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Analog Voice-Over Circuit

Group Members: Team Troubleshooters

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Abstract

This report provides an overview of the design and implementation of an analog voice-over circuit. The circuit is designed to get audio from a 3.5 mm audio jack and play it from a speaker after amplifying. In addition to that,there is the ability to suppress the audio stream and give priority to audio from mic when it is used. Switching between mic audio and the 3.5 mm jack happens automatically. In addition to main functionality, a smaller circuit was designed to provide the plus and minus voltages required to drive the opamps.

The main components used are resistors, capacitors, opamps and an analog switching IC. The main consideration for selecting the components were to make the output signal clear and free of noise. The report also details the designing of the PCB and enclosure using Altium Designer and Solidworks respectively. Finally, the report includes results from simulations and the future plans for this product.

Abbreviations and Acronyms

DC Direct Current

IC Integrated Circuit

CMOS Complementary Metal–Oxide–Semiconductor

PCB Printed Circuit Board

PLA Polyactic Acid

Contents

1 Introduction and Functionality

The analog voice-over circuit has a rather straightforward functionality. That is to switch between 2 audio channels, one from a 3.5 mm audio port and another from a microphone. Normally, audio comes from 3.5 mm port and a higher priority is given to voice from the microphone. The switching happens automatically after detecting voice from the microphone.

The audio from microphone is given to a pre-amplifier circuit before feeding to the decision-making switch as well as the output speaker. There is an audio pre-amplifier and a power amplifier circuit to drive the speaker. The main focus of the circuit is to achieve the functionality with as low noise as possible since it would affect listening quality. To achieve this, there are multiple filters in intermediate stages.

2 System Architecture

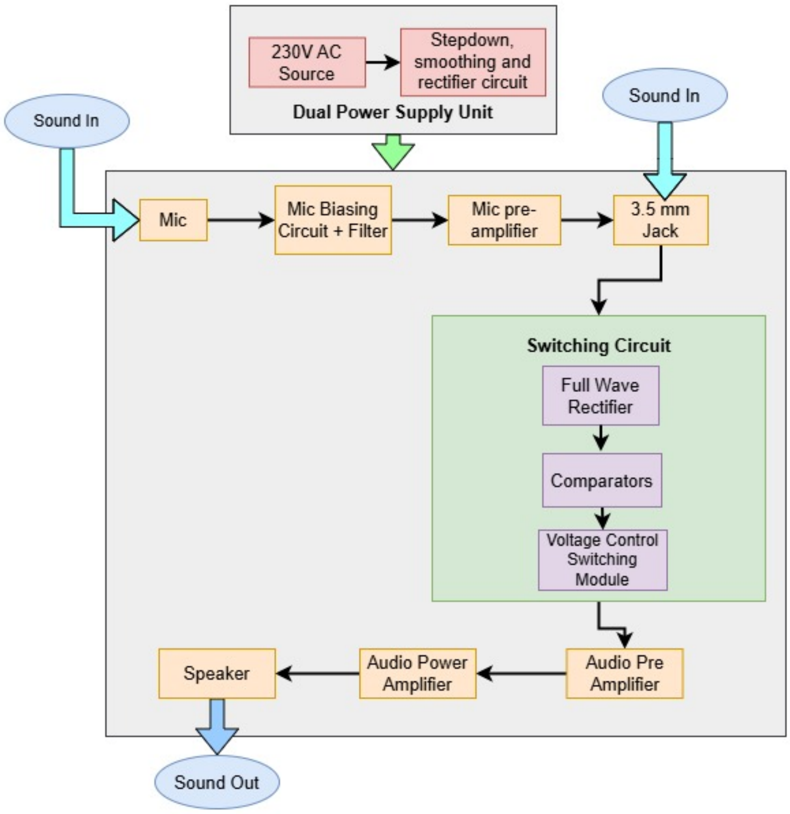


Figure 1: Functional Block Diagram

We can consider 6 main subsections in the circuit.

