Introduction

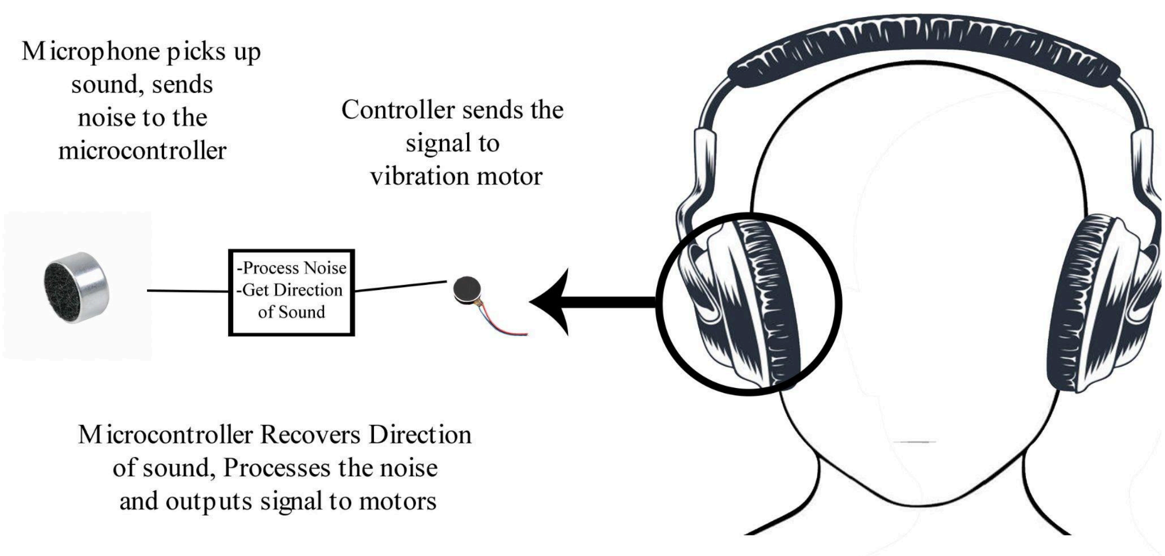
Problem:

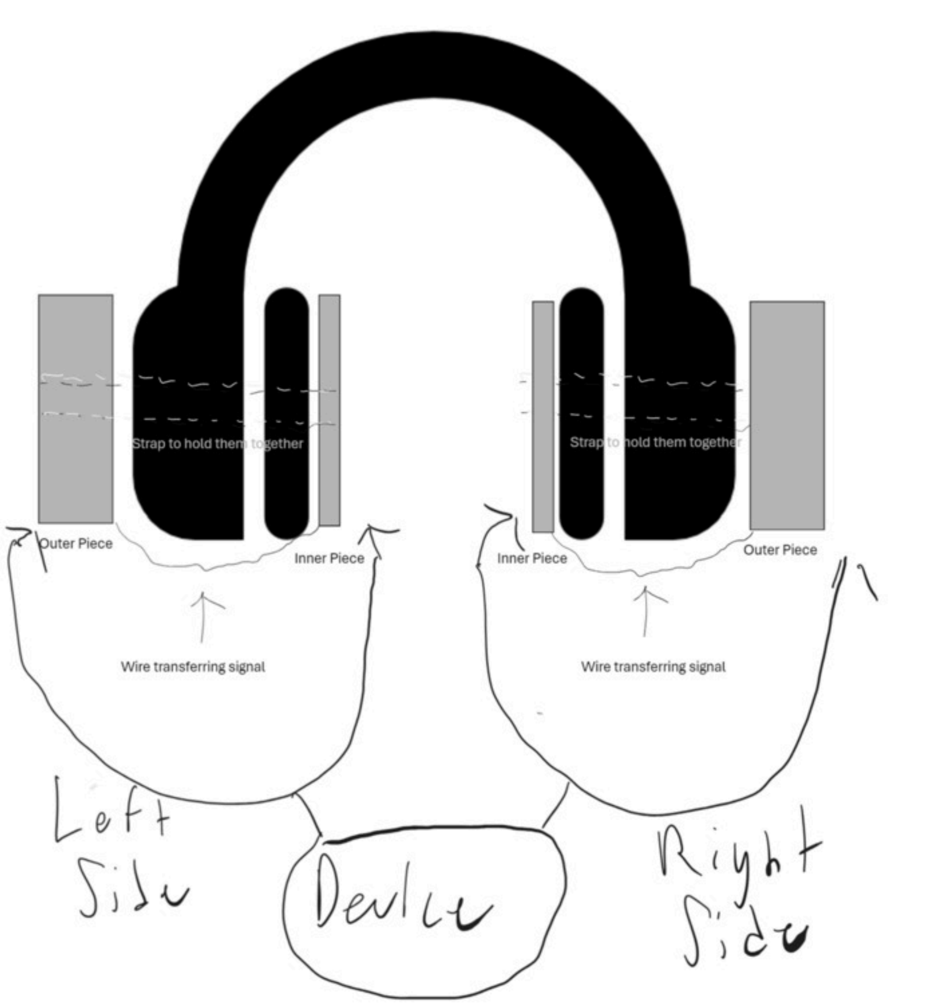
Hearing is one of our most essential senses. Hearing is the only sensory system that allows us to know what is going on everywhere in our environment at once. This property of hearing offers great advantages for survival as most alerts can be heard before they are ever seen. Deaf individuals, and those hard of hearing, have lost those advantages; Due to this, they lack the awareness of their environment offered with sound. We aim to mitigate some of the struggles of those with hearing loss.

