ECE 445: RONArmor

Project Proposal

Team # 31
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1. Introduction

1.1 Objective:

Since the end of year 2019, the world has been stuck under vicious cycles of a global pandemic and non-stop quarantine where we are responsible not only for our own well-being, but also for the health and safety of those around us. Throughout this entire process, we've been told three things: mask up, stay 6 feet apart, and wash your hands. So we thought, why not design a safe, reusable, and affordable facial shield that reinforces the social distancing process and possesses communication-friendly features? While initially everyone struggled to keep up with the supply of masks and settled for whatever they could get their hands on, now we can design new masks that offer proper safety, freedom of expression, comfort and utility.

RONArmor will be a form-fitting, protective facial shield constructed with recyclable plastic that reassures the safety of users by enforcing social distancing guidelines through sensors and ensuring improved and entertaining communication through audio amplification and modulation. We look forward to producing a product that will aid people in moving beyond a conventional mask to express themselves better and in a safer manner.

1.2 Background:

COVID19 has left the world scrambling for economic stability, social justice, vaccines, and face masks. Daily, frontline workers must gear up with the proper protective equipment and it has led to a shortage of N95 masks throughout the US [1]. As face masks have become normalized and a required necessity, enormous amounts of plastic waste have been generated throughout the world [2]. Furthermore, a common recurring issue that comes along with the enforcement of face coverings is difficulty with communication, specifically with the transmission and reception of speech. Companies like Razer and their Project Hazel have proposed to solve this issue with a mask that possesses voice amplifying technology in addition to a UV Sterilizer charging case for repetitive use [3]. However, it still remains a concept as the product is yet to be officially introduced in the marketplace [4]. Moreover, its ample amount of high-tech and smart features will most likely require longer production time as well as higher cost. Both of these factors pose obstacles for countries and their people who are struggling to fulfill their essential duties on a daily basis. We want to create an effective product that can combat these issues so that everyone can easily, affordably, and comfortably attempt to regain some normalcy to their everyday lives while ensuring the safety of themselves and their communities.

1.3 Physical Design:

The physical design of RONArmor consists of a facial shield constructed of recyclable plastic with the intention of being environmentally friendly and transparent. The silicon lining of the facial shield allows for comfortability and flexibility and is secured to the user's head with two adjustable head straps. Fixed to either side of the mouth are breathable filters and a speaker that is placed directly below in the chin. Status LEDs are positioned at either side of the user's face and within their peripheral vision. Located on the center of the upper head strap is a PIR sensor in addition to an on/off button and a modulation control dial on the right. Finally, a thermally insulated battery case is attached to the bottom head strap and includes a clip to attach to the user's clothing in order to keep volatile elements isolated away from the user's face, neck and head.

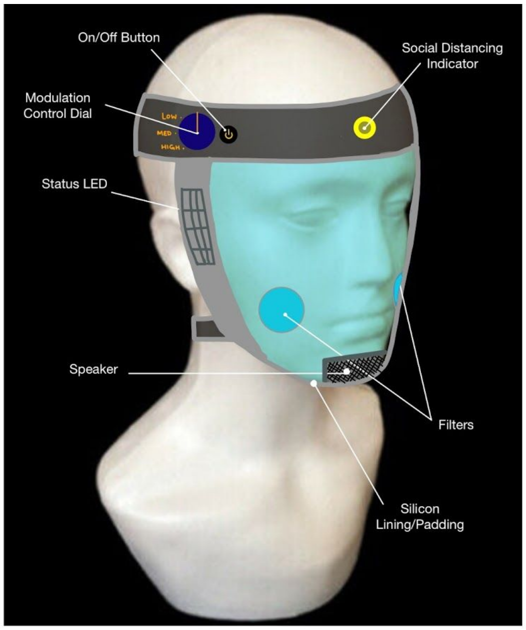

Figure 1a: Physical Design Front/ Right Side View

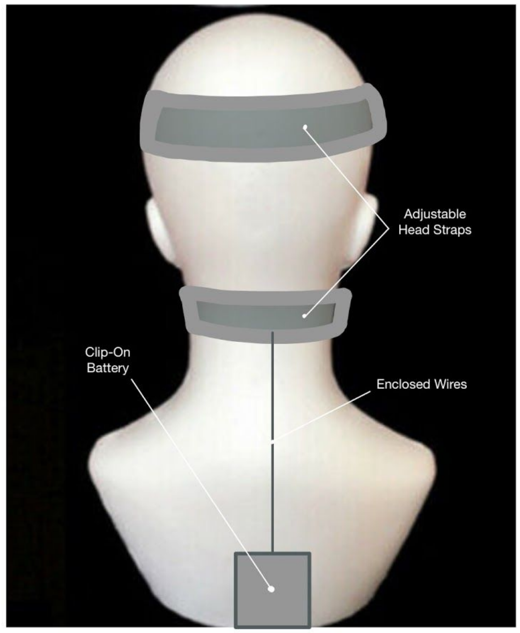

Figure 1b: Physical Design Back View

1.4 High-Level Requirements List:

i. Accurately assesses and notifies the user whether people are standing six feet away.

