouser Canada	• 10K • Includes switch for on/off • Clicks in off position	~$2
Audio Recording/ Storage	Micro Sd Reader:	254 Adafruit | Mouser Canada	Built in 3v-5v regulator	~$10
	Micro Sd Card: Message Storage	COM-15107 SparkFun | Mouser Canada	1GB but many size options	~$10
	Mic with Amp	1713 Adafruit | Mouser Canada		~$10
Overall Notes	There is an added cost and complexity to using an SD card for storage. This solution requires an SD card module, SD card, audio recording module and must use a micro controller. However, this concept allows the full control of functionality. It will be possible to add modes for multiple message capabilities, i.e.: Big Mack mode, step by step mode, voice repeat mode, etc. Almost no limit on record time.			**Total** ~70

Playing Audio Files

Recording and Playing Audio with Wav Files

For the Arduino use wav files for audio recording and playback, the TMRpcm library must be downloaded and used. This library is capable of reading wav files off an SD card and outputting the audio signal through a selected port on the Arduino. It must be noted that by default, the audio recording capabilities are disabled. To enable these features, the library configurations must be edited.

In the file pcmConfig.h file, there are two sections that must be edited:

In the General User Defines section, the "//#define buffSize 128" line of code must be uncommented by removing the "//" from in front.

In the Advanced User Defines section, at the bottom, lines "//#define ENABLE_RECORDING" and "//#define BLOCK_COUNT 10000UL" must also be uncommented.

Using Audacity to Add Sound Indicators

Audacity is a program that can be used to create audio files. If these files are going to be played from the Arduino using the TMRpcm library, the files must be created and saved correctly.

Step 1.

At the bottom right corner, select **Project Rate (Hz)**, and set to **3200, 22050, 16000, or 11025**

Note: 16000 Hz is the default sample rate for the TMRpcm library.

Step 2.

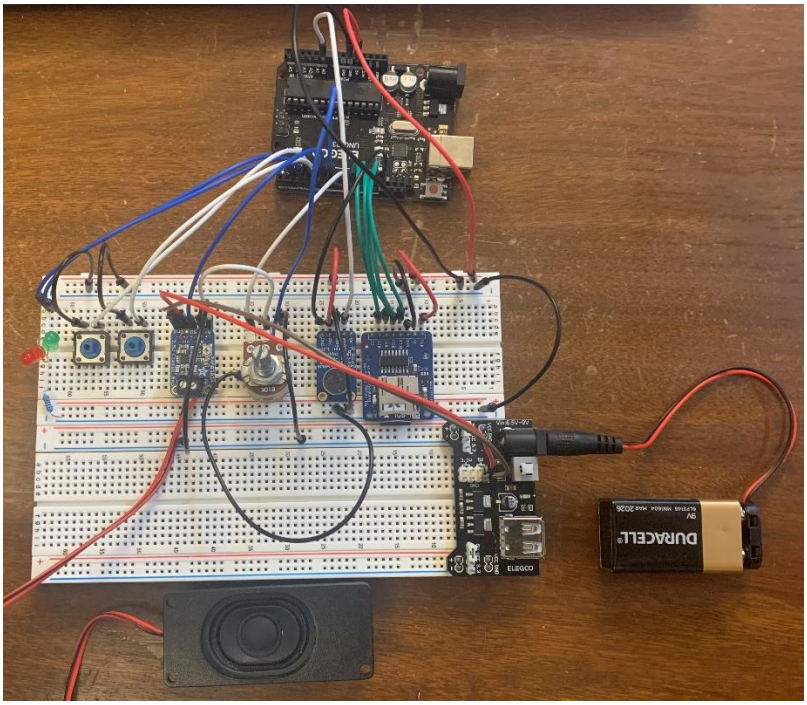
At the top of the screen, click **Tracks** -> **Add New** -> and select **Mono Track**. Create one or more of the mono tracks to create the sound file

Step 3.

Once the sound is complete, click **File** -> **Export** -> **Export Audio…** -> save as type: **Other uncompressed files**, Header: **WAV**, Encoding: **Signed 8-bit PCM**

The audio file can now be saved and added to the device Micro SD card to be used by the TMRpcm library.

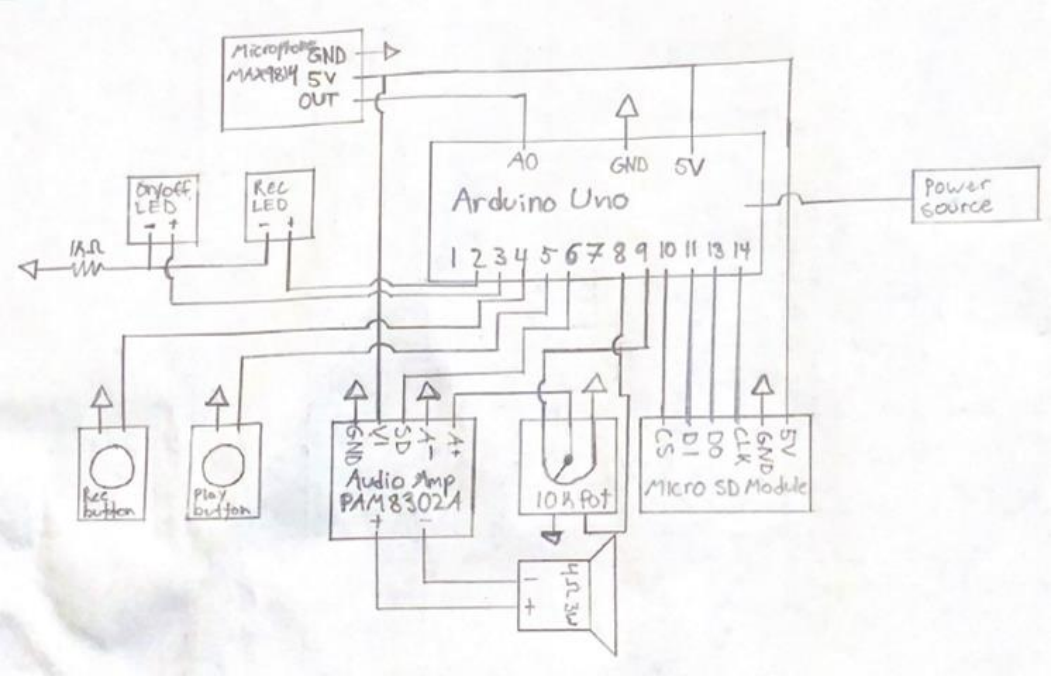
V0.1 Proof-of-Concept Prototype



POC Components

System	Component	Possible Product	Notes:
Controller	Micro Controller	Arduino Uno	Cheaper options?
Audio Playback	Audio Amplifier Module	2130 Adafruit | Mouser Canada	Pam8302A: • Mono sound • Shut off capabilities
	Speaker	3351 Adafruit | Mouser Canada	3W 4 Ohm, 2.8" x 1.2" • Easy to mount. • Recommended for Pam8302A or MAX98357A
	Capacitor		Protect speaker amplifier input voltage. • For use with PAM8302A 0.1uF to 0.22uF is ideal • low leakage tantalum or ceramic capacitor is the best choice
	Potentiometer: Volume Control	3395 Adafruit | Mouser Canada	• 10K Ohm • Includes switch for on/off. • Clicks in off position
Audio Recording/ Storage	Micro SD Reader:	254 Adafruit | Mouser Canada	• Built in 3v-5v regulator. • Connects to SPI pins
	Micro SD Card: Message Storage	COM-15107 SparkFun | Mouser Canada	1GB but many size options
	Mic with Amp	1713 Adafruit | Mouser Canada	
Basic Control	Playback Button	B3F-5050 Omron Electronics | Mouser Canada	Simple press button
	Record Button		
	Power/Play Light	LTL2R3KGD-EM Lite-On | Mouser Canada	Simple red and green LED's
	Record Light	LTL2R3KRD-EM Lite-On | Mouser Canada	

POC Wiring Diagram



POC Device Functionality

Controls: **Playback Button:** play button for primary user

Record Button: small button for secondary user

Volume Knob: small dial for secondary user

Indicators: **Power/Playback light:** Green LED

Record light: Red LED

Functionality: **Power On/Off:** small dial for secondary user.

- Turn volume knob past minimum to power on device.
  - Power light turns on.
  - Turning the dial controls the volume output.
- Clicking the dial into the minimum position turns the device off.
  - All lights turn off.

Record Mode: Accessed via record button.

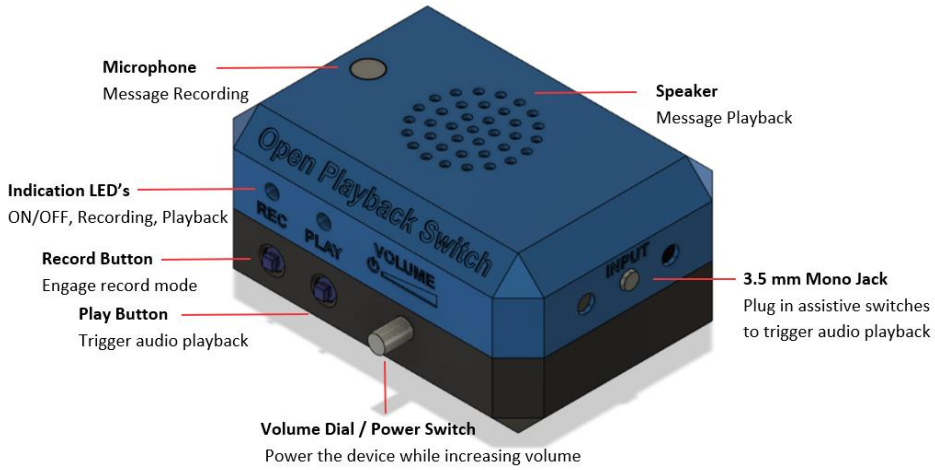
- Hold *Record Button* for 2 seconds to engage record mode
  - Messages in storage are deleted.
  - Record light turns on.

- Press and hold *Playback Button* to record a message.
    - Record light flashes during recording.

Message Playback: Accessed via play button.

- Press playback button to play message.
    - Each trigger plays next message in queue.
    - Goes back to first message after last message in queue is played.

V0.2 MVP Design

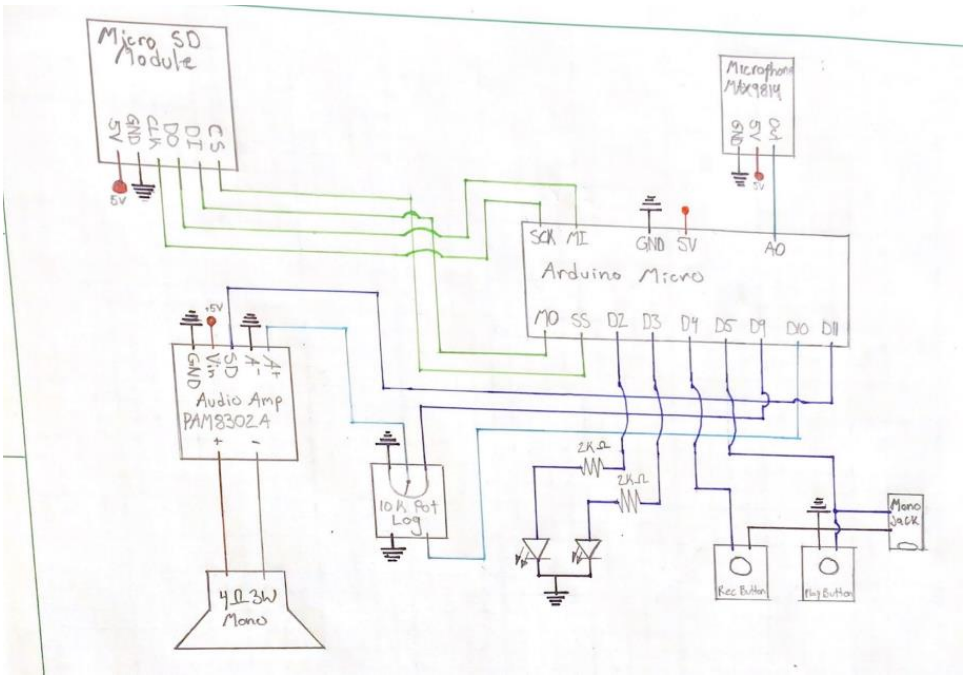


MVP Components

Component	Cost	Link
Micro Controller (Arduino Micro)	$30.50	A000093 Arduino | Mouser Canada
Audio Amplifier (Pam8302)	$5.45	2130 Adafruit | Mouser Canada
Mono Speaker (4Ω 3W)	$5.45	3351 Adafruit | Mouser Canada
Potentiometer with Switch (Log)	$2.07	3481 Adafruit | Mouser Canada
Micro SD Reader	$10.35	254 Adafruit | Mouser Canada
Micro SD Card	$9.49	COM-15107 SparkFun | Mouser Canada
Microphone (MAX9814)	$10.97	1713 Adafruit | Mouser Canada

