Protect-U

ECE 445 Design Document

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1 Introduction

1.1 Objective

Sexual assault and harrassment has been a common problem in society for many years. It is known to be the most underreported violent crime. Cases are often times dismissed or not even brought to court as the evidence presented becomes a "he said vs she said" case in which the victim's pleas struggle to gain validity without concrete proof. During sexual assaults or assaults of any nature, offenders seek to neutralize the victim's phone and take advantage of settings where there are no cameras or recording equipment. This causes an extremely low percentage of offenders being held accountable for their crimes.

Our solution seeks to help victims through the use of a wearable device that can record audio and emit a loud siren to attract attention to the situation. The user should be able to wear this device discreetly attached to a keychain, inside of a pocket, or hidden by attaching it to an undergarment. The audio that is recorded from the device will be saved to the user's phone via bluetooth, which then could ultimately be sent to the cloud, or authorities to provide the victim with evidence needed to bring justice to the perpetrator in the unfortunate circumstance that a sexual crime or assault is committed against them.

1.1.1 Background Research

According to statistics by the Rape, Abuse & Incest National Network (RAINN), 11.2% of college students experience rape or sexual assault through force, violence, or incapacitation [2]. More specifically, 23.1% of undergraduate females are victims of these crimes. Shockingly, only 20% of female student victims aged 18-24 report these crimes to law enforcement [2]. A major reason for this is the lack of evidence as the victim feels that he/she may lose the case. Overall, 995 out of 1000 perpetrators of sexual assault walk free [3]. 67% of sexual assault cases occur with no bystander present, which causes victims to feel isolated and unprotected.

As technology has evolved, there are no wearable products with prevalent market share that are made specifically for preventing or collecting evidence during these situations. Perpetrators will oftentimes seek to remove the victim's phone from them making it an unreliable defense. A simple phone app, thus would not suffice as it would be difficult for the user to unlock their phone, navigate to the app, and activate the alarm or recording without the perpetrator taking notice. A discreet wearable would minimize the amount of actions the victim would have to do in a critical situation. Sexual assault is still a prevelant part of society and it is time that technology is utilized to help protect victims and aid them in providing evidence to law enforcement.

1.2 Visual Aid

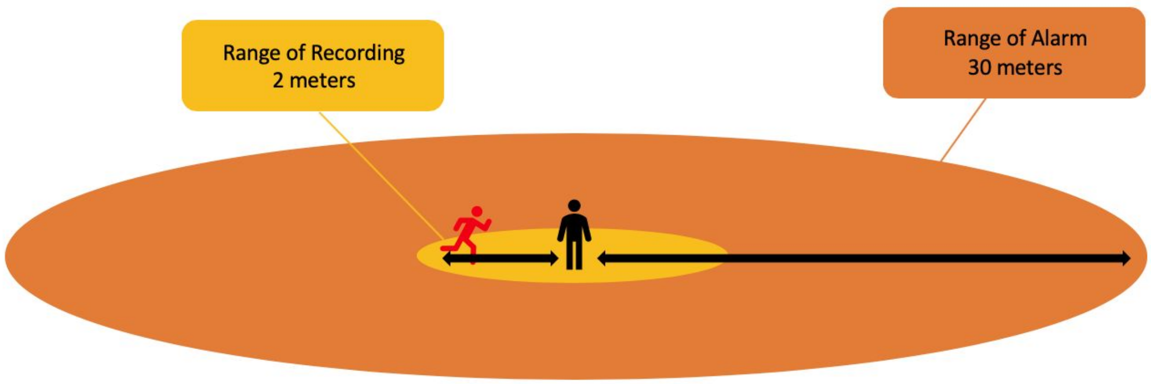


Figure 1. Device Range Diagram

We intend for our product to have a significant range of influence for the user. Having a 2 meter recording capability will ensure that audio evidence can be collected from the start of any uncomfortable and potentially dangerous interactions. In addition having the alarm be noticable for distances up to 30 mins ensures that people in the nearby vicinity can be altered to come help the user.

