Wearable Smoke/CO Detector for Hearing Impaired

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ECE 445 Project Proposal - Spring 2019
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1 Introduction

1.1 Objective

The U.S. Fire Administration [1] estimated a total of 1,319,500 building fires occurred in the year 2017, these fires caused around 2,400 deaths for the year. In 2015, the CDC [2] reported 393 deaths caused by unintentional non-fire related carbon-monoxide poisoning. Current smoke and carbon-monoxide detectors designed for the hearing impaired alert them of the presence of either with a high intensity strobe light in addition to the sound alarm. The Americans with Disabilities Act of 1990 requires new buildings to be equipped with high intensity strobe alarms [3], buildings that were built prior to 1990 were expected to upgrade their alarm systems in adherence to the new standard. The responsibility of adherement lies with the owner of the building, and the hearing impaired should not be at risk due to negligence.

Our goal is to rid the hearing impaired of this burden almost entirely. We will create a device designed to be worn on the wrist that will alert the wearer of the presence of smoke and carbon monoxide with a vibration.

1.2 Background

In addition to the high-intensity alarm, products are sold that will vibrate to the frequency of a specified smoke alarm and are placed under a pillow to alert the user during sleep. This device of course is reliant on the chosen smoke alarm, most are sold with the contingency of buying the alarm to go with the pillow pad. Wearable smoke detectors do exist, but with the intention of measuring cigarette smoke intake [4].

Our solution is the first of its kind in addressing a wearable smoke and carbon monoxide detector designed specifically for the hard of hearing.

1.3 High-Level Requirements

- Device will alert the wearer of smoke and/or carbon monoxide presence with the use of a vibration motor
- External LED will illuminate after battery capacity is under 20%
- External push button will halt the vibration motor upon user request

2 Design

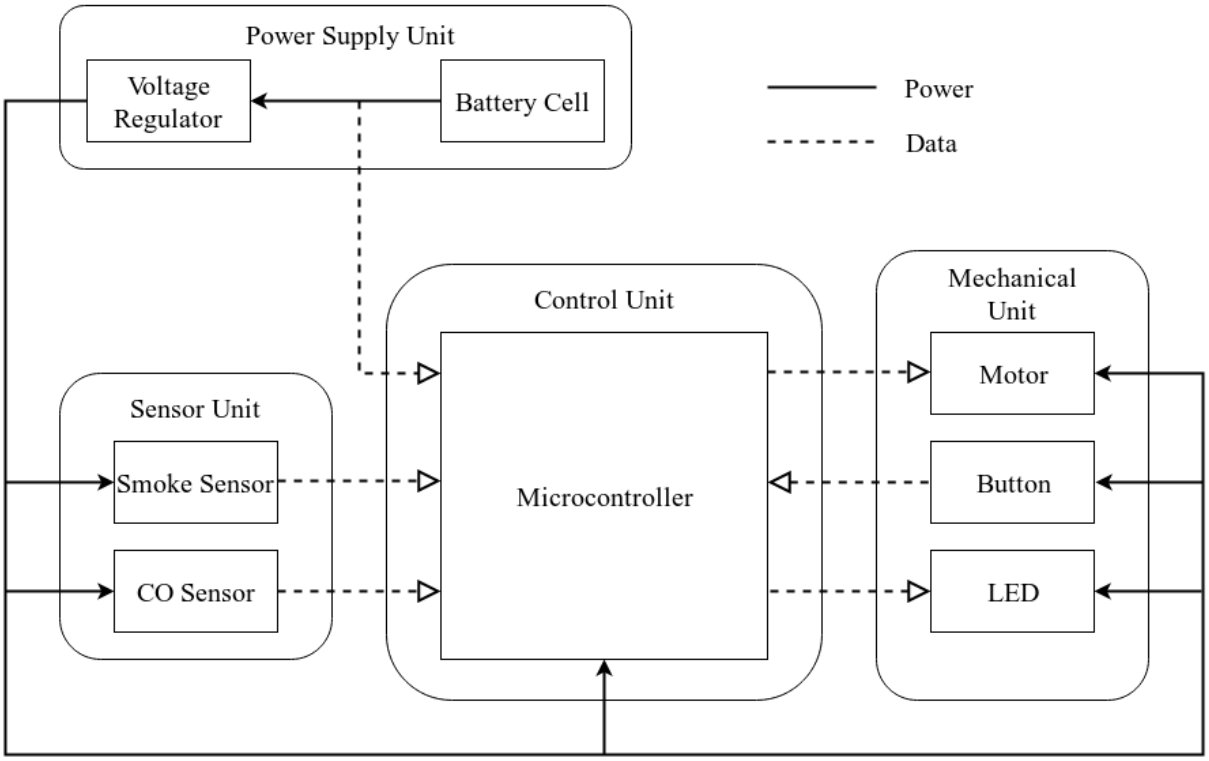

Figure 1: High Level Block Diagram

2.1 Power Supply Unit

The Power Supply Unit will provide power for all devices in the project. This unit will consist of a Battery Cell and a Voltage Regulator.