1. Microphone biasing and pre-amplifier
2. Full wave rectifier circuit
3. Switching circuit

4. Audio pre-amplifier
5. Audio power amplifier
6. Power supplying circuit

2.1 Microphone biasing and pre-amplifier

The proper operating voltage for the microphone is provided by the power supply using voltage divide principle. After the microphone we have a resistor and a capacitor which acts as a low pass filter with a cutoff frequency of 16kHz. This helps reduce echo and the feedback from speaker. After the filter, we have an amplifier using an op-amp in inverting amplifier configuration. This ensures that the weak audio signal from the microphone is properly amplified before it goes to the rest of the circuits. It will ensure minimum distortion from noise.[1]

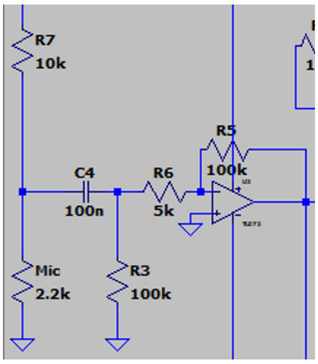


Figure 2: Microphone Pre-Amplifier

2.2 Full wave rectifier circuit

The full wave rectifier circuit is used to get the modulus of the input from the microphone, as we need a positive volage to control the switching circuit. Instead of a usual full wave rectifier using transformers and diodes, we use an op-amp based rectifier. In addition to op-amp there are also diodes and resistors. After this part of the circuit, we have a positive signal that can be used as control input to the switching circuit. The 2 cascaded op-amps in inverting amplifier configuration ensure that the output is positive.[2]

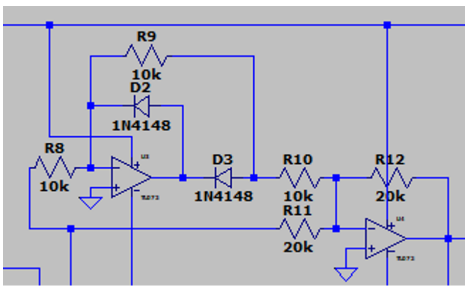


Figure 3: Full Wave Rectifier

2.3 Switching circuit

The main component of the switching circuit is the CD4066 switching IC. It can connect 2 parts of circuit connected to its pins based on the control signal of those pins. For the control signal, we use 3 comparators. The first comparator generates the proper control signal while the other 2 helps stabilize that voltage to feed to control pin. Each comparator is followed by a capacitor and a resistor in parallel which helps the output of comparators to be held for some time. The time constant of the holding circuit is 4.7 s.

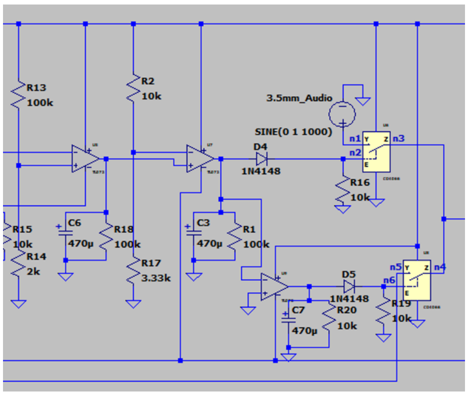


Figure 4: Switching Circuit

2.4 Audio pre-amplifier

Before the power amplifier, we need an audio pre-amplifier to boost the low-level parts of the signal without distorting the signal. It is done here using an op-amp in inverting amplifier configuration. We attach a variable resistor (potentiometer) in the feedback path of the op-amp so we can control the amplification factor of the op-amp. This essentially acts as a volume controller for the device.

