Senior Design EE-41430

Home Security System Proposal

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1 Introduction

According to the NFPA, 358,000 homes in the United States experience structural fires yearly. Further, more than 7 million property crimes were committed in 2020, with burglary being the second most common crime in the country. In addition, 32% of households in the US are fueled by natural gas, and leaks can be extremely hazardous to all living on the property. These and many other dangers can be mitigated by having an efficient home security system (HSS). HSSs make households safer and give homeowners peace of mind when absent.

However, these systems can be costly and are almost three times more present in households with incomes above $100K than among lower-income households, making them easier targets for break-ins and other crimes. In addition, less privileged families are often more likely not to have the necessary safety resources to prevent gas leaks and fires. Our ESP32-based home security system will be inexpensive and offer contact, motion, smoke, flame, and vibration sensors to insulate the house from the most varied dangers. In this way, we propose a product that ensures homeowners a safer and more secure life while being financially accessible to most people.

2 Problem Description

Current home security systems have a target audience willing to pay for non-essential features, such as interactive touch-screen displays, sophisticated product design, and memberships that give them access to professional security monitoring as well as installment and repair. Even low-end units are designed with aesthetics in mind and have features such as LED integrations to act as visual alarms, so a product that offers simple yet effective protection against home break-ins in an inexpensive format (i.e. minimalist product design, easy to install, no contracts necessary, straightforward alarm system) is not on the market.

The obstacles when designing such a product are outlined in the following:

2.1 Motion

When designing motion sensors, engineers can choose between two available technologies: microwave detection and passive infrared detection. Microwave sensors are the high-end option between the two with their ability for 360 degree detection, stability in terms of changing temperatures, and ability to sense movement through walls (this is done by emitting signals that travel through wall mediums). In contrast, PIR sensors, which rely on detecting heat, are consequently under sensitive in cold temperatures but over sensitive in warm temperatures. These sensors also only offer 90 degree coverage and often are unable to pick up on motion when something moves in a straight line towards it. When low cost is the goal in developing a motion sensing device, PIR sensors are preferable but the drawbacks must be accounted for to create an effective product.

2.2 Door Monitoring

Most door sensors depend on a magnetically activated mechanical switch consisting of two contacts usually encapsulated in glass. These contacts are magnetic and move when exposed to a magnetic field which is why a door alarm system using such a mechanism is composed of two compartments (one containing a reed switch and the other a permanent magnet) with one affixed to the door frame and the other on the door. Although this setup is both simple and needs no power, reed switches have several drawbacks mainly in terms of durability.

The most common issue is how fragile the glass capsule can be since it is susceptible to breakage when vibrated (which can happen when a door frame is rattled), during device installation, or when the PCB board is being assembled (i.e. the sensor may bend when soldered and break the glass). This can be solved by encapsulating the switch in a plastic but this increases costs as well as size. An additional issue is when the sensor experiences a bounce effect (i.e. the contacts “bounce” and turn alarms on and off several times) which results in a faulty and less effective product.

Hall switches are a common alternative to reed switches especially in higher quality devices such as smartphones, however they provide lower sensitivity and are not preferred in battery powered applications. This necessitates the use of an alternative that is as sensitive but more durable than a reed switch so that it reduces the cost of replacement.

2.3 Window Monitoring

Window sensors are often the same as door sensors. In fact, a product may function as both using a reed switch. However, these have durability issues and are also unnecessarily large and expensive considering one must be bought for every window in a house. A cheaper alternative that relies on sensing another symptom of someone breaking in (such as heavy vibrations from forced entry) in a smaller highly reproducible format would be preferable.

2.4 Detection of Gas Leaks and Smoke

Typical devices detecting gas leaks and smoke are not integrated with alarm systems that can alert you via phone notifications, and any products that connect with networks such as Homekit or Google Alexa, are unreasonably expensive (~$100-$150).

2.5 Ease of Use

Makeshift home security devices (which are designed with the goal of lowering costs for the person attempting to assemble them) often require someone to have a high level of understanding of coding and electronics. For example, an elderly person could not complete the construction and installation process.