ii. Audio is properly amplified and can be modulated between three pitches (low, medium, high) or left to the user's natural tone.

iii. Components near the face will avoid shorting, overheating, and other dangerous risks by maintaining a low amperage of less than 2 mA.

2. Design

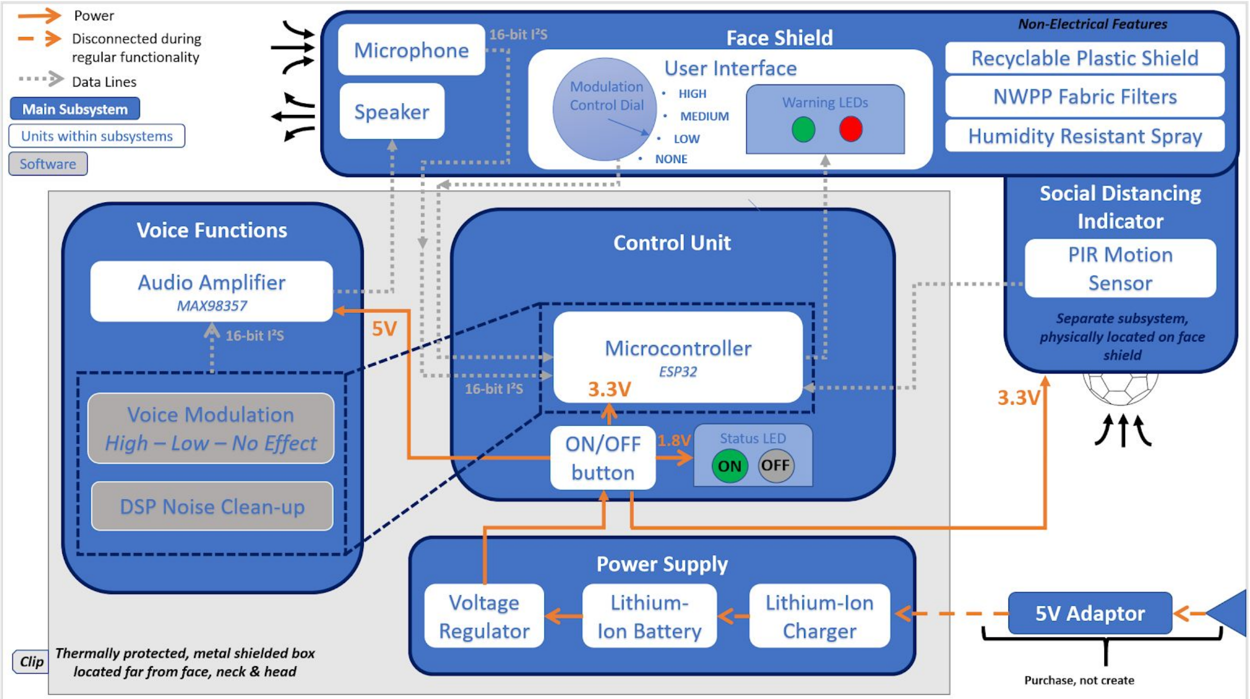

Figure 2: Block Diagram

2.1 Power Management & Storage

Since our project will need to be portable, we will use lithium ion batteries as our voltage source to power our entire project. We also want to incorporate a 5V Lithium ion battery charging circuit for recharging the batteries so that users could simply plug in their device opposed to constantly replacing its batteries. Lastly, we will have a voltage regulator to ensure that each unit in our design is supplied with appropriate voltage levels. Introducing rechargeable batteries so close to the users' head will require our group to have a great focus on safety precautions. The next block will highlight how we will ensure the protection of our users.

Requirement: Continuously supplies a minimum of 240mA at 5V to the entire system.