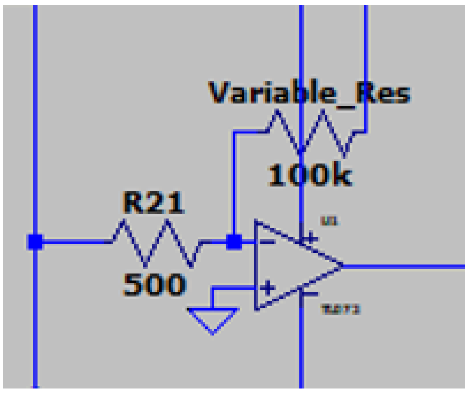


Figure 5: Audio Pre-Amplifier

2.5 Audio power amplifier

The power amplifier is used to provide the significantly large current required to drive the speaker. It consists of 2 complementary power transistors used in push pull configuration. The power transistors are capable of providing the high current required as well as dissipating the generated heat. The vertical capacitor and the accompanying diode helps to keep the 0.7 V bias constant despite the voltage swings from pre-amplifier output.

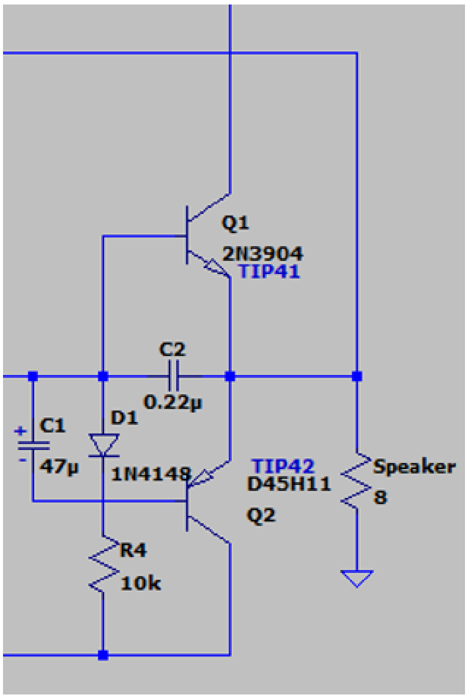


Figure 6: Audio Power Amplifier

2.6 Power supplying circuit

The power supplying circuit was built to supply +V, -V and ground potentials needed to power up the main voice-over circuit. It was designed to be powered from the wall power. It has a full-wave, bridge rectifier connected to a center tapped transformer. The outputs of the smoothing capacitors are connected to 7812 and 7912 voltage regulator ICs. They take the fluctuating DC voltage and outputs a steady +12 V and -12 V.

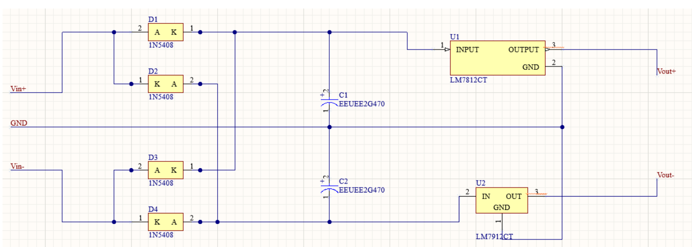


Figure 7: Power Supply Circuit

2.7 Equations and Calculations

1 - The cut-off frequency of the low-pass filter at microphone input. This helps get rid of high frequency noise and feedback from speaker.

$$\begin{aligned}\text{High pass filter in mic biasing circuit} &= \frac{1}{2\pi RC}\\ &= 16\,\text{Hz}\end{aligned}$$

2 - Discharge time of stabilizing capacitors near the comparators (the time constant). This should be high enough to hold the voltage value for enough time for switching to happen.

$$\begin{aligned}\text{Time constant} &= RC\\ &= 470\,\mu\text{F} \times 10\,\text{k}\Omega\\ &= 4.7\,\text{s}\end{aligned}$$

3 - The power calculation. This helps get an idea about the power dissipated by the circuit. It is useful for the thermal management of the device as well as choosing a battery capacity, should we decide to use a battery.

$$\begin{aligned}\text{We observed } V_{\text{peak}} &= 10\,\text{V at the load.}\\ V_{\text{rms}} &\approx \frac{10}{\sqrt{2}}\,\text{V} = 7.07\,\text{V}\\ \text{Average } P_{\text{load}} &= \frac{V_{\text{rms}}^2}{R_{\text{load}}}\\ &= \frac{7.07^2}{8}\\ &= 6.25\,\text{W}\end{aligned}$$

3 Component Selection

TL072 Op-amps

These op-amps are commonly used in audio application because of the desirable qualities they possess[3].

