Miniature, Lightweight, Unnoticeable, Hearing Aid

Senior Design Team 11

Pedro Hernandez, Rakshil Soni, Selina Cervantes

Dr. Mohammad Moghimi

College of Engineering and Engineering Technology Northern Illinois University, DeKalb, IL, USA

***Abstract* — Conductive hearing loss is a common defect in infants and younger children that can occur at birth or in later years. Conductive hearing loss involves physical deformation of the outer and middle portions of the ear [3]. If hearing loss is not resolved within a few days after being discovered, the infant may have trouble in developing language, speech, and communication skills throughout their life. The current solutions for conductive hearing loss include bone-anchored and cochlear implanted hearing aids [2, 3]. The problem with these devices is that they require invasive procedures such as surgery or implantable aid, which is not an ideal method to be carried out on newborn infants and younger children. The purpose of this device is to create a non-invasive solution for conductive hearing loss that is suitable for infants and young children.**

I. Introduction

According to Boston's Children Hospital, "conductive hearing loss is the most common cause of hearing loss in infants and young children. It happens when something is blocking the outer or middle ear and preventing sound waves from reaching the inner ear."

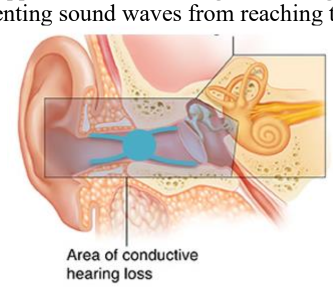

Figure 1: Common area for conductive hearing loss.

A blockage forms at the outer portion of the ear, this can be seen in blue in the above figure. The blockage prevents sound waves from reaching the middle and inner ear. Sound waves travel into the outer section of the ear and continue to flow into the middle and inner portion where the Tympanic membrane exists. The Tympanic membrane vibrates in response to these waves and allows us to hear [1]. Most children are either born with conductive hearing loss or others get an ear infection leading to this condition [2,3]. Existing devices and solutions are directed towards adults and are not proven to be suited for children under six years of age. These solutions require surgical procedures or implanted aid [4]. Waiting for a suitable age can be counterproductive: if hearing loss is not solved in the early stages of life, then a child can experience a struggle to develop language, speech, and communication skills, which will affect them in the long run.

II. Project Design

The design for this project is a miniature device that has a strip like form factor that sits on the hairless portion of skin behind the user's ear. This emulates the functionality of typical bone-anchored and cochlear implanted hearing aids without the need for any invasive procedures. The uniqueness of this design is that using a contact actuator, the device will be able to vibrate against the skull and send signals to the inner ear [3,4]. These vibrations will be perceived as sound, making the device safe for children as it requires no invasive procedures. The focus of this project is to prove this concept by designing a prototype of the miniaturized hearing aid. The prototype has proven that the simplistic miniature design can be achieved through further research and development [3]. The main components for this device include a micro-electromechanical systems (MEMS) microphone, piezoelectric actuator, breadboard, and other necessary electronic components (resistors, capacitors, etc.) to fulfill the design needs for the project. Figure 2 shows an overview of the device's functionality in the form of a flowchart along with an image of the prototype.

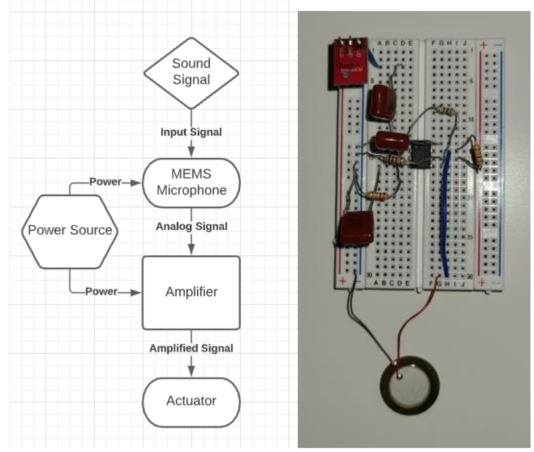

Figure 2: Flowchart and prototype

As shown in the flowchart the device can detect sound signals in the atmosphere using a MEMS microphone and convert that signal into an analog signal. The analog signal is filtered and amplified through the audio amplifier designed in the electronic circuit portion of the design. The electronic circuit and MEMS microphone are powered by an external power source. The amplified signal is finally sent to the actuator which will produce an analog vibration signal. To analyze the vibration signal being generated an accelerometer is used and placed on a flat surface along with the actuator.

