ECE 445: SENIOR DESIGN LABORATORY

PROJECT PROPOSAL:

BRACELET AID FOR d/DEAF AND HARD OF HEARING PEOPLE

TEAM #59

AARUSHI BISWAS (abiswas7)

ANITYA KAPOOR (anityak2)

YASH GUPTA (yashg3)

TA: Selva Subramaniam
PROFESSOR: Arne Fliflet

Table of Contents

1. <u>Introduction</u>

a. **Problem**

We are constantly hearing sounds around us that notify us of events occurring, such as doorbells, fire alarms, phone calls, alarms, or vehicle horns. These sounds are not enough to catch the attention of a D/deaf person and sometimes can be serious (emergency/fire alarms) and would require the instant attention of the person. In addition, there are several other small sounds produced by devices in our everyday lives such as washing machines, stoves, microwaves, ovens, etc. that cannot be identified by D/deaf people unless they are observing these machines constantly.

Many people in the D/deaf community combat some of these problems such as the doorbell by installing devices that will cause the light in a room to flicker. However, these devices are generally not installed in all rooms and will also obviously not be able to notify people if they are asleep. Another common solution is purchasing devices like smartwatches that can interact with their mobile phones to notify them of their surroundings, however, these smartwatches are usually expensive, do not fulfill all their needs, and require nightly charging cycles that diminish their usefulness in the face of the aforementioned issues.

b. **Solution**

A low-cost bracelet aid with the ability to convert sounds into haptic feedback in the form of vibrations will be able to give D/deaf people the independence of recognizing notification sounds around them. The bracelet will recognize some of these sounds and create different vibration patterns to catch the attention of the wearer as well as inform them of the cause of the notification. Additionally, there will be a visual component to the bracelet in the form of an OLED display which will provide visual cues in the form of emojis. The bracelet will also have buttons for the purpose of stopping the vibration and showing the battery on the OLED.

For instance, when the doorbell rings, the bracelet will pick up the doorbell sound after filtering out any other unnecessary background noise. On recognizing the doorbell sound, the bracelet will vibrate with the pattern associated with the sound in question which might be something like alternating between strong vibrations and pauses. The OLED display will also additionally show a house emoji to denote that the house doorbell is ringing.