Solution:

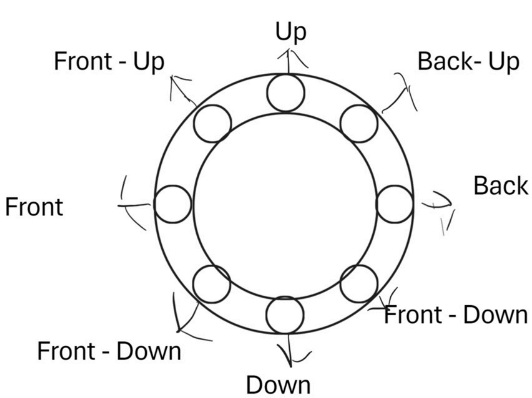
As a solution, rather than relying on the sense of sound, they can use the sense of feeling to get information they need from their immediate surroundings with directional haptic feedback. Haptic feedback is the use of vibration to convey information to the user (for example play station controllers or phone notifications). The idea is to place individual vibration motors along the outer rings on each side of over-ear headphones or ear mufflers. When a loud enough sound is played from any direction to the user, each individual motor vibrates in a way to give the user a sense of directional feedback. The goal of this device is to give the user heads up on where to look to see where the sound came from regardless of how little they can hear from their surroundings.

Diagrams:

