The Reverb – Written Technical Report

Team 31

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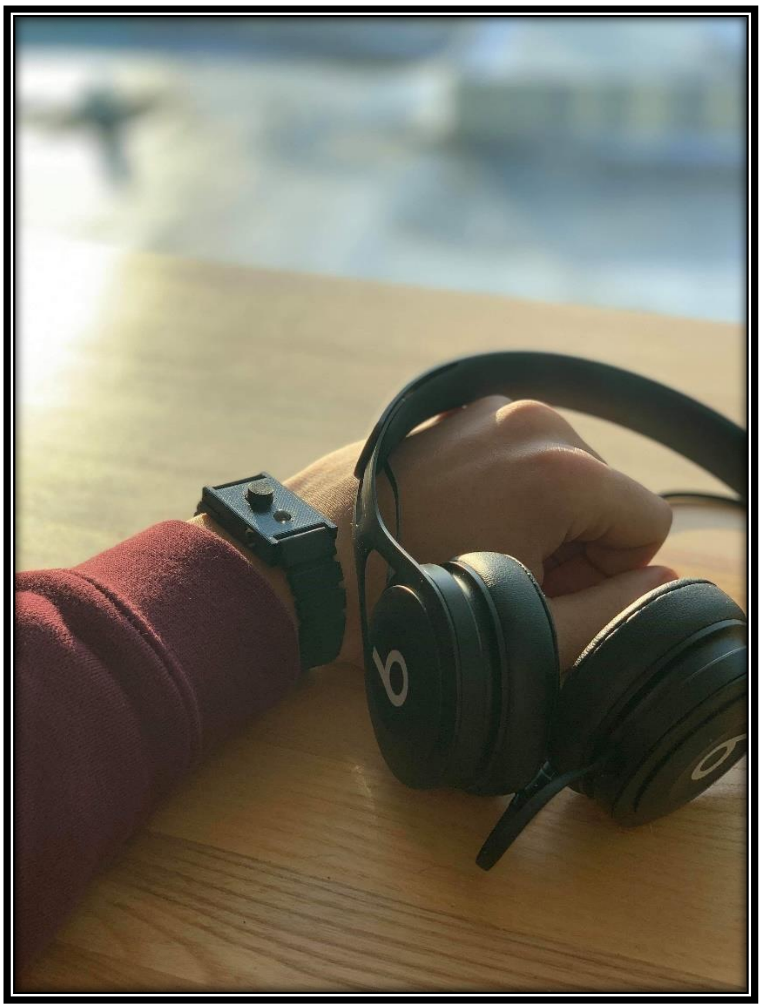
March 1, 2019



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Executive Summary

One of the most prevalent and fast-growing public health concerns is hearing loss, not only in Canada, but globally. In our era of evolving technology, no one is safe unless they are educated and protected from the dangers of progressive hearing loss due to prolonged exposure to loud noises. Moreover, hearing aid devices have become increasingly expensive over the years, making them difficult to afford. Hearing aid device prices now range between $1,000 to $4,000. [1]

Our solution to this problem targets the root and origin of this issue; a device that identifies unsafe surrounding noise levels and relays this message to you through different means of output. The Reverb is a wearable wrist device (like a watch) with a module containing a sound sensor that allows the user to know if they are in danger of hearing damage. This module can stay on the watch to detect general surrounding noise levels or can be detached and placed in any type of headwear such as headphones or ear mufflers to alert the user whether they are at risk of progressive hearing loss, or if they are within the safe range.

Moreover, the Reverb has a sleek and unique design which makes it visually appealing to the user, no matter who it may be. Users who would benefit from using the Reverb would be concert-goers, construction workers, commuters, airport workers, people carrying out activities like mowing the lawn, listening to music, etc. or almost anyone else.

Similar devices on the market cannot compete with the Reverb due to the many added capabilities on the Reverb such as the timed buzzer output that warns users when they have been surrounded by potentially damaging noise levels for an excessive period of time. In addition, the Reverb is the only detachable sound sensor that can be placed wherever the user wishes and provide a result/output on their wrist device.

These are the features that separate this device from the rest of the competition. These opponents do not put an emphasis on active tracking of ones hearing health and are comprised of simple notifications, and small messages. With the Reverb, we have placed an emphasis on the extremely dangerous threats that we face to our hearing, that we often neglect. As other devices regard a sound monitoring system as more of a “secondary concern,” we have directly tackled the issue that hundreds of millions of users face.

Introduction and Background Information

Hearing loss is an issue that affects many worldwide and is expected to only get worse as time progresses. Currently there are 466 million people across the globe that are experiencing some form of a hearing disability. This number is expected to rise to roughly 900 million by the year 2050. Although there are many reasons that could lead to a loss of hearing, 60% of hearing loss developed during childhood is due to preventable causes. The leading cause for this condition is the constant exposure to external loud noises on a daily basis. This includes the prolonged use of personal audio devices at high volumes and attending concerts and other such events. Roughly 1.1 billion of the world's young population aged between the ages of 12-35 are at a risk of hearing loss. Along with the negative effects experienced by the individuals themselves, there are also social and economic impacts. Individuals suffering a hearing disability are unable to communicate with others and express their ideas, having a poor impact on their social life. This can lead to loneliness, frustration, and a feeling of lack of belonging. The World Health Organization claims that hearing loss poses an annual global cost of $750 billion USD. This consists of healthcare costs, loss of productivity of individuals, and other societal costs [2].

With such a large majority of the population at risk of hearing loss, it is our responsibility to raise awareness about this issue and find a possible solution to ensure that the future is healthy. Our goal is to implement a solution into the everyday lives of individuals without them having to sacrifice the things they enjoy doing. Making use of a sound sensor, vibration buzzer, and an LED, we have designed a wearable device that has the ability to detect sound levels in the environment and warn users when they are in danger, the Reverb. Prevention is the first step we should be taking when considering issues such as these, especially since 60% of developed hearing loss is preventable. Our device focuses on just this and aims to prevent any damage from occurring to the ear. With the Reverb, individuals will have the freedom to enjoy their hobbies and favourite activities, while having the peace of mind that their hearing is protected. Hearing loss is a global issue that is steadily on the rise with many negative impacts. The Reverb is a new and unique solution that aims to prevent further cases with hopes for a healthier future.

Summary of Design Objectives

Design objectives consist of features that the final design is intended to obtain and fulfil. These aspects of the design take into consideration the perspective of the user and how they would interact with the final product. An initial list of criteria was created to guide us through the engineering design process and come up with the preliminary design idea. As we progressed through the design process and milestones, we began filtering out criteria that were not directly related to our wearable device or no longer applied. Starting with an exhaustive list of 30 criteria, the list was quickly simplified to six important design objectives that consumers would appreciate while using the device.