2.2 Embedded Safety Features & Control Unit

First of all, we plan to have our PCB located away from the shield so that in the chances of a worst case scenario, the user will not sustain harm to his or her face, neck or head. The majority of our components will be contained within a thermally protective metal box that clips onto the users' clothing. The thermal protection will prevent the user from getting burned if any components overheat. The metal of the box would protect the user from any EM radiation emitting from the device. Preventing any large overshoots or undershoots on our data lines, and will also function to protect the user from EM waves that may escape the box. Furthermore in regards to battery recharging we will disable the powering on of our shield's various functions while the batteries are charging and likewise disable the charging of batteries while our shield is on. Overall, throughout our design process, we will keep a close eye on each component's tolerances to ensure that we do not drive any component above its voltage, current, or power ratings. Finally, we plan to utilize a number of the following components to avoid unintentional shorts or component malfunctions: ground path capacitors, protection/ESD diodes , and fuses. The control unit of our device will largely be responsible for these safety measures. The core of our control unit will be a microcontroller responsible for processing the data from our sensors, determining the status of our user interface LEDs, and handling a majority of the signal processing performed from our microphone input to our speaker output.

Requirement: Surface temperature of the metal box must not exceed 110 degrees Fahrenheit [5].

2.2.1 Microcontroller

We intend to use digital audio since it allows for easier signal manipulation. To do so, we will use an ESP32 microcontroller. This microcontroller will permit us to control the two main units: the voice functions and the status LEDs. The ESP32 will receive, process, and deliver signals and commands in accordance to the user's inputs via the modulation control dial, the on/off button, and the social distancing indicator's signals. Each of these systems are connected via the GPIO connections on the microcontroller and will be controlled by the programmed embedded software.

Requirement: Needs to be powered at 3.3V as the I/O pins are not 5V tolerant. I/O pins are needed to control the other components so it is crucial that 3.3V is maintained [6].

2.2.2 On/Off Button

This button will allow the unit to power up and down as a whole, it determines when voltage can or cannot be supplied and when signals will or will not be transmitted to and from the microcontroller. When the unit is powered on a green LED will illuminate to indicate that the facial shield is active.

Requirement: Turns on/off only when a minimum actuation force of 0.8 oz is applied [7].

2.2.3 Modulation Control Dial

The dial will consist of 4 frequency options: none, low, medium, and high. When the dial is turned to a specific frequency setting, a signal will be sent to the microcontroller for signal processing. Once the microcontroller receives the voice signal it will improve the SNR ratio by performing DSP noise clean-up and then applying the appropriate voice modulation before outputting the new audio via a speaker mounted on the facial shield.

Requirement: Possesses a maximum response time of 1 second, but preferably within 100 microseconds [8].

2.2.4 Status LEDs

Each status LED will consist of red and green LEDs which correspond to the relative distance the user is in comparison to the people around them. Red represents less than 6ft apart and green represents a distance of at least 6ft. According to the signals received by the microcontroller from the social distancing indicator's PIR sensors, the embedded software will delegate which of the two colored LEDs is activated.

Requirement: Light intensity of the LEDs are below 10,000 cd/m² [9].

2.3 Social Distancing Indicator

One of the main functionalities of our project will be its ability to warn its user if there are people within a 6ft radius. To do this, we will utilize Passive Infrared (PIR) Sensors to detect people. We will send this data to our software in the microcontroller to establish whether the person detected is too close per the CDC's social distancing guidelines. Signals will then be sent to a range of LEDs from red to green that indicate to the user when social distancing guidelines have been breached and to what extent.

We intend to use the PIR sensor module controlled by the esp32 microcontroller to ensure the social distancing aspect of our project. The PIR sensor takes in 3.3V and is controlled via the GPIO pins on the microcontroller. A good PIR for our purpose is the Mini AM312 PIR motion sensor. It has a overlooking range of ~120-130 degrees and side-look range of 100 degrees as can be seen in the diagram below [10]. GIven the range of each sensor we may have to use up to 4 sensors per unit.

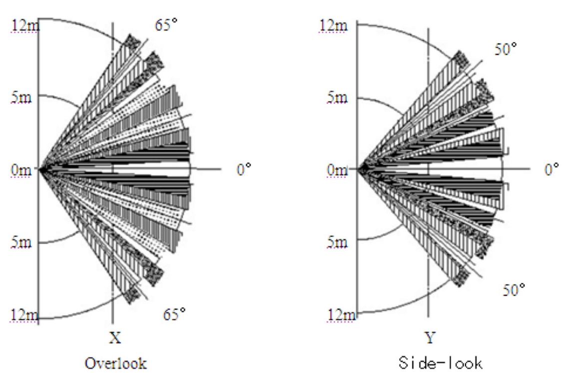

Figure 3: Range of PIR Motion Sensors

Requirement 1: Needs 3.3V to be powered. Successful connections from the GPIO pins of the microcontroller must be maintained for correct data transfer.

