System Design for SE 4G06, TRON 4TB6

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Revision History

Date	Version	Notes
Date 1	1.0	Notes
Date 2	1.1	Notes

Reference Material

This section records information for easy reference.

Abbreviations and Acronyms

symbol	description
SE 4G06, TRON 4TB6	Explanation of program name
[... —SS]	[... —SS]

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1 Introduction

Synesthesia Wear is a wearable product that assists users with certain vocal tasks that need attention. These tasks can be generic or custom to the user as needed. Furthermore, the product will use signal processing to gather and analyze information to determine the best and most appropriate feedback (via vibrations) to send to the user. As a result, this gives the users peace of mind knowing that if their attention is needed (doorbell, ring, name call, etc.), Synesthesia Wear will be able to alert them.

2 Purpose

The purpose of this document is to be able to identify and elaborate on all aspects of design involved in the creation of the Synesthesia Wear system. This involves decomposing the system into different categories and components that all have an impact on the system's overall design and functionality.

To add on, this document is intended to be viewed in conjunction with the *MG.pdf* (Software Architecture Design) and the *MIS.pdf* (Detailed Design) documents so that readers may have a full comprehension on the many aspects of Synesthesia Wear's design in its entirety.

3 Scope

3.1 Document Scope

As stated before, this document will split up the system design into different categories and components such that the readers may be able to better understand each components impact on the system's functionality/completeness.

With the above in mind, the scope of this document will involve:

- **Project Overview:** This section goes over the system's behaviour, undesired event handling, system components, and requirement-design connections.
- **System Variables:** As its name suggests, this section goes over variables/aspects to the system that has the potential to change.
- **User Interfaces:** This section involves elaborating on the interfaces that users interact with when using the Synesthesia Wear system.
- **Design of Mechanical Hardware:** In this section, details on what will be built, fabrication, materials, and drawings/sketches for mechanical components will be discussed in further detail.

- **Design of Electrical Components:** Similar to design of hardware, this section will instead involve details regarding electrical components.
- **Design of Communication Protocols:** For this section, details on the communication protocols used in the Synesthesia Wear system will be discussed.
- **Timeline:** This section will go over the schedules of all remaining tasks for Rev 0 and which team member will be responsible for each task's completion.

3.2 Assumptions

The system is designed with the following assumptions:

A1	Each user has a device and WIFI capable of installing the Synesthesia Wear application.
Rationale	Without a device and/or internet connection, the user will be unable to benefit from using Synesthesia Wear.

A2	The users set their sound configurations to realistic daily-life sounds.
Rationale	The system would be inaccurate when trying to process imaginary or rare sounds with a lack of audio samples (like a meteor crash).

The following are in reference to the critical assumptions in Synesthesia Wear's *HazardAnalysis.pdf* document:

A3	The battery will not need to be replaced during product lifespan.
Rationale	It is undesirable and annoying for users if they had to replace the battery frequently during use.

A4	The microphone is not blocked and has realistic access to the environment.
Rationale	If the microphone is intentionally blocked or put into an environment that hinders its detection (anechoic chamber), it is unreasonable to expect accurate results.

3.3 System Context

Figure 1: System Context Diagram

4 Project Overview

4.1 Normal Behaviour

When starting off, the users should strap the Synesthesia Wear bracelet onto either of their wrists as it was intended. Afterwards, users would have to install the Synesthesia Wear app onto a device of their choice and possibly look through the app to get more familiar with its features and user interface. When ready, the user would then input their desired sound configuration settings into the app and then save them so that the app can send these settings over to the bracelet for configurations. Once recieved, the bracelet can then start to detect for sounds where its built-in microcontroller will process these sounds and try to match it with the sounds configured in the settings. Lastly, once a detected sound has "accurately" (according to Machine Learning Algorithm) matched a configured sound, a vibration alert signal will be sent to the built-in vibration motor which will notify the user that their attention is needed.

4.2 Undesired Event Handling

Currently, there are only a few undesired events that can be indentified. However, as time progresses, more undesired events will be recognized and dealt with appropriately. So for now, any undesired events not yet discovered will be resolved by setting the Synesthesia Wear system into a dormant state and alerting the user. This makes it so that potential system issues are prevented while also keeping the user informed that the system is in a dormant state and needs a reset for continued use.

With the above in mind, an undesired event that has been identified is in regards to the bracelet trying to detect/process sounds before sound configuration settings have been set.

To deal with this, similar to unidentified events, the Synesthesia Wear system will be created such that it is in a dormant/inactive state until sound configuration settings have been inputted. However, one exception would be that there is no need to alert the user for a reset since they have just started using Synesthesia Wear in its refreshed/new state.

Another undesired event would be in regards to the components breaking or malfunctioning. In these cases, the system will be made such that it tests connections/signals between components (like microncontroller, application, etc.) and alerts the user when a connection test has consistently failed. Afterwards, the user would need to contact the Synesthesia Wear team and they would then try to fix the components or order new parts to replace the broken ones.

A third undesired event would be in regards to intentionally covering/hindering the bracelet to detect sounds via holding the bracelet or going into a anechoic (soundless) chamber. In this situation, the microphone in the bracelet will be unable to accurately detect sounds in the environment while its functionality is obstructed. With this in mind, it is believed that there is not really any resolution needed for this situation considering once the user reenters a "normal" or unhindered environment, so long as the components are undamaged, the system's functionality should still work as intended.