Upon careful consideration of milestone one's list of criteria, we decided that accuracy was the most crucial aspect of our product. The Reverb's main purpose is to detect sound levels and inform users when they are in threat of hearing loss. For this reason, it was obvious that accuracy would have to be the number one priority of this device. Aside from that, additional criteria were taken into account to ensure consumer satisfaction. Adjustability was another important factor in our design as this device will be worn by a variety of users from young children to adults with varying wrist sizes. A traditional adjustable watch strap was used to take into consideration the spectrum of expected consumers. Another essential criterion for a wearable wrist device is comfort. We had to ensure the device was comfortable and did not result in any negative side effects when worn for a prolonged period of time. To accomplish this the device body was designed to be thin and lightweight. Users would not feel the presence of the device and it would not restrict any movement of the wrist. The strap is also very comfortable and does not stick to the skin when worn by the user for quite some time. Lastly, the Reverb is also a very visually appealing unisex device, attracting users of all ages and genders. With a flushed black body and wristband, the Reverb can be worn as a fashionable accessory with a lifesaving purpose.

Proposing an idea is just the beginning. The design process that follows requires planning and careful consideration. With a strong focus on accuracy, adjustability, comfort, visual appeal, and a few more design objectives, we were able to successfully design and fabricate such a gadget that incorporated our final list of criteria.

Market Analysis

Although the Reverb is a unique product, there are still some similar options on the market that already exist. One of them is the Etymotic Research ER200 Personal Noise Dosimeter. The purpose of this product is the same as the Reverb; it is used to monitor the sound in the environment where it is being used and display when the noise becomes dangerous. It is a slim pencil-like device that is powered by an AAAA battery and has a threshold level of 75 decibels. This product does have some advantages over the Reverb in the sense that it has a setting where it can calibrate to your environment and provide a more accurate result [3]. However, the only form of signalling this device has is an LED light to indicate safe and unsafe ranges and many times this can go unnoticed. The Reverb has a dual warning system that alerts the user of the noise in their environment through an LED indication and vibration. Additionally, the Reverb plans to add cell phone compatibility in the future so that all exposure can be monitored and saved. Consumers who reviewed this device have said that this device is too basic and that it cannot be used for workplace monitoring due to the lack of data logging. Additionally, users stated that some of the modes on the device did not work as they wanted to. In general, this device is very similar to the Reverb however, it isn’t as versatile and comes in at $150 which is very expensive for a device of its sort.

Another similar product to the Reverb is a phone app called Decibel X. This app measures the noise level in the consumer’s surroundings using the cell phone’s built in microphone and displays the decibel level on the screen. It can measure between 30 and 130 decibels, displays average noise levels, and shows graphs of exposure over a long period of time (however this is only accessible in the Pro version which is $3.99 a month) [4]. Although this is a good app for monitoring sound levels, that is all that the app can do. It does not warn the user of dangerous noise levels at all. Many consumers have written reviews stating that although the app is accurate at measuring decibel levels, the other features such as the graph are very poor and that it is recommended to not purchase the premium version [5]. It is clear that this app is very limited in functionality and despite the Reverb initially costing more (if a monthly plan is purchased, the costs can exceed that of the Reverb), it will offer better sound monitoring, recording and warning than this application will.

Both products are effective in their own way; the app is a convenient way to monitor sound and the Dosimeter is useful for warning the user about dangerous noise levels. The Reverb combines the features of these two and has added functionality, clearly making it a worthy opponent in the marketplace when released.

The Reverb will be priced at around $50. The production cost is roughly $36 as mentioned in the bill of materials, and this does not include the computational device necessary for making the sensor function and labour costs for producing the device. Since this is the first product being released by this company and of its kind, it is a smart idea to keep the price relatively low so that the Reverb can be accessible to more people and make its mark in consumer society.

Description of Design

The Reverb is a wearable, multipurpose sound sensor that is housed in a wristband. The primary purpose of the Reverb is to collect data from the environment around a user in real time and provide feedback to warn a user if they are in danger of acute or chronic hearing damage caused by exposure to loud noises. The Reverb is primarily designed for use by workers in industries with a high level of exposure to loud noises, such as forestry, mining and factory work. The Reverb would warn workers if they are exposed to loud noises for an extended period of time and would also be used by employers to gather data about their working conditions. The Reverb can also be used in the home, for example in earphones and other devices to warn users if they have been listening to music at too high a volume for too long.

Our device consists of an adjustable wristband with a rectangular modular base. On the outer face, the sensor module sits inside a circular depression, held in place by magnets. An LED warning bulb also sits on the outside face, and an on/off button is embedded on the side of the body. The modular base also houses the computer, vibration motor and power supply, as well as the wireless charging unit. While the Reverb can be worn with the sensor coupled to the housing, it can also be detached and stuck magnetically into a hardhat, inside the cup of a headphone, or stuck to an object. The sensor is connected to the wristwatch via Bluetooth, giving the user increased flexibility.

The primary material used to cover the modular base of the watch would be thermoplastic polyurethane, or TPU. TPU is a plastic elastomer that is widely used in wearable electronics such as FitBit bands due to its favourable mechanical properties. TPU has a high durability, toughness, elastic modulus and tear strength. It is also biocompatible and is safe to be worn on the body for long periods of time [6]. The Reverb is meant to be worn in operating environments such as factories, forests, mines, or at airports and must be waterproof and highly durable as well as provide comfort to the wearer. The wristband is comprised of a polyester and nylon weave, made breathable and waterproof by the addition of electro spun polyurethane web. The polyurethane web is created by the process of electrospinning, where a polymer solution is drawn through a spinneret by an electric force provided by a high voltage power supply and the threads are collected. Addition of this polyurethane web to the polyester and nylon weave resulted in higher air permeability, vapour transmission and thermal insulation properties than a resin coated fabric [7], making it ideal for use in the Reverb's wristband.

The Reverb measures sound from the external environment by converting the vibration of magnets from changes in external air pressure into an induced current in a coil and measures the voltage across the coil. A green LED is used to indicate that the noise level in the surrounding area is in a safe range, below 85 decibels. If the noise level exceeds this value, then the green LED will turn red, indicating visually to the user that they are experiencing unsafe levels of sound. If the red LED stays on for an extended period of time, then a buzzer will turn on, acting as an alarm to warn the user that they are in danger of experiencing hearing damage and should move to another location.

The Reverb provides active feedback to a user as they move through an environment, listen to music or encounter changes in sound intensity. The Reverb would be used over a long period of time in order for data to be collected in an environment. Each use of the device would be isolated from the next after it is turned off and turned on again, and stored information from previous usages would not factor into responses in future uses. The Reverb can be turned on and off using a convenient button on the side of the wristband, and the power supply consists of a 3V coin battery.

Design Specifications

Description of Tangible Prototype

The Reverb is made of three main physical components: the adjustable wrist strap, the modular base, and the sound sensor module.

The adjustable wrist strap is made of an electro spun polyurethane web coated polyester/nylon weave which allows for greater flexibility and comfort during many daily activities. Each strap comes in two parts, just like a conventional watch strap. One end from each of the individual straps connects to the modular base through a stainless-steel compressible bar. This bar is compressible since it contains a spring inside which makes it easy to assemble and disassemble if needed. These stainless-steel bars go through a tunnel at the ends of the individual strap pieces and hang around three millimetres from each side of the tunnel. The overhangs are then inserted into holes made in the modular base of the device, securing the wrist strap to the body of the device.