3 Proposed Solution

To create an efficient, accurate and economic home security system available for people of all economic statuses, all of the sensors integrated in the design must work simultaneously and communicate with a website/app real-time that informs users of the dangers they may be encountering. To create a proper home security program the following devices will be used: motion sensors, contact sensors, gas/smoke sensors, vibration sensors and flame sensors. They will be implemented as described below.

3.1 Motion

The motion detecting portion of the system will be made up of a motion sensor which will be placed around the perimeter of the house the system is being used on. The motion sensor that will be used is the AM312 Mini PIR motion sensor. This sensor operates based on passive infrared technology and makes use of low-power pyroelectric sensors. The specific sensor that will be utilized have a sensing range of $\leq$100 degree cone angle and detect motion as far away as 3-5 meters. An alarm will sound when this specific sensor picks up any unusual activity and a notification will be displayed on the website/app providing the user with more specific information on what is being picked up by the sensor.

3.2 Door and Window sensors

The force application portion of the system will consist of contact sensors and vibration sensors. The contact sensor that will be used is a magnetoresistive door sensor that will be placed on all doors which open up to the exterior of the house. The sensor used will be the HMC1512-TR which is a magnetoresistive piece that when in contact allows electricity to flow. When the magnetic piece and sink are no longer in contact, electricity is cut off and the website/app will receive a notification of this change in state which would then be relayed to the user. The fast vibration sensor switch will be placed on all windows of the house. This sensor contains a spring which coils around a metal pin and when the sensor is disturbed the spring touches the center pole. So when motion occurs the pins act as a closed switch. When the website/app picks up on this the user will be informed through a notification.

3.3 Flame and gas leak detector

The final portion of our system will consist of a gas/smoke sensor. The specific sensor that will be used is the MQ2 gas/smoke sensor and will be placed in the inside of the house. To begin using this sensor, the gas that it will be detecting must first be introduced to the sensor before it can be put to use. By introducing the gas to the sensor the digital pin will rest at 0V when the gas is not detected and jump up to about 5V when it is. When gas is detected a notification will pop up on the website/app allowing the user to know gas is detected.

3.4 Website/App

The program will be communicating with the user through either a website or app. The website or app that will be used to notify homeowners of the information being picked up by the sensors and will be designed from scratch. It will be designed to be easy to use and understand. To ensure this, the notifications will differ based on the system being breached. The notifications will be short and directly relay the message of which sensor picks up any unusual activity and which area of the house is being affected.

4 Demonstrated Features

4.1 Motion

- There will be an alarm that is activated when the **motion sensor** detects a distance (to a door outside the house) closer than a predetermined limit. The distance must be below the limit for at least five readings in a row, taken almost instantaneously, to avoid any issues with bad readings.
- The motion sensor will also instantly relay information to **the website/app** to notify the homeowner about a breach and which area is affected. The information provided will also include distances, within the predetermined limit, at each instance.

4.2 Door and Window sensors

- There will be an alarm that is activated when any door outside the house is opened or closed as detected by the **contact sensor.**
- The contact sensor will instantly relay information to **the website/app** to notify the homeowner about any contact made with the door to open or close it. The information will include timestamps and the door affected if there are multiple.
- There will also be an alarm that is activated when any window is opened or closed as detected by the **vibration sensor**.
- The vibration sensor will instantly relay information to **the website/app** to notify the homeowner about contact made with the window and which window if there are multiple.

4.3 Flame detection and Gas leaks

- There will be an alarm that is activated when a natural gas (methane, butane, petroleum) is detected at a high concentration/level (beyond a predetermined limit) or smoke is detected by the **gas/smoke sensor**.
- The gas/smoke sensor will instantly relay information to **the website/app** to notify the homeowner about the situation.

4.4 Website/App

- The website/app developed will provide instant notifications to users in the event of any home security concern (attempted break-ins, fires, or gas leaks)
- The website/app will also provide detailed information on which security issue is occurring: the sensor that detected the breach and the area of the house affected.
- The website/app will also include a feature that provides a history of security issues that have occurred since installation of the home security system.