4.3 Component Diagram

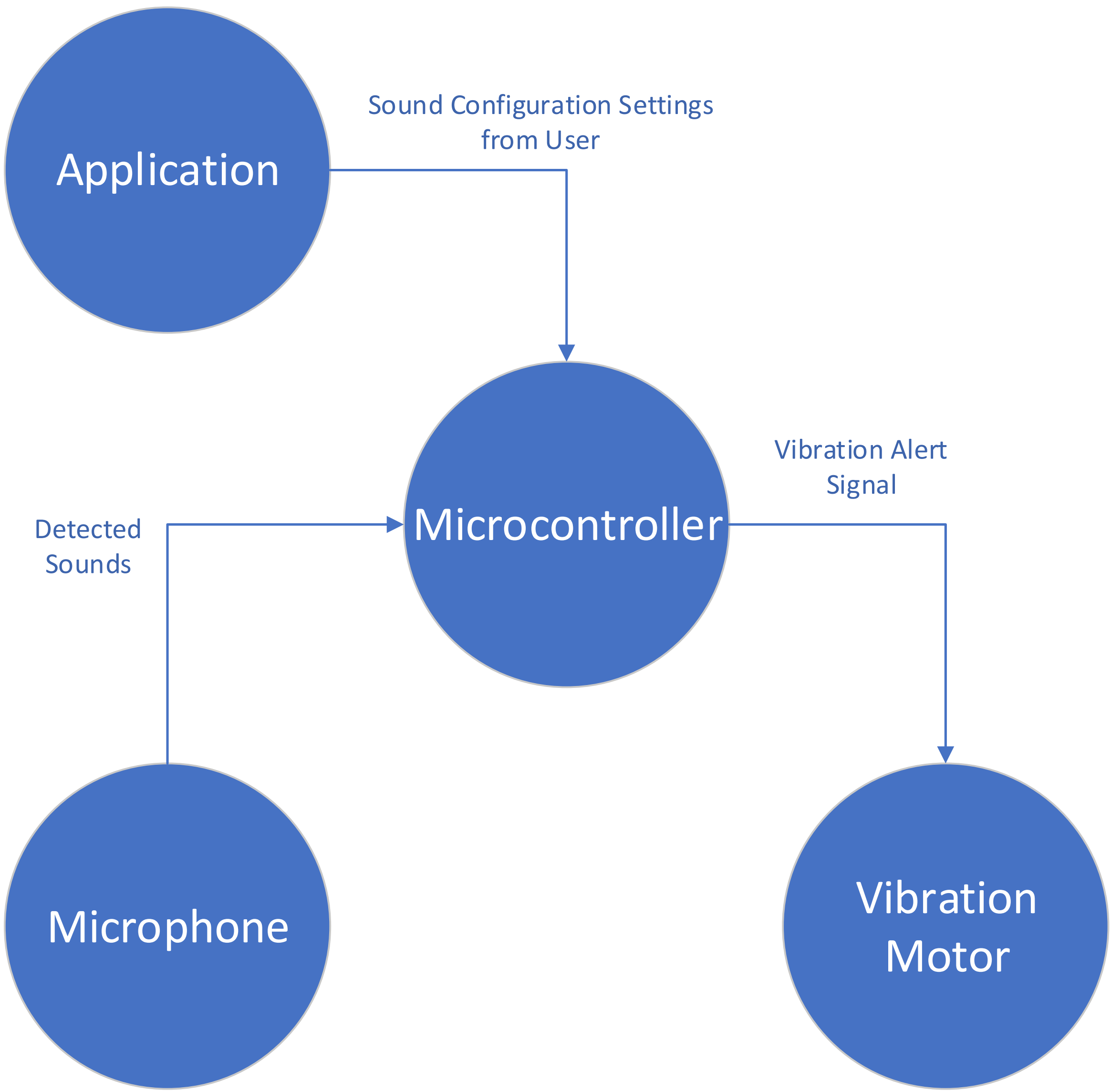


Figure 2: Component Diagram

4.4 Connection Between Requirements and Design

The following requirements were taken from Synesthesia Wear's *SRS.pdf* document:

Table 1: Requirements and Design Connections Table

Requirements	Design Decision
Capability to pick up sounds.	Need to purchase and integrate a microphone.
Capability to classify different sounds.	Need to purchase and integrate a programmable microcontroller that can run machine learning classification algorithms.
Ability to set/change sound classifications.	Need to create an application that allows users to change classification settings.
Ability to effectively give the user feedback on a sound classification match.	Need to purchase and integrate a vibration motor into the Synesthesia Wear bracelet.
Battery of the device should be shielded to prevent any direct contact with the user.	Need to design/build/purchase a case around the bracelet where the battery will be stored to prevent damage and any contact between user and battery.
The product dimensions should allow fitment on wrist of the user.	Need to purchase and integrate a microcontroller with built-in modules (bluetooth, microphone, etc.) to reduce product dimensions as much as possible.

5 System Variables

[Include this section for Mechatronics projects —SS]

5.1 Monitored Variables

5.2 Controlled Variables

5.3 Constants Variables

6 User Interfaces

[Design of user interface for software and hardware. Attach an appendix if needed. Drawings, Sketches, Figma —SS]

6.1 System Context

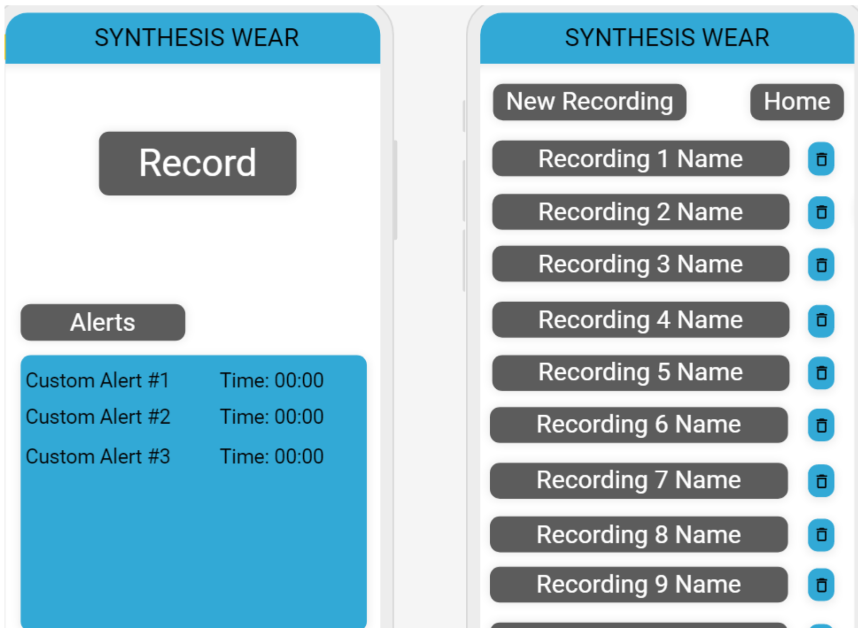


Figure 3: User Interface Mobile

Record	Allows users to record new audio to be stored
Alters	Notifies user of which alter and the timing
New Recording	Alternative button to change a existing recording
Recording Name	Name of stored recording
Delete	Deletion of stored recording
Home	To go back to main screen

7 Design of Mechanical Hardware

For our project there is limited mechanical hardware required. Most of the components are electrical componets. Regardless the non-electrical componets required are.

Table 2: List of non-electrical components required

S.No	Component	Material	Link	Cost
1	Base enclosure	PLA	In house	5
2	Base lid	PLA	In house	3
3	20mm Watch strap	Silicon	shorturl.at/hEFM1	16.99
4	Super glue	Glue	shorturl.at/CFG09	6.27

7.1 Base Enclosure

This is main housing for all the electrical componets. It houses the microcontroller, the vibration motor, the battery and the battery management system. It will be 3D printed using PLA as the Material. This housing also provides the additional abilityto attach 20 mm watch straps to it. Below are two isometric of the Base enclosure.

