Senior Design EE 41430
Home Security System Design

Table of Contents

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 Statement and Proposed Solution

Current home security systems have a target audience willing to pay for non-essential features, such as interactive touchscreen displays, sophisticated product design, and memberships that give them access to professional security monitoring, installation, and repair. Even low-end units are designed with aesthetics in mind and have features such as LED integrations to act as visual alarms. These components add up to a total cost that can be restrictive to families in lower income ranges.

In that sense, offering a product that provides simple yet effective and affordable protection against home break-ins represents the ideal alternative to the market. This will be done by creating an HSS with a minimalist product design that is easy to install, with no contracts necessary, and a straightforward alarm system. The system counts motion, contact, and vibration sensors that will alert homeowners in real-time about break-ins whenever they’re absent or sleeping. Further, it also has smoke and gas detection sensors which can be fundamental to averting major disasters in the household.

3 System Requirements

To create a cheap yet efficient home security system multiple sensors will be used to ensure different types of physical inputs will successfully be detected. The product will also consist of a user interface which will communicate any concerning activity detected by the sensors to the user through a website. The home security

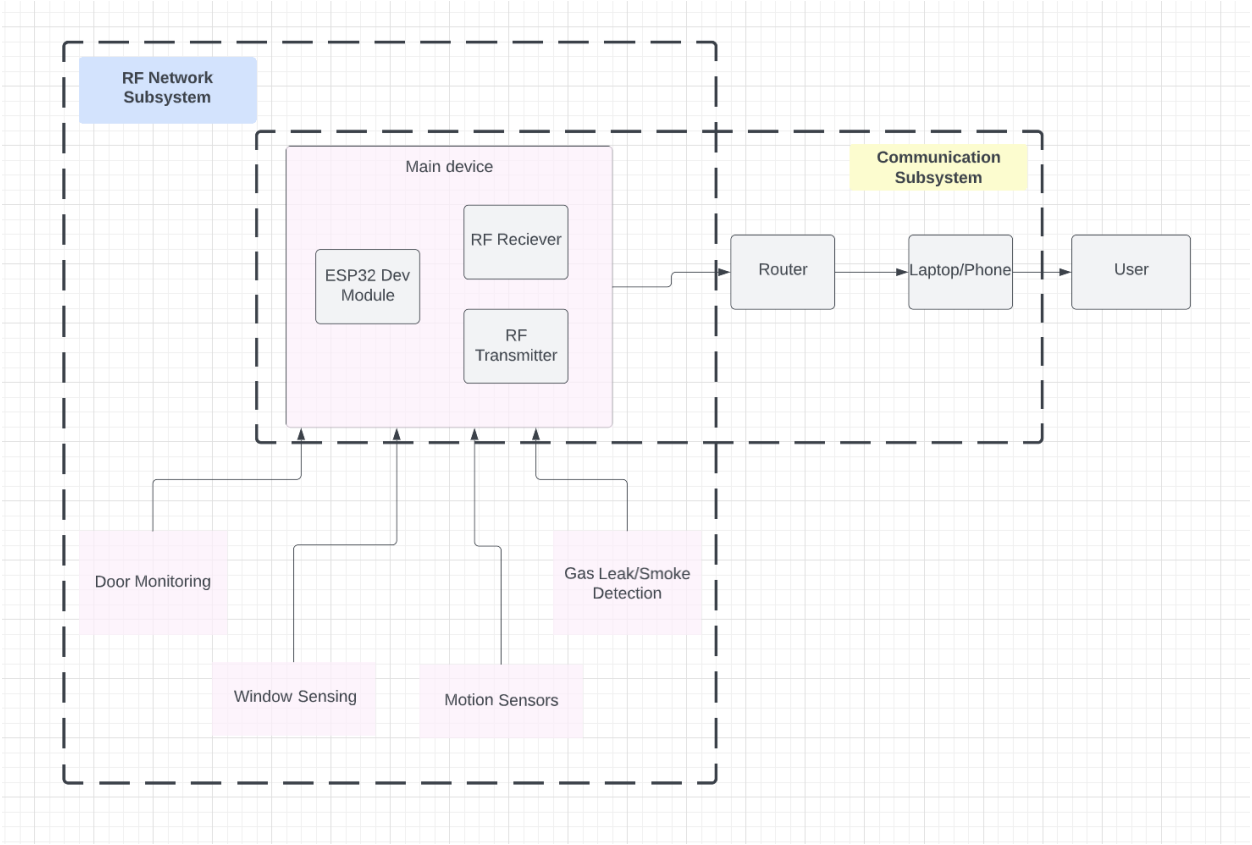
system will consist of 4 different types of sensors. These are magnetic, motion, vibration and gas sensors. The product will come with five initial sensors and users will have the ability to add any more they need. One of the original sensors which will come with the security system will be a magnetoresistive sensor which can be placed on the main entrance of the house, alongside this sensor there will be a motion sensor which can be placed on top of the main entrance, two vibration sensors will be included and will go on the windows located on the first floor of the house, and finally one gas/smoke sensor will be placed in the inside of the house.