Buttons (B3F-5050)	$1.52	B3F-5050 Omron Electronics | Mouser Canada
3.5 mm Mono Jack	$1.95	35RAPC2AV Switchcraft | Mouser Canada
Green LED (5 mm)	$0.44	LTL2R3KGD-EM Lite-On | Mouser Canada
Red LED (5 mm)	$0.44	LTL2R3KRD-EM Lite-On | Mouser Canada
Resistor (1k Ω)	$0.66	MBA02040C1001FRP00 Vishay / Beyschlag | Mouser Canada
Proto Half Breadboard	$6.21	1609 Adafruit | Mouser Canada
Male Through Hole Header	$0.80	https://www.mouser.ca/ProductDetail/910-HDR100IMP40MGVTH
Female Through Hole Header	$3.80	HDR100IMP40F-G-V-TH Chip Quik | Mouser Canada
Notes:	The MVP device uses many of the same electrical components as the POV. The key differences are: • A logarithmic potentiometer is used for increased volume control. • An Arduino Micro is used to decrease the size. • A mono jack is wired in parallel to the Play Button. • Electrical components are soldered to a protoboard. • Powered by a 9V battery in series with the power switch.	

MVP Wiring Diagram



Feature Set

- Modular (i.e., standalone)

The MVP will be a modular device intended to be used with external switches connected to a 3.5 mm mono jack

User Controls

- Input Jack
- Playback / Test Button
- Recording Button
- Volume Knob
    - Integrated power control

Indicators

- PLAY LED
    - Green LED
    - Turns on while device is on
    - Flashes during message playback
- REC LED
    - Red LED
    - Turns on while in record mode
    - Flashes during message recording

Operating the device

Power On/Off

- Turn volume knob fully counterclockwise until it clicks to turn off device
- Turn

Record Mode

- Hold Record Button for 2 seconds to engage record mode
    - Messages in storage are deleted
    - Record light turns on
    - Press and hold *Playback Button* to record a message
        - Record light flashes during recording

Message Playback

- Press playback button to play message
    - Each trigger plays next message in queue
    - Goes back to first message after last message in queue is played.

Testing

Recording is great; tricky to replace batteries

One box, multiple switches

Grandview testing

“The recorder is great! It was a bit tricky changing the battery because of all the wires and the challenge of not being able to open it all the way, but the sound quality and volume adjustment and general use are really easy!

It would be really neat to have one box where you could plug in two switches for different messages but that would probably be way more complicated.

“It's such a great device!!!!”

Opportunities for Improvement

1. Battery cover for easy replacement.
2. Separate power/volume control switches.
3. Volume knob for volume potentiometer.
4. Multiple input jacks.
5. ¼”-20 mount

V0.3 Design

Component Considerations

To reduce cost, complexity, and meet some of the opportunities for improvement from the MVP, the following components will be investigated to determine if there are more suitable options:

- Micro Controller
- Microphone
- SD Card Reader
- SD Card
- Audio Amplifier
- Speaker
- LED Indicators
- Volume Potentiometer
- 3-way switch
- On/off switch

Microcontroller Options

Possible Product	Cost	Power Output	Input Voltage	Notes:
Arduino Micro (Used with MVP)	~$30	2.7 – 5.5V	7 – 12V	Convenient choice while prototyping but not necessarily the best choice based on the price.
Adafruit Feather Adalogger	~30	3.3V Only	5V USB or 4.2/3.7V Lipo	This board is being considered due to its integrated MicroSD reader. This saves the cost and complexity of wiring an external SD reader to the protoboard. However, this board can only output 3.3V which is not enough for the audio amplifier, which will result in an added cost to properly power it.
Arduino Nano	~$22.00	5V	6 – 20V	Similar to the Micro. Will work for this project.
Seeeduino Nano	~$10.50	5V	6 – 20V	This inexpensive board has the identical pinouts to the Arduino Nano and should be compatible with all other components.
QT PY SAMD 21	~10.50	3.3 – 5V	5V	There are a series of small microcontroller like this one from $5 - $15. This could help reduce the size of the device but does not have enough I/O pins.
Final Selection	As the **Seeeduino Nano** is the most similar and inexpensive microcontroller considered, it will be the board used for this final version.			

Microphone Options

Possible Product	Cost	Input Voltage	Impedance	Notes:
MAX9814 (Used with MVP)	~$11.00	2.7 – 5.5V		Includes amp. Automatic gain control
MAX4466	~$10.50	2.4 – 5V		Includes amp. Fixed gain
Final Selection	Both microphones include an amplifier and gain control at a very similar price. We will proceed with the **MAX9814** as it worked well with the MVP and performs well with noisy backgrounds.			

Micro SD Card Reader Options

Possible Product	Cost	Power Input	Interface Type	Notes:
Adafruit 254 Micro SD Board (Used with MVP)	~$10.50	3.3V or 5V	SPI or SDIO	
Adafruit 4682 Micro SD Board	~$4.00	3.3V Only	SPI or SDIO	Won't work with current micro controller directly
SparkFun DEV-13743	~$8.00	5V Only	SPI	
SparkFun BOB-00544	~6.50	3.3V Only	SPI	Won't work with current micro controller directly
Final Selection:	Both boards that can operate using 5V are suitable for the final version. As the price difference between them is minimal, it will be best to proceed with the **Adafruit 254** version.			

Micro SD Card Options

Possible Product	Cost	Storage	Notes:
SparkFun COM-15107 (Used with MVP)	~$9.50	1GB	More storage than necessary
5249 Adafruit Micro SD	~$5.00	64Mb	
5250 Adafruit Micro SD	~$5.50	128Mb	Not stocked by Mouser
5251 Adafruit Micro SD	~$6.00	256Mb	Not Stocked by Mouser
5252 Adafruit Micro SD	~$7.00	512Mb	
Final Selection:	As message storage does not require much storage, the **64Mb option** still fits within the scope if this project and is the most inexpensive option.		

Audio Amplifier Options

Possible Product	Cost	Power	Impedance	Notes:
PAM8302 (Used with MVP)	~$5.50	2.5W	4Ohm	
Final Selection	This amplifier works very well for the current setup as it can operate using the microcontroller power output. If the max volume needs to be increased further, the entire audio output system will need to be upgraded, along with an external power supply. To reduce cost and complexity, we will proceed with the **PAM8402**.			

Speaker Options

Possible Product	Cost	Power	Impedance	Notes:
Adafruit Mono Enclosed (Used with MVP)	~$5.50	3W	4Ohm	Enclosed mono speaker
Adafruit Mono Cone	~$3.00	3W	4Ohm	3” round speaker
Final Selection	Both speakers considered are ideal for the audio amplifier selected. We well proceed with the **enclosed speaker** as it offers more directional sound output.			

LED Indicators

Possible Product	Cost	Colour	Size	Notes:
Dual LED’s (Used with MVP)	~$1 ($0.5 per)	1 red, 1 green	5 mm	Two LED’s: One for playback/power indication, and the other for record mode/message recording indication.
Bi Colour LED	~$1	Red/green	5 mm	Bi colour led that can turn green for message playback and red for recording.
Final Selection	To avoid confusion between the two LED’s and simplify the user interface, we will proceed with the **Bi colour LED**.			

Volume Potentiometer

Possible Product	Cost	Resistance	Taper	Notes:
Adafruit Audio Pot	$2.07	10KOhm	Log	Includes on/off switch for power
BI Tech Pot	$2.39	10KOhm	Audio	
Final Selection	We will not include integrated power control in the volume dial, therefore a on/off switch is not required.			

3-Position Switch

Possible Product	Cost	Switch Function	Type	Notes:
G-1328S-0000 CW Industries | Mouser Canada	$3.16	ON-ON-ON	Slide	Screw holes for easy mounting
S112032SS03Q C&K | Mouser Canada	$5.80	ON-OFF-ON	Slide	Screw holes for easy mounting
G-329L-0019 CW Industries | Mouser Canada	$2.44	ON-ON-ON	Slide	Screw holes for easy mounting. Single pole, triple throw.
Final Selection	We will use the **third** option considered. More information can be found page 17 of the following recourse: Standard Switch Catalog S2120II03.doc (cwind.com)			

On/Off Switch

Possible Product	Cost	Switch Function	Mount Style	Notes:
C1300ALAAA Bulgin | Mouser Canada	$1.95	ON-OFF	Snap In	
RA11131123 E-Switch | Mouser Canada	$0.93	ON-OFF	Snap In	Has ON and OFF written on the side for easy use.
Final Selection	We will use the **second** option.			

Component Selection

System	Component	Selected Product	Quantity	Cost	Notes
Controller	Micro Controller	Seeeduino Nano	1	$10.49	• Identical pinout to the Arduino Nano
Audio Playback	Audio Amplifier	PAM8302	1	$5.45	• 2.5W Class D
	Speaker	Adafruit Mono Enclosed	1	$5.45	• 3W 4Ohm enclosed mono speaker
Message Storage	Micro SD Reader	Adafruit MicroSD Reader	1	$10.35	• 3V/5V regulator • SPI
	Micro SD Card	Adafruit MicroSD Card	1	$4.83	• 64Mb
Message Recording	Microphone/Amplifier	MAX9814	1	$10.97	• Integrated amplifier and automatic gain control
User Inputs	Volume Control	10K Audio Pot	1	$2.13	• Log taper for audio control
	Play/Record Buttons	B3F-5050 Buttons	2	$1.52 ($0.76 per)	• Simple to solder and use • Easily mountable to enclosure