Figure 2. Example Usage with Bra

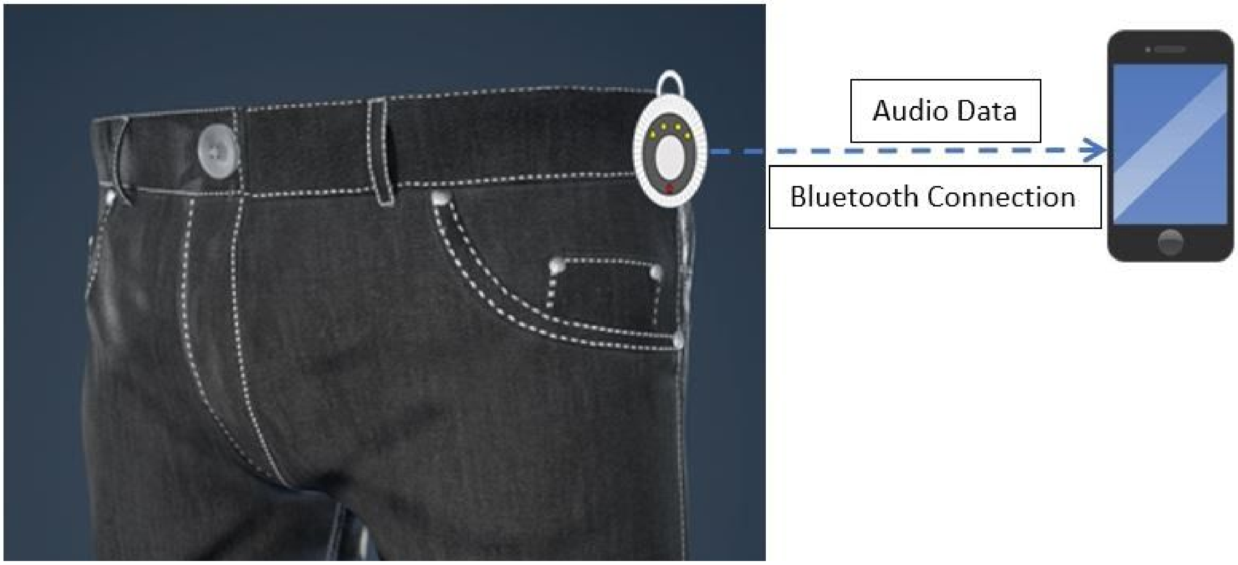


Figure 3. Example Usage with Pants

The vision for this product would be that it would come with optional plastic clips that the user may choose to attach to the back of the device. The visual aids depict potential usage of the product in everyday life. Women that wear bras can clip the device to the side of the bra so that it can be concealed under their clothes. This can help them inconspicuously activate the audio recording or the alarm. Men or women wearing pants may also clip the device to their pants. Additional usage examples include keeping the device in a pocket or attaching it to a key chain. The device will communicate directly with the user's phone within 3 meters.

1.3 High-level requirements list

- The device will only be activated when the user taps it 3 times within 2 seconds to turn on its recording capabilities or 5 times within 3 seconds to turn on the in-built alarm.
- The device can record up to 10 minutes of audio and save it in internal memory.
- The audio saved on the device is transmitted to the user's phone through a bluetooth connection and it will be saved to the phone through a software application.

2 Design

2.1 Overview

The successful functionality of the device hinges on the proper execution of 4 main systems, the user interface, the control unit, the functional unit and the power system. The user interface is the system that facilitates the interaction between the user and the device. This includes the trigger mechanism necessary to deploy the functionality of the device, the phone application to put in necessary information and access the data stored by the device and the LED Indicators that display device status information. In addition the functional unit carries out the main functionalities of the device, primarily the alarm system and the audio recording capabilities. Both these systems are driven by the control unit, which contains the device memory to store any recorded audio, the bluetooth module which will transfer the data to the phone and the microcontroller which will drive all the interactions between the components. Finally all of this is only possible with the power system, which will be driven by a rechargeable battery.