Since the modular base will contain most of the electrical components of The Reverb, including the battery and button, it will be made of a hard resin that will not be able to bend easily, therefore, minimizing the chances of the electrical components breaking. The modular base will also contain a neodymium magnet within its centre, above which there will be a depression where the sensor module would be resting. The module will be covered by a case made of thermoplastic polyurethane.

The sensor module would be in the shape of a cylinder. An attracting neodymium magnet would be placed into the sensor module. It has been designed that way so that the module would always be attracted to the base. Also, this sensor module is detachable from the modular base and would attach to the inside of any headphones using a provided magnetic base. This was also be done in accordance to ensure the sensor picks up accurate noise level measurements the ear is exposed to.

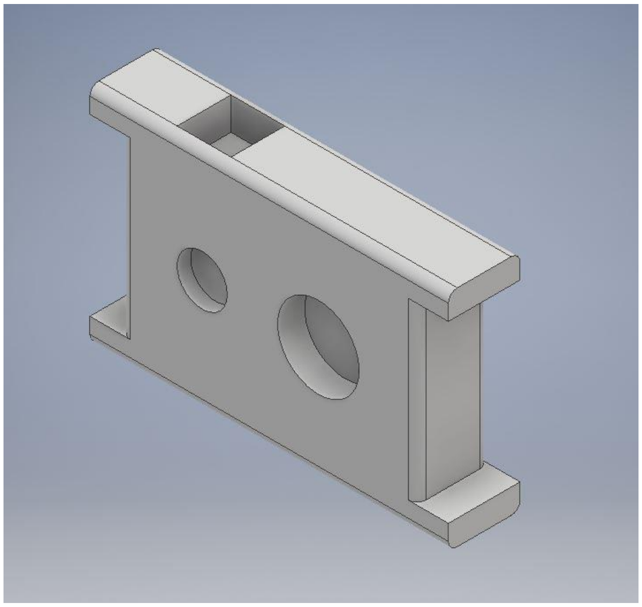


Figure 1. CAD model of modular base

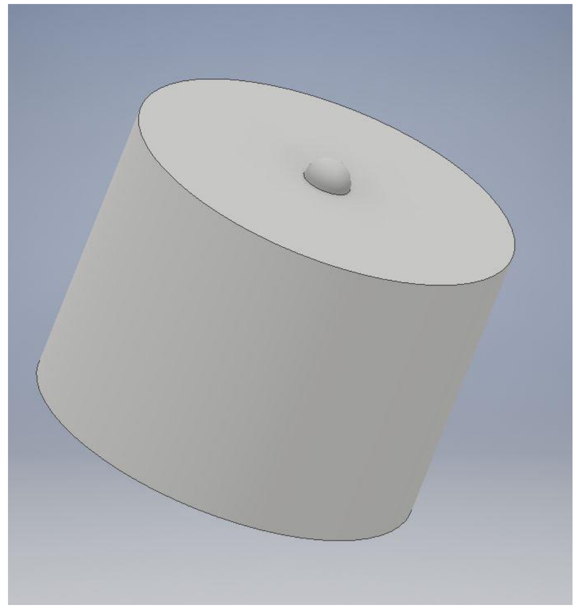
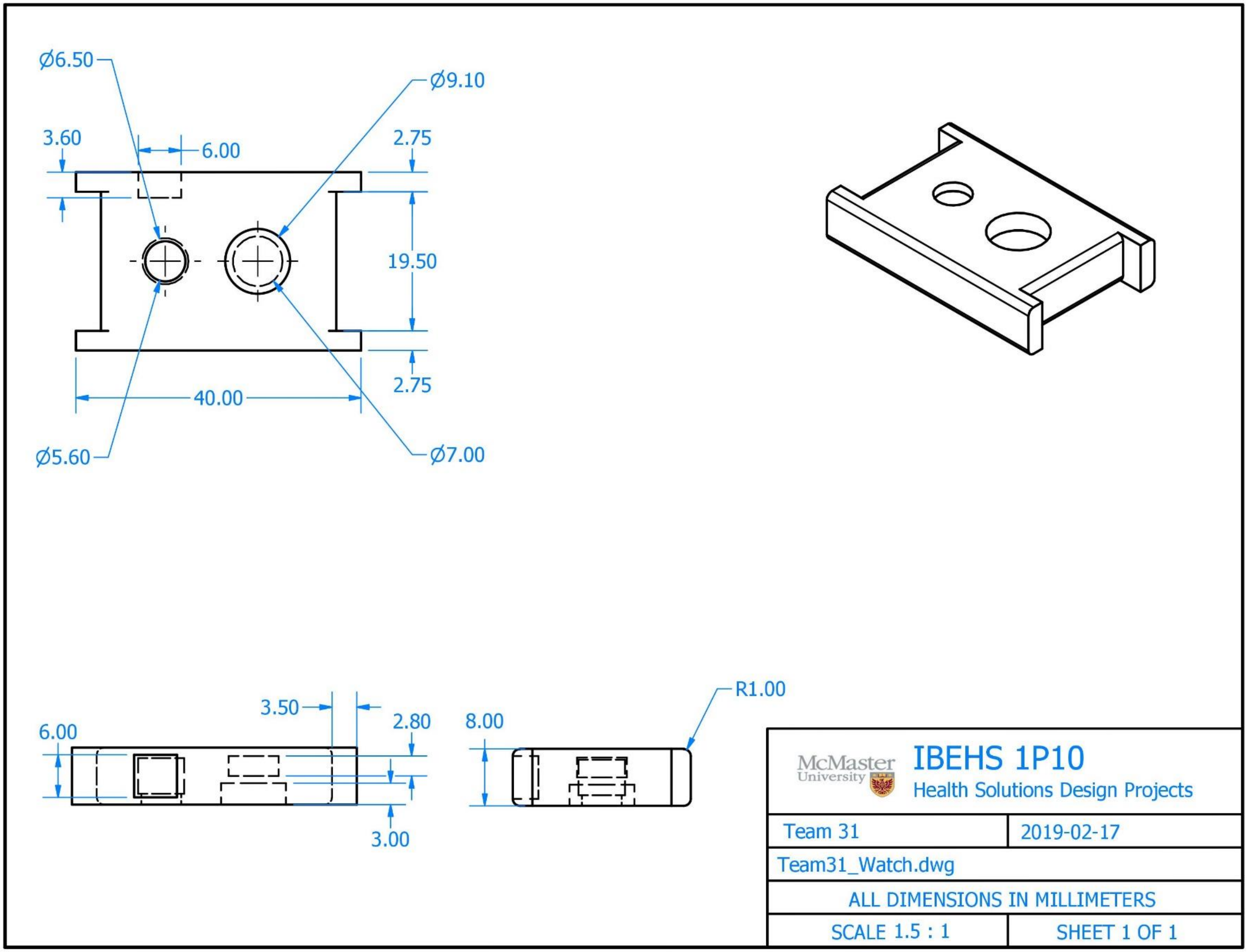