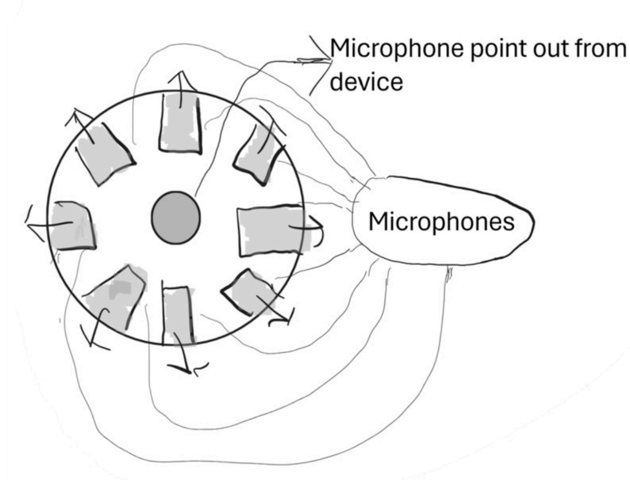


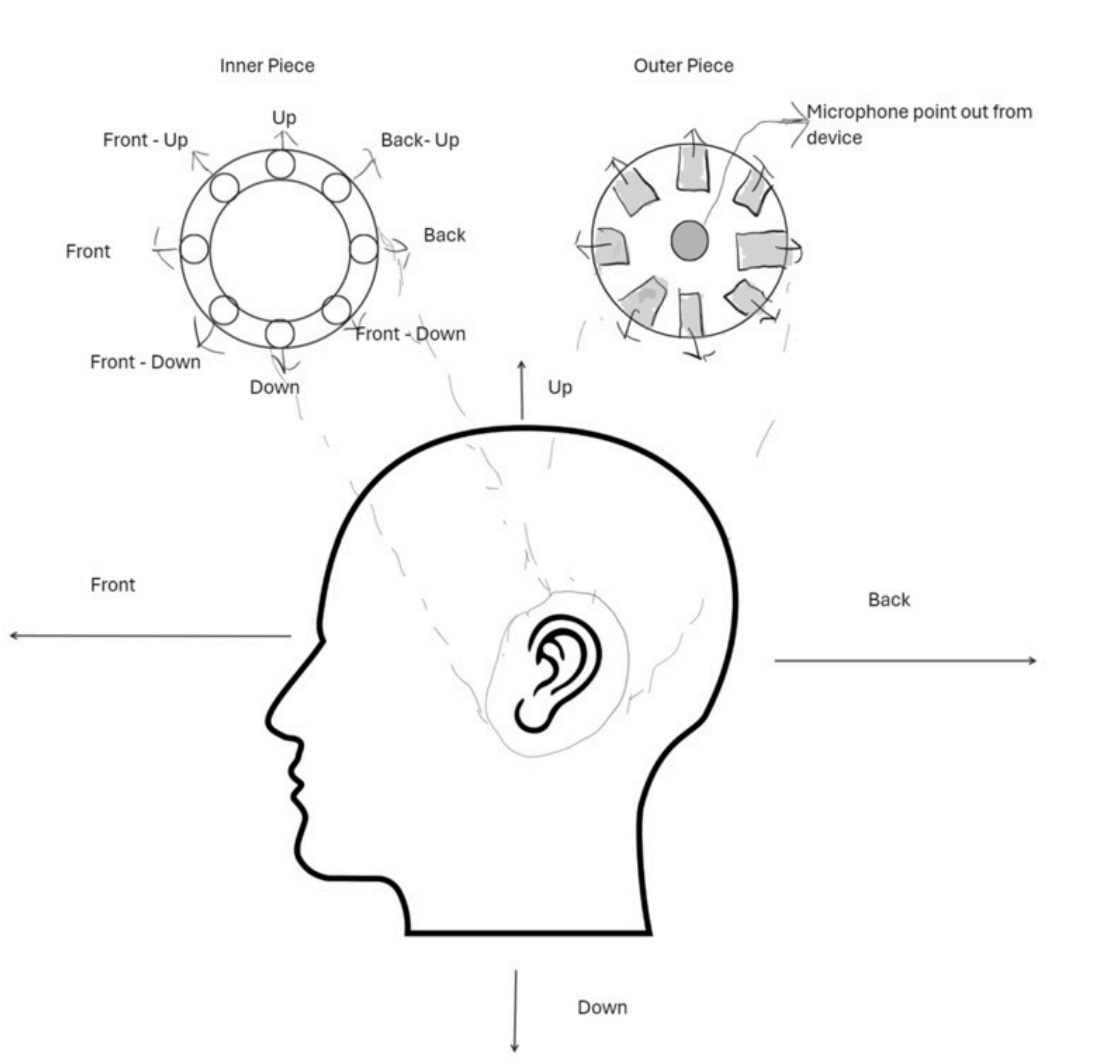


Inner Piece



Outer Piece





High-level requirements list:

1. Audio Sensing: Sound sensors are able to pick up loud sound from the surrounding environment and determine the direction of the sound based on the trigger sensors.

