# AN IOT-BASED SMART DOORBELL SYSTEM FOR MITIGATING STEALTH ATTACKS

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**ABSTRACT**

*The need for smart doorbell systems has increased in recent times. This is due to the general tendency for burglars to use stealth when breaking into homes and businesses. Also, visitors are known to spend time searching for doorbells around the house. Thus, to address this problem, this paper presents a smart doorbell system that detects human presence at the door and automatically notifies the homeowner. The system consists of a microcontroller, an ultrasonic sensor, a GSM module, and software. When a human presence is detected within the configured range of 1 to 70cm, the ultrasonic sensor sends a signal to the microcontroller, which in turn sends a command to the GSM module to notify the homeowner. The performance of the system was tested using various parameters, with results showing that the device can detect human presence within the range of 1-80cm.*

*Keywords: IoT, Smart doorbell, GSM module, Ultrasonic sensor.*

## 1. INTRODUCTION

The Internet of Things (IoT) has significantly improved our daily lives by empowering us to monitor and control crucial processes (Nguyen et al., 2021). This is achieved using gadgets fit for detecting, handling and remotely transmitting information to remote storage like a cloud which stores, breaks down and displays this information in a valuable structure (Zielonka *et al.*, 2020). From the cloud, this information can be accessed through various front-end user interfaces such as web or mobile applications, depending upon suitability and requirements. One of these application areas is a smart doorbell system.

Over the years, traditional doorbells have moved from historical switches to the use of modern touchpads, sensors, and IoT. This is because traditional doorbell systems have limited functionalities which make homeowners susceptible to burglary or other unwanted visitors. Furthermore, these doorbells are often located in inconvenient places, such as near the ground or out of reach, making it difficult for some homeowners to see or hear the doorbell (Priyanka *et al.*, 2022).

Smart doorbell systems address these problems by providing a more convenient, functional, and secure solution for homeowners. Specifically, they offer the ability to notify users in real-time and often include security features such as motion detection, facial recognition, and package detection. These features can provide homeowners with greater peace of mind and enhance the overall security of their homes (Thakkar & Ukani, 2022).

These systems typically include a doorbell button, a camera, and a connection to the homeowner's smartphone or other devices. The camera records video and sends live streams to the homeowner, who can view and interact with the person at the door through the doorbell's speaker and microphone (Aguilar-Gonzalez, 2019). The doorbell may also be connected to other smart home devices, allowing homeowners to control their lights, locks, and other systems from the same app used to control the doorbell. Some smart doorbell systems also have features such as facial recognition, package detection, and motion detection to enhance their usefulness and security.

However, smart doorbell systems sometimes suffer from unreliable operations and high energy usage. Also, when the owner is in a remote location without data coverage, they may not be able to receive notifications or access footage from their doorbell. A smart doorbell system should provide accurate notifications and require low energy usage (Shaout & Theisen, 2021). In this paper, a low-energy doorbell is developed that can accurately detect human presence and automatically send a notification irrespective of where the homeowner is located.

The IoT-based Smart Doorbell System presented in this paper makes significant contributions to addressing contemporary security challenges and enhancing user convenience. By autonomously detecting human presence at the door, the system addresses the growing trend of burglars using stealth techniques for break-ins while providing a

solution to the common issue of visitors struggling to locate doorbells. The integration of a microcontroller, ultrasonic sensor, and GSM module showcases a comprehensive technological approach to smart doorbell functionality, allowing for proactive and automatic notifications to homeowners. The extended detection range from 1 to 80cm, as demonstrated in empirical testing, highlights the system's improved capability to sense human presence over a wider area, contributing to its overall effectiveness in mitigating stealth attacks and providing a robust security solution.

**Table 1:** A Survey of Related Works

| References | Work done | Approach |
|---|---|---|
| Giorgi et al. (2019) | An iris+ voice recognition system for a smart doorbell | Utilizes ML, iris, and voice recognition to verify the identity of the user at the door. |
| Chaudhari et al. (2020) | Smart doorbell security system using IoT | Utilizes a Doorbell interfaced with Raspberry Pi, captures the face of visitors, checks it against a registered database, and opens the door for authorized individuals, while sending an OTP and intruder photograph to the server mail for non-authorized persons |
| Khan et al. (2021) | Smart Home with Wireless Smart Doorbell with Smart Response . | Broadcasts visitor videos and body temperature. Additionally, it establishes a connection to a "SmartWDB" Android application via Bluetooth, sending notifications of visitor arrival, body temperature, and video using WiFi signals, both intruders and the novel coronavirus |
| Shahrom et al. (2021) | Smart calling doorbell using GSM module | Utilizes a GSM module, Arduino UNO R3, and SIM900 GSM GPRS Shield, enabling homeowners to identify visitors through a phone call without physically approaching the door. |
| Gomathy et al. (2021) | Smart Door with Facial Recognition | The system utilizes a Raspberry Pi ARM processor for facial recognition, and voice lock processing, allowing for communication with the owner and control of electromagnets acting as locks. |
| Pandiya et al. (2023) | Design and Realization of Smart and Energy-Efficient Doorbell | Introduces a touchless-operated doorbell integrated with a smart system designed for hands-free sanitization of both individuals and belongings. |