- High slew rate (13V/µs) : Since high frequency components of voice can change rapidly, we need a high slew rate to prevent distortion.
- Low noise amplification (Low input offset/bias current): Prevents unwanted DC components in output signal. Make sure the speaker is not stressed by the DC component.
- High bandwidth (3 MHz unity gain bandwidth) : A high bandwidth is required to ensure that the higher frequency components of the signal does not get clipped off, thus distorting the signal.

TIP41 /TIP42 Transistors

These are 2 commonly used power amplifier transistors. They are a complementary pair which is used as push pull amplifiers.

- High collector current (Upto 6A) : A high current is required to drive the speaker wih enough power to be audible. These transistors have the capability to provide that power.
- High power dissipation (65W) : Since the speaker draws a significant current, it generates more heat. The transistors must be able to dissipate the generated heat without burning up.

IN4148 Diode

This diode is commonly used in high-speed switching applications. While not designed for high-power rectification, the 1N4148 is used in low-current rectifier circuits.

- High reverse voltage (75 V) : This is required to ensure that the diode does not get damaged during operation.
- Low reverse recovery time (4 ns) : This quality is useful while operating at higher speeds/ frequencies.

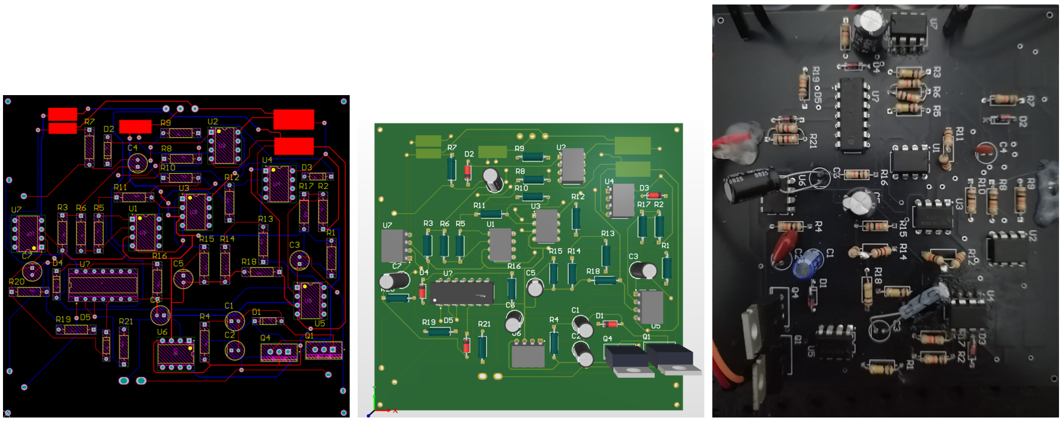
CD4066 Switch IC

This is a CMOS switching IC with 4 analog/digital switches that can conduct in both directions. Each of the switches have independent control inputs.[4]

- Logical switching : The switches are CMOS based unlike mechanical relays. This ensures fast switching. There is also no mechanical wear which increases the longevity of the circuit.
- Compact size : The IC is more compact than relays, which make it suitable for compact circuits.