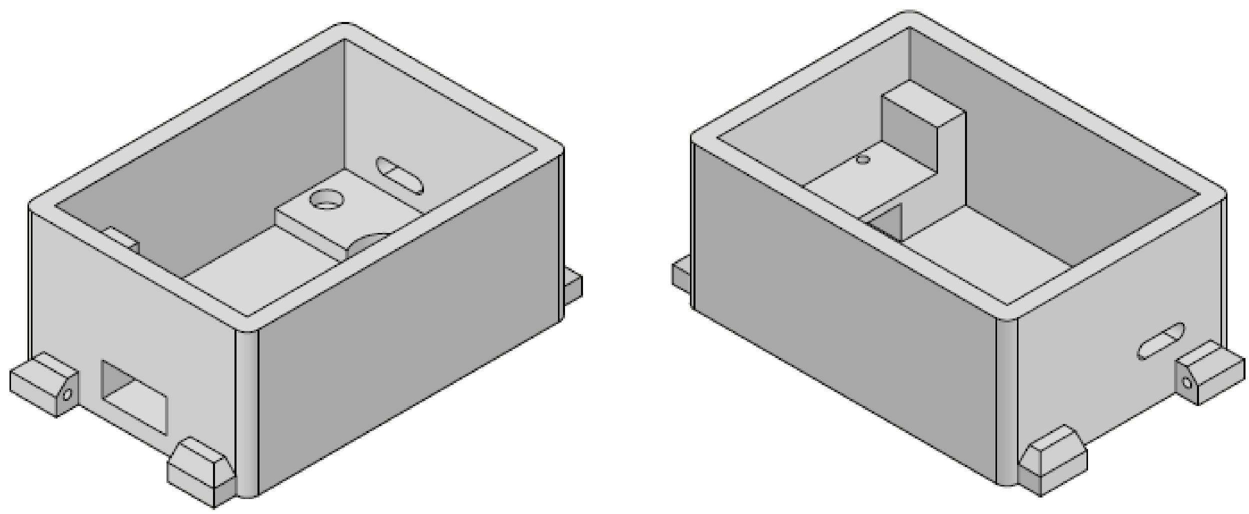


Figure 4: Enclosure isometric figures

There are specifc slots for all the major componets like the microcontroller, vibration motor, battery, etc. There are also cutouts for the usb C charging port for the battery and a cutout for the battery enable switch. For a detailed drawing refer to the Appendix. The drawing does not show all the dimensions for clarity reasons but it does show the outer dimensions. An explosed diagram with all the components will be shown later in the section.

7.2 Enclosure lid

This is the lid for the enclosure that was shown above. It will also be made in house on a 3D printer with PLA plastic. It will be secured to the enclosure using super glue once proper functioning of all the components is achieved. Below is an isometric diagram for the lid.

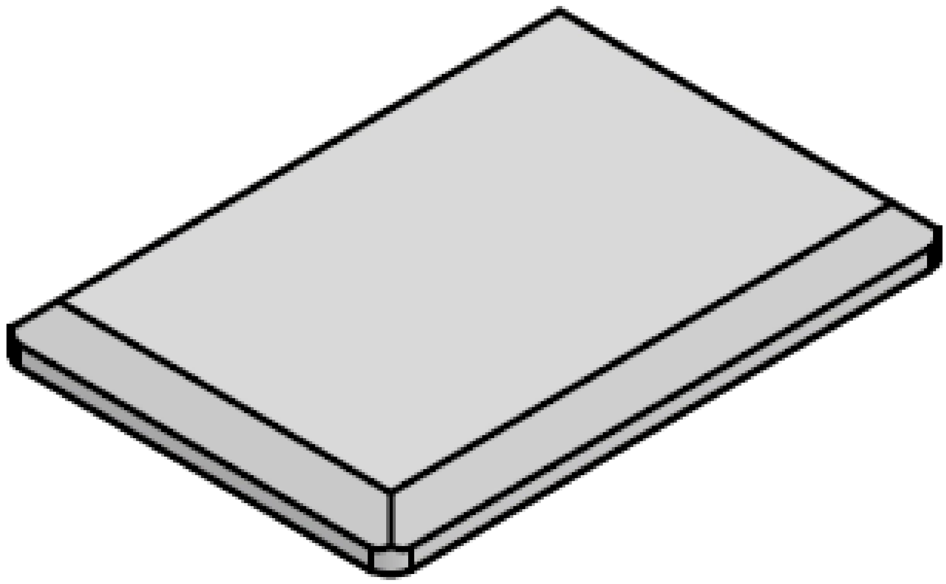


Figure 5: lid isometric figure

For a detailed drawing refer to the Appendix. The drawing does not show all the dimensions for clarity reasons but it does show the outer dimensions.

7.3 Watch straps

A pair of standard 20 mm watch straps will be aquired from external sources. For the material, we have selected silicone rubber as it would be the most durable along with it being cost effective. It is estimated to cost 16.99 CAD. This will attach to the base enclosure using standard 1.5 mm spring jumper lugs that come included with the watch straps. This should enable the user to have the device mounted on the user without the user having to carry it in the user's hand.

7.4 Super glue

Super glue will be used to secure most of the componets in place either directly or indirectly. For the lid it can be directly attached using super glue. However for the PCBs they have to be attached using plastic dowels with a lid and super glue. There are already holes placed in the enlosure for these fastners. The use of threaded fasterners was not used due to the difficulty of adding threads accuratly to the plastic enclosure. The disadvange of using the super glue along with the plastic dowels is that once secured they are permenent.

7.5 Complete assembly

The entire hardware is enclosed between the enslosure and the lid. An isometric of the complete assembly is shown below.