Figure 2. CAD model of sound sensor module

Figure 3. High fidelity prototype of modular base along with sound sensor module housed within the magnetic depression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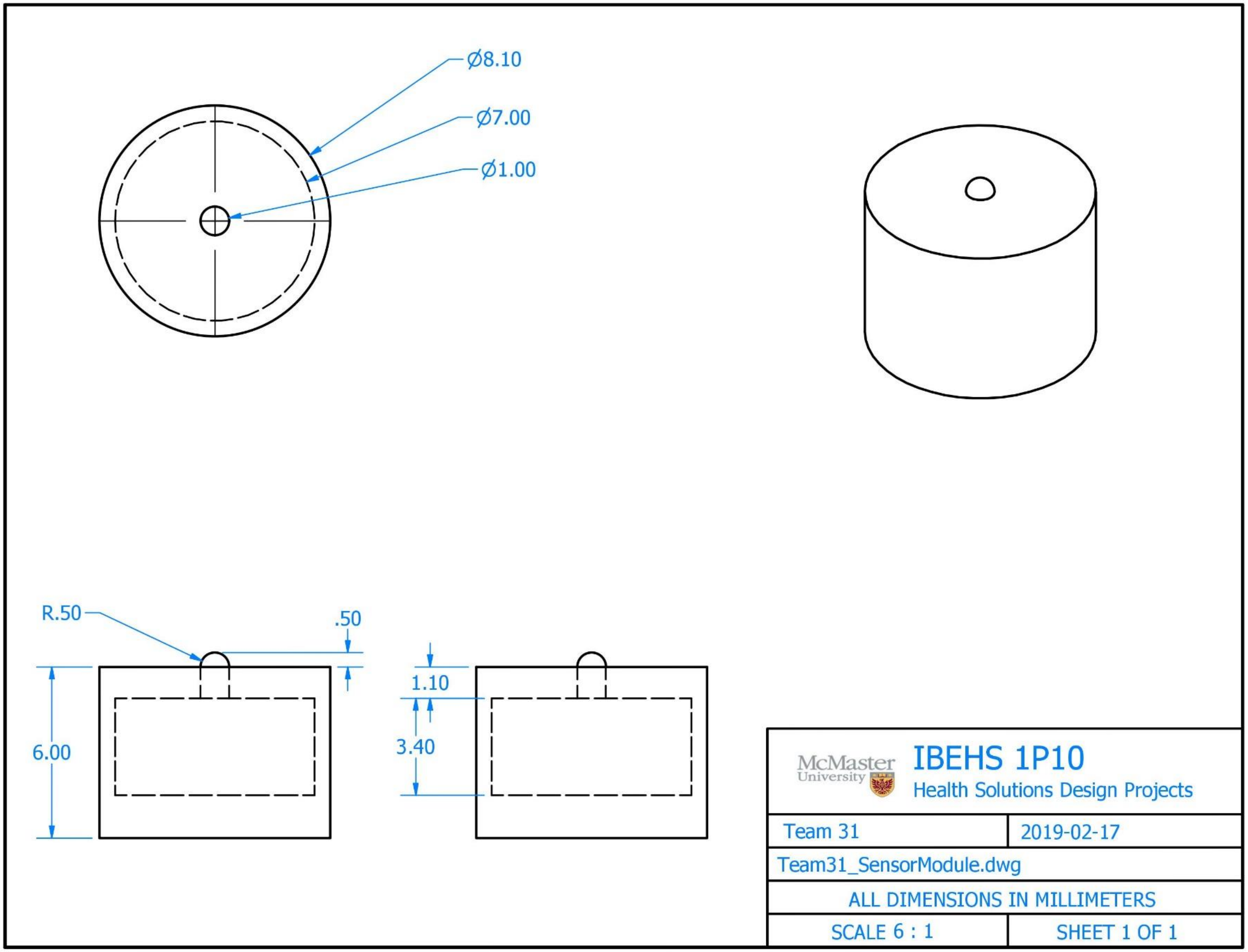
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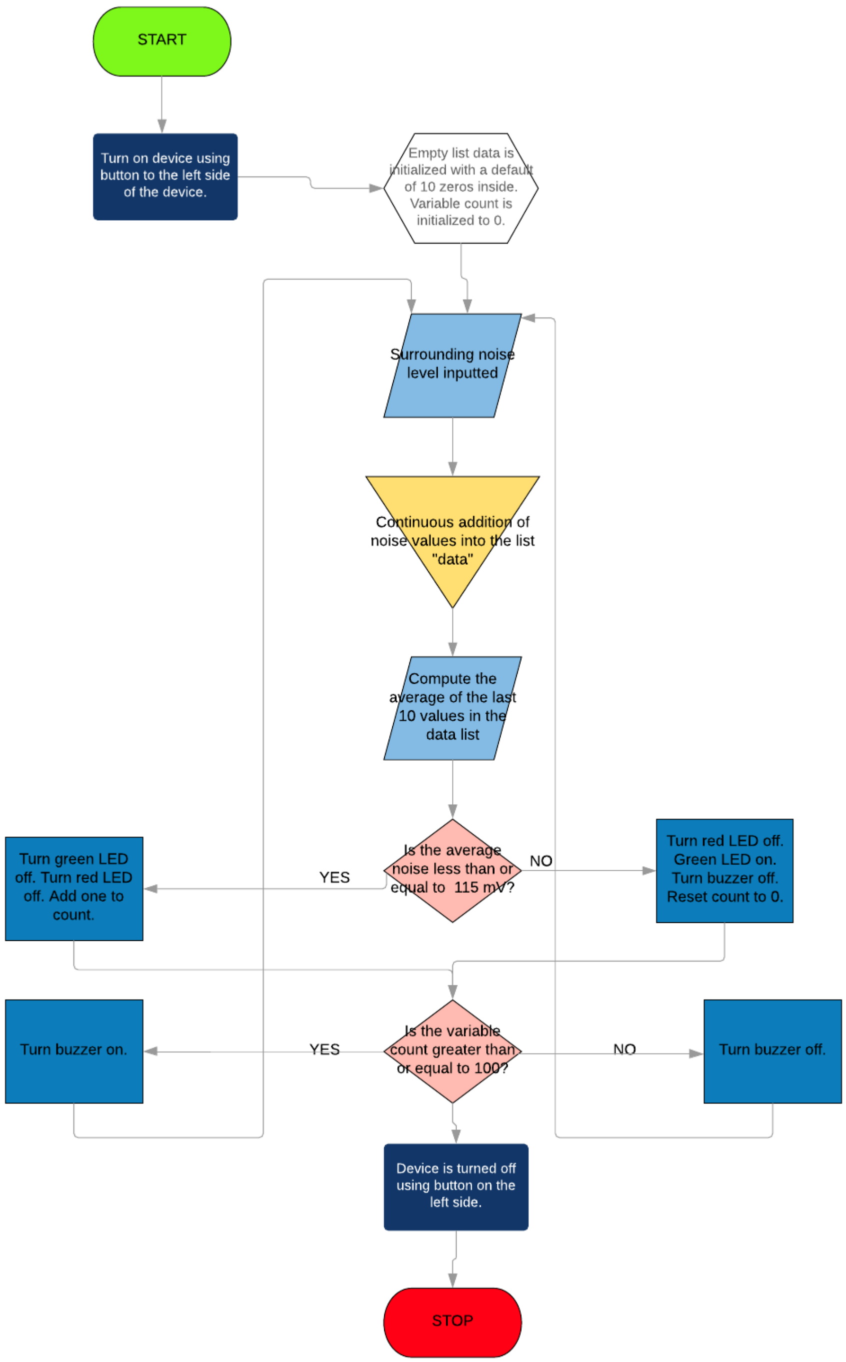
Description of Physical Computing Prototype