Requirement 2: Must be able to detect human presence even in low-lighting environments.

2.4 Voice Functions

The other main characteristic of our project will be its voice amplification and/or modulation features. This subsystem will utilize a microphone inside the shield to take in the user's voice signal. This signal will then be sent to the microcontroller via an I^2S protocol where software will perform noise filtering and the appropriate voice modulation. Finally the new audio signal will be sent through a digital audio amplifier to a speaker on the shield, making the voice more audible. The modulation to be performed will be determined by a dial on the shield with 4 functions for the user to select from: no modulation, low pitch, medium pitch, and high pitch.

For voice functions we will use SPH0645 breakout board (I2S digital microphone) and MAX98357 (I2S audio amplifier) [11]. Each of these operates on 3.3V inputs and has low amperage of about 20mA. Since these utilize only digital signals, we will be able to test and monitor the desired nature of audio using the microcontroller. The interaction between the controller and these chips will be done via C code using specific libraries for the ESP32 board. The ESP32 microcontroller has good support for I^2S protocol and by using the separate breakout boards we will ensure that there is no loss in quality since the microcontroller natively supports only 8 bit stream while the breakout boards support 16bit and 32 bit. Using DSP, we will also be able to provide noise filtering and voice modulation options.

Requirement: Projects clear and denoised audio with a latency time frame between 8-12 ms in order to maintain proper conversation flow [12].

2.5 Mask/Shield

As for the nonelectrical components of our project, we will use clear, recyclable plastic for the shield itself, silicon lining and padding around the face, and spunbond non-woven polypropylene (NWPP) fabric filters around the edges for filtration. Lastly, the inside will be coated with a transparent humidity resistant spray.

Requirement: Applied anti-moisture coating spray must be safe for inhaling.

2.6 Risk analysis

The Control Unit is going to be the most crucial part of the project. The Control Unit is responsible for handling the data communication between voice functions and social distancing modules. As is highlighted in the control flow and design sections, most of the data processing is going to be done using the microcontroller. Thus, maintaining the required power for the microcontroller will be crucial. Further, it is crucial that all the connections from the GPIO pins are correctly connected, lest it lead to incorrect transfer of data and thus wrong computation. Apart from this, the only crucial part will be maintaining correct power requirements and connections for the microphone, amplifier and PIR sensors.

3. Ethics and Safety

The main concern we are focused on as we begin to develop RonaAmor is the potential safety hazard that lithium-ion batteries present. This hazard cannot be completely eliminated due to the necessity of a high energy density, portable power supply for our facial shield. Nevertheless, we are committed to upholding the IEEE standard of prioritizing “the safety, health, and welfare of the public [by striving] to comply with ethical design and sustainable development practices” [13]. In doing so we will center our attention on taking the necessary precautions to ensure the longevity of our facial masks and the safety of the community members who will be wearing them.

Lithium-ion batteries have been known to cause fires, explosions, and other harmful accidents. Studies have shown that these accidents are largely caused by poor electrical designs such as short circuits, overcharging batteries and exposure to temperatures beyond their thermal rating [14]. In order to reduce these risk factors, we will integrate an appropriate charge management controller into our power supply subsystem. A good contender for a power management IC (PMIC) is Microchip Technology’s MCP73831/2 linear charge management controller. Once this PMIC has reached its Charge Complete mode (meaning the average charge current has diminished below an established percentage of the programmed charge current), the MCP73831/2 will latch off the charge current to prevent overcharging the battery. Furthermore, this PMIC is also designed to suspend charge if the die temperature exceeds 150°C and will not resume charging until the die has cooled to 10°C [15].

Another precaution that RonaAmor takes in order to prevent the harm of its users is the isolation of the battery pack from the user’s face, neck and head. Our design allows for the battery recharging circuit, the battery itself, and much of the supplemental circuitry to be located inside a thermally protective box fashioned to clip onto the users’ clothing a safe distance away from the facial shield itself. In this way we are both preventing electrical accidents, as well as preparing for the worst case scenario. Overall all the engineers on this project are committed to the IEEE standard “to seek, accept, and offer honest criticism of technical work [and] to acknowledge and correct errors” as we launch this new and exciting product that we hope will provide some relief in the midsts of this global pandemic [13].

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