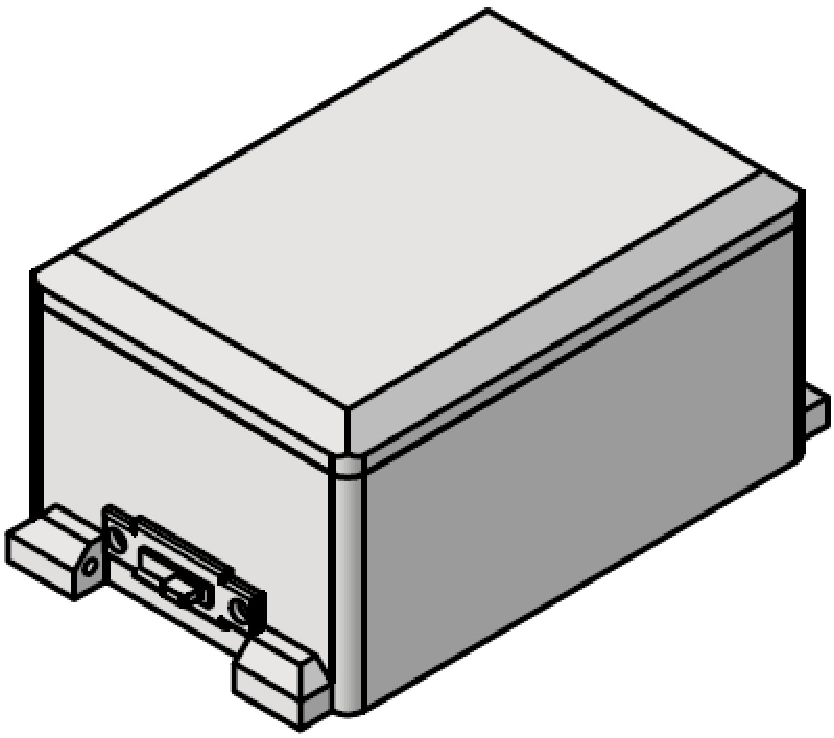


Figure 6: Assembly isometric figure

The exploded assembly is shown below.

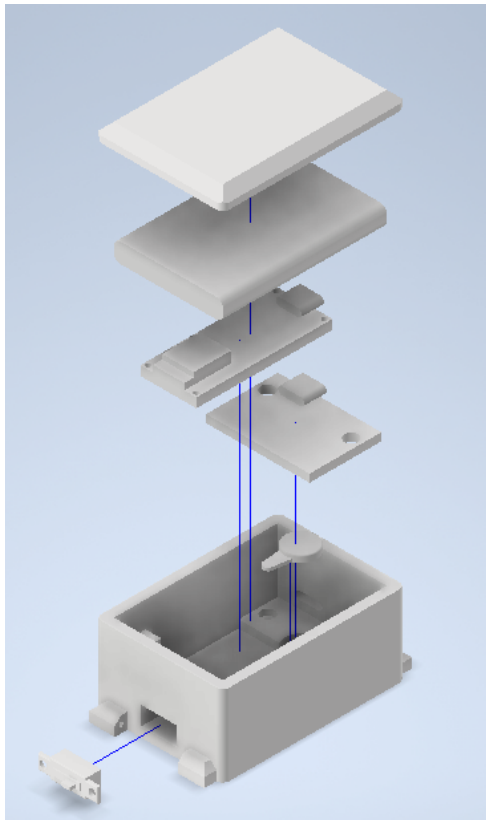


Figure 7: Exploded view of the assembly

For a detailed drawing refer to the Appendix. The drawing does not show all the dimensions for clarity reasons but it does show the outer dimensions.

8 Design of Electrical Components

A list of electrical components required is listed below.

Component	Amount	Cost (in CAD$)	Dimensions	Link
Arduino Nano 33 BLE	2	80	48 * 18	https://www.amazon.ca/Arduino-Nano-33-BLE-Sense/dp/B07WV5GF17
Lithium-Ion Polymer (LiPo) Battery (3.7V 1000mAh)	1	10	50*32*5	https://www.canadarobotix.com/products/588
0.1 microfarad capacitor	2	1.11	5*3	https://rb.gy/vyewya
Resistor 1000 ohm	1	NA	5*3	At home
Resistor 20 ohm	1	NA	5*3	At home
Vibration motor	5	10	10*2	https://www.amazon.ca/dp/B089NTLLWB?ref_=cm_sw_r_apin_dp_YEQ7CS0SNQV7HKHZZVFD
Transistor NPN - PN2222	1	NA	5*3	At home
Diode - IN4007	1	NA	5*3	At home
Power Management module	2	17.5	35*22	https://www.digikey.com/en/products/detail/sparkfun-electronics/PRT-14411/1568-1723-ND/7725301
E-Switch Slide switch	1	1.04	19*6*5	https://www.shorturl.at/jMN791

Table 3: Electrical Components List

8.1 Complete electrical layout

The entire electrical system can be split into 3 parts

- Microcontroller
- Battery System
- Vibration motor and related electrical components

The complete layout of the electrical componets are shown below, explanations for the components will come in the later sections.

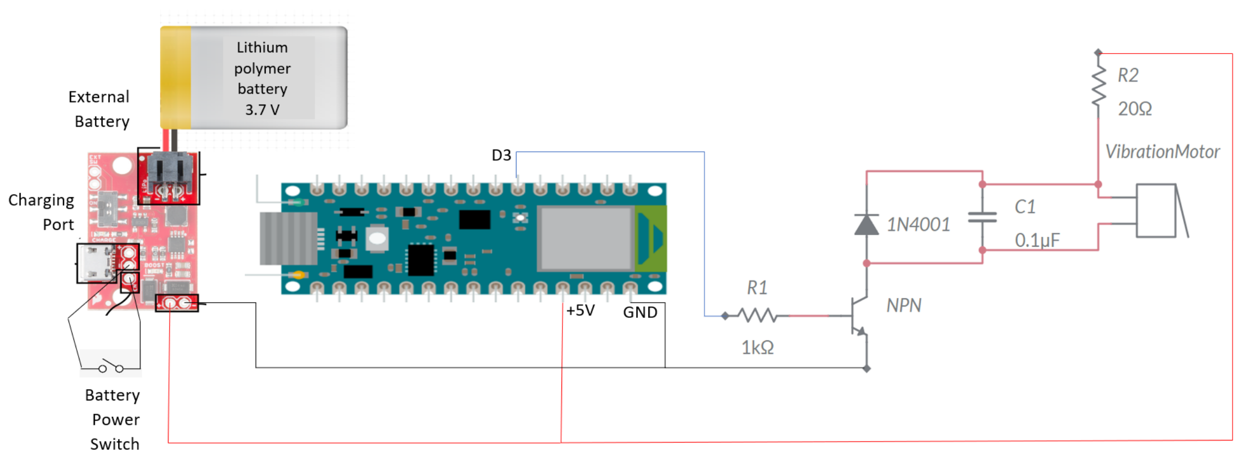


Figure 8: Complete electrical schematic

8.2 Microcontroller

The microcontroller is responsible for most of the the application of the device. It will handle audio dectection, audio processing classification and bluetooth communication. The microcontroller selected is an arduino nano 33 BLE. This was selected as it is relatively compact with bluetooth and microphone already built into the device. It will be supplied by an external power source of 5V connected directly to the +5V and GND of the arduino. A digital pin (D3) will be used to control the vibration motor. Below is the schematic of the microcontroller.