4 PCB Design

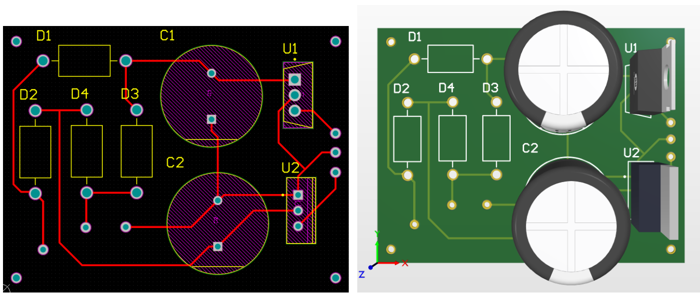
For the main voice over circuit, we designed a 93 mm × 100 mm PCB using Altium Designer. The PCB was manufactured by JLCPCB. The power line traces of the PCB are 0.33 mm and 0.4 mm wide, while the normal traces have a width of 0.25 mm. The components were placed in a wide area to avoid induced noise, as this was an audio application. The traces were also spaced relatively far apart to reduce cross-talk[5]. The audio input for microphone and output speaker was placed on two different edges to eliminate the audio feedback. This is a dual layer PCB.



(a) PCB Design (b) 3D view of PCB (c) Soldered PCB

Figure 8: Stages of PCB Design and Assembly

In addition to the main PCB, a smaller PCB was designed for the circuit to supply the required +-12V DC voltage for the circuit. It has a size of 57 mm × 44 mm. Since this PCB is for power, it has traces with the width 0.38 mm. It is a single layer PCB. It was also manufactured by JLCPCB.

