# The First Responder's Safety Alert Device

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***Abstract*— The First Responder's Smart Badge is a device that notifies its user if they are in proximity of harmful materials in the air and monitors how the levels of hazards are changing. These materials negatively affect the health of people and with this device the user will be alerted if these hazards reach dangerous thresholds. The safety device will also track how long users are exposed to these harmful materials. With the help of Faculty funding and guidance, a device has been fabricated that uses the I2C protocol, as a basis, to send data from various sensors to a database. This device is in the form of a breadboard that holds the various sensors, a microcontroller, and wires. The Arduino IDE was used to program the device and allow sharing over WiFi to a database. This device is particularly useful for First Responders since they are often exposed to harmful materials monitored by the Smart Badge..**

***Index Terms*—Arduino, $CO_2$, CO, ESP32, ENS 160, GPS, I2C, IOT, PM2.5s, SCD-40, VOCs, Wi-Fi.**

## I. Introduction

### *A. The First Responder's Smart Badge*

The First Responder's Smart Badge is a device designed to safeguard the health of first responders. It is a compact device that houses sensors that can detect the following hazards: particulate matter 2.5 micrometers in diameter (PM2.5s), volatile organic compounds (VOCs), carbon dioxide ($CO_2$), carbon monoxide (CO), temperature, and humidity. By measuring the metrics of these potentially harmful elements, the device alerts the user via a light emitting diode (LED) and buzzer which will provide a visible and audible alert respectively. The safety device also tracks and sends data regarding the exposure to these hazards which is tracked on an independent database to monitor long term exposure to the listed hazards. It identifies the concentration and length of exposure in the user's environment. This data is saved long term and can be referenced at any given time by clicking a date on a drop-down menu.

### *B. Background*

There has been interest in equipping first responders with portable sensors for quite some time. Reference [4] shows the results of an investigation, conducted in 2012, as to whether there were any commercially-available, portable hazardous material (hazmat) sensors that met a first responder's needs. Their conclusion is that there were not any such sensors that fully met a first responder's needs. Additionally, [5] and [6] show that there was research being done in the area in 2019. However, the focus of the wearable technology that was being discussed focused more on analyzing the wearer. Our device aims to analyze the environment around the wearer and alert them of danger. Unfortunately, there do not seem to be any published results of the research that was being conducted. The lack of a device to properly monitor the hazmat surroundings of the user is what inspired our device development.

### *C. Methods and Results*

Our method for constructing the device was straightforward. For simplicity, all of our components were placed in a breadboard. We then connected the different sensors to the controller, and tested the sensors by connecting the controller to a computer. After seeing the data that was sent, it became clear whether the sensor was connected correctly or not. We then compared the readings of the sensors when measuring a predetermined concentration of a known hazardous material. By comparing the reading of the sensor to our known tested value, we verified whether the sensor was calibrated correctly. This was repeated for all of our sensors to ensure that they were working properly. Through this method, we successfully tested all of our sensors and were able to receive data from each of them. Once all the sensors were verified to work correctly when independently tested, we then moved on to connecting multiple sensors. Care was taken and rewiring was implemented to ensure enough charge was being delivered to all the sensors simultaneously. Finally, we ensured that all measurements were recorded fully and uninterrupted to a remote server.

## II. Main Body

### *A. Hardware*

1. The First Responder's Smart Badge is able to detect the presence of harmful particles in the air in large part due to the hardware used in its fabrication. The device consists of a microcontroller, the ESP32, LEDs, buzzers, as well as a series of sensors including the SCD-40, ENS160, and PM2.5 air quality sensor.
2. The smart badge can be seen in a simple solderless breadboard setup [Fig. 1]. The microcontroller for the smart badge connects to a series of sensors. The sensors can track and report data to the microcontroller about the concentration of predefined hazards. The microcontroller will communicate the data from the sensors to a server and the server will calculate if the hazards reach dangerous thresholds. If the server calculates that dangerous thresholds have been met then it will send a signal to the microcontroller to activate the LEDs and buzzers attached to the Smart Badge.