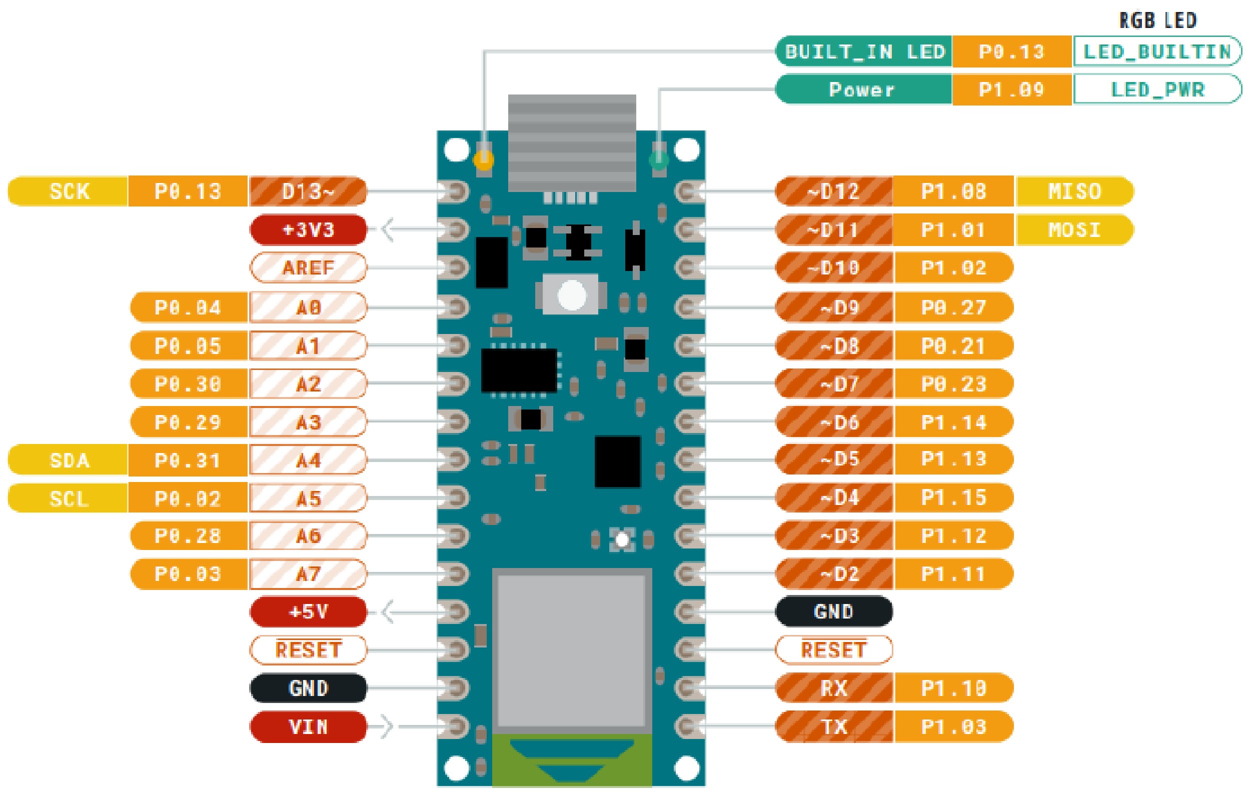


Figure 9: Arduino schematic

8.3 Battery/Power System

The arduino will be powered by a 5 Volt battery system that can supply up to 1A of current. This should be well within the operating region of the arduino. The battery system consists of a 3.7 Volt 1000mAh LiPo battery, a SparkFun LiPo Charger/Booster and a small slide switch. The 3.7 Volt LiPo was selected as it is small enough to fit within the design and has enough capacity for a day of usage. The SparkFun LiPo Charger/Booster is used to boost the voltage from 3.7 to 5 Volts as that is required by the arduino. It also provides the additional benifit of protecting the battery from high currents. The battery can also be charged using the usb C port on the SparkFun LiPo Charger/Booster. A switch will be soldered on to the enable pin of the charger/booster, this will provide a way to isolate the battery from the microcontroller and can act like a reset switch. The ardunio power input will have to be soldered onto the booster output connection. The battery can either be attached using a JST connector or can be soldered on. Below is the schematic for the battery system.

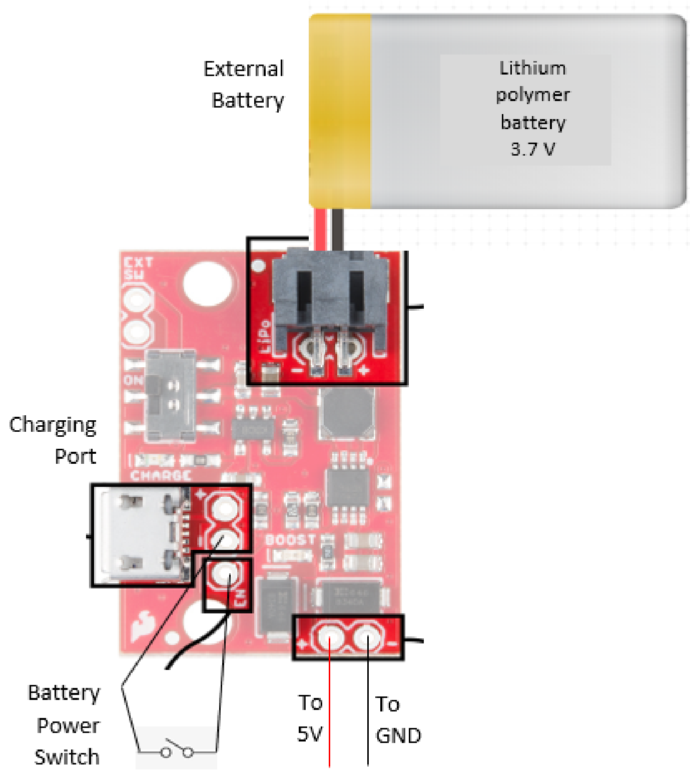


Figure 10: Battery system schematic

8.4 Vibration motor and related components

The user will be alerted using the vibration motor that is recessed into the enclosure. The vibration motor needs a significant amount of current that the digital output pin cannot supply. Hence the digital pin is just used as a enable pin and the current for the motor is drawn from the 5V pin. To achieve this a NPN transistor (PN2222) is used as a switch with the digital output pin being its enable. Resistors are also used to limit the current draw of the motor. A capacitor is used to protect from high current impluses and a diode is used to protect the arduino from backflow in case the motor stalls. The schematic for the circuit is given below. The components will be soldered together with little wires and heat shrink will be used over them to prevent shorts. The componets will be placed next to vibration motor right below the battery booster board.