2.2 Block Diagram

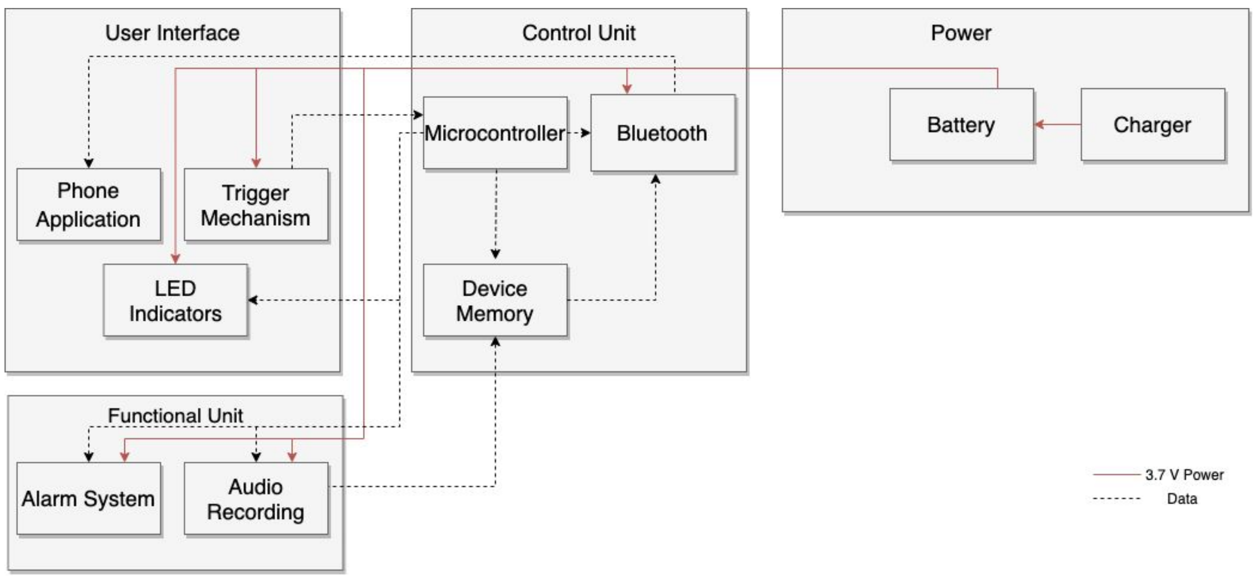


Figure 4. Block Diagram

2.3 Physical Design

The design is intended to be easy to utilize as well as discreet. The device will be a flat circular shape with a single button in the middle that will be large enough that it can be pressed in a hurry. With a diameter of 3 inches it is also a compact design that allows the user to wear it easily. The outside of the circle will be raised in level compared to the button to minimize the case of accidental triggerings. In addition the outside casing will have ridges and the inner casing and the button will have different textures so that a user can easily feel for where the button is in a quick fashion. In the inner casing there will be 4 LEDs to help indicate the charge level of the device and there will be a single LED on the bottom to indicate that the device is recording. On the back of the device, the inner casing will be perforated to allow for the speaker to be clearly heard outside of the device without other parts of the in the case that the alarm is being utilized. Finally there will be a clip-on loop to allow the device to be placed on any garment, undergarment or keychain.

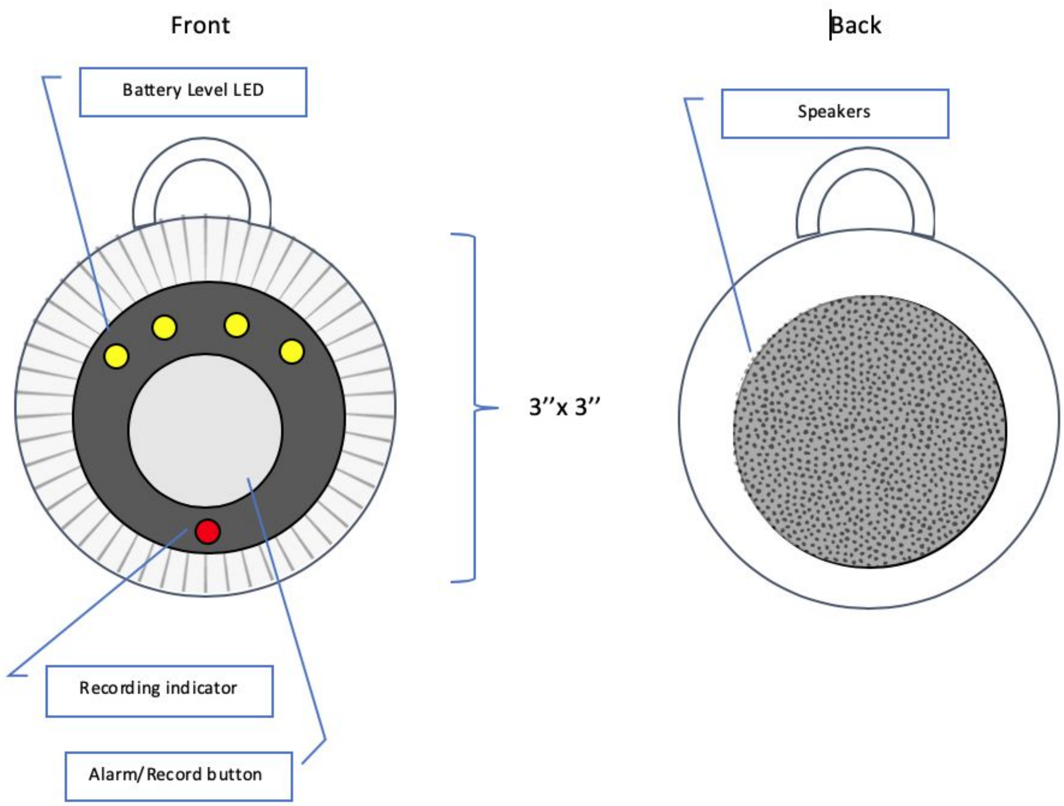


Figure 5. Physical Design

2.4 Functional Overview

2.4.1 User Interface

Trigger mechanism:

A button on the wearable device that upon a three taps will begin recording audio and upon five taps will deploy an alarm and reach out to parties for help. This button must have a clear capacity to detect individual taps in quick succession in order to identify if the user is trying to activate a functionality or if it was just accidentally pressed.

Requirements	Verification
1. Easily pressable and distinguishable from the rest of the device 2. Must be able to distinguish individual button presses from other ones even in rapid succession 3. Must be able to identify when 3 presses have occured in 2 seconds 4. Must be able to identify when 5 presses have occurred in 3 seconds without triggering the recording mechanism	1. Confirm that with 100% accuracy that when blindfolded, 5 different users can find the button on the device within 5 seconds 2. Connect the switch to an Arduino microcontroller and make a quick program to timestamp when the switches were pressed. Once this program is working, have 5 different people try to press the button as quickly as possible for a prestated number of presses. Validate with 100% accuracy that the button was able to isolate each button press. 3. When the button is pressed 3 times in a span of 2 seconds, an LED is turned on and stays on. While the LED is on, if the button is pressed 3 times in a span of 2 seconds, the LED should turn off and stay off. If the LED is pressed less than 3 times in a span of 2 seconds, the LED should not toggle 4. When the button is pressed 5 times in a span of 3 seconds, an LED begins flashing by staying alternating between on and off every second. While the LED is on, if the button is pressed 3 times in a span of 2 seconds, the LED should turn off and stay off.Have the user press the device 5 times over a span greater than 3 seconds and verify that the LED does not toggle from flashing to not flashing. When the button is pressed 3 times within 2 seconds as well as 5 times in 3 seconds, the LED should begin flashing and not solidly glow