III. Results

The output of the device is tested by removing the MEMS microphone device and replacing it with a signal generator so that a constant signal is being sent through the device to get accurate results. Figure 3 represents the data collected from the experiment comparing the Input signal to the output voltage. From the graph it is made clear that there is almost no signal loss from the system when tested from a frequency range of 20Hz-20kHz. The only major deficiencies occurred when the device was operating from 20-100Hz, this is because at lower frequencies the electronic components struggle to pick up such small signals.

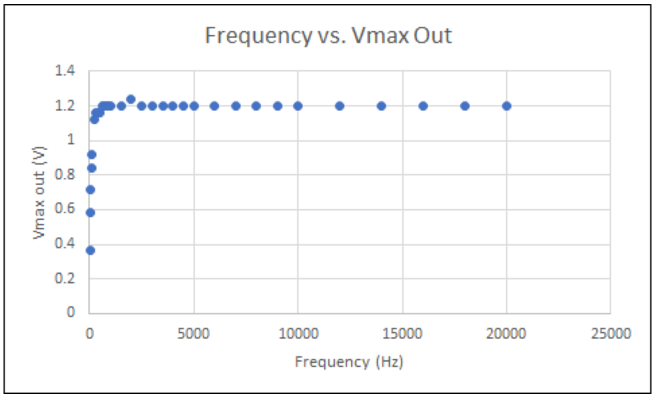

Figure 3: Graph of Frequency vs. Vpp Out

A test that was run involved testing the device with the MEMS microphone and the PE actuator connected. In this test it was observed that when speaking into the microphone the vibrations created by the PE actuator do in fact correspond to the audio signal being inputted [2,5]. The image in Figure 4 shows the input signal from the microphone in yellow and output audio signal going into the PE actuator in green.

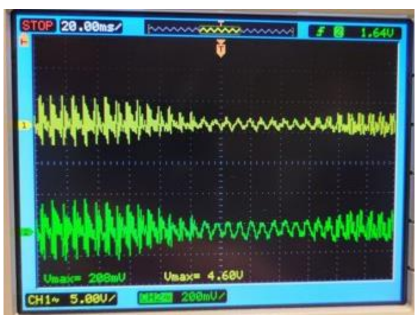

Figure 4: Input/Output signal of the device via speech

Additional testing was done to characterize the actuator [3]. The chosen actuator has a small radius and is thin (less than 1um). This actuator would have a resonance frequency below 1kHz in order to encompass the most common noises and was driven by the circuit used for the device [2,5]. Dampening of the actuator (by PDMS) was taken into account when deciding the final prototype actuator. In Figure 5 the input signal (green) versus the output signal of the chosen actuator (yellow) is shown.

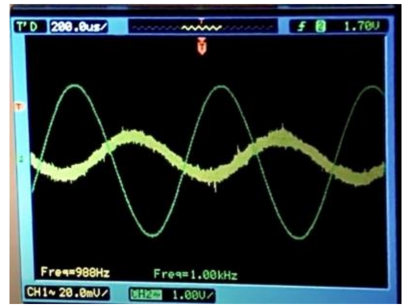

Figure 5: PE actuator signal compared to input signal

IV. Conclusion

The next step to improve the device would be to fabricate the circuit and try to package the device in a smaller form factor which allows the device to be tested on individuals to see if the vibration signals are producing a strong enough signal for the individual to hear. This prototype has provided the proof of concept for future research and development. Along with that the device needs to be tested with a battery device such as a flexible battery as the external power source being used in this prototype is obviously not miniaturized for the final design.

Acknowledgment

Members of this group would like to thank faculty mentor and client, Dr. Mohammad J. Moghimi and TA, Sandhya Chapagain for their support and guidance through this project. The group would also like to thank Mr. Edward Miguel for allowing the group to work in his lab and help us with our circuit design needs.

References

[1] Alberti, P. W. (2006). The anatomy and physiology of the ear and hearing. Retrieved October 3, 2020, from https://www.who.int/occupational_health/publications/noise2.pdf

[2]Qin, X., & Usagawa, T. (2017). Frequency characteristics of bone conduction actuators – Measurements of loudness and acceleration. *Applied Acoustics, 126*, 19-25. doi:10.1016/j.apacoust.2017.05.007

[3] Shin, D., & Cho, J. (2018). Piezoelectric Actuator with Frequency Characteristics for a Middle-Ear Implant. Sensors, 18(6), 1694. doi:10.3390/s18061694

[4]Center for Devices and Radiological Health. (n.d.). Overview of Device Regulation. Retrieved from: https://www.fda.gov/medical-devices/device-advice-comprehensive-regulatory-assistance/overview-device-regulation

[5]M. (2018, February 5). Piezoelectric sound components. Retrieved from https://www.murata.com/~/media/webrenewal/support/library/catalog/products/sound/p37e.ashx?la=en-us