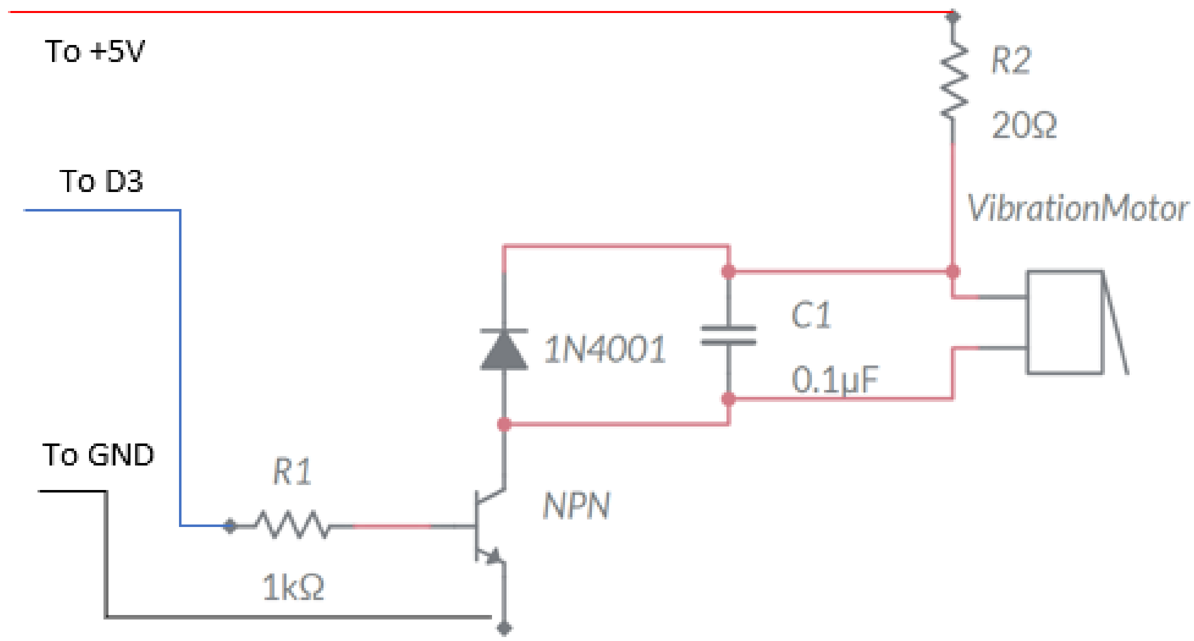


Figure 11: Vibration motor schematic

9 Design of Communication Protocols

In regards to communication protocols, the only relevant aspect of Synesthesia Wear would revolve around the bluetooth functionality of the system. As stated in Table 1, the microcontroller used for Synesthesia Wear has a built-in bluetooth module that was purchased for the purposes of reducing product dimensions as much as possible. With this in mind, the system was set up so that this same bluetooth module would be able to connect to the Synesthesia Wear application on the user's device and thus be able to communicate between each other.

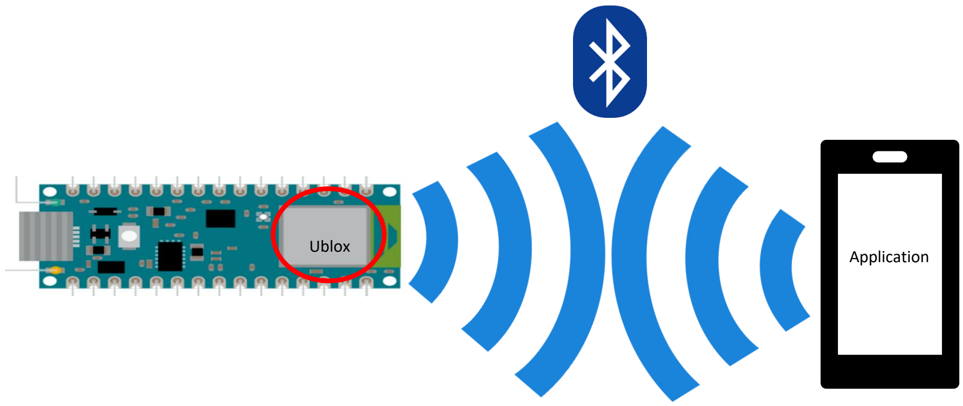


Figure 12: Bluetooth Connection between device and microcontroller

10 Timeline

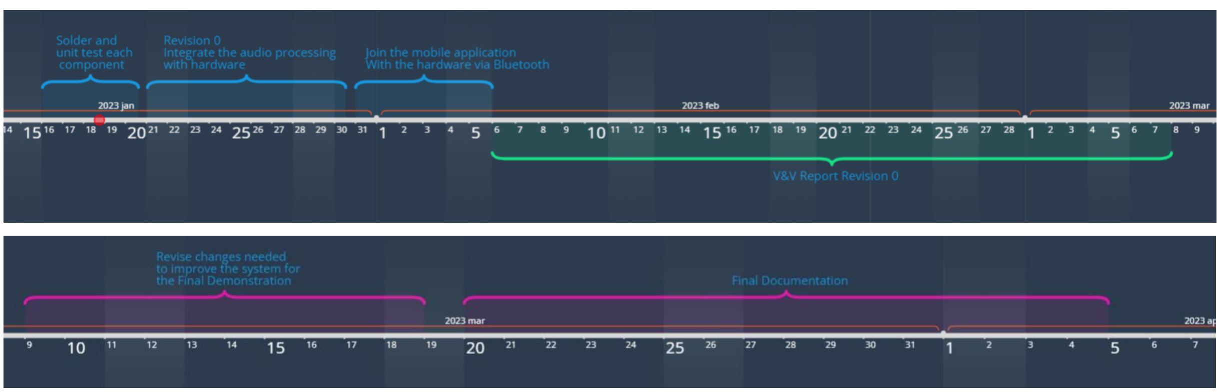


Figure 13: Timeline

10.1 Solder and Unit Testing

- Connect and Test, Micro controller with vibrating motor.
- Use module "Start" as part of Arduino library to test the vibrating motor.
- Use module "Record" as part of Arduino library to test the microphone.