The sensors will all be using different mechanisms to function. The motion sensors will operate based on passive infrared technology. It has a conic sensing range of up to 100 degrees and can detect motion up to 5 meters away. The magnetic sensor will consist of a magnetoresistive piece and sink that when in contact will allow electricity to flow. The vibration sensor will consist of a spring which coils around a metal pin that will come in contact with each other when a strong enough of a vibration is picked up resulting in the sensor acting as a closed switch. The last sensor which will be used is a gas/smoke sensor which must initially be introduced to the gas it will be detecting so that when it is picked up inside of the house the digital pin will jump from 0V to 5V. When activity is picked up by these sensors the user will be notified of the disturbances through a website. The website will produce different alarm noises based off of the disturbed sensors and will display to the user an image which highlights the areas of the house being disturbed.

Each sensor will be enclosed by a case that offers protection to external forces such as weather, heat and debris. The cases will facilitate product installation as they will be able to attach to a mounting plate and look aesthetically pleasing. The cases enclosing the sensors must be large enough to enclose the RF transmitters and additional PCB boards needed for some of the sensors. Sensors will require RF transmitters to communicate with the central board of the system. The only sensor that won’t require an RF transmitter is the gas/smoke sensor because it will be encased and directly connected to the central board. These sensors will be powered through different means. The magnetoresistive sensor will be powered by a 5V battery since, the PIR sensor will need its own PCB board to function and avoid interference, the gas/smoke sensor will output 5V when gas is detected, and the vibration sensor will use a transducer to convert the mechanical energy of the coil vibrating against the metal pin to electrical energy and act as a closed switch.

4 System Block Diagram

4.1 Overall System:



4.2 RF Network Subsystem

The basis of the radio frequency (RF) network subsystem are nodes (each with their specific defined addresses) composed mainly of a microcontroller wired to RF transmitter and receiver devices. The bottom nodes (in our case the door monitor, window sensors, motion sensors, and gas and smoke detectors) communicate with a node 0 (the main device as seen in the block diagram) which handles interpreting the data received and upholding defined protocol (ex. node 0 receives a signal that corresponds with a window sensor being triggered and transmits an alarm message using the communication subsystem).

4.3 Communication Subsystem

The main device, consisting of the ESP 32 Dev module, RF Transmitter, and RF Receiver, will have a wireless connection to the router. This connection will enable the transmission of data from the main device to the laptop/phone which provides the data in a presentable format to the user via a mobile app or website.

other main requirement of this system is to notify
the user via a WiFi module that will interface with a home-area WiFi network.

4.4 Future Enhancement Requirements

1) Miniaturizing window sensors so that they can be installed in a “sticker” format. This would involve determining a way to retain the RF communication aspect as well as the quality of vibration sensing but in an extremely compact design.
2) Providing a function that automatically alerts for help when a break-in occurs and provides a short description containing geographical location and the current problem.
3) For a prospective mobile app, there will be separate notification sounds sent to the users phone based on which alarm is triggered.

5 High Level Design Decisions

One of the most important high level design decisions of this system is to have a separate PCB for each subsystem. Since a home security system must have components at separate locations in the house, it would not be feasible to physically connect each of the subsystems. Therefore, the subsystems will interact with one another using RF communication.

Only one ESP32 will send data to the website used for the user interface, which will be a website. The purpose of the user interface is to allow the user to be notified about any security breaches in the house and to store the data collected by the sensors. The ESP32 has WiFi capabilities that allow it to be connected to a router and therefore access the Internet to send the data to the website. This central ESP32 will have RF communication with the other ESP32 devices that will control the sensors on each subsystem. The high level design decisions for each sensor are described in the sections below.

5.1 Motion Detection System

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 ≤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.

5.2 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.

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.

We will be using three different **vibration sensors** with varying sensitivity levels (low sensitivity, medium sensitivity, and high sensitivity). These will all trigger at different levels of vibration. Fast Vibration Sensor Switch that triggers different vibrations. We will be using multiple sensors to ensure thunder, animals, knocks, etc… do not activate the security system. These sensors differ from one another because each type will contain springs of different stiffness that will activate the sensor when they come in contact with the metal coil surrounding them.

5.3 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.

6 Major Component Costs

- Microcontroller Board: ESP32 DevKitC
  Mouser Part Number: 356-ESP32-DEVKITC32E
  Price: $10.95
  Quantity in stock: 6125
- Contact Sensor: Nanopower Series Magnetoresistive Sensor ICs
  Digikey Part Number: HMC1512-TR
  Price: $4.49

Quantity in stock: 947

- Motion Sensor: Mini PIR motion sensor (AM312)
  Adafruit Product ID: 5578
  Price: (If 1-9 are purchased) $1.95
  Quantity in stock: 100's
- Gas/Smoke Sensor: MQ2 Gas/Smoke Sensor
  Digikey Part Number:1568-SEN-17049-ND
  Price: $5.50
  Quantity in stock: 46
- Vibration Sensor: Fast Vibration Sensor Switch
  Adafruit Product ID: 1766
  Price: $0.95
  Quantity in stock: Not specified (In stock)

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.

References

- Complete Guide for RF 433MHz Transmitter/Receiver Module With Arduino
- RF gateway (433mhz/315mhz)