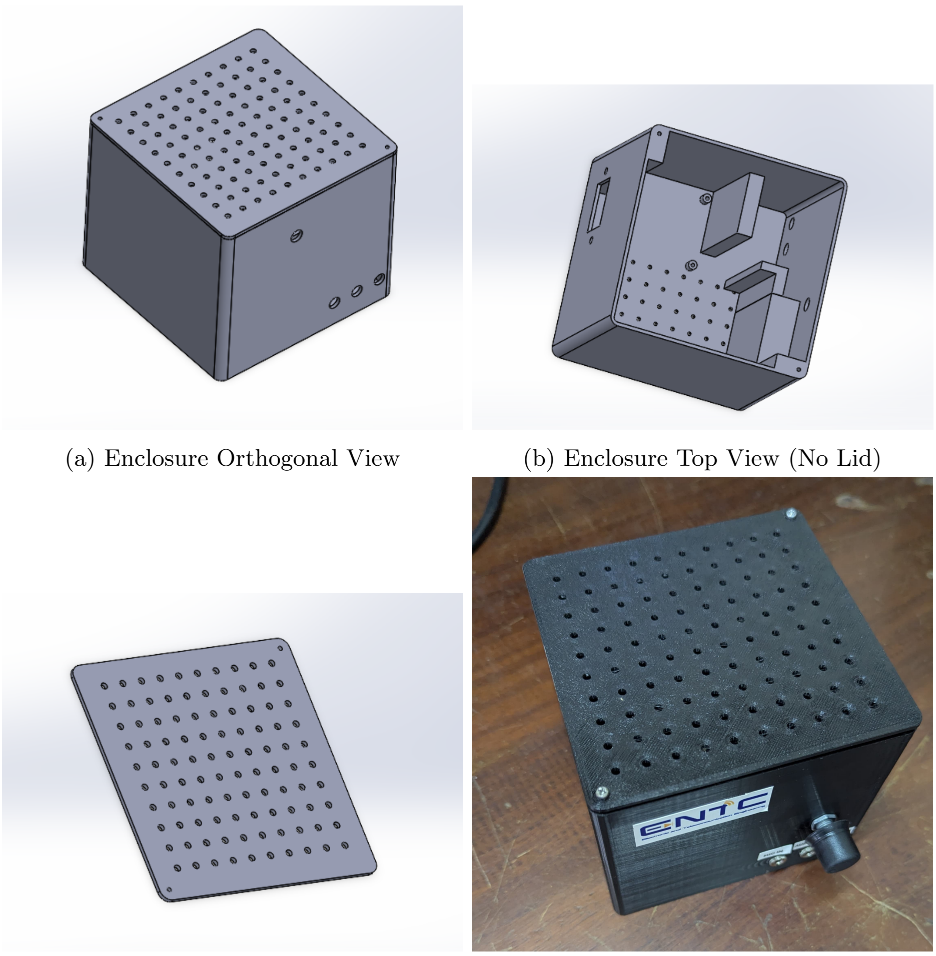


(a) Power PCB (b) 3D view of power PCB

5 Enclosure Design

The enclosure for the audio voice-over circuit is designed to protect the components while maintaining functionality and ensuring portability. We also considered internal and external requirements such as ventilation and connectivity. The enclosure was designed using SolidWorks software. The enclosure has dimensions of 11 cm $\times$ 11 cm $\times$ 10 cm. It has ventilation holes on top to ensure proper ventilation for heat dissipation(transformer & power transistors heat). Size and spacing were optimized to balance airflow and structural integrity.

There are internal mounts for PCBs and other components. There are screws and fasteners for secure positioning of components. There are also access ports on the sides for power supply, audio jacks, potentiometer & switch. Dimensions match standard connectors to ensure compatibility. The enclosure was manufactured using black PLA for durability and lightweight properties.



(a) Enclosure Orthogonal View

(b) Enclosure Top View (No Lid)

(c) Top Lid

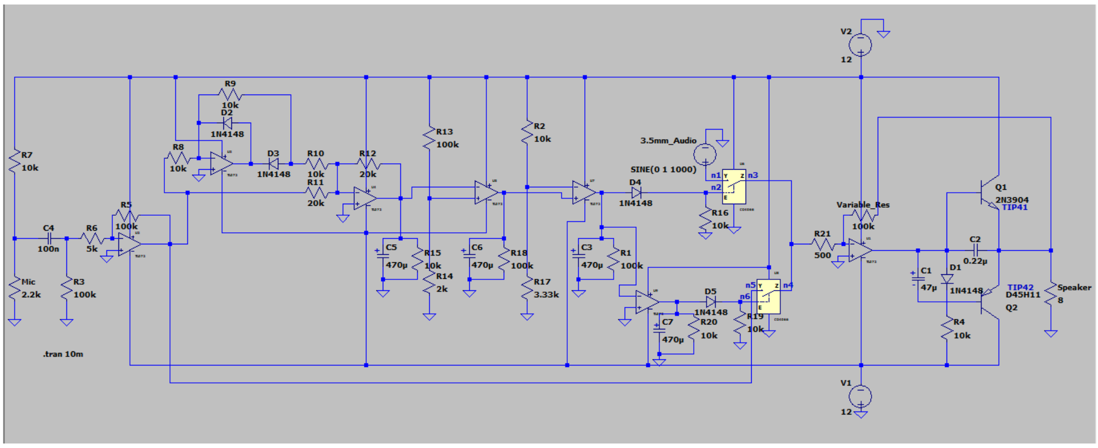
(d) Finished Enclosure

Figure 10: Enclosure Figures

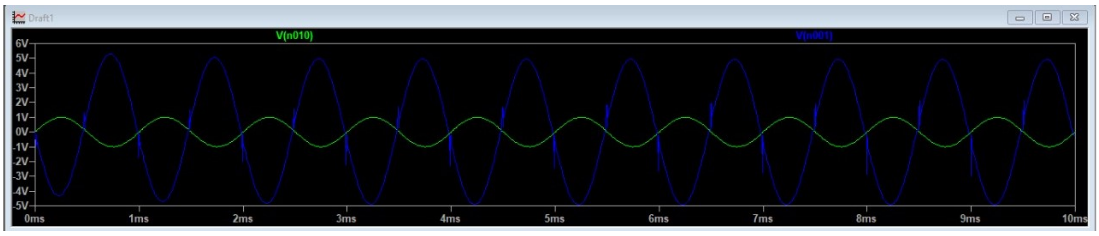
6 Software Simulation and Hardware Testing