Phone Application:

A mobile application that will interface with the bluetooth from the device. The application needs to be able to receive bluetooth data files even when being run in the background. Once the appropriate permissions are given to the application, it must be able to store data directly on the phone or even send out the data to parties that could provide assistance to the user.

Requirements	Verification
1. If permissions are granted to the phone application, even if the application is running in the background, it will be able to receive and save audio files to the phone's file system via bluetooth	1. Audio will be sent via bluetooth to the phone, within 2 minutes of sending the recording, the phone should have the audio saved in it's file system while the application is running in the background

LED Indicators:

LED lights which are placed on the top of the device that will indicate to the user when the recording is activated, and the current charge level of the device. To indicate the current charging level, a charge detection circuit will be used on the battery to illuminate zero to four of the LEDS, four indicating 100% charge and each LED representing 25%.

Requirements	Verification
1. LED lights are able to accurately display how much battery life the device has to the nearest 25% 2. A red LED will shine when recording is taking place.	1. Use a voltage meter to detect both the fully charged and discharged voltages of the battery then validate that at the appropriate intervals of voltage the appropriate LEDs are glowing to indicate remaining charge 2. Test that whenever audio recording is enable the red LED will be shining

2.4.2 Functional Unit

Alarm system:

Once the alarm is triggered, the device must be capable of outputting a loud enough siren to attract attention from people in the vicinity. A speaker with an amplification circuit would be used here. The sound produced will be a sharp high frequency noise that will instantly grab anyone's attention who is in the vicinity.

Requirements	Verification
1. The alarm must be noticable and attention grabbing at 30 meters away	1. Using a db recording application, check that the alarm is able to produce a 50db sound 30 meters away

Audio recording:

Device must be able to record audio in the nearby vicinity. We will use a microphone with an amplification circuit to accomplish this. The device needs to be able to detect voices through clothing and has to have a range of at least 2 meters.

Requirements	Verification
1. The microphone is able to pick up conversations between individuals at a distance of 2 meters even under clothing	1. Have the device placed under an individual's shirt and let them have a scripted conversation with another individual that is standing 2 meters away. Have another individual that is not aware of what was said in the conversation discern the contents of the conversation by writing it down on a transcript. The transcript must be 90% accurate

2.4.3 Control Unit

Bluetooth:

Device can send the audio recording via bluetooth to the victim's mobile device through the HiLetgo HC-05 Wireless Bluetooth RF Transceiver module. It must be able to transfer a recording of one minute in less than a minute so that there is no build up of queued audio files to send. Its functionality also ensures that even if the user has become separated from their phone due to the attacker, the audio is still being streamed to the phone.

Requirements	Verification
1. Bluetooth must be able to transfer at a rate around 3 mbits/s (~400 KB/s)	1. Using audio files that are sampled at 22.05KHz with 16 bit-depth the bluetooth must be able to transfer a 1 min audio file in under 30 seconds

Microprocessor:

The Arduino Pro Mini microprocessor will act as the main driver for all the data flow. It will be primarily responsible for recognizing the button pressing patterns from the user and triggering the correct flow of actions to be carried out by the device. The microprocessor will then also be responsible for coordinating data saving to the SD card along with data transfer to the user's phone and make sure that during this process no audio recording is lost.

Requirements	Verification
1. The microprocessor must initialize audio recording if and only if the button has been pressed 3 times in 2 seconds 2. The microprocessor must initialize the alarm sound if and only if the button has been pressed 5 times in 3 seconds, and in the situation that the first 3 clicks occur within 2 seconds, it must not initialize the audio recording 3. The recording must be saved to the device SD card as it is being recorded	1. Have the user press the device 3 times over a span greater than 2 seconds and verify that no recording starts. Repeat the process but have them tap the button 3 times under 2 seconds and ensure the audio recording begins 2. Have the user press the device 5 times over a span greater than 3 seconds and verify that no alarm starts. Repeat the process but have them tap the button 5 times under 3 seconds and ensure the alarm begins.

and once the recording is complete the device must transfer the file to the device via bluetooth	Finally have the user press the button 5 times within 3 seconds where the first 3 taps were under 2 seconds and ensure that the alarm begins. 3. Once the recording LED light is on press the button 3 times in 2 seconds to indicate that the recording must be stopped. Verify using the LED that the recording has been stopped. Plug the microSD card into a seperate SD card reader to ensure that the recording was properly transferred. Now set up the circuit once again but with an LED where power would need to be delivered to the bluetooth module and repeat the process to ensure that after the audio recording is stopped that it will initialize the bluetooth.