5 Available Technologies

5.1 Microcontroller Board: ESP32 DevKitC
Mouser Part Number: 356-ESP32-DEVKITC32E
Price: $10.95
Quantity in stock: 6125

5.2 Contact Sensor :MR Sensor
Digikey Part Number: HMC1512-TR
Price: $4.49
Quantity in stock: 947

5.3 Motion Sensor: Mini PIR motion sensor (AM312)
Adafruit Product ID: 5578
Price: (If 1-9 are purchased) $1.95
Quantity in stock: 100’s

5.4 Gas/Smoke Sensor: MQ2 Gas/Smoke Sensor
Digikey Part Number:1568-SEN-17049-ND
Price: $5.50
Quantity in stock: 46

5.5 Vibration Sensor: Fast Vibration Sensor Switch
Adafruit Product ID: 1766
Price: $0.95
Quantity in stock: Not specified (In stock)

6 Engineering Content

6.1 Printed Circuit Board (PCB) Design

It is fundamental to design the board efficiently and effectively so that the hardware components interact harmoniously with the ESP32 and with the different subsystems of the project. Additionally, the board must be designed with manufacturing limitations in mind and leave space for either through-hole soldering or surface mount assembly if access to surface mount technology (SMT) devices is available. The level of voltages used in the circuit must also be considered since high voltage devices necessitate the inclusion of plated mounting holes that connect to the enclosure for grounding.

Another important aspect to take into account is that the PCB must be tested after it is manufactured. The testing of the PCB requires test points to be placed in the board design at strategic locations.

Because there are multiple sensors being implemented, it is necessary to ensure adequate interfacing between the subblocks of the design. The board will be designed using software such as Eagle or KiCad.

6.2 Board Manufacturing

The PCB board will be ordered from a manufacturing company with a lead-free hot air soldering leveling (HASL) surface finish since it provides a comparable level of quality in terms of oxidation prevention compared to an immersion gold finish but at a lower cost. This finish is necessary to ease hand soldering since metals interact molecularly resulting in a quick joint formation.

After the board is ordered, its corresponding components will be manually assembled onto the board. If there are no SMT components (which would be assembled by an outside company with the proper machinery), the next step would be to hand solder using the plated holes. Flux remover would be used to clean up the final board since it not only improves PCB reliability by preventing corrosion from contamination but it also elevated the aesthetic of the product as is necessary in industry standards.

6.3 Microcontroller Programming

Another important aspect of the home security system is that code that will be uploaded to the microcontroller. The platform that will be used to program the ESP32 will be the PlatformIO IDE on Visual Studio Code. It would be important to add libraries such as the WiFi library, which enables the connection of the microcontroller to the WiFi, and the Arduino library.

6.4 Computer-Aided Design (CAD)

The home security system will need a mountain system to be strategically placed in the optimal positions in the house. It would be particularly important to have a mounting system that

allows the motion sensor to be placed close to the door and the contact sensor to be placed at the door. This mounting system will be designed using a CAD software such as SolidWorks or Tinkercad and 3D printed.

6.5 User Interface

An important aspect of this home security system is that it must notify the user if anything triggers the alarms. There are two main alternatives that could be used to do that. The first one would be to create a website in which the user could log in to access the readings of the sensors and check the history of the security breaches in the house. In that case, the user would be notified through a text message to log in to the website whenever a security breach occurs. The second alternative would be to create an app that allows the user to keep track of the security of the house instead of using a website. In that case, the user would get phone notifications instead of text messages.

In order to make this user interface possible, it is necessary to connect the system to the internet and use a database in the backend of the app or website to store the data collected by the home security system. In order to code either the app or the website, it would be possible to use a combination of HTML, JavaScript, CSS, and React to create the application.

7 Conclusions

In conclusion, this Smart Home Security System (SHSS) provides an inexpensive layer of safety to homeowners in the United States. Using an intelligent design to connect the ESP32 to the different hardware subsystems, SHSS offers a motion sensor that can detect movement when the client is not home, a vibration sensor that alerts the owner if their door is opened when they're not present, and a smoke and gas detector that can send real-time notifications if triggered. Making use of ESP32's 150 Mbps data rate, it is possible to connect SHSS to the user through an app or website. This allows for an interactive and fast way for the client to be promptly updated about any anomaly happening at their property when they are absent. Because of how low cost and maintenance the final product is, it is not only accessible but can also be easily implemented by anyone.