Simulation

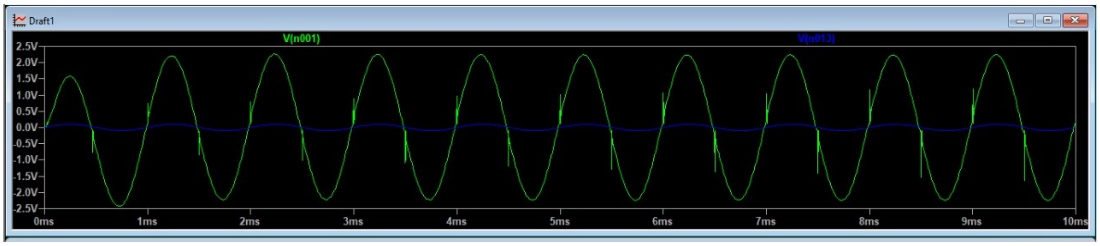
The circuit was first simulated using LTSpice simulation software. The microphone and 3.5 mm audio sections were simulated separately because the software did not have a model for CD4066 switching diode. The circuit was verified using its results before the initial breadboard implementation.



(a) Simulation circuit



(b) Output from 3.5 mm input

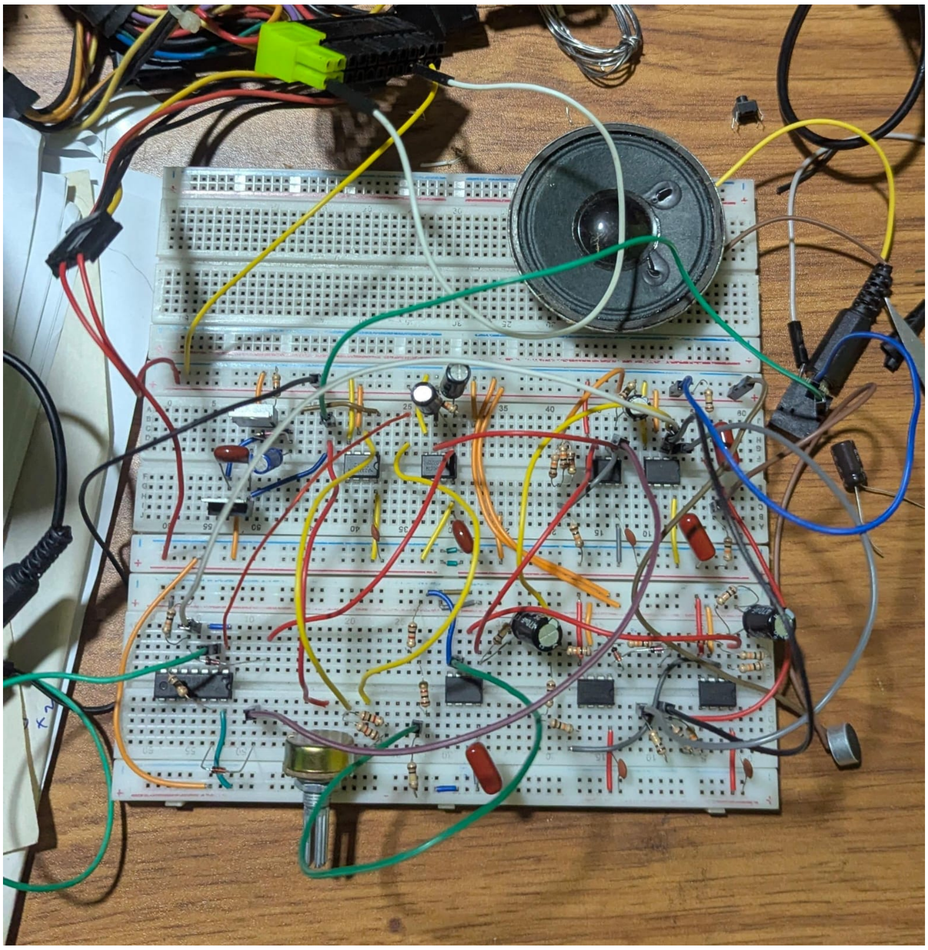


(c) Output of microphone input

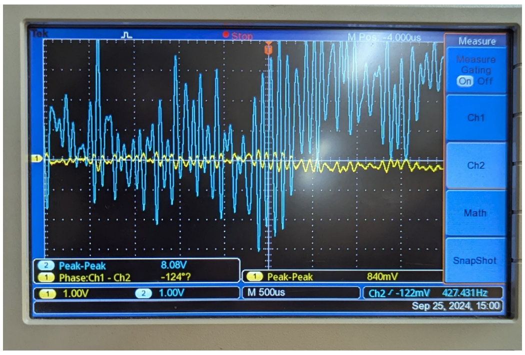
Figure 11: Simulation and Results

Hardware and Testing

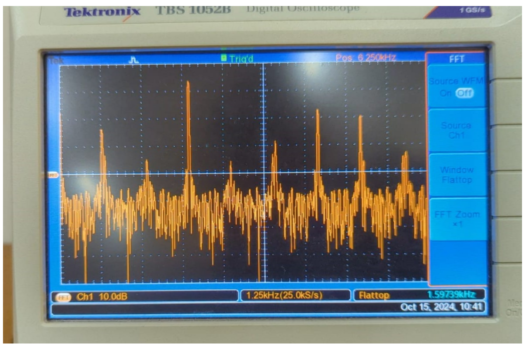
The circuit was implemented on a breadboard and the spectrums of audio inputs as well as echo were studied using an oscilloscope.



(a) Final Breadboard Implementation



(b) Output and Input from 3.5 mm



(c) Echo Spectrum

Figure 12: Hardware Implementation and Results

7 Conclusion & Future Works

In conclusion, our project meets the requirements given in the project description. We have also improved upon the requirements by making the circuit switch between channels automatically instead of using a button as described. While designing the circuit, the main issue was noise and feedback from the speaker. That is remedied by implementing a high pass filter near the microphone input. By using components optimal for audio applications, we were able to get clear audio output.