Device Memory:

Micro SD card to store audio recordings on the wearable device. This has the role of acting as a place to store the audio files on the device to simplify data transfer via bluetooth. It also has the responsibility of acting as another location where the audio files can be stored in the circumstance that the user's phone is out of range and completely neutralized.

Requirements	Verification
1. Must have the capacity to store up to 1 hour of wav file audio.	1. Plug the SD card into an external device and transfer in wav files that together total an hour long. Ensure that 100% of the files are properly stored in the device and be played back properly.

2.4.4 Power System

Battery:

The battery will be a 3.7V lithium ion battery. It will be rechargeable by a charging circuit and USB-to-serial converter. It will have a thermal and heat regulator to ensure that the device does not overheat. In addition there will be a voltage regulator to ensure that the voltage entering the circuit is regulated to meet the safe operating limits of all the components.

Requirements	Verification
1. Battery should supply 3.7V and current at a rate of 500 mA.	1. Use a voltmeter and ammeter to verify the supplied voltage and current values.

Charger:

Micro-USB charging port will be used to charge the battery. The charger itself will be capable of utilizing a 120V charging outlet and will charge the device at a rate of 100mA. The charger will be able to recharge the battery at a quick rate while also not posing a risk of the battery overheating.

Requirements	Verification
1. Charger should charge the battery at a rate of 100 mA.	1. Discharge the battery 2. Use an ammeter to verify the charging current while charging the discharged battery.