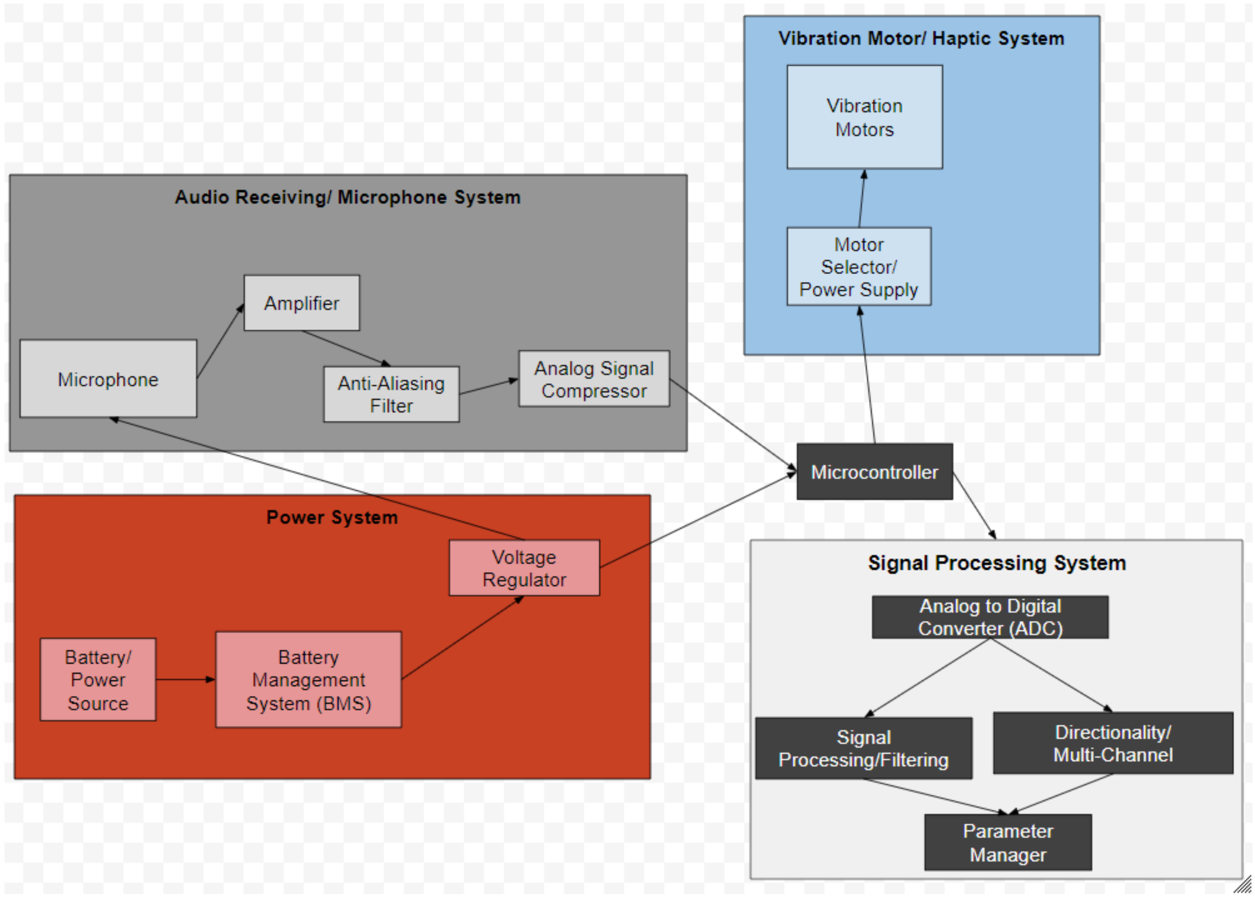
2. Haptic Feedback: When given a direction, the appropriate vibration motors will trigger to inform the user of the direction.