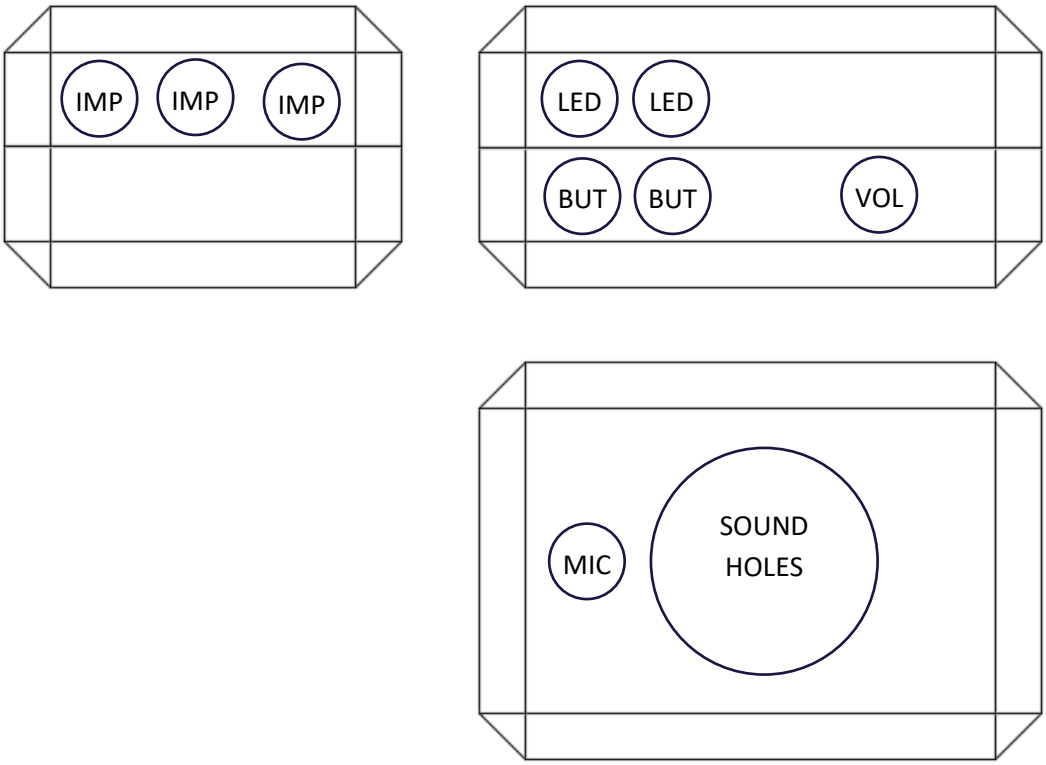
	Switch Inputs	3.5 mm Mono Jack	1	$2.13	• Standard for assistive switches • Threaded ring for easy mounting
	Power Control	On/Off Switch	1	$0.93	• Snap in rocker switch. • On/off labels
	Level Control	3 Position Switch	1	$2.44	• 3 position slide switch with detents
Visual Indicators	Play/Record Light	Bi Colour RG LED	1	$0.98	• Red / Green LED
Power Supply	9V Battery	Consumer 9V	1	$3.48	• Any standard 9V battery will work
	Battery Connector	9V Battery Clip	1	$1.79	• Simple clip for connecting the battery
Assembly	Protoboard	Proto Half Breadboard	1	$6.21	• Smallest size that can connect the micro controller, SD reader, and audio amp.
	Male Headers	Male Through Hole	2	$1.60 ($0.80 per)	• Used for micro controller, audio amp and SD card reader
	Female Headers	Female Through Hole	2	$3.80 ($1.90 per)	• Used for micro controller, audio amp and SD card reader.
	Resistors	2K ohm Resistor	2	$0.66 ($0.33 per)	• Any standard 9V battery will work
	Screws			$	
				$	
				$	

Enclosure Design

The enclosure requires the following features:

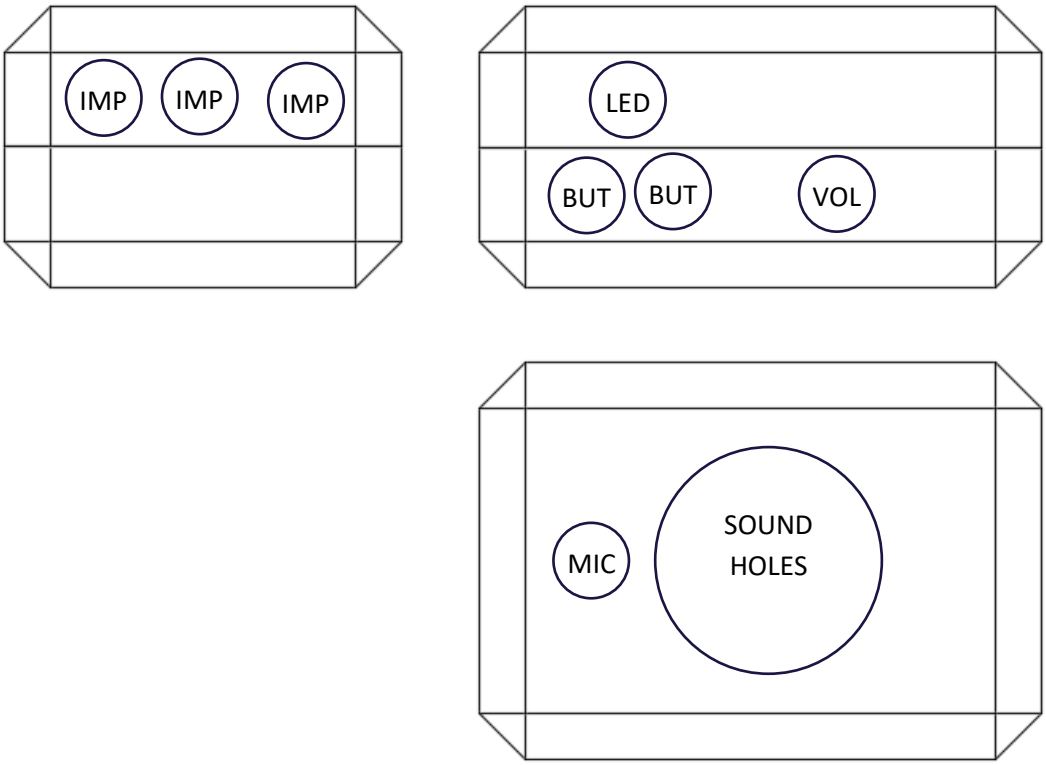
- Input Jack (IMP)
- LED
- 2X Button (BUT)
- Volume Potentiometer (VOL)
- Microphone (MIC)
- Speaker Holes
- On/Off Switch (PS)
- 3 Position Level Select Switch (LS)

MVP LAYOUT



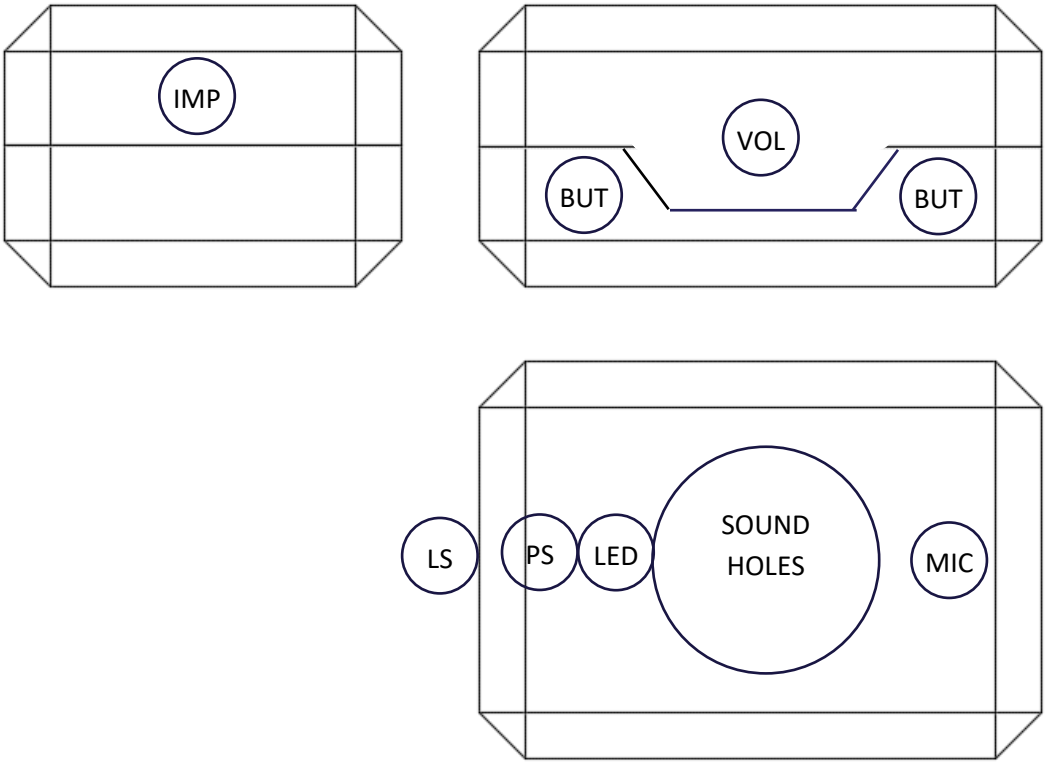
NOTES: Enclosure was made larger to incorporate a battery cover and only one input jack was used.

Possible Final Layout #1

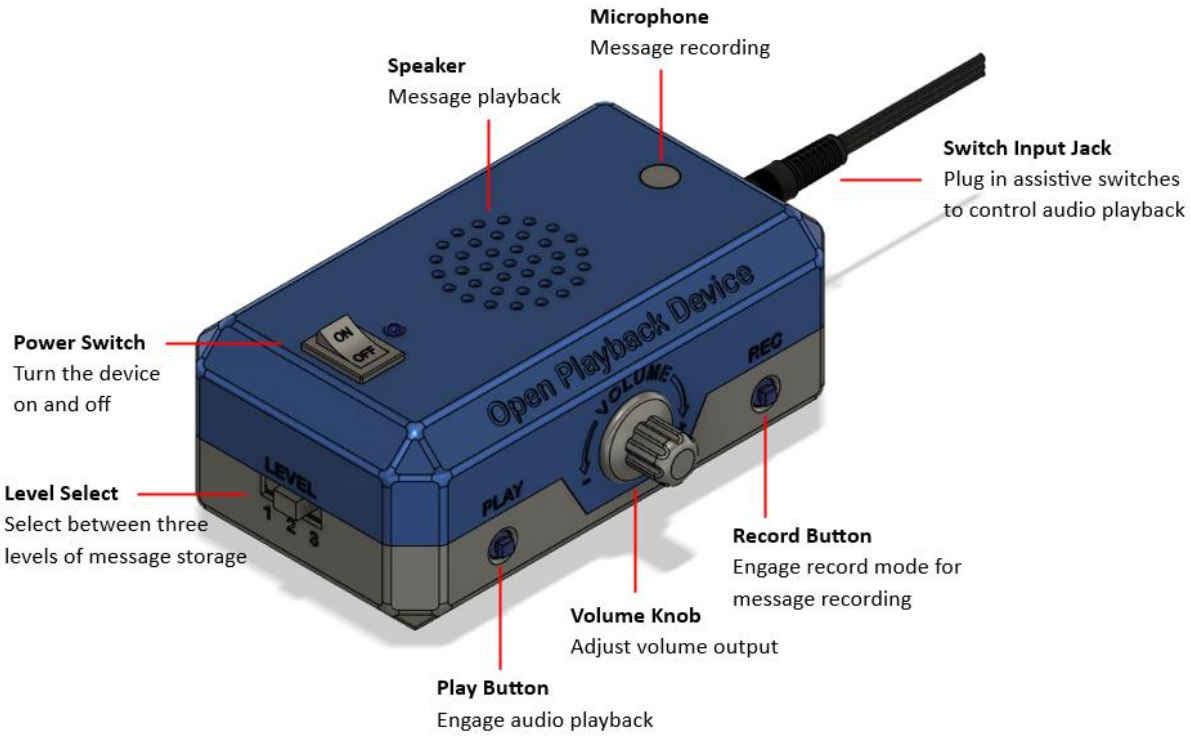


NOTES:

Possible Final Layout #2



NOTES:



Sound Indicators

V0.3 Feature Set

- Similar functionality to the MVP
- 3 level switch has been added to swap between 3 levels of message storage

Device Naming

Existing Names:

- Big Mack
- Big Step-by-Step
- iTalk
- TalkingBrix
- QuickTalker

Possible Names:

- Open Playback Button
- Open Playback Switch
- Speech Generation Device
- Yak Back – Stephen
- Playback Parrot – Brad
- Record and Play
- Open Playback Device
- Open Playback Record
- Open Playback Recorder
- Multi-message Playback Recorder
- Open Record and Play
- Open Voice Recorder
- Open Audio Recorder
- Audio Record and Play

After running through the name generation exercise, the following names were chosen as possibilities.

- Playback Parrot
- Record and Play
- Command Chronicler
- Rewind Recorder

Opportunities for Improvement

Alterative Versions

- Current version focused on recreating the “Big Mack” experience
    - One playback button
    - Sequential lists of messages
    - 3 level select

Full Feature Version

- Without concern for cost, a full feature version could eliminate some of the limitations of functionality.
- Features to add.
    - Louder speakers
    - Screen to make set up and operation easier
- Multiple Input Jacks
- Output Jacks

Inexpensive Version

- Instead of using a microcontroller to add functionality to the device, a cheaper rec/playback module could be used.
- Limited record time.
- Limited number of tracks.
- Use of audio output jack to eliminate cost of audio amp and speakers.