Programming the Reverb has been optimized and tested to run on a GPIO from a Raspberry Pi. Future alterations and modifications to its computing execution can be made to be more efficient and less energy consuming, which would greatly help increase battery life performance. This is how the software will run on The Reverb:



The individual sensor values are not used directly in lighting up the red/green light bulb, but instead the average of the last ten sensor inputs are used to control the light bulb and the buzzer. The reasoning behind this logic is due to the error of the sound sensor picking up the noise level. If output decisions were only as a result of the individual sound readings, then the counter for the buzzer to turn on would be extremely inaccurate due to the random error in readings.

The electrical components used are an analog to digital converter (ADC), sound sensor, dual colour LED, and buzzer. Regarding the battery, the modular base will consist of a rechargeable lithium-ion cell button battery that will be able to be recharged wirelessly. The module will also have a similar rechargeable battery which will be able to charge form the battery from the base, since they will already be magnetically attracted to each other.

Figure 4. Sunfounder AD Converter

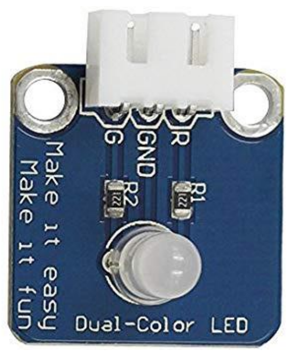


Figure 5. Sunfounder Dual-Colour LED

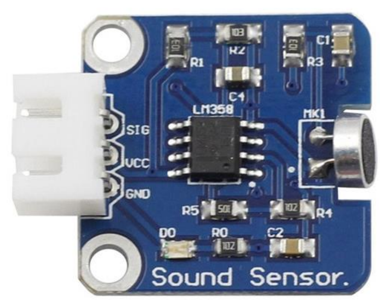


Figure 6. Sunfounder Sound Sensor

Figure 5. Vibration Module

Figure 6. Lithium-Ion Rechargeable Battery

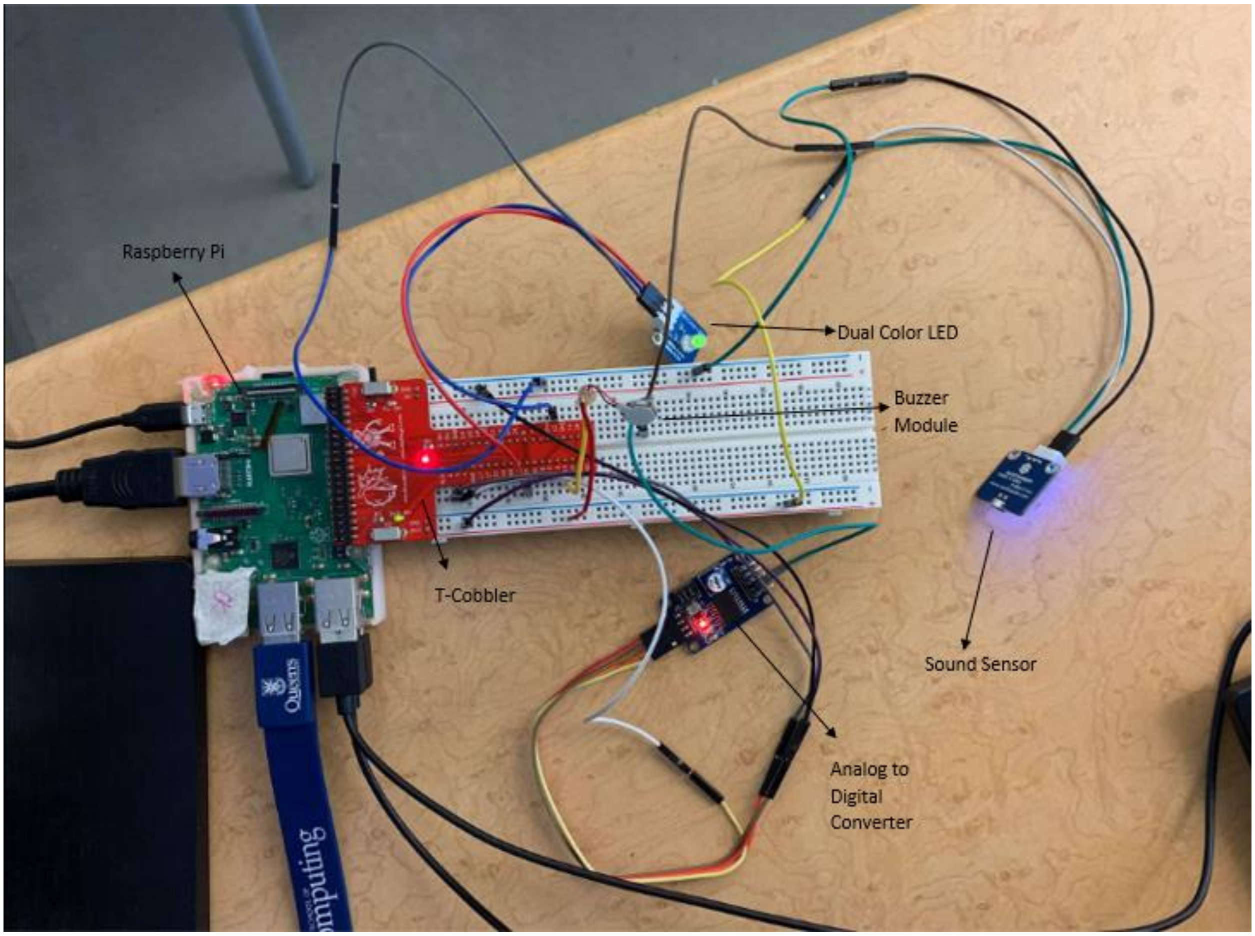


Figure 7. Labelled diagram of the physical computing prototype

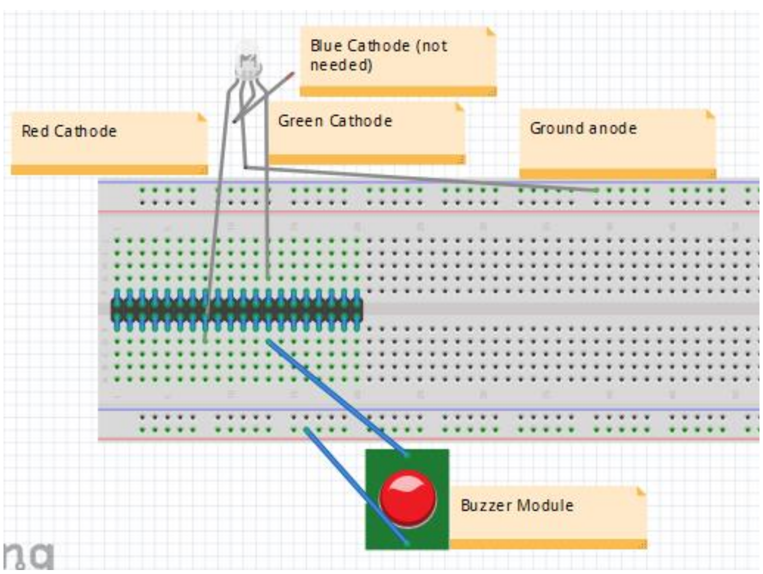


Figure 8. A simple schematic indicating how I/O devices connect to Raspberry Pi GPIO

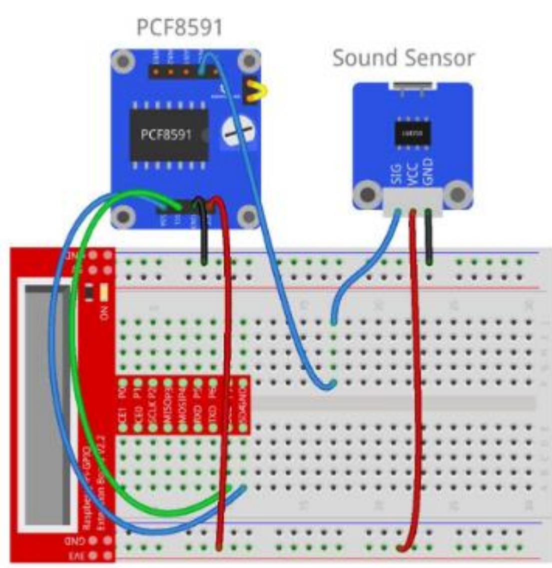


Figure 9. A simple schematic indicating how I/O devices connect to Raspberry Pi GPIO