c. Visual Aid

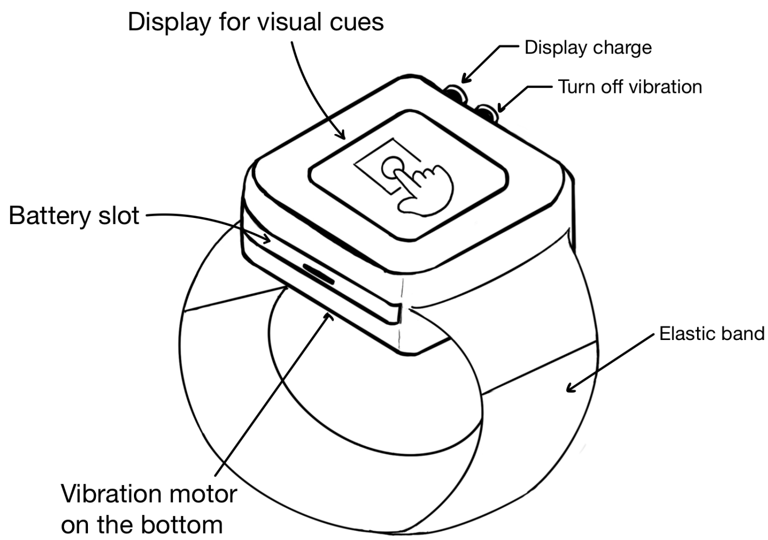

Figure 1: Bracelet Prototype

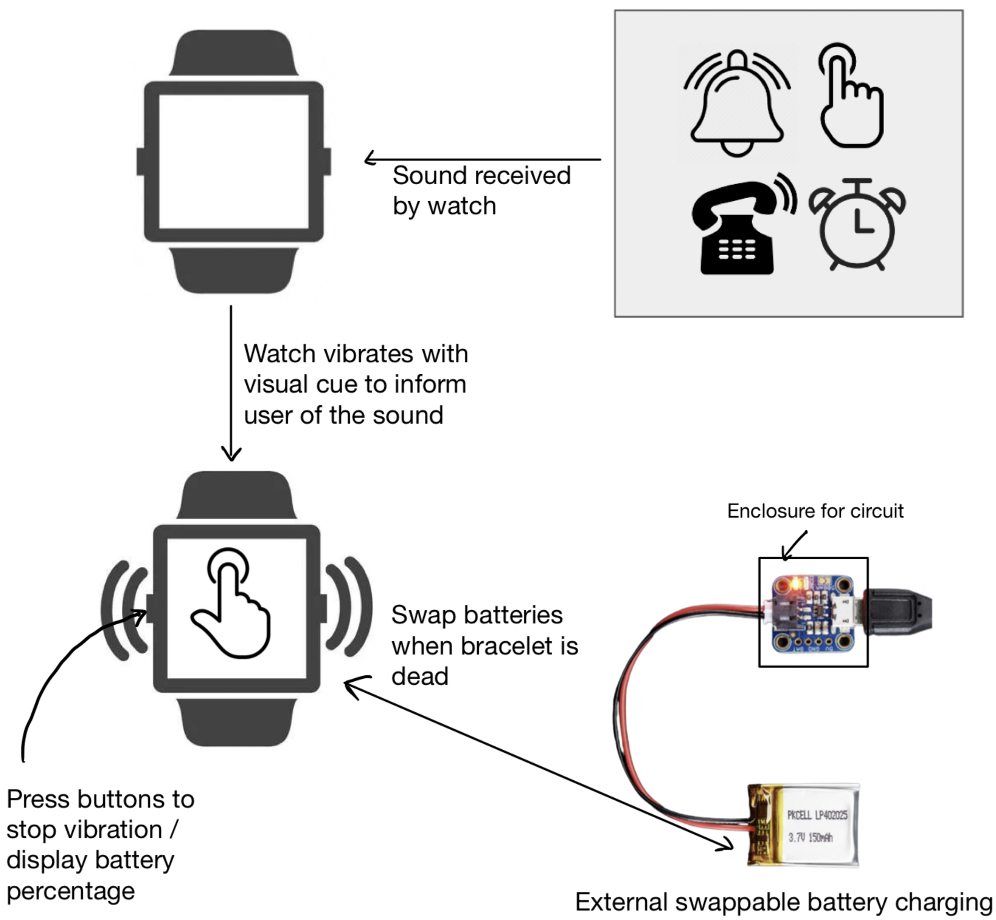

Figure 2: Visual Aid on how the bracelet works

d. High Level Requirements List

- The device should have a small form factor and should be light such that it can sit on a person's wrist without feeling bulky or overbearing, as the device will sit on their wrists for most of the day. It should weigh less than 70 grams for a successful product.
- The device should be able to recognize multiple notification sounds and create different vibration patterns that are recognizable and distinguishable by the user. It should be able to produce at least 10 distinguishable vibration patterns.
- The device should have a feedback time (i.e. time taken for the device to recognize crucial sounds and notify the wearer) of at most 10 seconds