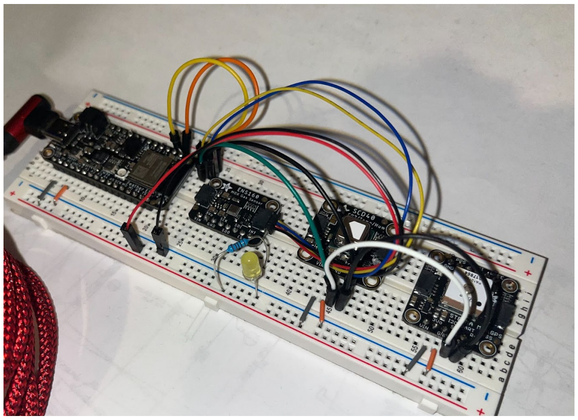

Fig. 1. Exposed hardware of First Responder Smart Badge

3. The ESP32 is the microcontroller for our device and has Wi-Fi as well as bluetooth capability. The ESP32 is wired to the SCD-40 (via I2C protocol) and is able to track and report the concentration of $CO_2$, temperature, and humidity. The ESP32 is also able to connect to the ENS 160 via the same I2C protocol and receive data regarding VOCs. Again, the ESP32 uses I2C protocol to connect to the PM2.5 air quality sensor to receive data regarding PM2.5s. Once the ESP32 receives the data from the aforementioned sensors, it will communicate with a computer via arduino IDE to determine if any hazard metric has reached dangerous thresholds and will send out an alert through the wired LEDs and buzzers. Simultaneously, the ESP32 will send the same data to an independent server to track cumulative exposure to the listed hazardous materials.
4. The Smart Badge is able to connect to the listed sensors and communicate with a server to display the values of the hazardous materials that are in its current environment. Tests have been run with different conditions as well as exposure to different compounds. The safety device has been able to perform well with the current tests. Signals can also be sent to activate the sensors and LEDs when predefined conditions are met. Tests were run with a wired connection to a computer to use as a power source. Further tests were performed using a lithium battery as the sole power source to improve portability. .

### B. *Software*

The Smart Badge uses various different software to track data from the sensors and send it back to the database.

The Smart Badge makes use of one of the most popular communication methods: I2C Protocol. Reference [1] discusses an implementation of I2C that allows for reusability using a protocol level, signal level, and interface level. I2C is extremely important in this case because it allows the device to easily communicate with other devices and send our data to a database.

Google Firebase is used as the cloud provider for the realtime database the data is sent to. Reference [2] discusses the use of Google Firebase as the backend and real-time database for an Internet-Of-Things (IOT) system. This indicated that Google Firebase can exclusively store and handle all the data coming from the device in a real-time database. Figure 2 below shows how the data is stored in Google Firebase.

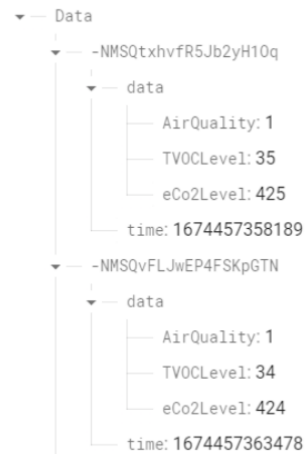


Fig 2. Google Firebase Data Representation

The data stored in Google Firebase is not very readable for the user. To solve this, we created a web application that displays the data in a user-friendly manner. The website is shown below in Figure 3, where data is fit and represented using a graphical representation. These graphs show the exposure to many different materials in an easy to view manner.