2.1.1 Battery Cell

The battery cell provides power for all components in the device.

Requirements:

- Voltage must be bigger than 5V.
- Dimension must be smaller than 20mm x 20mm x 15mm.

2.1.2 Voltage Regulator

The voltage regulator must be able to control the voltage coming from the battery cell and convert it to a safe operating level.

Requirements:

- Output voltage must be 5V±10%
- Input voltage must be at least 6V

2.2 Sensor Unit

The Sensor Unit will provide readings for the microcontroller. This unit will consist of a Battery Voltage Reader, Smoke Sensor, and a Carbon Monoxide Sensor.

2.2.1 Photoelectric Sensor

The photoelectric sensor will send information to the microcontroller based on the presence of smoke or the lack thereof.

Requirements:

- Responds to the presence of smoke
- Less than 100 mA current draw

2.2.2 Carbon Monoxide Sensor

Carbon Monoxide levels will be monitored by an electrochemical sensor. If the carbon monoxide concentration reaches dangerous levels, the sensor will notify the microcontroller.

Requirements:

- Detect carbon monoxide level of at least 40 ppm ± 5% [5]
- Less than 50 mA current draw

2.3 Control Unit

The Control Unit will consist of a Microcontroller. This unit will be have inputs from the Sensor Unit and have outputs

2.3.1 Microcontroller

The microcontroller will take readings off the Sensor Unit, make decisions based on those readings, and send those decisions to the Mechanical Unit

Requirements:

- Microcontroller must be able to read at least 4 inputs at the same time
- Microcontroller must be able to give at least 2 different outputs

2.4 Mechanical Unit

The Mechanical Unit will be the interface between the microcontroller and the user. This unit will consist of the Motor unit, the LED unit, and the Button/Switches Unit.

2.4.1 Motor

The motor will start or stop vibrating upon inputs from the microcontroller.

Requirements:

- Less than 75 mA current draw
- Strong enough vibration to successfully alert the wearer

2.4.2 LED

The LED will inform the user whether the device is on and notify the user about the capacity of the battery.

Requirements:

- Less than 25 mA current draw
- Capable of displaying different colors

2.4.3 Buttons/Switches

The button/switches will give the user the ability to turn on/off the device, to stop the motor vibration, and to turn on the battery LED indicator.

Requirements:

- The button/switch must be smaller than 10mm x 10mm

2.5 Risk Analysis

The size constraints pose the biggest risk to hampering success of our project. The wearable nature of the device will require design to be small enough to be comfortably worn around the wrist and also lightweight. These constraints will undoubtedly drive a considerable amount of our design choices.

Directly related to size constraints, is the lifetime of our battery bank. If the wearable device is to be considered functional, it must have a significant battery life. Battery capacity and dimensions are proportional, we must weigh the costs and benefits associated with different battery configurations within our system.

The control system is an additional risk to the success of the device. The control system must be able to accept sensor inputs and create output signals capable of actuating the vibration motor and controlling the color displayed from the battery management LED. Breakdown of the control system would make the device non-functioning.

3 Safety & Ethics

One of the most obvious safety considerations was made in choosing the proper sensors for smoke. An ionization detector contains a small amount of radiation, the exposure is much less than that of background radiation [6]. Still, no amount is radiation exposure is better than a small amount of exposure. Any potential risks associated with working around radioactive material has also been avoided with this design choice. This reflects IEEE Code of Ethics #1: “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment” [7].

Since our device will be designed to be wearable, it will be making direct skin contact with the user, this poses obvious health risks in the event of a malfunction. Adherence to standard practices and extensive testing of equipment reliability is essential to ensure public health and safety. IEEE Code of Ethics #5 requires individuals to disclose all limitations [7]. Transparency throughout the design process is paramount to informing others of any devices shortcomings.

Our device will be designed to operate under raining conditions, thus the protective casing must effectively shield the inner components from rainfall. Failing in this regard effects not only the reliability of the components, but also poses a health risk due to the potential short-circuit conditions created from rain passing through the protective casing. This again speaks to IEE #1 [7].

The sensitive nature of wearables will require us to be one-hundred percent honest with observed data. Any data obscuring would be putting the public at risk. Honesty in data presentation and estimates based upon the underlying data speaks to IEEE Code of Ethics #3 [7], and should be respected throughout the design process.

References

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