## 2. MATERIALS AND METHODS

### 2.1. Hardware Design and Implementation

The proposed system combines software, a microcontroller, an ultrasonic sensor, and a GSM module to form a Smart doorbell system. The system will use the Ultrasonic sensor to detect human presence at some range to the door or entrance and then send a command to the microcontroller once the sensor receives a wave response from the environment. Once the signal is received, the microcontroller will send a command to the GSM Module. The GSM module will send an SMS notification to the user to notify him of the presence of the person. Table 2 presents the hardware components that will be used for the doorbell:

**Table 2:** Hardware Requirement

| SN | Components | Quantity |
|---|---|---|
| 1 | Arduino Uno Microcontroller | 1 |
| 2 | GSM Module | 1 |
| 3 | Ultrasonic Sensor | 1 |
| 4 | Switch | 1 |
| 5 | LED | 1 |
| 6 | Power Supply | 1 |
| 7 | Buzzer | 1 |

Other Required Components include:
   i.   Vero-Board
   ii.   Breadboard
   iii.   Ribbon cables
   iv.   Connecting wires
   v.   Power supply Regulator
   vi.   Adaptable box

## 2.2.   Description of some components

**i. Arduino board**: The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced with various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and is programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. This board shown in Figure 1 will be used for controlling all components in the system.

**Figure 1:** Arduino Uno Board

**ii. Ultrasonic sensor:** The ultrasonic sensor shown in Figure 2 operates by determining distances through the use of ultrasonic waves. The sensor head transmits an ultrasonic wave and records the wave that is reflected from the target. By measuring the elapsed time between the wave emission and reception, the ultrasonic sensor can calculate the distance to the target. This sensor is used to detect and prevent stealth attacks from intruders since it automatically detects and reports human presence.

**Figure 2:** Ultrasonic Sensor

The formula for this calculation is Speed x Time. The ultrasonic sensor used in this system has a range of 1-70m with a precision of 3mm. The sensor module encompasses an ultrasonic transmitter, receiver, and control circuit. Table 3 presents the pin configuration. The operation is as follows:

i) A trigger sends a high-level signal for a duration of 10us.
ii) The module automatically sends eight 40 KHz signals and then detects if a pulse is received.

iii) If the signal is received, it is in the form of a high-level, and the duration of the high level represents the time difference between the transmission and reception of the signal.

**Table 3**: Ultrasonic Sensor Pin Configuration

| Pin Number | Pin Name | Description |
|---|---|---|
| 1 | Vcc | The Vcc pin powers the sensor, typically with +5V |
| 2 | Trigger | The trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending a US wave. |
| 3 | Echo | The echo pin is an Output pin. This pin goes high for a period that will be equal to the time taken for the US wave to return to the sensor. |
| 4 | Ground | This pin is connected to the Ground of the system. |

The ultrasonic sensor operates on a voltage of 5V and has a theoretical measuring distance range of 2cm to 450cm, with a practical measuring range of 2cm to 80cm and an accuracy of 3mm. It covers a measuring angle of less than 15°, requires less than 15mA of operating current, and operates at a frequency of 40Hz.

**iii.**    **GSM module**: The Sim800l GSM/GPRS module shown in Figure 3 is a compact device designed to add both GSM and GPRS capabilities to projects, specifically those using the Arduino platform. The module operates on a frequency of 40Hz and has a voltage supply range of 3.8V to 4.2V. In terms of power consumption, it has a low sleep mode of under 2.0mA, an idle mode of under 7.0mA, and an average GSM transmission of 350mA, reaching a peak of 2000mA. With dimensions of 25 x 23 mm, the module has a UART interface and utilizes



**Figure 3:**  The Sim800l GSM/GPRS module

AT commands for communication. It also includes a microSIM card socket and supports quad-band frequencies (850/950/1800/1900 MHz) with an IPX antenna connector. The module also features LED status signaling and a working temperature range of -40°C to +85°C. Other Components are the Breadboard, Jumper cables, and Buzzer.