User Interface Changes

- Move recording/playback LED closer to the microphone/away from the power switch so it doesn’t look like a power indicator
- Potentially move level selection from being a slide switch to 3 LEDS and a button/switch to scan through them to give primary user control over level selection

Maker Experience Changes

- Make all connections between halves of the build in one spot/anchor everything to protoboard so joints don’t snap during assembly

Questions for Clients

How long do the stored messages need to be?

- Big Mack max length = 2 minutes
- Big Mack Step by Step = 4 minutes
- Pet training buttons = 30 seconds

In what ways will this device be used? In what ways could multiple messages be used?

- Communication aid
- Sequential message storage: E.g., recording steps of a recipe
- Speak therapy: record and listen

Would mono cable input jacks be useful to the user?

- Input jack to allow playback activation from external switches
- Input jack to allow the Playback Button to be used as a switch for external devices

Power control integrated with volume knob or not?

- Does volume level need to be consistent?

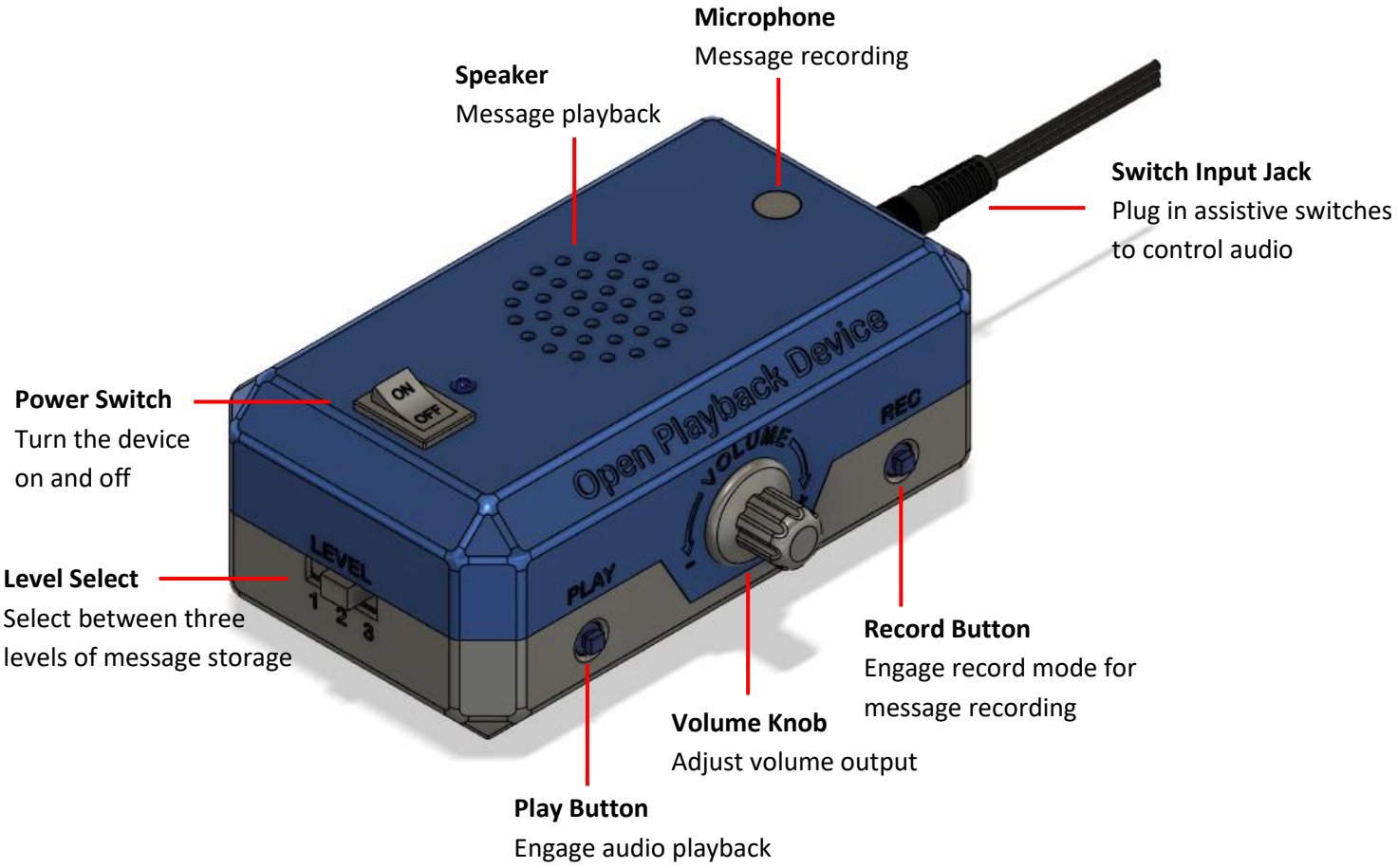
User Feedback

Status Light

Record Mode entered: Flashes red

Recording: Solid red

Playback: Green



Opportunities for Improvement

- Add button to cover tactile buttons
- Fix spelling of Makers Making Change label
- Consider the positioning of record light (i.e., move away from power control to reduce confusion)
- Label microphone (either with words or symbol
- Wire spaghetti with components between top and bottom parts of enclosure

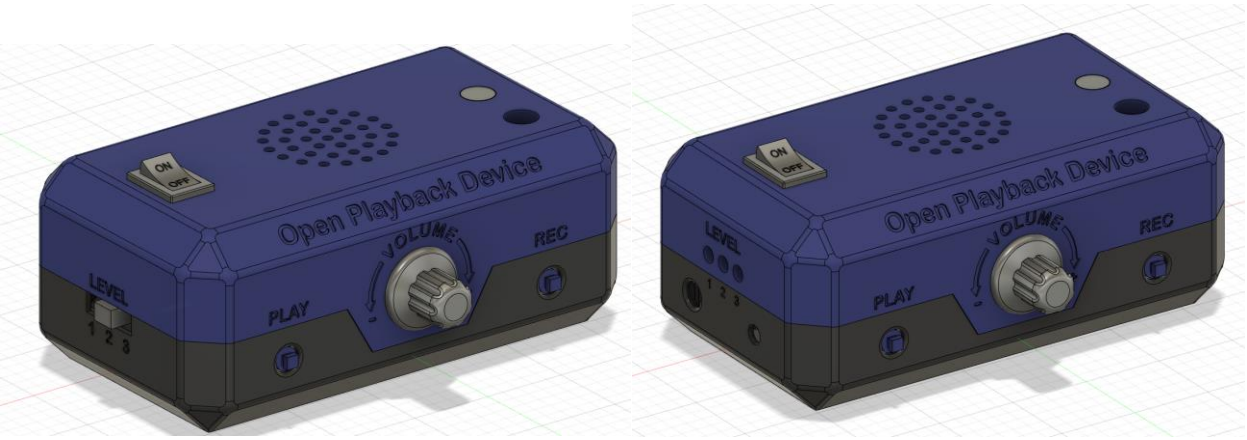
V1.0

Goals

- 3 level switch has been added to swap between 3 levels of message storage
    - Slide switch or press button?
- Move record/play LED to more intuitive location so it doesn't look like a power indicator
- More maker friendly build experience, make one set of cables between halves and reduce the "cheese pull" of wires connecting the two sides
- Consider replacing the microcontroller, SD card reader, and audio amplifier with the Adafruit Audio BFF
- Miscellaneous CAD changes
    - Add shadow lines
    - Add a deboss around the LEDs/button/jack on the press button version
    - Make the battery cover easier to remove
    - Microphone cover

Level Selector

Two concepts were generated for the level selection. One used a three level slide switch and a resistor ladder connected to an analog input, and one used a push button in parallel with a switch jack to change the level.



The slide switch indicates the current level to the user with the physical position of the switch, and the push button indicates the position to the user using three LEDs, with one corresponding to each level.

Since the press button is in parallel with a switch jack, the level of the device can be changed by the primary user. Preliminary testing shows that the button does need a hardware debounce, most likely a lowpass filter.

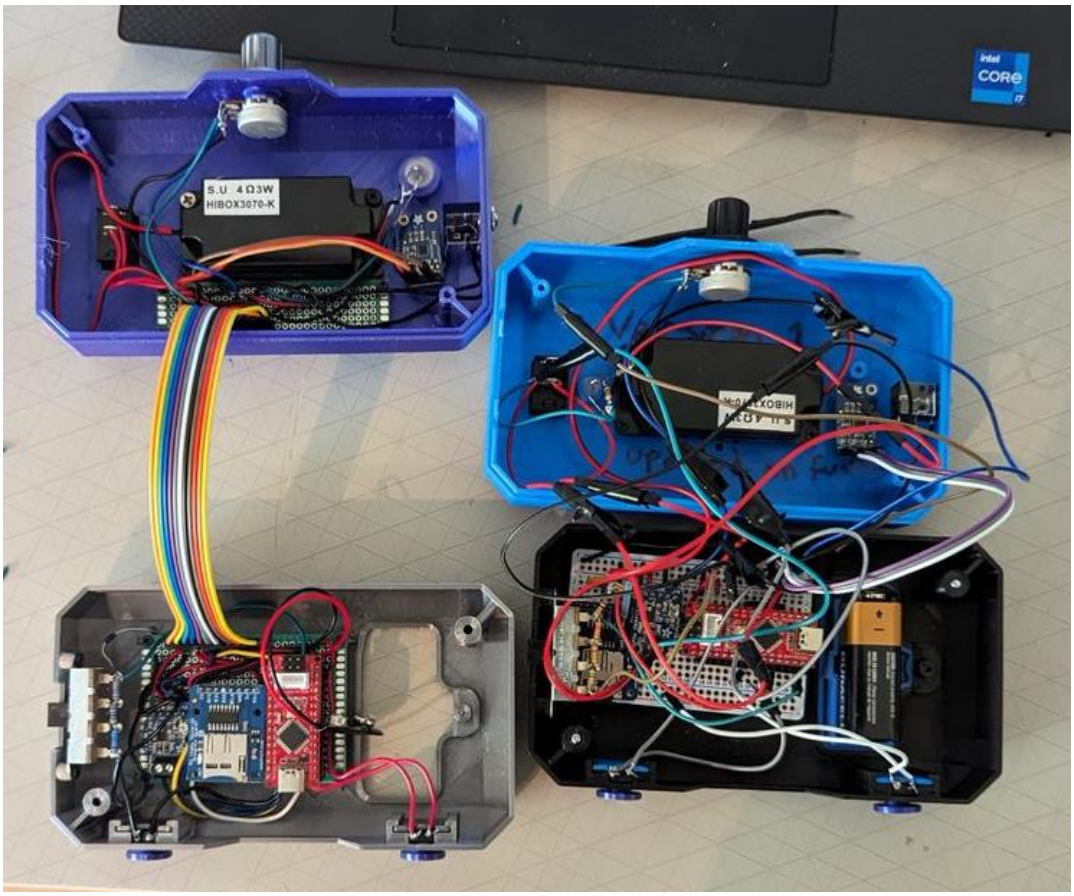
Final selection was the button press, with a redesign of the UI to keep all controls on one side.

Human Design Factor Update

The record and play LEDs were split into two LEDs to make it more clear which mode is active for colour blind users. All the LEDs and buttons were moved to the front side of the enclosure, with both jacks moved to the same side.

Maker Friendly Improvements

In the initial prototype, there were roughly 10 wires that connected the two halves. This made it difficult to assemble the two halves, as all the wires had to be inside the enclosure, and the act of opening or closing the enclosure put stress on the more fragile solder joints, repeatedly causing them to break during prototyping. A new design was created that used to protoboards to connect all the wires on each side, then connecting the two protoboards using a ribbon of breadboard wires. This is still very stiff, and there is still room for improvement finding a more flexible cable that allows the halves to close easier.