10.2 Integrate Audio Processing

Listed in order of high priority:

- Create module "Bluetooth Connection", establish a successful connection
- Create module "Output Signal", what will be the output signal for each signal
- Create module "Sound Classification", category of sound produced
- Create module "Battery Status", indication of low battery status
- Create module "Microphone", collect the audio recording

10.3 Mobile Application and Hardware Connection

- Create module "Login", create a personalized login
- Create module "Keyword Selection", categorize the recordings
- Create module "Profile Module", load the user data
- Create module "Bluetooth Communication", communication integrator

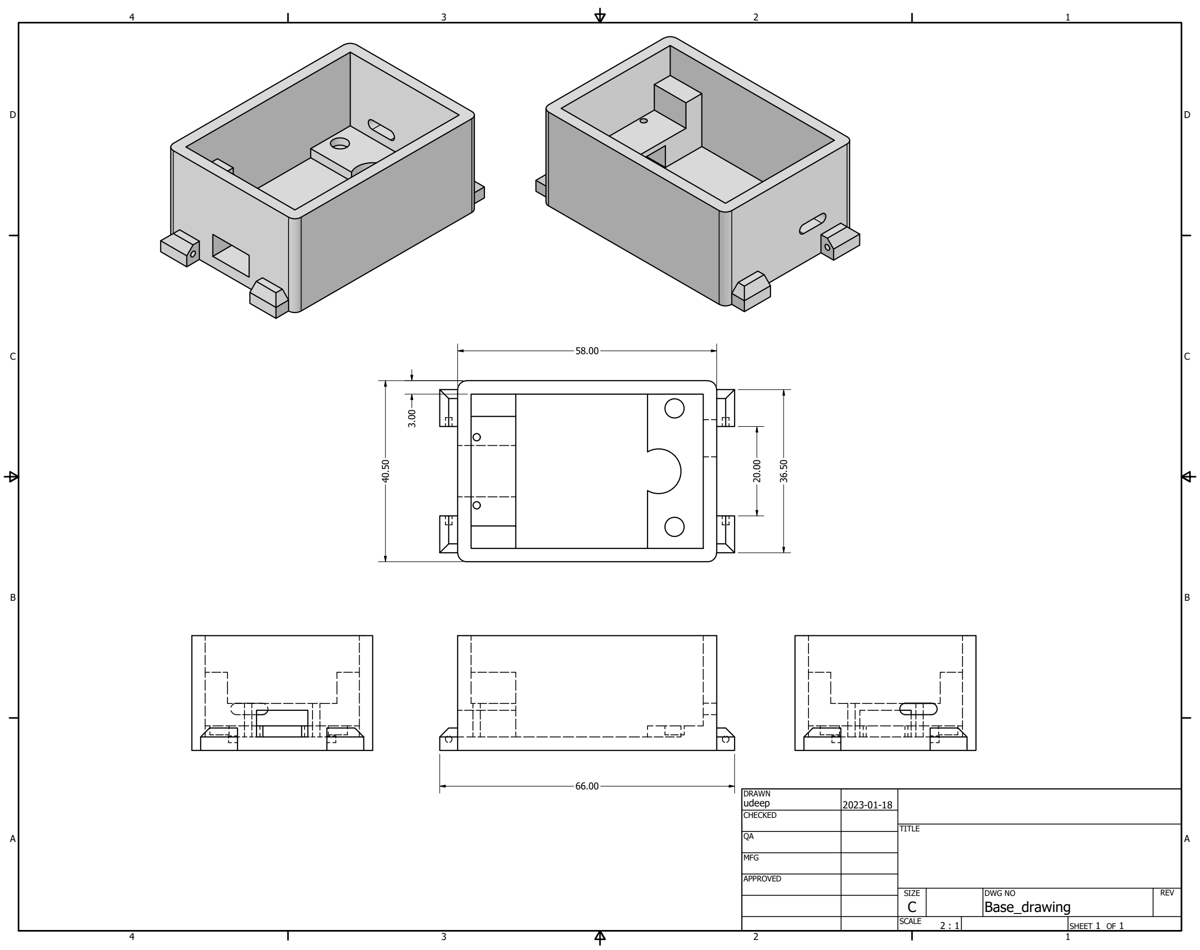
Appendices

A Interface

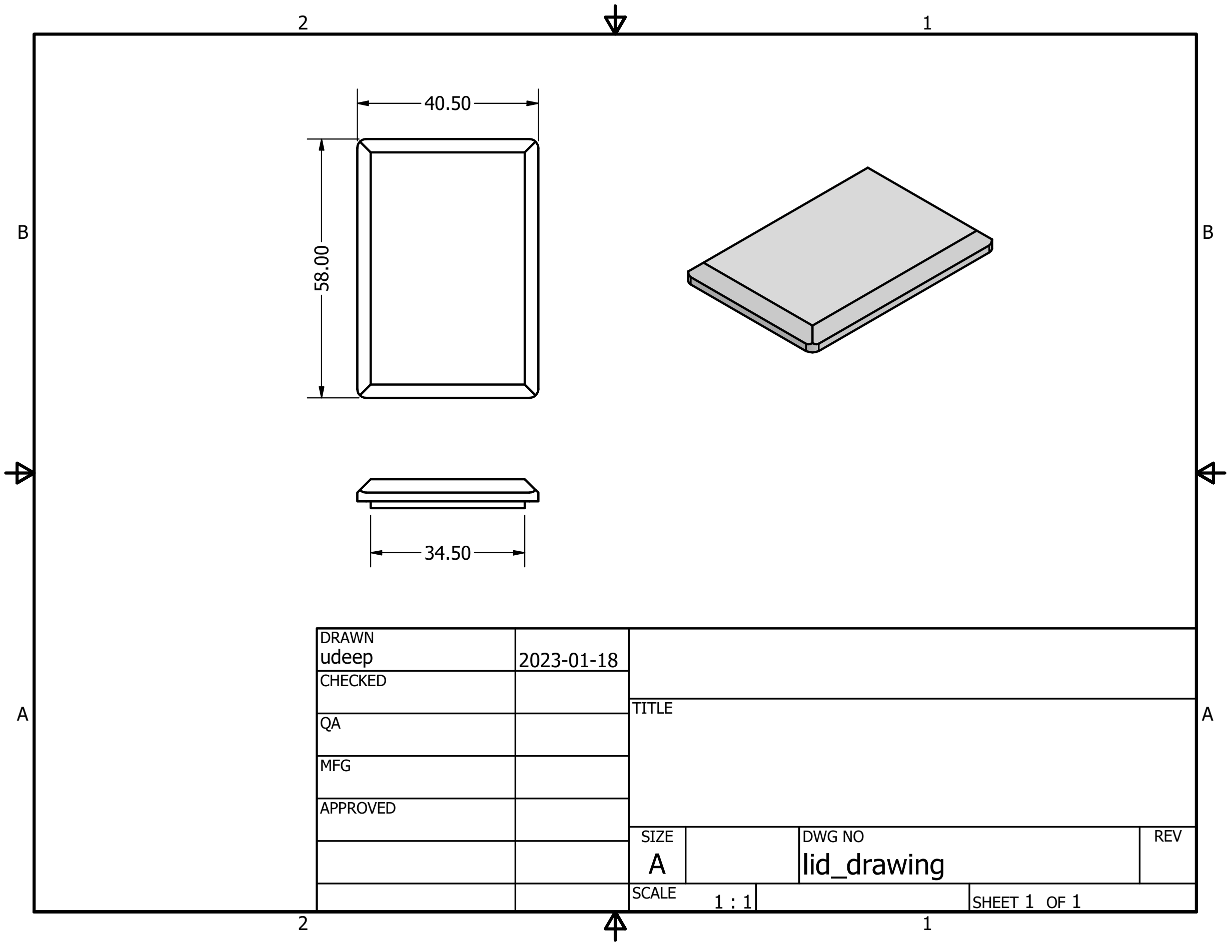
[Include additional information related to the appearance of, and interaction with, the user interface —SS]