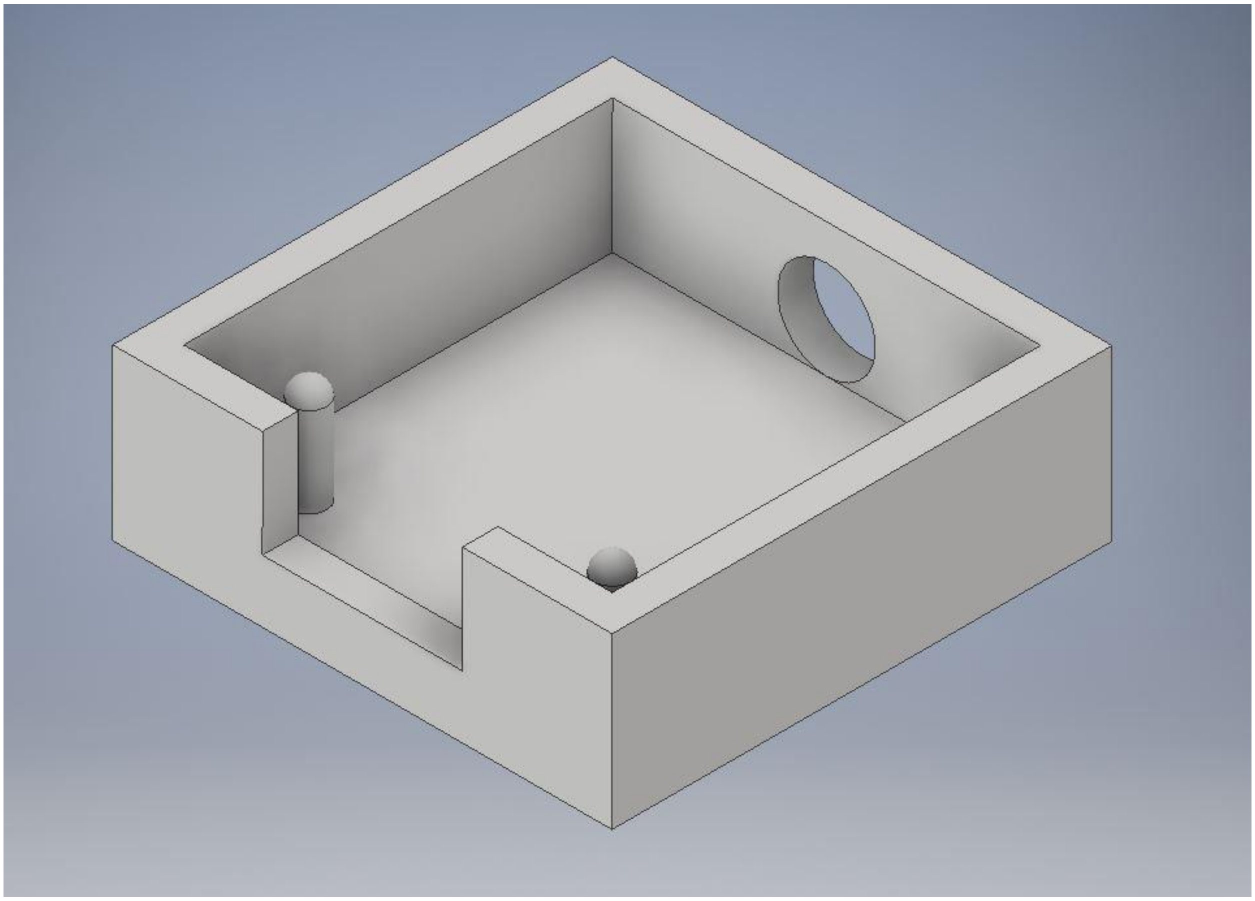


Figure 10. CAD model of sound sensor housing

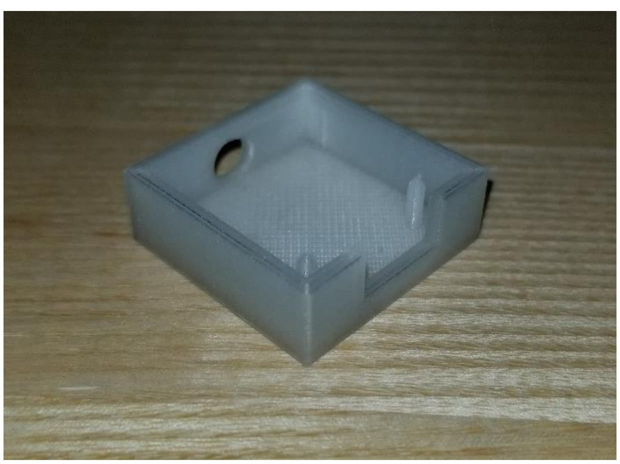


Figure 11. 3D model of sound sensor housing without sensor

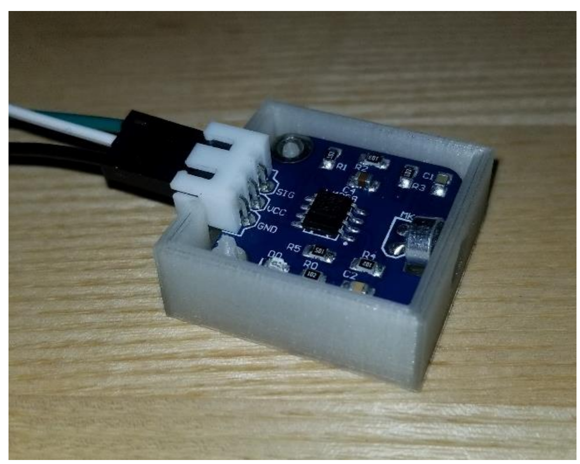
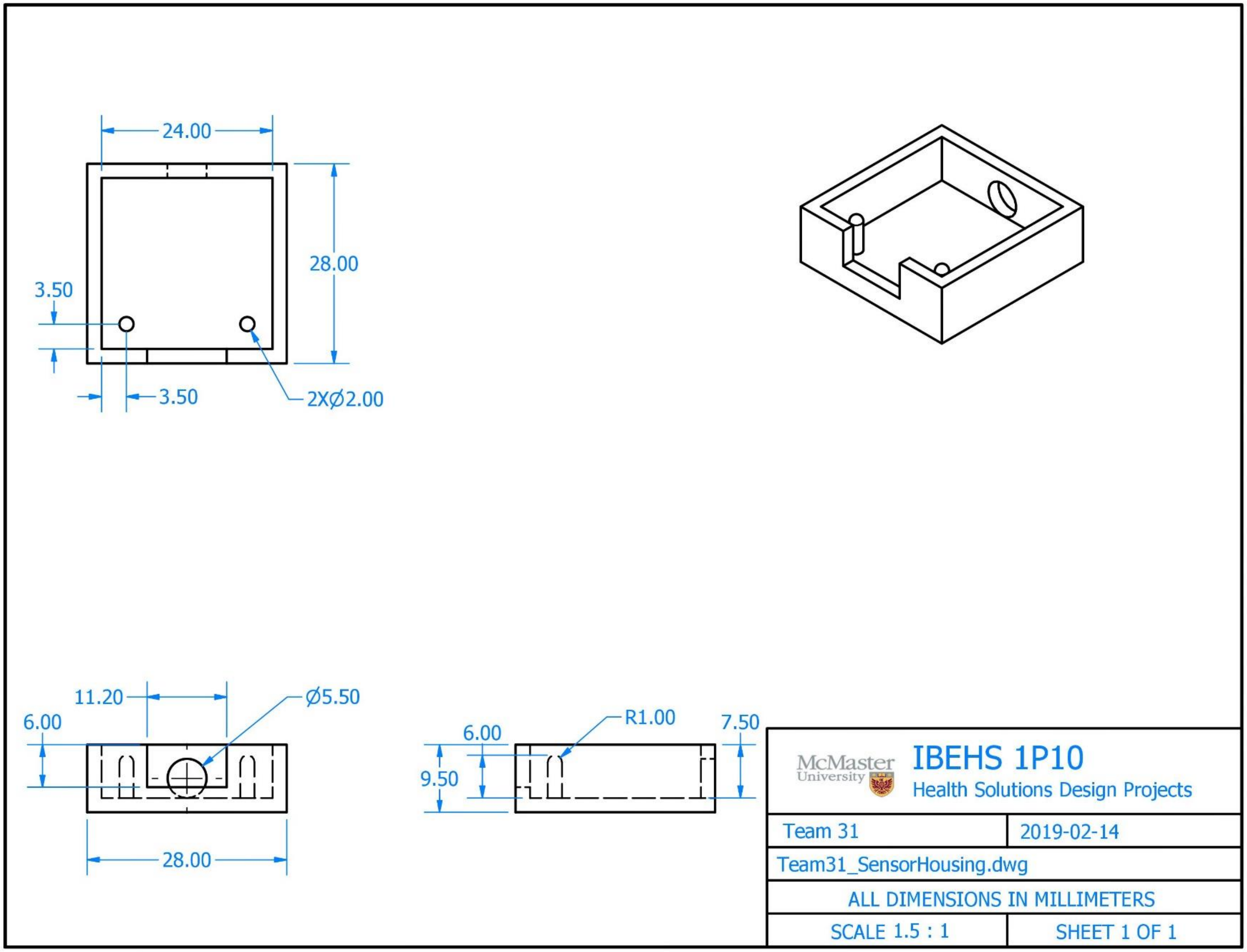


Figure 12. 3D model of sound sensor housing with sensor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ALL DIMENSIONS IN MILLIMETERS
SCALE 1.5 : 1
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Bill of Materials

Material	Price/Part ($/Part)	Quantity	Cost ($)
Adjustable Wrist Strap [8]	0.60	1	0.60
Sound Sensor [9]	6.17	1	6.82
Analog to Digital Converter	10.99	1	10.99
Magnets [10]	0.10	2	0.20
Dual Colour LED [11]	6.98	1	6.98
Modular Base	0.75	1	0.75
Module (Sound Sensor Housing)	0.11	1	0.11
Buzzer [12]	4.99	1	4.99
Rechargeable Li-Ion Battery [13]	2.49	2	4.98
TOTAL COST			**36.42**

Design Verification

Upon testing the computing prototype, we were met with a good result. The program functioned exceptionally well, accurately measured volume, and made indications accordingly. We began with the quietest noise out of all the trials. The static white noise was played at the first volume bar on a team member's phone. The result was a persistent green light, without any buzzer activity. This is because the sound being played was in a safe range and did not reach the unsafe threshold. For the first volume bar, the voltage displayed on the screen was within the range of 140-150 (around 55.4 dB). Next, the volume bar on the team member's phone was increased linearly, and each instance inside the "safe zone" indicated a green LED with no buzzer activity. The third bar on the phone displayed a voltage from 120-130 (around 75.7 dB). Upon reaching the seventh volume bar, the range displayed was from 90-110 (around 92 dB). The predetermined threshold was set to a value of 100. When the voltage was above 100, the LED remained green. When the voltage was below 100, the LED turned red because this is the "unsafe zone." Finally, when we reached the maximum level on the volume bar (around 102.6 dB), this was loud enough where the LED instantly turned red, as it was indeed above the threshold. Then, after a certain amount of time remaining red, corresponding to a pre-set count threshold, the buzzer began to vibrate, indicating the user has been exposed to the unsafe range of noise for too long. After the maximum volume level was reached, the noise was turned off and the light instantly turned back to green and the buzzer ceased to vibrate; indicating a return to a safe range of volume. Overall, the device performed as it was expected. Once the pre-set thresholds were reached, the appropriate responses were present. The device accurately responded to each change in volume the sensor was exposed to.