Alternative Audio Setup

Recently, Adafruit has come out with a device called the Audio BFF board, which is a backpack style expander board for the QT Py or Xiao style microcontrollers. This board contains both a microSD card reader and a MAX98357 audio amplifier. This would replace the current microSD breakout board, and the audio amplifier. The BFF costs around 6 USD, while the microSD breakout and audio amplifier costs

around 15 CAD. The microcontroller would also need to be changed to one that matches the BFF footprint. This would cause issues with the number of pins needed for the device. It is possible to get GPIO pin extender, but that would bring the cost of the new solution to roughly the same price.

Current Setup		BFF Setup	
Part	Price (USD)	Part	Price (USD)
Seeduino Nano	7.60	QT Py	7.50
MicroSD Breakout	7.50	Audio BFF	5.95
Audio Amplifier	3.95	GPIO Extender	4.95
		Stemma Cable	0.95
Total Price (USD)	19.05	Total Price (USD)	19.35

Changes

1. Finalize naming
2. ¼”-20 mount?
3. Secondary / Primary User Adjustable Levels?
    - Add an input to switch between levels
    - Add an indicator to indicate which level is selected
    - Could be both tactile button and/or external switch input
4. Output Jack
    a. What is the use case here?
5. Optimize assembly / enclosure to ease wiring
6. Swap from protobreadboard to protoboard

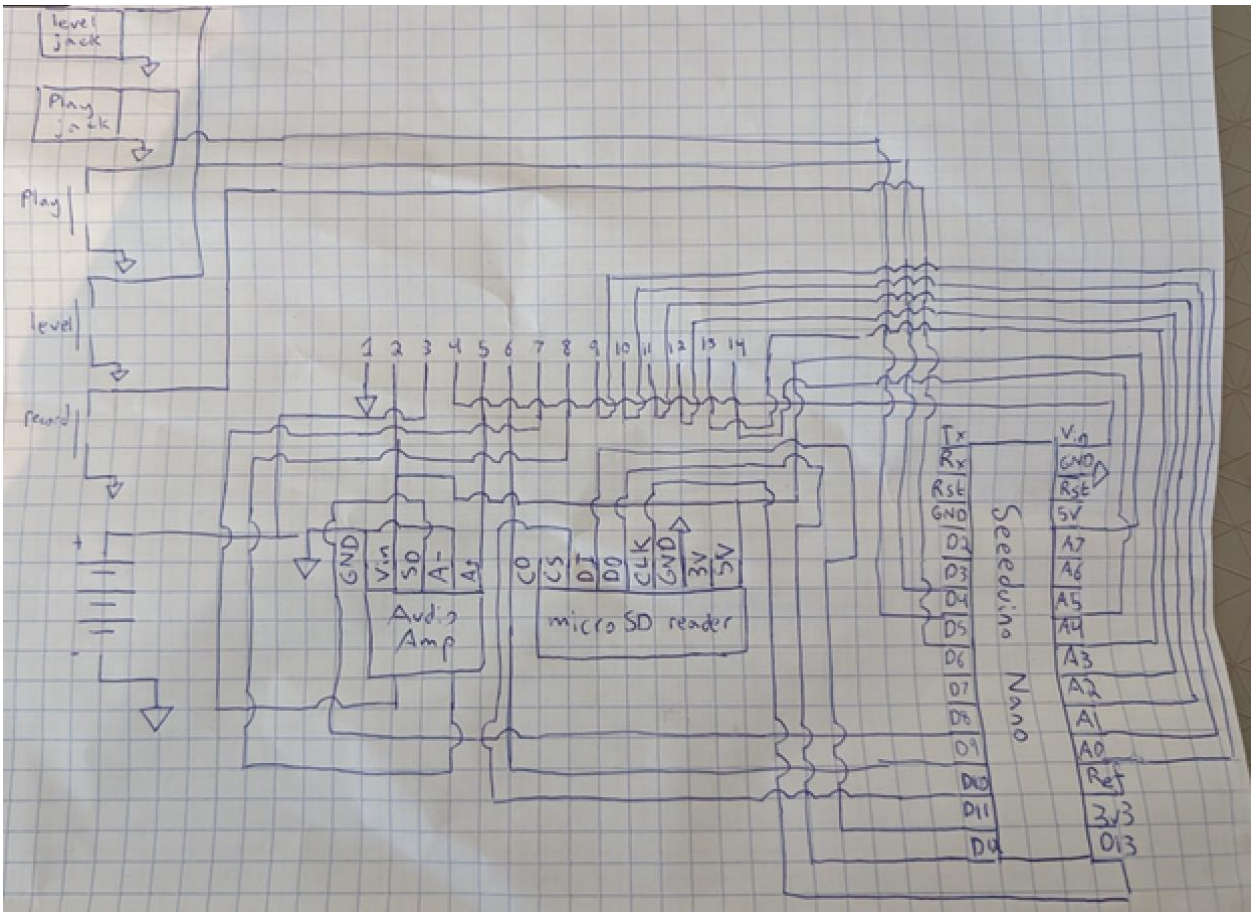
Final Changes

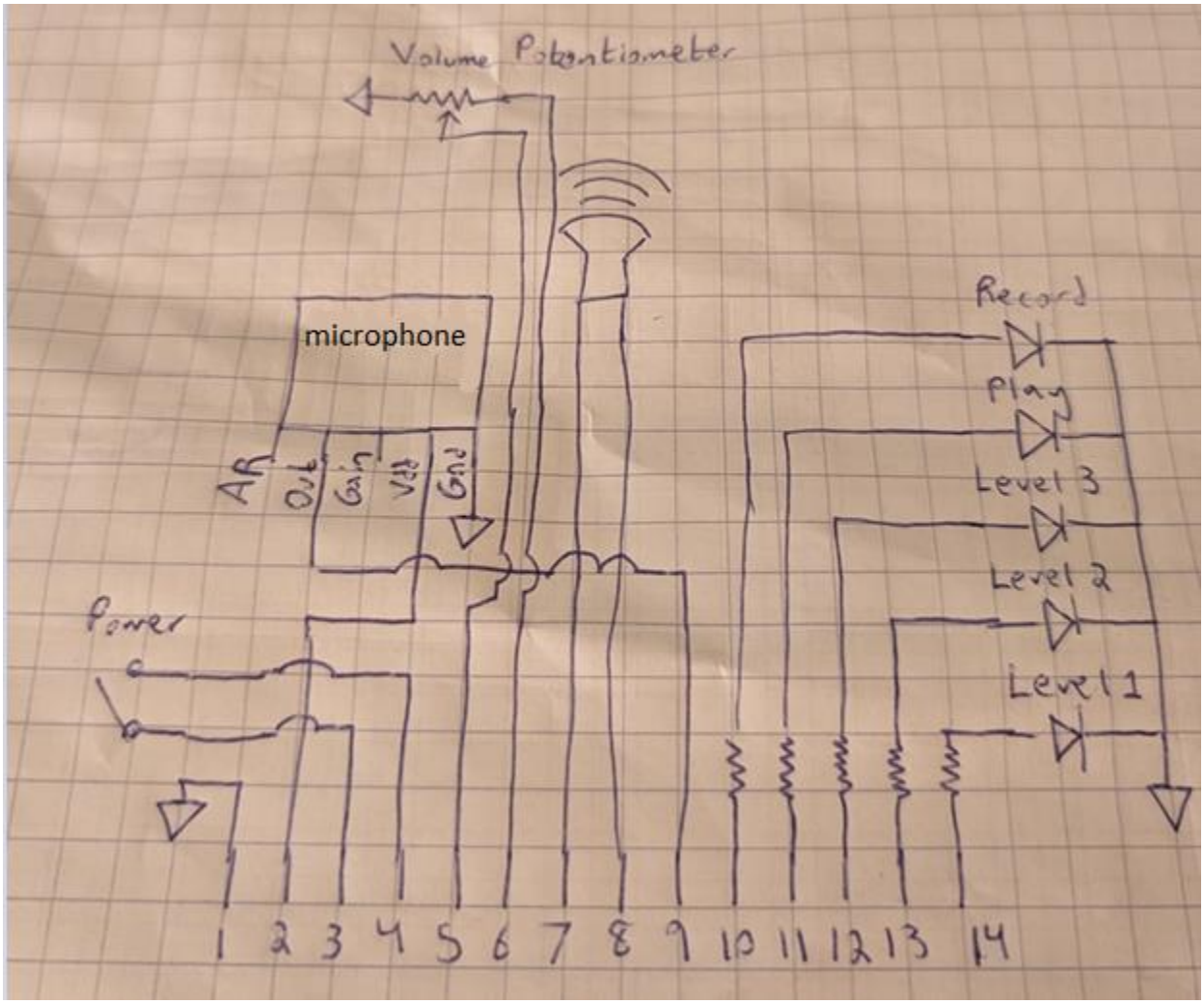
- Added jack/button for level selection
- Moved all buttons and lights to front face
- Moved all jacks to left side

OFIs

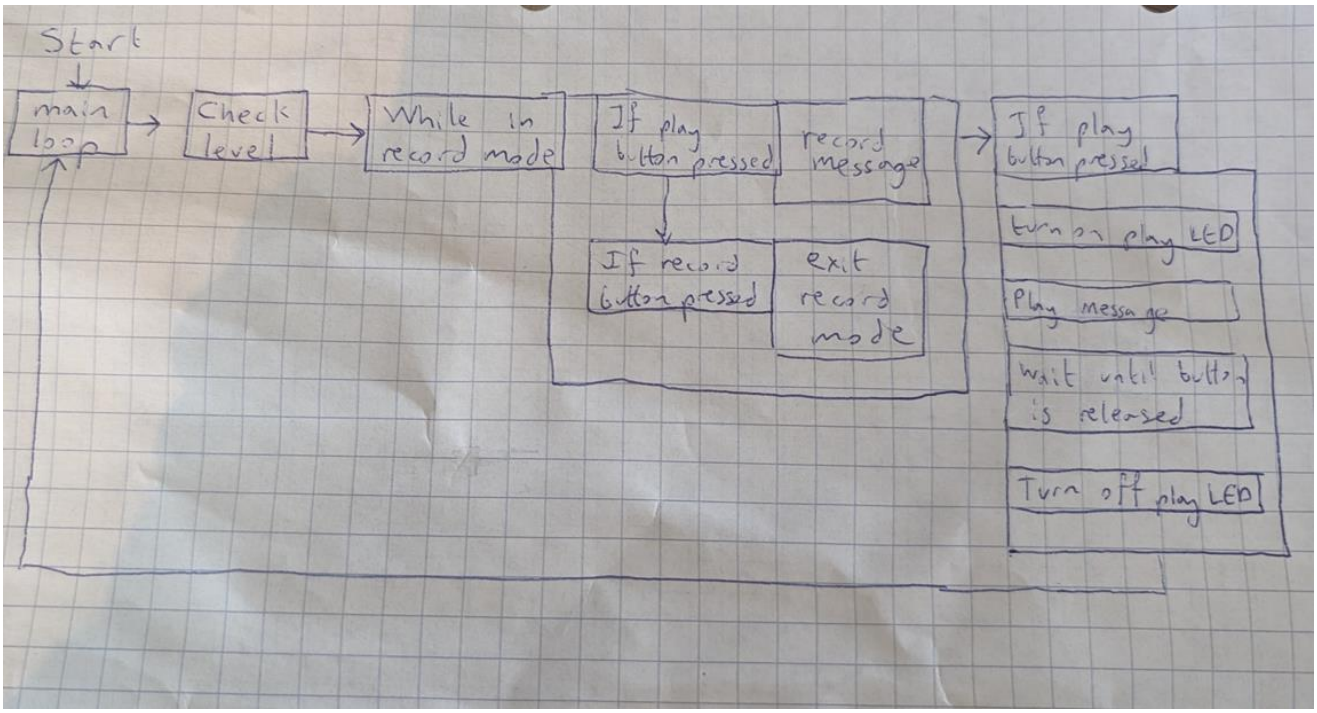
- Look into rechargeable 9V batteries
- Look into adding an output jack
- May be able to improve BoM by ordering wire by the foot from digikey or mouser

Final Schematic





Code Architecture



V2.0

After building several Open Playback Recorders, it was decided that the build process took too long and had too many points of failure, which made it difficult for makers to build the device. It was decided to redesign the internals using a PCB to cut down on the cost and complexity of the device for makers.