3. Comfortable Fitting: The device fits well and comfortably on the user.

4. User Efficiency: Users can effectively tell where external sound is coming from through the haptic feedback.

Design

Block Diagram:



Subsystem Overview and Requirements:

Power Subsystem

Overview:

One of the most important subsystems for an electrical project is the power component. After research, we plan on using a rechargeable lithium ion battery to power our system(safety specs outlined in ethics and safety portion). Standard industry practice is to use a battery that supplies between 2.75 and 4 volts. After creating detailed design plans we can narrow down exact voltage specs. The Li ion battery will be hooked up to a battery management system(BMS) and a voltage regulator which is standard practice when commercially working with batteries to make sure that power levels stay at a safe value.

Requirements

1. The battery will be hooked up to the rest of the systems via the microcontroller/pcb, controlling the energy dispersion of the headphones as a whole.
2. 2.75-4 volts for safe power range.

3. The Li ion battery will feed directly into the BMS and voltage regulator before being sent off to the rest of the system.
4. Battery must be small enough to fit comfortably in the headset in order to create as much comfort as possible for the user.

Microphone Subsystem

Overview:

This subsystem uses 2 circular microphone arrays, one centered around each of the user's ears, to pick up the sound from the surrounding environment. Each array consists of 9 small unidirectional microphones, each pointing to a different direction including the following: Front, Up, Down, Back, Front-Up, Front-Down, Back-Up, Back-Down, as well as Left or Right depending on if the array is centered around the user's left ear or right ear. This is intended to preserve the directionality from the audio picked up from the surrounding environment.

There is a raw signal to ADC pipeline for each microphone in the microphone arrays, and it consists of the following: a microphone circuit with power supplied by a voltage regulator, an amplifier circuit that increases the signal amplitude, an anti-aliasing filter that limits the signal's bandwidth, and one more voltage regulator that compresses the output signal voltage between 0V to about 3V in order to protect the microcontroller's ADC while converting the signal from analog to digital.

Requirements

1. The subsystem must be able to distinguish the direction of sound sources within reasonable degrees of accuracy.
2. The subsystem must be able to pick up and output sounds within a reasonable hearing range such as 7m.
3. The subsystem must be able input audio signals to the microcontroller's ADC with minimal compromising of the sound integrity without damage to the ADC.

Vibration Motor/ Haptic System

Overview:

The information about a sound and where it is coming from is relayed through haptic feedback from the vibration motors along the ear. Vibration motors will be placed along the ring of each earpiece on both sides of the headphones. Each earpiece (left and right) will have 8 vibration motors around the ear (Front, Up, Down, Back, Front-Up, Front-Down, Back-Up, Back-Down). Based on the sensor's read, the corresponding vibration motors will trigger to give the impression of direction from the user. For example: Sound coming from directly to the left, will trigger the vibration motors on the left earpiece; Sound coming from above and behind, will trigger the Back-Up, Up, and Back vibration motors on both the left and right earpiece; Sound coming from above and in front but to the right, will trigger the right earpiece's Front-Up, Front, and Up vibration motors. The path flow of the subsystem is from the microcontroller to the motor selector (likely a MUX) to the appropriate vibration motor. The Motor selector will supply the power to the motor based on the input received from the controller.

Requirements:

1. The microcontroller must be able to send an appropriate signal to the system which gives the direction that the motors are expected to indicate.
2. The motor selector must trigger the correct motors based on the direction of the incoming signal. The motor selector must also ensure that the motors that should not be triggered are off as well.
3. Vibration motors must be strategically placed around the ear and vibrate at appropriate intensities to effectively indicate to the user the direction that was given through the microcontroller.