2. Design

a. Block Diagram

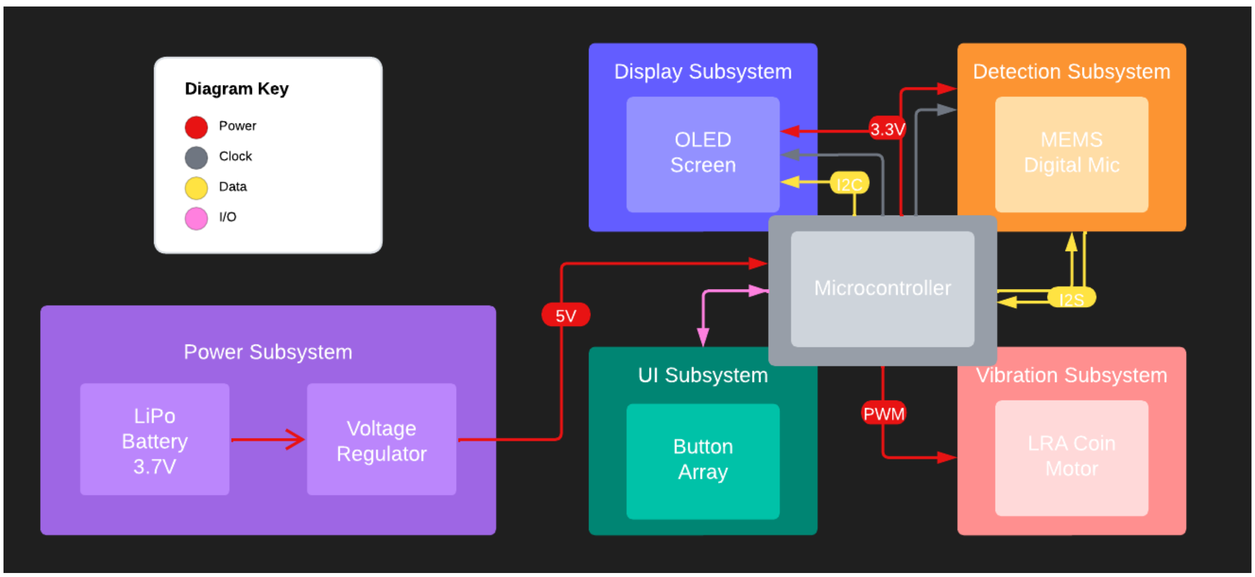

Figure 3: Block Diagram

b. Subsystem Overview And Requirements

1. *Power Subsystem*

The power subsystem handles voltage regulation and makes swapping batteries easy and secure on the device. On the charging side the subsystem will have a simple USB to JST converter with protective charging circuit built into it so that the user may charge the additional battery provided in the kit while the primary battery is used for minimal downtime. The following are the requirements for this subsystem:

a. The charging circuit should have undervoltage, overvoltage, and general Li-Po battery protection.
b. It should have a voltage regulator on the device so that there are no spikes or dips in voltage.
c. It should be able to keep the device powered for at least 24 hours, and provide a stable 3.7V across the device.

2. Sound Detection Subsystem

The sound detection subsystem involves the MEMS digital microphone and the auxiliary circuitry to allow the microphone to detect a range of frequencies. The microcontroller will run FFTs when it detects sounds and check whether the peak frequencies match that of any of the predetermined sounds our device can detect. The following are the requirements for this subsystem:

a. The subsystem should be able to detect different sounds with a frequency range of at least 200 Hz to 15 kHz
b. It should provide a digital output, preferably with an I2S output interface.
c. It should have a small profile, and should have a maximum current draw of 5mA.

3. Vibration Subsystem

The vibration subsystem is responsible for providing haptic feedback to the user when a predetermined sound is detected by the microcontroller. With varying vibration amplitudes the vibration motor will be given signals by the microcontroller that will generate unique patterns for corresponding sounds detected by it. The following are the requirements for this subsystem:

a. The vibration motor used should have a mostly linear relationship of their vibration frequency with regards to input voltage.
b. It should be driven by a PWM input, originating from the microcontroller package.

4. Display Subsystem

The digital display subsystem is responsible for providing visual feedback to the user when a predetermined sound is detected by the microcontroller. The user will be shown a visual representation of the sound detected by the microcontroller (Ex. a fire emoji when the fire alarm is detected). The following are the requirements for this subsystem:

a. The display subsystem should have a current draw less than 20mA.
b. The entire subsystem should be light and not excessively large.
c. The display board should be compatible with most microcontrollers and should have a general, widely used interface.

5. User Interaction Subsystem

The user interaction system contains a set of buttons that will be used to control the bracelet. Button 1 will display the battery percentage and Button 2 will stop the vibrations once the user is notified. This means that the first button will require the system to interact with the power subsystem and the second one will require interaction with the vibration and display subsystems. The following are the requirements for this subsystem:

a. The two buttons should be responsive and not be difficult to use.
b. They should not be too large that they are pressed accidentally but not too small that they are hard to interact with.

c. Tolerance Analysis

A critical portion of the entire design is the vibration aspect of the device, which is handled by a vibration motor. The vibration motor used, the VG1040003D, can produce up to 2.1Grms vibration acceleration, which is an expression of the intensity of the vibration. However, one major issue that our design might face is that a vibration might cause the motor to move off of its pressure tab, and stop functioning, or even that the vibration might cause contact issues with other peripherals. Therefore, we want to ensure that the maximum magnitude of amplitude movement is less than 0.05mm.