Project Charter

Purpose

- The Open Playback Recorder has proven to be a popular device, and there have already been over ten requests since the product was launched.
- Current protoboard and DuPont wire design takes ~8 hours to build, which is a significant barrier to makers

Objectives

- The objective of the project is to maintain the functionality of the Open Playback Recorder but improve the makeability by adding a PCB and re-evaluating the components to reduce opportunities for mistakes

What Success looks like

- Success would be an updated version of the Open Playback Recorder that maintains the same functionality, but with an improved makeability, with the possibility of a slightly modified form to accommodate the PCB and updated components

Project Scope

Deliverables

- PCB Schematics for the updated design
- New BoM with the updated parts list
- Updated Maker Guide with the updated design
- Update the User Guide with updated photos and references if the form changes
- Update GitHub ReadMe
- Updated MMC Library Device page
- Document design update process in Design Rationale
- Updated CAD to accommodate the PCB

Requirements

- Build time must be cut in half from the protoboard version
- Cost must not be increased by more than 50 dollars
- Number of soldered joints/points of failure must be cut in half.
- User functionality must not be changed.

Out of Scope

- Any changes to the functionality are out of scope for the project. This project is strictly focused on improving the maker experience, and should have minimal to no effect on the user experience.

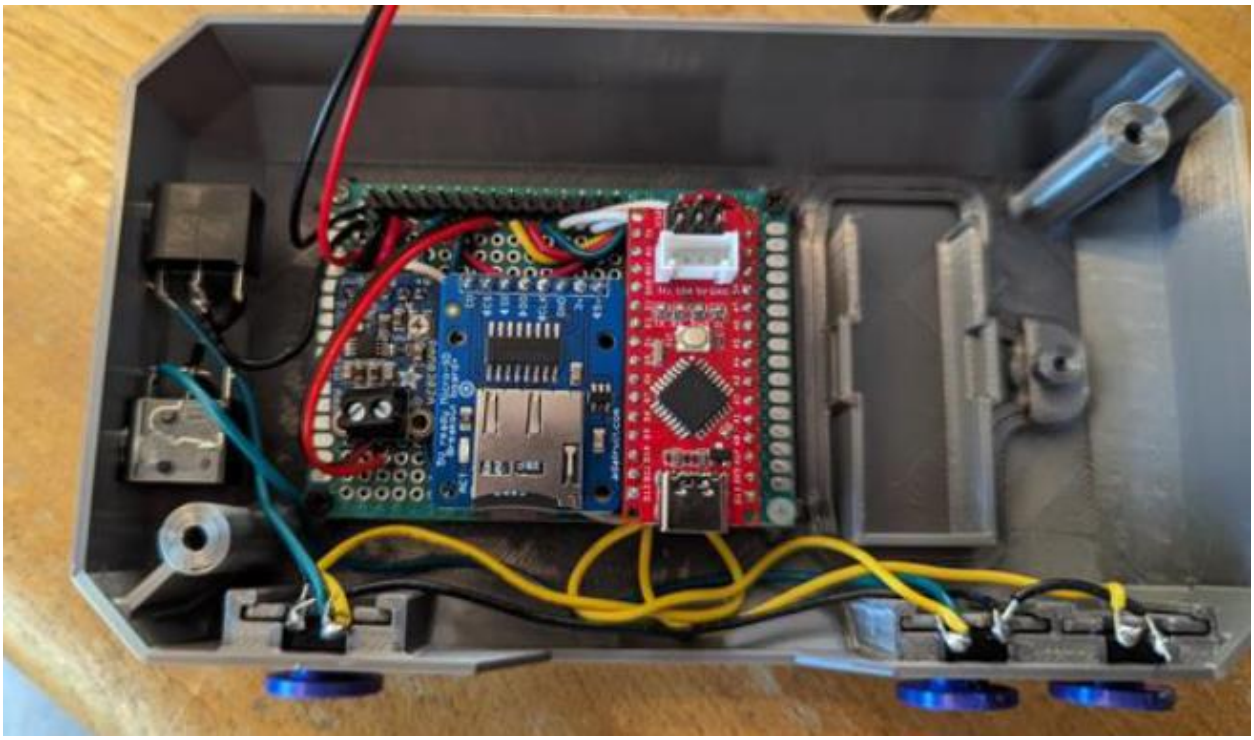
PCB Layout

Limiting factors

- Eagle Design Space
    - Max area of 80 cm^2
- PCB Boardhouse pricing
    - Gets more expensive if not in 10cmx10cm area
- Component spacing in the Open Playback Recorder
    - Base
        - Buttons on front, jacks on side
    - Top
        - LEDs and potentiometer on the front
        - Microphone, power switch, speaker on top

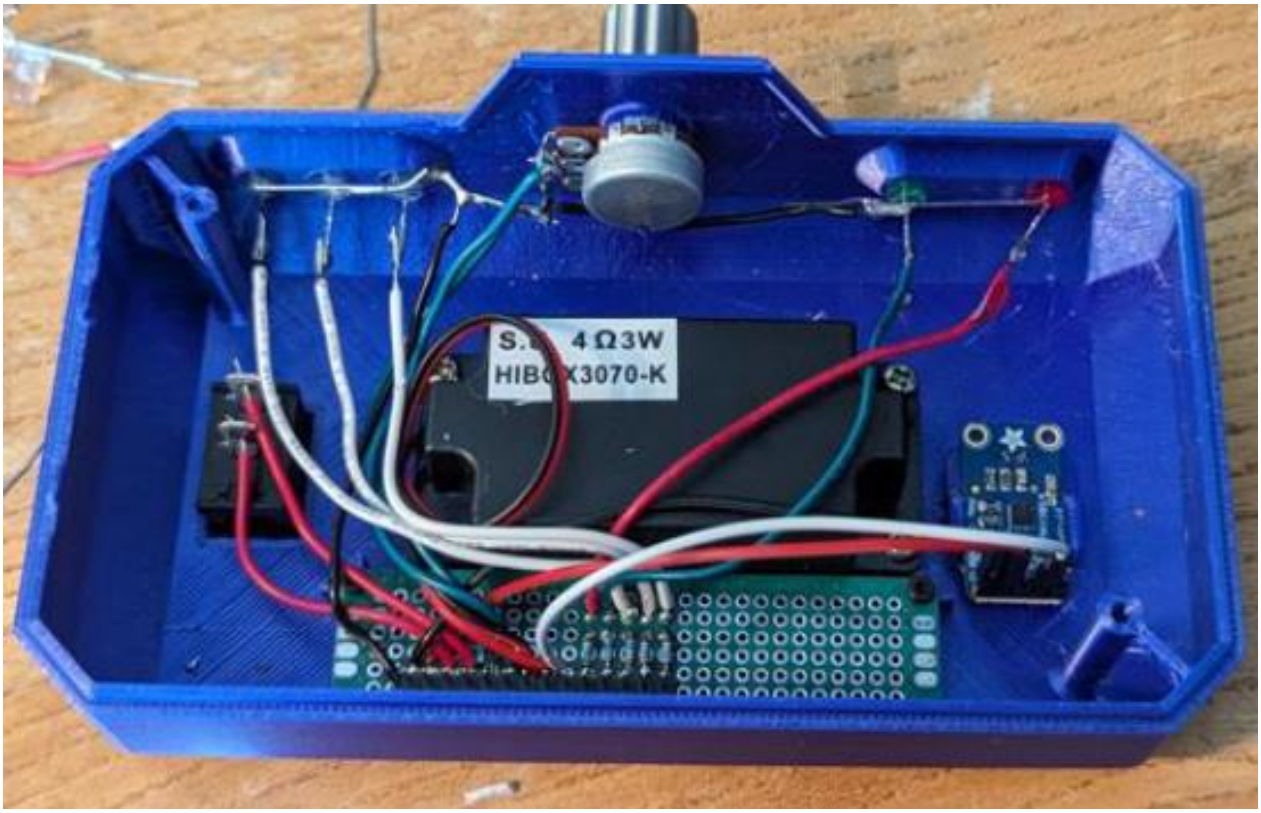
Current Protoboard Layout

Base



In the top, there is a central protoboard that contains the microSD card, the speaker amplifier, and the microcontroller. The protoboard is mounted in the center of the base, with the buttons and jacks panel mounted and connected to the protoboard via wires.

Top



In the top, there is a narrow protoboard for all the panel mount components to connect to. The only components mounted on the board are the resistors and the header that connects the two halves

Layout Options

One PCB

In this layout, there is only one PCB. Either all the components top and bottom are connected to the one PCB via wires like in the initial prototype, or only one of the protoboards is replaced with a PCB. Both options do not reduce the complexity of the device enough to warrant ordering a PCB.

Two PCBs

In the two PCB setup, each protoboard is replaced with a PCB

In the bottom, the protoboard is replaced with a single PCB. Given the size restrictions on designing and ordering PCBs, the overall size of the device would have to either shrinks significantly, the user interface components would have to be all moved to one corner of the board, or either the buttons or jacks remain panel mounted.

In the top, the protoboard would be replaced with a PCB. The DuPont header connection would be replaced with a ribbon cable for a more secure connection, with no risk of individual wires being crossed or coming undone. The PCB can either be mounted in the location of the current protoboard, or it can

be moved closer to the front of the device to allow the option of PCB mounting the LEDs and the potentiometer.

Three PCBs

In the three PCB setup, the top protoboard is replaced with a PCB, and the bottom protoboard is split into two separate PCBs for the buttons and the jacks.

In the bottom, the protoboard would be replaced with two PCBs, one with PCB mounted buttons, and one with panel mounted switch jacks. The other components that were mounted on the protoboard are split between the two PCBs. This allows the PCBs to slot in from the side from one direction, preventing assembly issues from slotting in components from multiple sides at once.

In the top, the protoboard would be replaced with a PCB. The DuPont header connection would be replaced with a ribbon cable for a more secure connection, with no risk of individual wires being crossed or coming undone. The PCB can either be mounted in the location of the current protoboard, or it can be moved closer to the front of the device to allow the option of PCB mounting the LEDs and the potentiometer.

More than three PCBs

The option of more than three PCBs will be explored if there are any serious roadblocks with the two or three PCB options that would require another PCB.

PCB Recommendation

Two PCBs strike a good balance between makeability and price. It allows for both protoboards to be replaced with PCBs and PCB mount most of the components, with the exception of the speaker. A third PCB in the base would allow more flexibility in assembling the device, but the cost of including a third PCB would outweigh the benefits.

Component Review

Panel Mount vs PCB Mount

- PCB components reduce complexity, but can make assembly into the enclosure more difficult. (See Forest Hub for example)
- PCB components require the board to extend to the sides of the enclosure for user interface components
- Panel mount components make assembly easy, but need extra wire to get them to the board

Current User Interface Components

- Bottom
    - Buttons
    - Jacks
- Top

- Speaker
- Microphone
- Power Switch
- LEDs
- Potentiometer

Component Selection

User Interface

Top

Power Switch

- Current switch [Link]
- Slide switch [Link]
- Currently mounted on the top, but power is coming from the base, and is consumed at the base. Would make sense for it to be at the bottom.

Speaker

- Wires come from the speaker, connect to the protoboard
- Solder to the protoboard
- Either continue to solder into the board, or add a terminal block to connect the wires to the PCB

LEDs

- Current LEDs can be used both as panel mount or PCB mount. If PCB mount, a spacer like the one used in the Forest Hub would be useful

Potentiometer

- Currently using a panel mounted logarithmic potentiometer [Link]
- PCB mounted 10kohm logarithmic potentiometer [Link]

Microphone

- Currently using electret microphone amplifier [Link]
- Looked for stemma version to reduce soldering but not available

Bottom

Jacks

- Current selection [Link]
- PCB mounted option [Link]

Buttons

- Current selection is the button used in the raindrop switch [Link]
- PCB mounted button [Link]

Internal

Microcontroller

- Needs to be 5v for some of the components
- Needs a large amount of pins
- Potential to get one with a built in SD card

MicroSD card reader

- Potential to combine the microSD card reader with the microcontroller
- Potential to

Speaker Amplifier

- Currently using the provided terminal block with wires going to the header. Possibility to replace the terminal block with the same headers used in the data lines providing the spacing is the same.