Tolerance Analysis

The biggest hurdles that our project must overcome will be picking up the noise through the microphone effectively and processing the noise within the microcontroller. When it comes to sensing the sounds from the environment, the capability of the hardware is limited. We must find microphones that can reliably pick up sounds coming from the direction they are pointing at and ignore the sounds coming from different angles. The importance of finding reliable microphones will directly impact the sound sensing sub system and the noise processing of the microcontroller. When it comes to processing the noise in the microcontroller, we expect to differentiate the various ambient noise of the environment and the sounds that are cause for notice to the user. For the project to be successful, the processing must be fast and efficient from the given signal to the output signal. The area of risk is programming the microcontroller to process many sounds from different environments at different intensities and determining what to send to the motors and what to ignore. Many microcontrollers are efficient in audio processing; Arduino is compatible with many controllers such as the ESP32 and the STM32 which do have capabilities with sound processing. Furthermore, many microphones are capable of reading noise from only the direction they are pointing at a frequency range around from 100Hz and 20kHz. Finally, the micro controller must be able to process the many inputs of each unidirectional microphone to determine the direction of the sound. This requirement poses a risk as the microcontroller may not be able to handle the number of inputs. A solution to this could be to limit the number of inputs and outputs. This solution will also limit the precision device for the sake of hardware, precision limitations can be a benefit to the other subsystems such as the sensors as they will not need to signal as many different directions.

Ethics and Safety

Ethics and Safety

When undertaking any project it is paramount to consider the safety and ethical implications of said project. Our group's understanding is that there are not many ethical guidelines, as specified by the IEEE, that directly apply to our project. Creating a haptic headset to aid in spacial awareness for those both hard of hearing and hearing people does not raise any moral/ethical conundrums right off the bat. However, we believe that it is important for our team to keep these ideas in mind. (ACM Code of Ethics) [1.1-1.7], within this section, the ACM discusses contributing to society in a positive manner which we hope to do for the community by increasing spatial awareness with our headset. The rest of the section discusses how to make the team's efforts fair and and honest by being collaborative and not discriminatory to your teammates and potential users of your product. It is also to keep in mind (7.8 IEEE Code of Ethics) which describes many of the same topics. The IEEE code also places a big emphasis on integrity which we plan to put into every ounce of our project.

Another category that is important to the success of our project is safety. Safety goes hand in hand with ethics, and to make sure our product is as ethical as possible, it's important to make sure it is as safe as possible. Unfortunately unless you are working with a company or have special access, the IEEE will not let you look at safety specifications unless you pay for them but we are able to look into which codes offer the safety information we need. The key aspects to keep in mind when considering safety for our project are the audio and battery risks. Using the IEEE guidelines found in IEEE[269-2010], any audio that we decide to produce through our headphones(if at all) must be between 60-85 db, and 100-8500 Hz for headphones specifically. It is important that we make sure that vibration motors we use will not cause harm to the product user but the items we have researched do not have nearly enough strength for that to be a problem. After going through the lithium ion battery safety sheet provided for us on the senior design website and the overview of IEEE[1725] it is apparent that battery safety is paramount in designing our project. The Li ion batteries we have considered using would all be rechargeable and any battery we purchase we must make sure that the manufacturer is certified by either the IEEE or ACM(preferably both). We will keep an eye out for any swelling of the battery,(which we hope will never happen) in order to safely dispose of any faulty and dangerous materials we could encounter during the project. We must be wary of any faulty connections that could be made when soldering with a battery as well as connecting wires inside the headset. If we keep the battery safety in mind during the course of our project as well as headphones regulations, we are confident that we can have a safe, ethical, and successful project.

References:

[1]IEEE Code of Ethics. IEEE. Retrieved February 7, 2024, from https://www.ieee.org/about/corporate/governance/p7-8.html
[2]ACM Code of Ethics and Professional Conduct. ACM. (n.d.). Retrieved February 7, 2024, from https://www.acm.org/code-of-ethics
[3]IEEE Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets, Handsets, and Headsets. IEEE 269-2010. Retrieved February 7, 2024, from https://standards.ieee.org/ieee/269/4739/
[4]IEEE 1725 and battery powered products, IEEE. Retrieved February 7, 2024, from https://ieeexplore.ieee.org/document/5356015