Test Plan

Use the first video on YouTube when “static noise” is searched and place your phone close to the microphone

Input	Approximately 1 volume bar on phone	Approximately 3 volume bars on phone	Approximately 7 volume bars on phone	Approximately max volume on phone	
Count/Time	Does not apply	Does not apply	Does not apply	Less than 10 counts (a few seconds	More than 10 counts (longer time)
Expected Output					
Average Reading on Screen	140-150	120-130	90-110	60-90	
LED	GREEN	GREEN	If under 100: RED If over 100: GREEN	RED	RED
Vibration Buzzer	OFF	OFF	OFF	OFF	ON

Design Critique, Discussion, and Recommendations

Throughout the design process there existed a theme of constant critique. Although we managed to tackle majority of the underlying issues with some of our early designs, there were still some challenges that we faced, given our limited resources. Issues that were presented later in the process involved different factors like size, security, and susceptibility to environmentally induced corruption.

Firstly, we have the issue of the sensor-carrying module potentially not being large enough. This issue arose when considering the size of the internal parts. For example, the module is wireless; therefore, inside that small device one would be charged with fitting a microphone, and a transmitter. The size of the module in our tangible prototype may not be large enough to fit the appropriate hardware to support a fully functional device. However, this may be easily fixed. In the future, we can look to simply increase the size of the module without increasing the risk of discomfort when the module is carrying out its task in a pair of headphones. We would also have to pay attention to how an increase in size would affect the visual appeal of the device, but this is only a minor detail compared to the overall functional purpose.

Secondly, the issue of module security arose. Although the magnet secures the device quite well to the frame, we cannot ignore the fact that it is free to move in its position. There is nothing preventing it from falling off the frame other than an extremely unreliable magnetic field. When a user performs a task that involves the rubbing of their arm onto another surface, it absolutely could pose a risk of detaching the module. In the future, we will look to improve this security by adding some sort of physical obstacle. For example, a clamp system could be added in order to secure the module in place. Then, whenever the user needs to manually detach the device, there would be some sort of mechanism to release the grip of the clamps. This physical harness can also come in the form of a small clip, where the device is snapped into a locked clip.

Finally, and probably one of the most challenging questions that we must overcome, is the susceptibility to corruption through various environmental influences. For example, when the module is placed inside the headphone, there is a chance that excess heat, sweat, and other external factors may corrupt the device. Not only would excess heat inside the headphone cause damage to the module and the headphone, but may also potentially harm the users themselves. In the future, we will look to use a material that would ensure water resistibility for the module device. For the issue of overheating, we would have to maximize battery efficiency in order to use the least amount of power possible. One must also consider that the module is already extremely small and does not possess the technological capabilities that would necessarily cause this overheating. Of course, there is the chance that this will take place, as the circuit will inevitably experience some resistance. However, this inevitable resistance would be so minute that we would deem it negligible. This issue would also require a fix that would result in the largest change in the device. making a fix to a negligible issue like this unfavorable. However, this still remains something to carefully consider. Another solution would be to directly integrate the microphone module into the headphones themselves. This would allow for a much safer use of the device, where it can be integrated into the already safe headphones.

These are some of the issues that we have come across during the design process. They provide us with an unceasing motivation to improve the product as we seek to preserve the gift of hearing.

Appendices and Supporting Documentation

Original Gantt Chart

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Development/Planning						
Problem Definition						
Concept Evaluation						
Design Review						
Computing Prototype						
Tangible Prototype						
Written Report						

Updated Gantt Chart

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Development/Planning						
Problem Definition						
Concept Evaluation						
Design Review						
Computing Prototype						
Tangible Prototype						
Written Report						

Summary of Team Meetings

For the first few design studios, our team was always on track in terms of milestone submissions and keeping up to date with design project work. Once the milestones were completed, we began creating the CAD model of our design as a team, designing the device and discussing how it would function. Our goal was to finish the high-fidelity prototype before the pitch proposal so we could present it to the judges, which we were able to. After reading week, we started the computing prototype, spending a few nights at design studio getting the code to work. The report was also started upon returning to school after the reading week. We met quite a few times after the final design studio on the Friday before reading week to finish up our project and report.

Team Contributions

Name	Contributions
Aliasger Saifi	Autodesk Inventor modelling, helped creating tangible and computing prototype, few sections in report, put together final report
Hunter Csetri	Created script for pitch proposal, helped creating tangible and computing prototype, few sections in report
Luka Mircetic	Created slide deck for pitch proposal, helped creating tangible and computing prototype, few sections in report, demonstrated the computing prototype in video
Luka Zivkovic	Assisted in Autodesk Inventor modelling, helped creating tangible and computing prototype, few sections in report, created demonstration video
Yousam Asham	Created slide deck for pitch proposal, helped creating tangible and computing prototype, few sections in report

Screenshot of Code

```
#All appropriate libraries and classes are imported.
#Specifically, the classes for the buzzer, LED light, and sensor.
from gpiozero import LED
from gpiozero import Buzzer
import PCF8591_3 as ADC
import RPi.GPIO as GPIO
import time

#LED and buzzer are set to their appropriate pins, matching their positions on the breadboard.
red_led= LED(11)
green_led= LED(12)
buzz = Buzzer(13)
#LED and buzzer are both initially turned off until the datat can be collected from the sensor.
buzz.off()
red_led.off()
green_led.off()

def setup():
        ADC.setup(0x48)

#Core function is defined
def loop():
#Variables are initialized
    count = 0
    data = [0,0,0,0,0,0,0,0,0,0]
    sum_data = 0
    avg_data=0
#Loop defined that will carry out the main function of the program and run continuously.
    while True:
#Sound sensor collects data continuously at an interval of 'time.sleep(#)'.
        voiceValue=(ADC.read(0))
        time.sleep(0)
#Conditional statement made to cancel out inaccurate sensor fluctuations.
        if voiceValue <= 190:
#data from sensor assigned to a list. Then, the average of the last 10 values of the list at every single iteration is determined.
                data.append(voiceValue)
                sum_data = data[-1]+data[-2]+data[-3]+data[-4]+data[-5]+data[-6]+data[-7]+data[-8]+data[-9]+data[-10]
                avg_data = sum_data/10
                print("Sound value: ",avg_data)
                print("-------------------------------------------------------")
#After the average values are continuously printed, they are used in a conditional statement.
#If average values are lower (louder) than a safe range, red LED turns on and count begins.
#If in the safe range (quieter) then light is green and buzzer stops.
                if avg_data <= 115:
                    green_led.off()
                    red_led.on()
                    count+=1
                else:
                    red_led.off()
                    green_led.on()
                    buzz.on()
                    count=0
#When count reaches a certain value (specific amount of time has passed in the unsafe range), buzzer turns on.
                if count >= 100:
                        buzz.off()
                else:
                        buzz.on()

if __name__ == '__main__':
    try:
        setup()
        loop()
    except KeyboardInterrupt:
        pass
```

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