Battery

- CAD needs to be tweaked to add more tolerance to make the battery cover easier to remove
- Currently using a cable connected to the protoboard [Link]
- Possibility to add terminals to the PCB and plug the battery directly into the PCB [Link]

Part Recommendations

Top

- Microphone
  - Continue to use the same microphone as before, but solder it directly to the PCB using headers.
- Speaker
  - Continue to use the same speaker as before, soldered to the PCB or using terminal blocks
- LEDs
  - Continue to use the same LEDs as before, but use a 3D printed spacer to get the LEDs in the correct orientation
- Potentiometer
  - 10 kOhm PCB mounted logarithmic potentiometer

    - If possible when doing the PCB layout, move to the bottom of the device to cut the required number of cables in the ribbon from 12 to 10
- Connection
    - Ribbon cable for a secure connection and make it impossible for wires to get crossed
    - Either 10 or 12 wire cable, depending if the potentiometer will fit on the bottom or not

Bottom

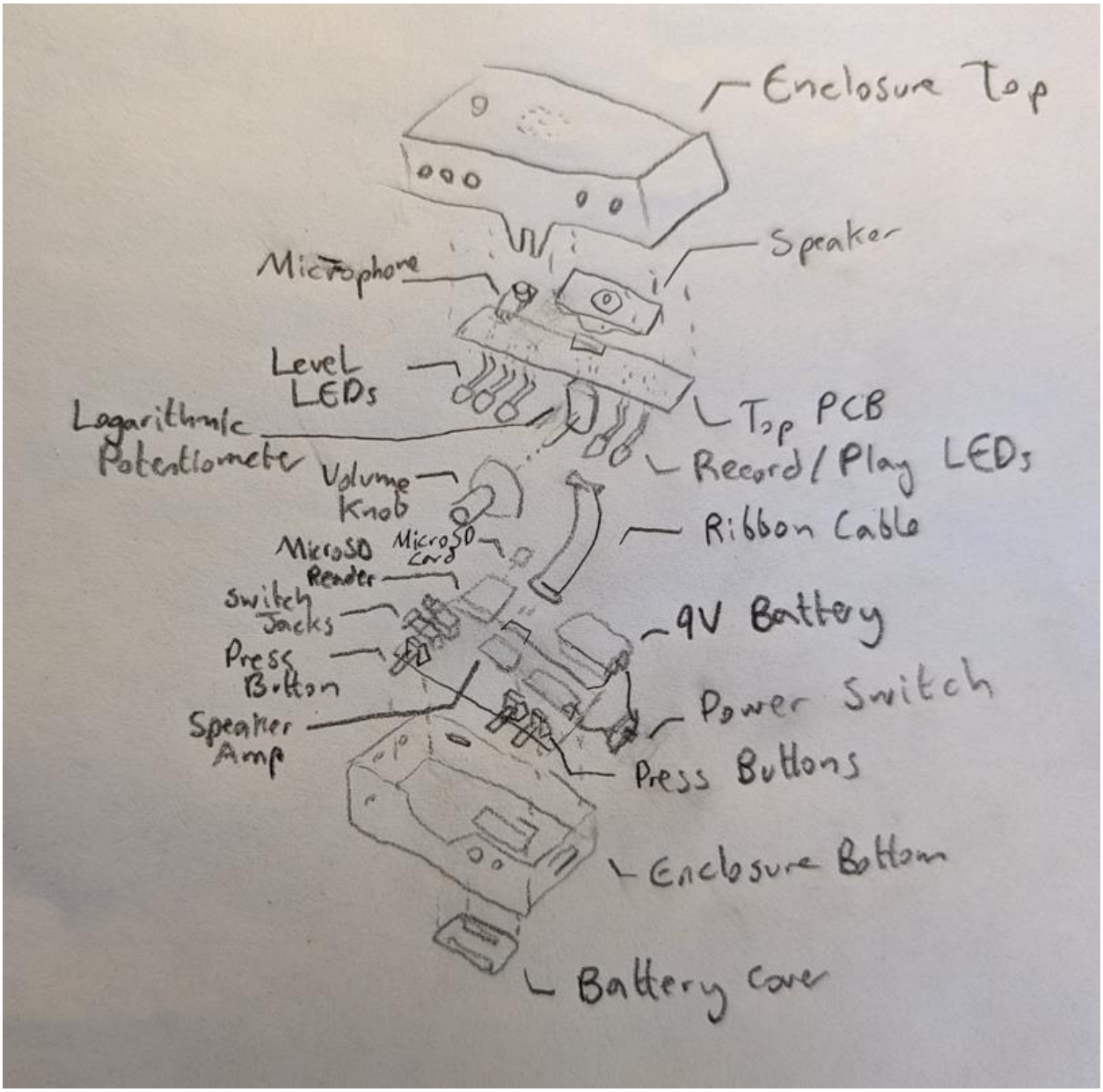
- Buttons
    - PCB mounted to reduce number of wires and soldered connections.
    - Capture the button covers internally to prevent them from falling off.
- Jacks
    - PCB mounted to reduce number of wires and soldered connections.
    - Move them closer to the front so they fit within the 100mm x 100mm area.
- MicroSD card reader
    - Continue to use the same one as before, but move the port so the SD card is accessible by the secondary user
- Battery connection
    - Keep existing connector
    - PCB mount connectors are hard to reliably source on Digikey and Mouser
- Power switch
    - Move to bottom of enclosure
    - Slide switch to prevent bumping on or off
    - PCB mount to simplify wiring
- Speaker amp
    - Continue to use the same speaker amp as before, but replace the terminal block with additional headers to connect the output back into the PCB
- Microcontroller
    - Continue to use the same microcontroller as before.
- Connection
    - Ribbon cable for a secure connection and make it impossible for wires to get crossed
    - Either 10 or 12 wire cable, depending if the potentiometer will fit on the bottom or not

Proposed V2.0 Device Layout

In the proposed V2.0 layout, both protoboards are replaced with PCBs, and the overall size of the device is shrunk to accommodate the 100mmx100mm PCB restriction. All components with the exception of the speaker and battery connection are moved to through hole PCB mount. The power switch, and if possible, the potentiometer, are moved to the bottom PCB to reduce unnecessary crossings between the top and bottom. Since there will be PCB mounted components on 3 sides of the bottom PCB, the clamshell design will need to be modified for insertion of the PCB.

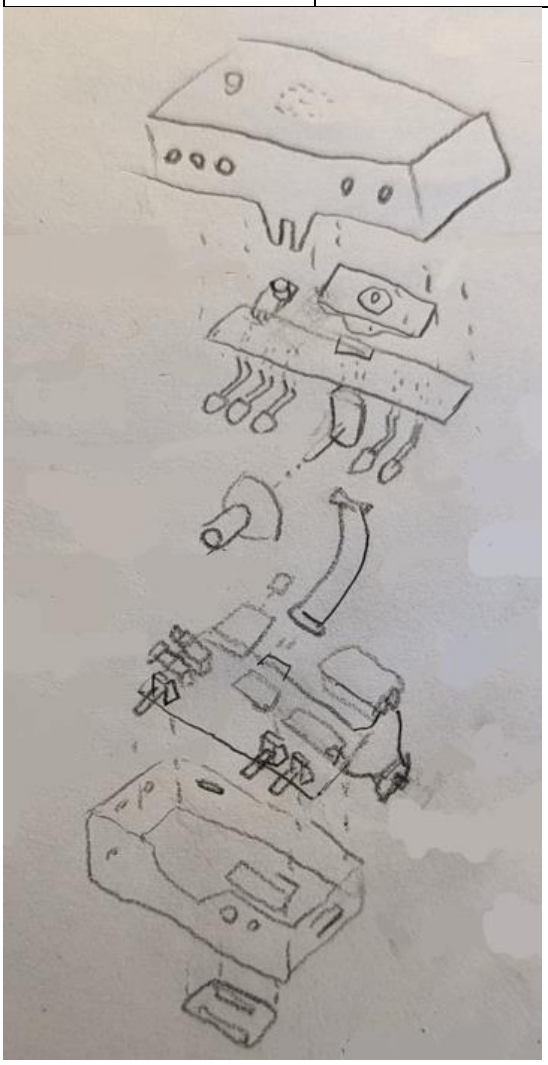
The top PCB will contain the speaker connection, the 5 LEDs, the microphone, a ribbon cable connection, and potentially the potentiometer. The previous version had several connections that started and ended on the bottom board and just passed through the top, and part of the goal of the redesign is to minimize that.

The bottom board will have the jacks, buttons, power switch, microcontroller, battery connection, microSD card reader, speaker amp, and potentially the potentiometer. By making as many connections as possible on the PCB, it reduces the number of hand built wire traces to zero, and cuts the number of solder joints in half.



Updated Components

Component	Quantity	Price	Link
Jack	2	1.98 (2.13)	Link
Button	3	0.82 (0.76)	Link
Power Switch	1	0.89 (0.93)	Link
Potentiometer	1	2.64 (2.13)	Link
10 wire ribbon cable	1	1.82 ()	Link
10 wire ribbon cable connector	2	0.86 ()	Link

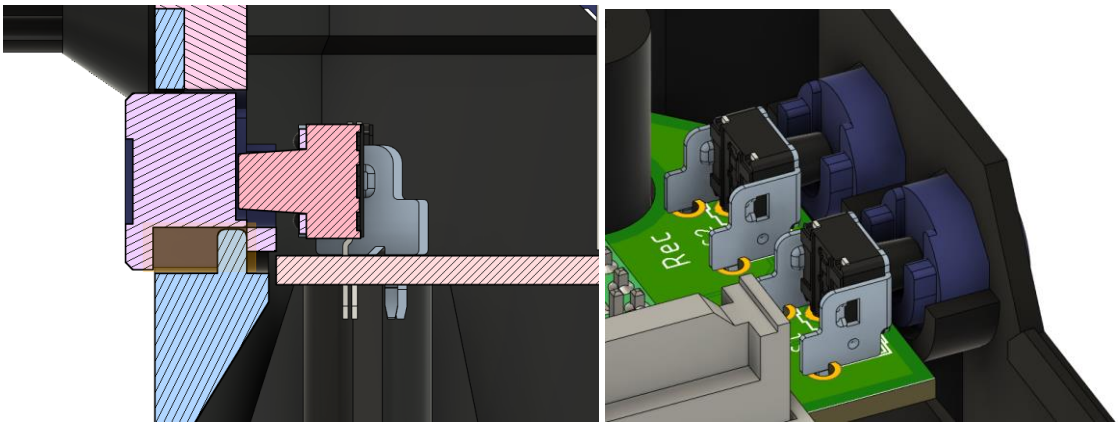


Updated Enclosure Design

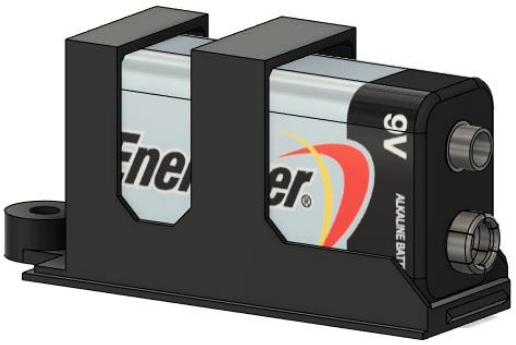
Since the PCBs are so much smaller than the original enclosure, the fact that the buttons and jacks are PCB mount means that the enclosure must be redesigned around the PCBs. After the first draft of the PCBs were made, all the components were imported into Fusion and arranged in the most compact

manner possible. From here, the basic enclosure was modeled around the components. At this point, several changes to the PCBs were required to allow clearance for the screws holding the enclosure together, and to change the position of the microphone to make the enclosure more symmetric.