2.5 Schematics

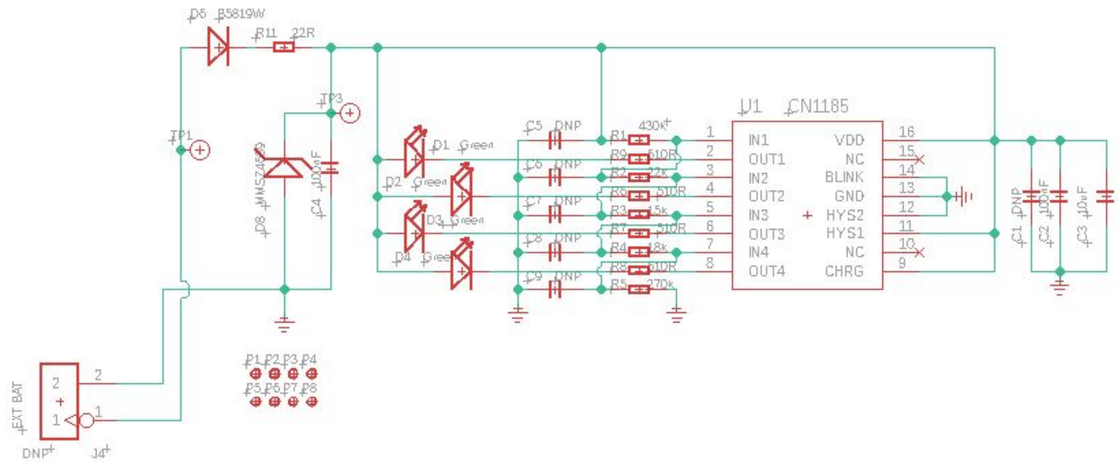


Figure 6. Voltage Indicator Circuit

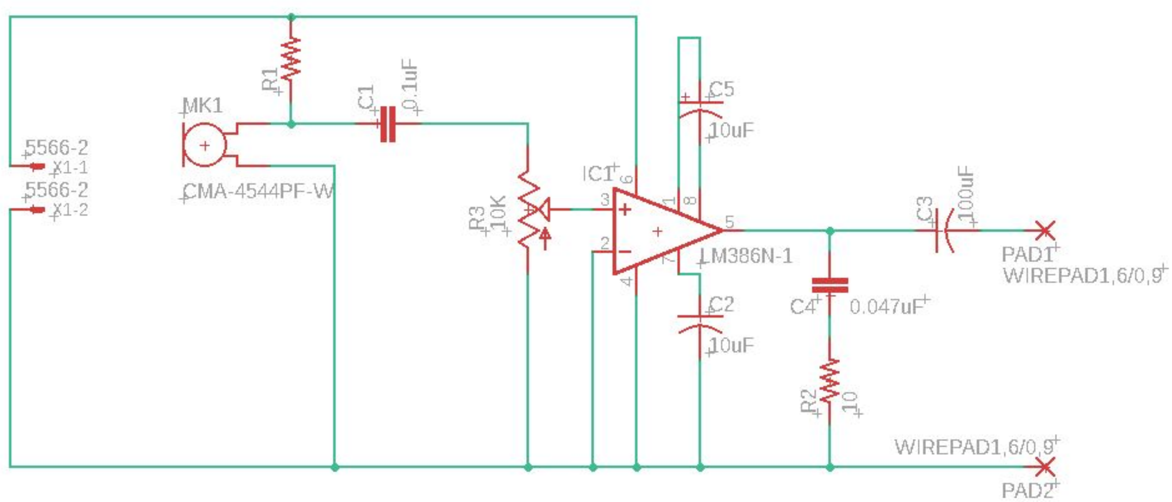


Figure 7. Microphone Amplification Circuit

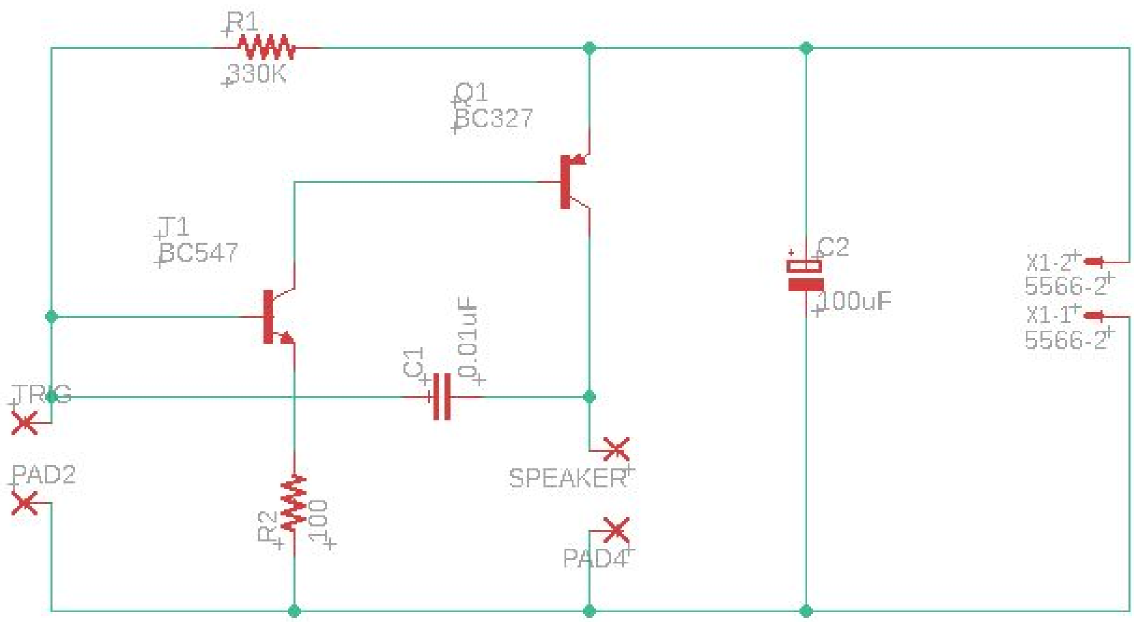


Figure 8. Speaker Circuit

Voltage Indicator Circuit works with CN1185, which is a four-channel voltage monitoring chip that gives a quantized output depending on the input coming from the battery.

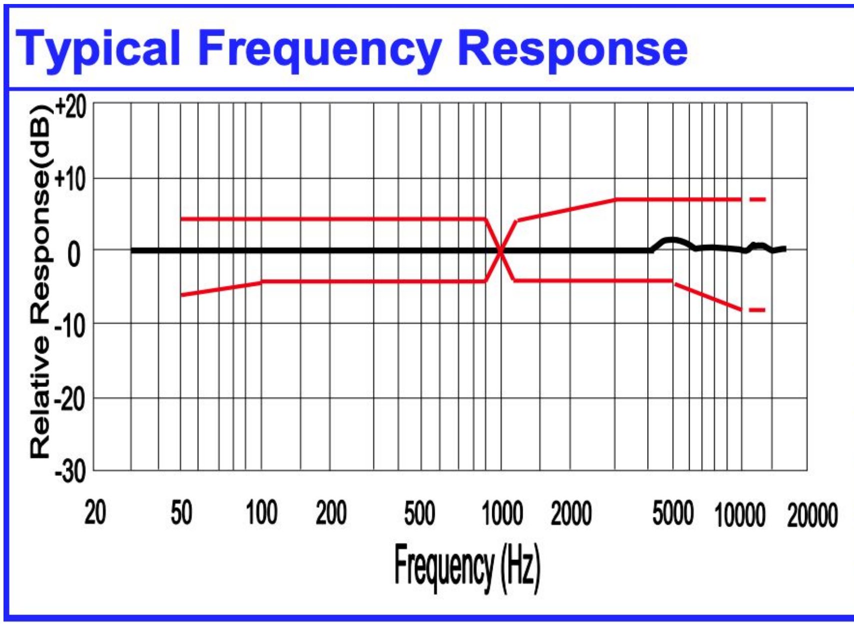
Microphone Amplification Circuit works with LM386, which is an op-amp chip. The circuit utilizes DC signal for power but AC signal for sound amplification. C1 and C3 are used to block the DC signal from the sound. C2 is used to avoid oscillations. C5 is used to set the voltage gain at the op-amp.

Speaker Circuit works with two transistors, one NPN BJT and one PNP BJT. Triggering the switch will make the NPN transistor work which will let the current reach to the speaker and activate the speaker.