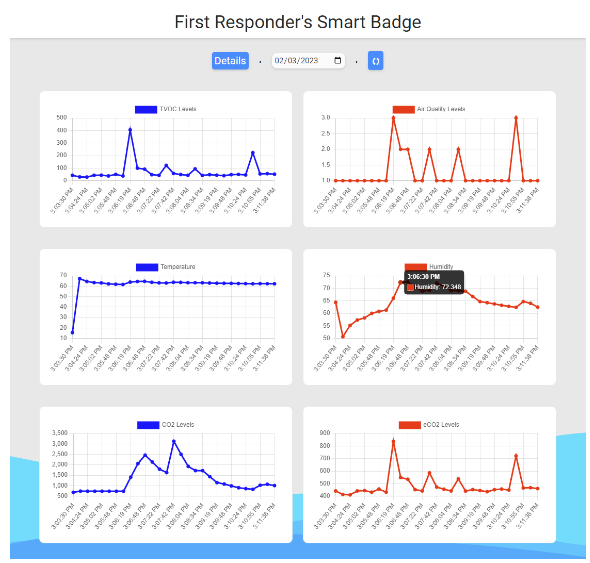


Fig 3. First Responder's Web Application

A software library from [3] allows for seamless communication between the ESP-32 microcontroller and Google Firebase. The library allows for a WiFi connection to be made on the ESP-32. There is an initial setup where the software connects to the correct I2C pin, the WiFi, and the realtime database from Google Firebase using authentication. This ensures that only the owner of the device has access to the data attributed to the device. The library provides multiple setter functions. In particular the First Responder makes use of the setFloat method which allows us to store the air quality, TVOC level, and eCO2 level with accuracy.

## III. Methods

The software referred to in the previous section was compiled using Arduino IDE onto the ESP-32 microcontroller. From there, the device was placed in different environments, where the parameters sent to Google Firebase were different. Air quality, TVOC levels, and eCO2 levels were all tracked and sent to Google Firebase. Each data point was updated every 30 seconds. Data sent to Google Firebase was tagged with the time it was sent, which allows the device to track the amount of exposure the user may have. The figure below shows an example of the output that was shown in the COM3 serial monitor of Arduino IDE.

## IV. Results and Performance

Data was tracked every 30 seconds, where the different sensors would send their values to Google Firebase. Based on a good internet connection, the ESP-32 was able to handle data collection every 30 seconds from all the sensors and send it to the database. The figure below shows an example of the output that was shown in the COM3 serial monitor of Arduino IDE. Based on the different environments, the ESP-32 reads different levels for each value which indicates that it is correctly tracking the data.

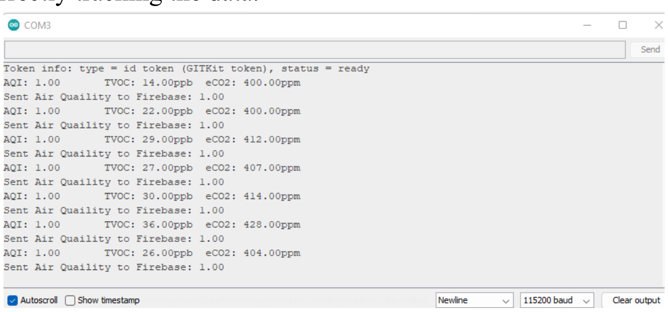


Fig 4. COM3 Serial Monitor Output

## V. Summary

A safety device for First Responders is proposed and features hardware and software communication. The device is part of an IOT system and utilizes I2C communication to ensure reusability and compatibility. The device features an ENS-160, SCD40, and PM2.5 controlled by a ESP-32 microcontroller. It makes use of a software library that allows communication between the ESP-32 and Google Firebase via a WiFi connection. Google Firebase stores all the time-stamped data in a realtime-database.

The device was tested by placing the device in various different environments and analyzing the values received in each environment. Since air hazards are difficult to measure, average values for the general area were used to compare with the values received.

The data is stored on a remote server and is able to reference specific dates when monitoring the hazmat environment the Smart Badge was in. Concentration of exposure to hazardous materials and duration are recorded to provide safety insights on the health of the operator. As the operating conditions for first responders are stored in a time referenced table we believe greater care can be provided to these valiant individuals. Coupled with the alert systems, we also hope to provide crucial information to first responders to better inform their decisions. The summary result we wish to achieve is to protect the health of first responders both in the field and after they come home.

## VI. Conclusion

The proposed safety device is able to correctly detect abnormal levels of hazardous materials in the air by utilizing its various sensors. The device works correctly in different environments and is able to send the correct time-stamped data to Google Firebase. Audible and visual alerts are able to be sent to provide a warning signal to the wearer. Long-term care for the user can be supplemented by recording the data remotely on a server which can be referenced with time context.

## Acknowledgment

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