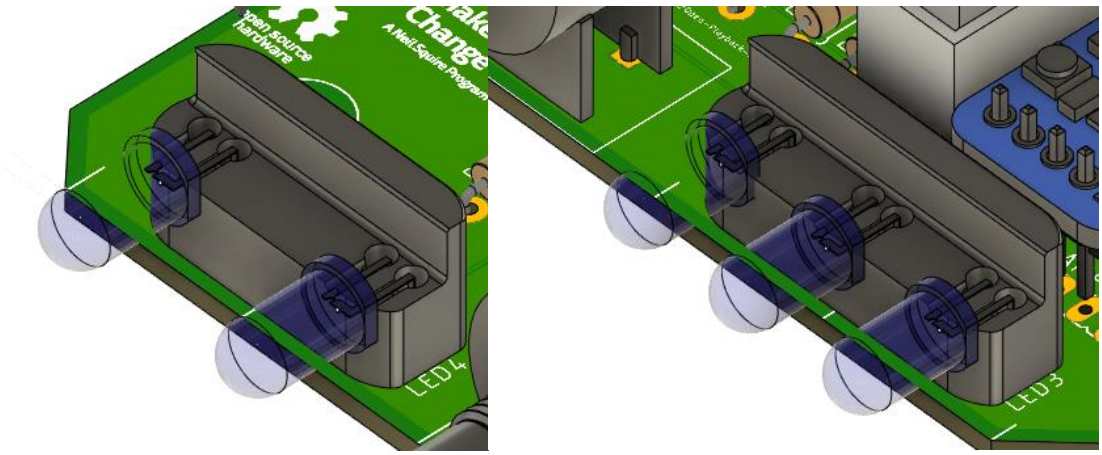
The design of the buttons and the battery holder was also overhauled from the initial version. The buttons on the initial enclosure were press fit onto the actual buttons, with a bit of hot glue holding them in place. This was fragile and prone to being knocked off, so the updated enclosure includes buttons that are inserted from the inside, and held in place by the PCB buttons after the PCB is inserted.



The battery holder was also redesigned, both to securely hold the battery so it can't be shaken loose internally, and to allow the battery holder to more easily be removed from the enclosure with minimal force.



The LEDs used on the top circuit board need to be bent 90 degrees at a specific point to fit into the corresponding holes in the enclosure. In the past, 3D printed jigs have been used to bend components at a fixed point to eliminate the need to measure and guess. 3D printed spacers have also been used in the past to offset LEDs from the PCB. These two concepts were combined in this project to create a tiered spacer that allows the LEDs to be soldered to the board at the correct height, then bent using the spacer as a jig to get the correct angle and distances.



Initial PCB Design

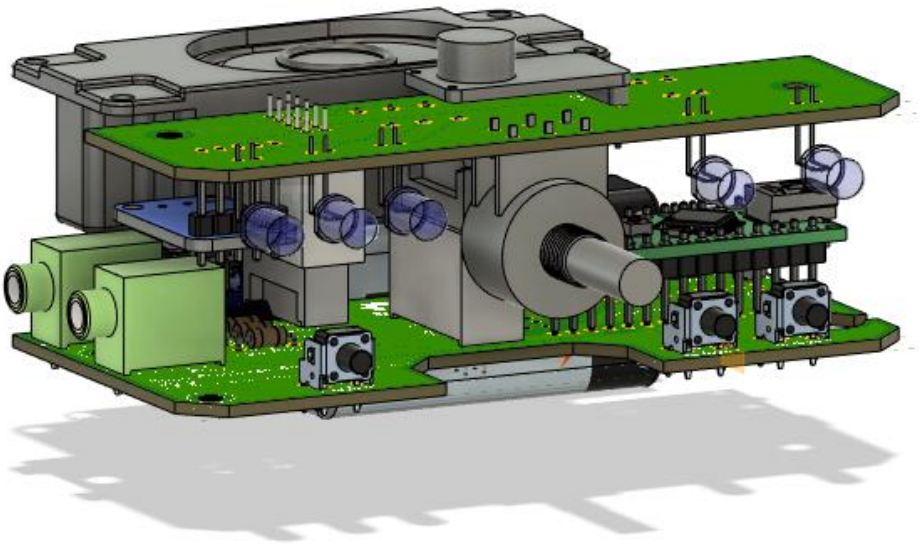
The first PCB design designed alongside the new enclosure, and the PCBs and parts were ordered. Once everything arrived, the device was assembled using the previous code with no changes. The basic functionality of the device worked well, but there were three noticed issues that required a PCB rework.

The primary issue noticed was with the headers that connected the two halves of the device together. The actual headers were much larger than expected, and without a 3D model to incorporate them into the CAD, it went unnoticed that the headers would interfere with each other and the microcontroller. To fix this, in the next iteration of the PCBs the location of the header on the top PCB has been moved. Now that the header parts have arrived, they have been modeled and it has been verified that they will not interfere when assembled.

The second issue that was noticed was that the LED for level 3 was lighting when the device was in level 1, and vice versa. While this was an easy fix in software, since changes were already being made to the PCBs it was decided to swap the two LEDs to keep the software the same between the protoboard and PCB designs.

Finally, it was noticed that when a switch was connected to the Play jack, the level would also activate whenever the switch was pressed. This behavior stopped when a multimeter was used to measure the voltage on the input pin or when a 10k resistor was connected between the input pin and the 5V pin. This behavior seems like a floating input pin, but internal pullups have been enabled on all the microcontroller inputs. To solve this, optional pullup resistors were added to each of the microcontroller inputs to allow the maker to add resistors if the input is floating.

Final V2.0 Design



V2.0 Testing and Validation

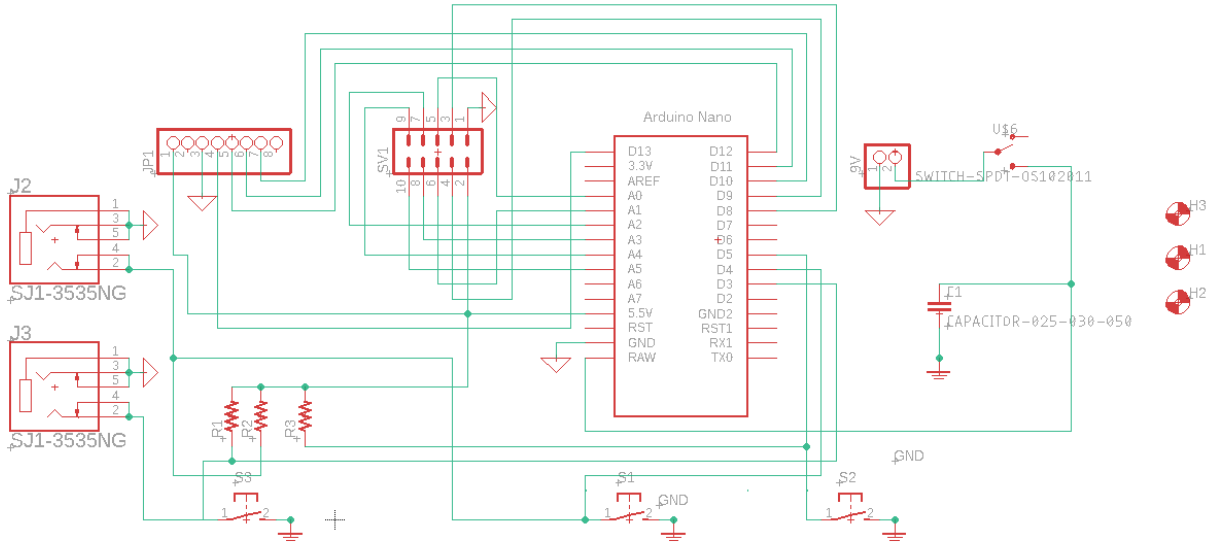
V2.0 Internal Testing

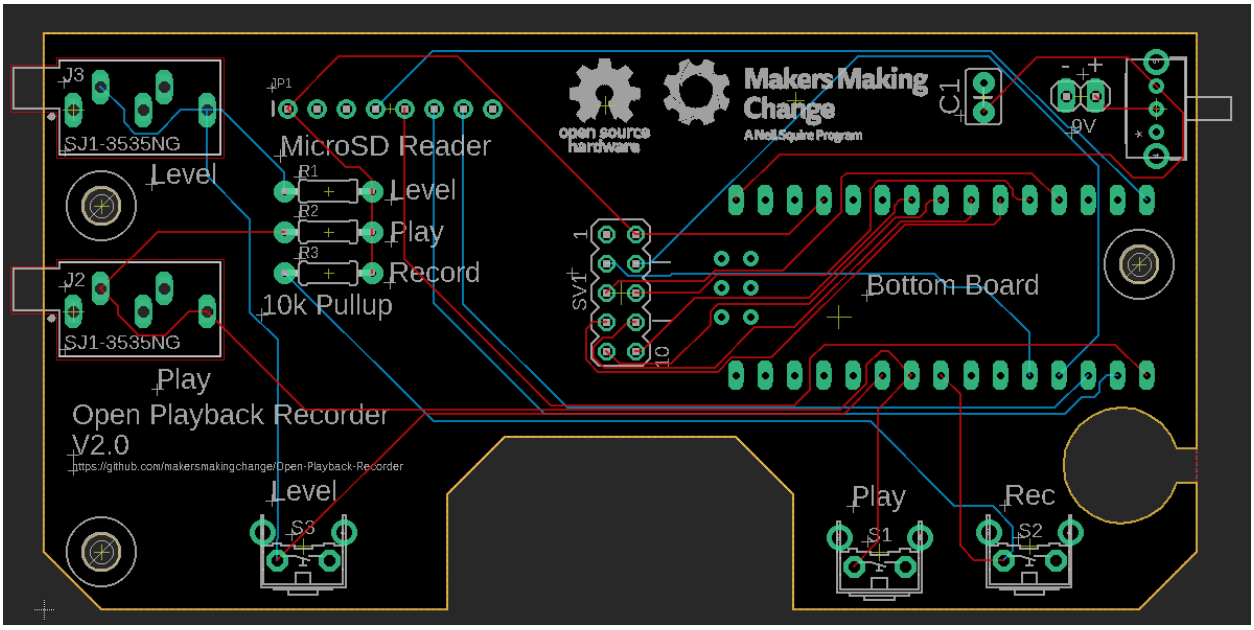
Test pull-up resistors and input ghosting

Input Ghosting

When an assistive switch is connected to the play jack and it is pressed, the level switch will sometimes also activate, with nothing connected to the level jack and the level button not being pressed. There is already an internal pullup resistor on both the play and level input pins. On the first prototype PCB, this was eliminated by soldering a 10k resistor between the level pin and the 5V pin on the microcontroller.

On the second iteration of the board, a footprint was added for the pullup resistors, however this made them less effective, with the ghost input happening roughly half the time.





After reviewing the software for the OPR, it was found that the fact that the level switch input was an interrupt was causing issues. Since interrupts cannot trigger within an Interrupt Service Routine(ISR), things such as timers and delays cannot be used within the ISR for the level change. This makes it difficult to debounce the level switch in software since any debouncing after the ISR would simply be interrupted when the ISR is triggered again by the bouncing. Since the level change is only needed in the main loop and is not used while playing or recording messages, the interrupt was removed and an if statement added to the main loop to poll the state of the level pin. This change solved both the input ghosting and the switch bouncing issue with no changes needed on the PCB.

V2.0 User Testing

Test if having the microcontroller and microSD card accessible is a useful addition

Test to make sure that no functionality was lost

V2.0 Build Testing

Test maker guide to verify the instructions are clear, easy to understand, and have no errors.

OFIs for V2.1

- Add sliding covers for microcontroller, power switch, and the microSD card
- Get OSHWA certification
- Possible to lose the microSD card in the enclosure when removing it