2.6 Tolerance Analysis

As stated in our introduction, sexual assaults are the most underreported violent crime. This can be attributed to the lack of incriminating evidence that can be brought up against the abusers. The method that we have proposed for providing this evidence is the use of audio recordings in situations where an individual is in the threat of being assaulted. While one-party consent audio recording is legal in 38 of the 50 states in America, a major consideration for designing this product is to ensure that any audio recordings that are created by the device are admissible in court. The best way to guarantee this is to ensure that the audio file is not altered in any way. This limits the amount of processing that can be done to the audio in order to improve its quality, hence it is imperative to ensure that the audio quality that we derive from our electret microphone is the highest audio quality that we can ensure.The main factors to consider in the tolerance analysis will be the frequency response, sensitivity and sampling rate for the microphone.

The primary purpose for this microphone is to accurately and clearly record speech between individuals. The frequency range of human speech is between ~70Hz to ~4.1kHz [6] meaning that this is the primary range of audible frequencies that need to be recorded by the microphone. The electret microphone that we have selected for our project has the following specifications with regard to the typical frequency response.



Microphone Response Toll Window		
Frequency (Hz)	**Lower Limit (dB)**	**Upper Limit (dB)**
50	-6	+3
100	-3	+3
800	-3	+3
1000	0	0
1200	-3	+3
3000	-3	+8
5000	-3	+8
10000	-8	+8

Figure 9. Typical Frequency Response - *This graph shows the voltage output by amplitude (dB) for a given frequency input to the electret microphone.*

A 6dB increase is considered close to a doubling in perceived volume (amplitude)[5]. This means that for the range of human vocals the largest differences will be a .75 times decrease in the perceived volume of the frequency or a 2.5 times increase in the perceived volume. While there is a slight bias towards higher frequencies in the vocal range there are no biases in regards to decreases in amplitude, which we deem is a reasonable threshold for the microphone’s frequency response.

The sensitivity of the microphone is also a major factor to consider. The sensitivity essentially dictates the perceived loudness that the microphone can pick up. This is an important thing to consider because the microphone must be able to pick up speech at the aforementioned distance of 2 meters while also not running the risk of clipping due to loudness if it is near the mouth of the user. Sensitivity is measured in dBV which indicates how many volts will be outputted for a given dB input. The exact calculation is given by Eq.1 in order to convert between the input voltage sensitivity to

$$Sensitivity(dBV) = 20 * log10(Sensitivity(mV/Pa)/1(V/Pa))$$

Eq.1

This shows the output sensitivity of the mic with respect to it’s input sensitivity measured in millivolts per pascals. The logarithm is of this input sensitivity over the standard reference output ratio[7]. Ultimately, this indicates how in order to pickup the vocals at a high range we need a fairly sensitive microphone, but we still need to be cognizant that it is very possible that due to the user’s destress during the situation they might be in a situation where they are far louder than the attacker, which must be accounted for in the sensitivity of the device. The final sensitivity that our electret microphone is rated for is -46 dBV +/- 2 giving it around a 5mV/Pa input sensitivity which is a good range to meet the needs of the design.

The final primary concern for the design is figuring out the optimal sample rate to capture the clearest audio, all the while trying to minimize the amount of data taken up by the recording. Our design hingest on an efficient and quick way to transfer data, so it is vital to try to limit the sampling rate as much as possible. The sampling rate is the rate at which the analog audio signal is recorded and converted into a data file. In order to ensure that no data is lost in the recording it is necessary to make sure the sampling rate is greater than twice the frequency of the highest frequency sound waves that we want to capture. This is called the Nyquist frequency.

$$Nyquist\,frequency\ (Hz) = f * 2.0$$

Eq.2

As we stated above, the highest frequencies of speech sit around 4.1kHz, thus we would need to sample at a value around 8.2kHz according to Eq.2. This calculation ignores the problem of aliasing though. Aliasing is the problem that arises when a sampling frequency is lower than background noise in the audio, which leads to unwanted distortions in the final recording. This is visualized below.

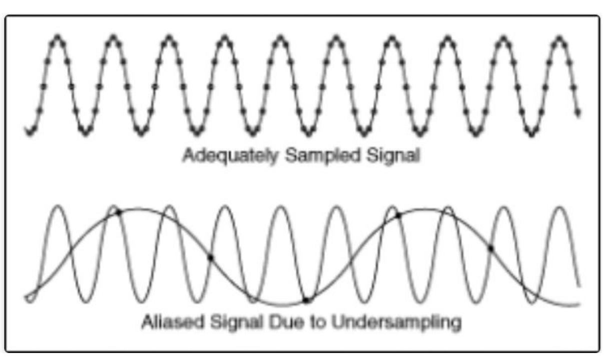


Figure 10 - *Illustrates how distortions form in the audio recordings due to aliasing[8]*

Based on Fig 2.6.1, it is clear that the microphone is rated to record all frequencies up until a little less than 11kHz, and as this extra band of frequencies above what is able to be sample will inevitably lead to noise, we need to accomodate for it. There are two options which exist, the construction of a low pass filter, which would reduce frequencies above a certain range or increasing the sampling rate up to 22kHz. Our current solution is the later, as it would also have the benefit of providing a clearer audio recording, but in the situation that it leads to data transfer slowdowns, we will have the option to build the low pass, or a hybrid solution as well.