From the datasheet, we can see that the maximum vibration produced is about 2.1Grms, with a tolerance of ±30%, at a frequency of 170Hz [6]. Since the vibration acceleration is in rms, we can convert them to peak measurements by multiplying by the square root of two, and converting to metric by dividing by multiplying by 9.81 as follows:

Grms	Acceleration Peak in metric
2.1	27.74
2.73 (+30%)	37.86

1.47 (-30%)	20.38

Table 6: Grms to Peak Acceleration

Now from the standard harmonic motion equation found here [7]:

$$a_{peak} = \pm(2\pi f)^2 A$$

Thus, we get the following values for Amplitude magnitude:

Grms	**Magnitude of Amplitude in mm**
2.1	0.0243
2.73 (+30%)	**0.0332**
1.47 (-30%)	0.0178

Table 7: Grms to Magnitude of Amplitude in mm

As can be seen above, the maximum magnitude of amplitude displacement due to the vibration itself, is 0.0332 mm, which lies well within the tolerance included above, ensuring that there should not be any impact on the contact of components due to the vibration of the motor.

3. Ethics and Safety

Ethics

Our group followed the IEEE Code of Ethics and the ACM Code of Ethics to commit ourselves to the highest ethical standards possible which includes the following:

1. According to the IEEE Code of Ethics 1.1, we will promptly disclose any factors of our product which might cause harm to the user and will prioritize safety, health, and welfare of our customers while designing and building our product. This includes ensuring that we use safe and top quality material and components for our technology and disclose any safety hazards to our projects, more of which can be found under the ‘safety’ section.
2. According to the IEEE Code of Ethics 1.5 and ACM Code of Ethics 2.4, we will seek and accept any criticism about our technology and work on improving it. This includes meeting with our assigned TA and Mentor Jack Blevins regularly to keep them updated on the progress of our technology and get feedback on any

possible improvements. We will also ensure that we credit and cite all possible sources and references used.

3. According to the IEEE Code of Ethics 1.6 and ACM code of Ethics 2.6, we will use this opportunity to develop our skills and experience. We will make certain that each of us has the proper certification required to take on a particular technological task. Each of the members completed the lab safety training before using the lab and underwent soldering practice and training before undertaking the task of soldering for our final technology. We also ensured to complete any other training as assigned by the course.

Safety

Safety concerns have been considered in the design of this proposal, illustrated in the following points:

1. Since we will be using a set of two, hot-swappable Li-Po batteries in this product, we will have to consider safety precautions for the user. This necessity for Li-Po battery safety stems from the issue of spontaneous combustion which can occur from excessive or rapid charging and discharging. To ensure that we do not face any issues related to this, we will ensure that we read through the datasheet for the battery carefully, and design our power subsystem around this issue.
2. On a similar note, we will have to ensure that the electrical components in the device are properly enclosed and are not at a risk of short circuiting and causing battery issues. To combat this potential issue, we will work with the machine shop to ensure that none of the important and/or dangerous electrical components are exposed, especially the power subsystem.
3. Another smaller safety issue is regarding the charging circuit. This circuit will also have to be shielded and enclosed from the user and the surroundings, which is why we will ensure that the charging circuit also has an enclosure designed by the machine shop.

References:

1. "ACM Code of Ethics and Professional Conduct." *Association for Computing Machinery*, https://www.acm.org/code-of-ethics. Accessed 9 February 2023.

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3. "LRA Coin Vibration Motor - VG1040003D." *Vybronics*, https://www.vybronics.com/coin-vibration-motors/lra/v-g1040003d. Accessed 9 February 2023.

4. "Insight Into ESP32 Sleep Modes & Their Power Consumption." *Last Minute Engineers -*, https://lastminuteengineers.com/esp32-sleep-modes-power-consumption/. Accessed 9 February 2023.