B Mechanical Hardware

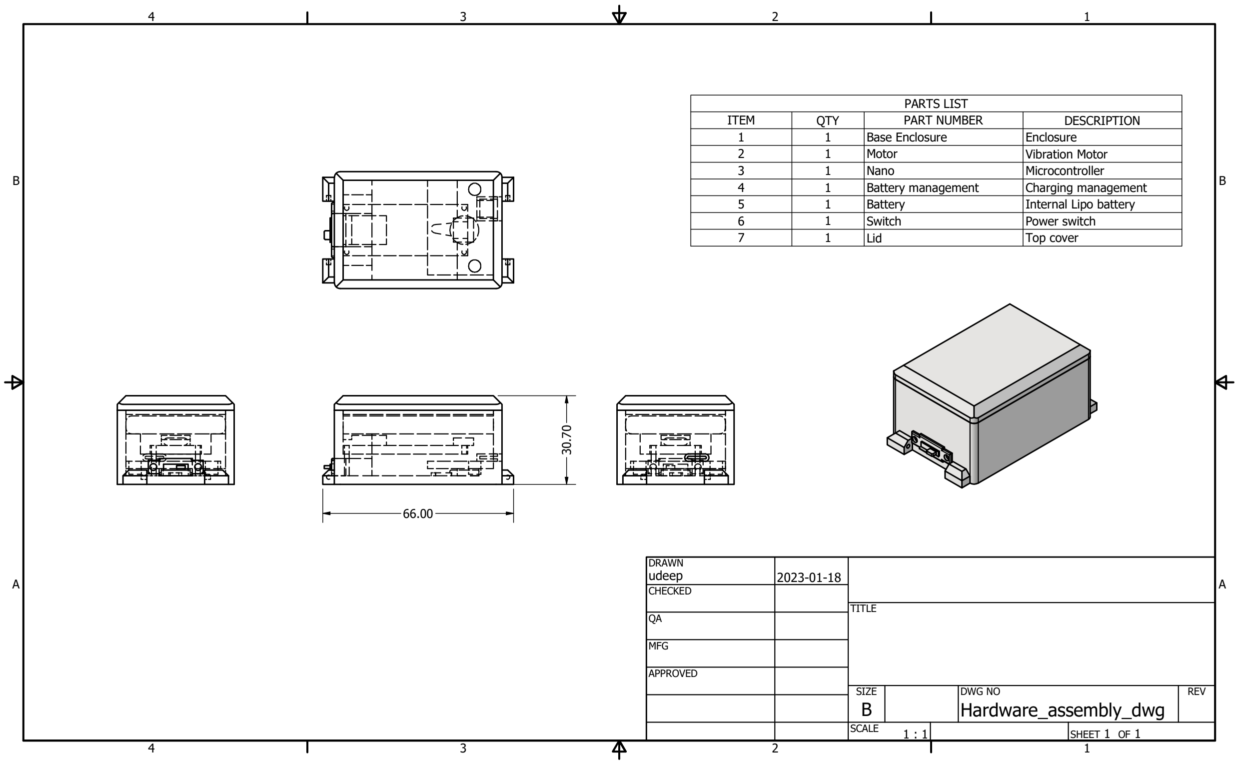
B.1 Enclosure Drawings



B.2 Lid Drawings



B.3 Assembly



C Electrical Components

D Reflection

1. **Limitations of the design** - Currently the product is quite bulky in terms of size it is atleast 6.5 cm in lenght, 6 cm in width and 3 cm in height. It might not seem like much but the final goal was to make it the size of a small watch instead of a large bulky object. It also cannot function for a long time, at most a day, the vibration motor and the microphone draw a significant amount of current. It also has sever limitations in terms of mantainabilty as once assembled it cannot be seperated. If given enough resources we can go for a custom PCB with inbuilt bluetooth, microphone, motor, charging slot and LiPo support. This would make the overall design more efficient, both in terms of power and size. We can also also increase maintanbilty by changing the enclosure to a metal enclosure(insulated) with threaded inserts to hold all the components in place.

2. **Other Solutions** - The first solution we thought was to use the microphone and processor of a phone to do the sound recording and the classification. It would then send a signal to the microcontroller if any distinct sounds were detected. The benifit

this had was that the actual hardware could have been smaller and more compact. This had the drawback that the microphone might not be able to hear sounds accuratly as the phone might be inside someone's trousers or be far away from them (in the case of charging the phone). Also it relies heavily on the smartphone and having it work efficiently for all types of smartphones would not have been fesible.

The second solution we thought was to use a microphone on the hardware and to then transmit the sound to the smartphone, have it process and classify it and then transmit the classifed signal back to the microcontroller. This does not have the disadvantage of the smartphone being stuck in trousers as the hardware microphone is used. An additional benifit is that the microcontroller can be less powerful and hence more power efficent. However, the major disadvantage id that the smartphone needs to be in range all the time.

The current design does all of the processing, recording and classification on the hardware. This results in a bit more bulky hardware. It only communicates with the smartphone when the user requires to update prefernces. This is the major advantage of this design, it can work independently (after the inital configuration) and does not have to rely on an external smartphone. This was the main reason we selected this design as we wanted a product that could be independent and self-sufficent. We also do not have to make classification software compatible with different smartphones and operating systems.