3 Cost and Schedule

3.1 Cost Analysis

Our fixed cost analysis is separated into labor and parts. Labor will be calculated assuming an hourly rate of 35$ an hour for each of the team members. We will also assume a 10 hour work week for a total of 14 weeks. Our final calculation comes out to 3 * 35 * 10 * 14 * 2.5 = $36750

Part	Cost per Unit ($)	Quantity	Total Price ($)
Lithium Ion Polymer **Battery** - 3.7v 500mAh	7.95	1	7.95
Adafruit Micro Lipo - USB LiIon/LiPoly **charge**r - v1	5.95	1	5.95
HiLetgo HC-05 Wireless **Bluetooth RF Transceiver**	7.99	1	7.99
Arduino Pro Mini 328 - 3.3V/8MHz	9.95	1	9.95
FT232RL FTDI **USB To TTL Serial** Converter Adapter Module	5.68	1	5.68
Speaker Digi-Key CPI-2207-95-SMT-TR	3.43	2	6.86
Button Digi-Key	8.72	1	8.72

EG4704-ND			
Digi-Key **Resistors RC0402JR-070RL**	0.10	20	2.00
Digi-Key **LEDs LTST-C171TBKT**	0.28	10	2.80
Digi-Key Mini condenser mic **CMA-4544PF-W**	0.77	1	0.77
Estimated Tax (10%)			5.87
Total			64.54

3.1 Schedule

Week	Bhavish	Santan	Berk
02/24/20	Work on Design Document		
03/02/20	Working on developing method of bluetooth connectivity and data transfer to phone		Design battery level indicator PCB
03/09/20	Mic and recording testing		Design mic and speaker amplification PCB
03/16/20 (break)			
03/23/20	Write microcontroller code for alarm and audio trigger mechanism		Design overall PCB connecting microcontroller, speaker, mic, bt, etc.
03/30/20	Create phone application with bluetooth connectivity	Test speaker and alarm functionality	Test mic functionality with amplification circuit
04/06/20	Test bluetooth connectivity and data transfer of audio files MicroSD card to phone through bluetooth module		Test storage of audio file onto MicroSD card from mic input
04/13/20	Prepare Mock Demo		
04/20/20	Design outer casing for 3D printing		Put together PCBs and all hardware

		subsystems
04/27/20	User acceptance testing of hardware and software of final product	
05/04/20	Preparing final presentation and report	

4 Discussion of Ethics and Safety

Given that this product aims to help victims in providing evidence to the victim, it is important that the audio data recorded is not modified in any way by the device. This is in compliance with number 3 in the IEEE code of ethics in which we will be honest about the data used in the device [4]. We will keep this in mind during the development stage of the product. One-party consent recording is legal in 38 states, however 12 states still require all-party consent for audio recordings. If this device were to make it to market, this would need to be clearly stated so the user doesn't accidentally record audio illegally in certain states. This is in accordance with number 5 in the IEEE code of ethics in which we are urged to improve the understanding of individuals on the societal implications of our technology [4]. Additionally, in compliance with number 1 in the IEEE code of ethics, we will ensure that all safety precautions are taken in the construction of the device to ensure that there is very minimal risk of harm to the user, and if any such risk does exist, information would be provided to the user to inform them of the proper usage to avoid said risk.

Since this device is a wearable and can potentially have close contact with the human body, extra precautions are necessary to protect the user. The outside of the wearable device will be an insulating casing that will make sure that no wires are exposed. This will minimize the risk the user faces when using the device while it is raining outside or when the user is sweating. Although lithium ion batteries have become the standard in rechargeable consumer products, there is still a level of risk that must be mitigated when using them. The battery will be purchased from a reputable company with a protection circuit built into the battery. The protection circuit will prevent the battery voltage from getting too high or too low and will cause the battery to cut out at 3.0 volts. This also prevents the other circuitry in the device from shorting or being damaged by improper power input. The manufacturer recommended charger for the battery will also be used to prevent malfunctions in the battery. The charging will have three stages: a preconditioned charge, constant-current fast charge, and a constant-voltage trickle to top the battery off. These stages prevent overcharging of the battery. There will also be a voltage detection circuit that can visibly notify the user when the battery has charged.

When working on developing this device, our group will take many precautions to ensure our safety and the safety of those around us. All members of the group have completed and passed the required lab safety training. We will make sure to not modify circuits while the power is connected, as well as be vigilant of any burning parts to make sure we do not start a fire. The lab will also be equipped with a fire extinguisher in case of emergency. Additionally, our group will have at least two members present when working in the lab to help prevent accidents. In the situation the group needs to work with equipment that the members of the group are unfamiliar with, we will ensure that there will be the necessary supervision to validate the proper usage of the equipment. Finally, the group will not use other individual's work without the proper citations, and certify that the idea and design of the project is original and unique [1].

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