Future Works

- Use both wall power and a battery in unison so the device can be used without wall power for some time. Also implementing rechargeable batteries so they will charge when the device is plugged to wall power.
- Improve signal fidelity of the PCB by adding ground and power planes.
- Implement equalizers to control different qualities of the audio instead of just the volume.
- Make the enclosure more ergonomic and attractive.

8 Contribution of Group Members

Index Number	Name	Contribution
220683P	Weerakoon W.M.B.H	Circuit Design , Simulation, Testing and Debugging
220257N	Jayasekara S.P.R	PCB design, PCB Testing, Documentation
220663F	Viduranga J.K.A	Circuit Design, Testing and Debugging
220452H	Peiris P.I.U	Enclosure Design, Resource Management

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[2] D. Das, *Half wave and full wave precision rectifier circuit using op-amp*. [Online]. Available: https://circuitdigest.com/electronic-circuits/half-wave-and-full-wave-precision-rectifier-circuit-using-op-amp.

[3] Alldatasheets.com, *Tl072 datasheet*. [Online]. Available: https://www.alldatasheet.com/datasheet-pdf/pdf/28775/TI/TL072.html.

[4] Alldatasheets.com, *Cd4066 datasheet*. [Online]. Available: https://www.alldatasheet.com/datasheet-pdf/pdf/26882/TI/CD4066.html.

[5] Z. Peterson, *What is signal integrity?* [Online]. Available: https://resources.altium.com/p/signal-integrity.