**2.3 Block and Circuit Diagram**

The block and circuit layout of the system is shown in Figures 4 and 5 respectively. They show how each component is connected.
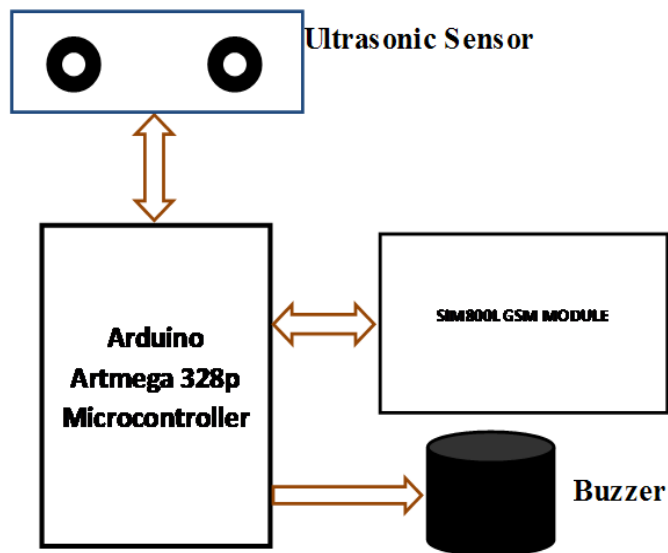
**Figure 4:** Block Diagram

The trigger pin of the ultrasonic sensor is connected to Digital Pin 3 of the Arduino Microcontroller. The ultrasonic Echo pin is direct to Digital pin 4, while the VCC and GND are connected to 5v and Gnd of the microcontroller. The GSM Rx and Tx are connected to the Rx and Tx Pin of the Arduino microcontroller. Arduino Microcontroller voltage regulator steps down the 12v to 5v for each component within the system. The sensor module consists of an ultrasonic transmitter, receiver, and control circuit. A high-level signal is sent for 10us using Trigger. The module sends eight 40 KHz signals automatically and then detects whether the pulse is received or not.
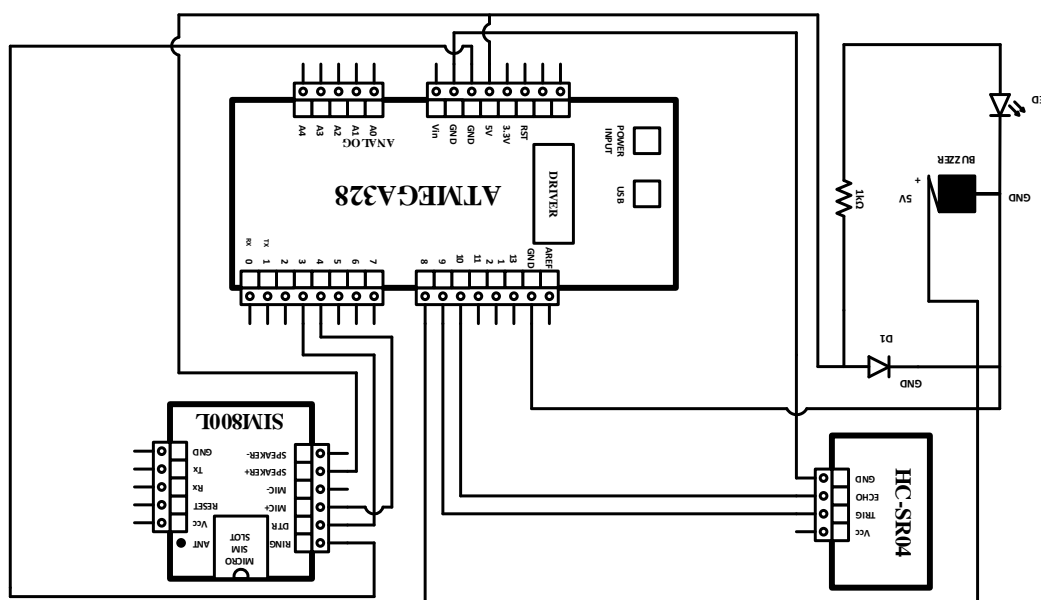


**Figure 5:** Circuit Diagram

## 2.4. Software Design and Implementation

The system will be programmed with C++ through the Arduino Integrated Development Environment. Each Pin will be configured with the program with the Setup function of the code to specify the default configuration of the hardware components. The Loop method will contain the main body of the program that specifies the logic and functionality of the system. Figure 6 shows a code snapshot from the Arduino IDE that was used to develop the system.

```
intrusionSystem §

#include <SoftwareSerial.h>
// rx(9-arduino) connect to tx(gsm module)
// tx(10-arduino) connect to rx(gsm module)
SoftwareSerial SMS(4, 3);// rx(9) and tx(10)

String inputString;
String number = "+2348138475240";

int sensor = 7; //The output of PIR sensor connected to pin 7

int buzzer = 8; // buzzer connected at pin 8
int sensor_value; //variable to hold read sensor value
int sms_count = 0;

 void sendAlert()
{
  SMS.println("AT+CMGF=1"); //AT command for text mode of gsm module
  delay(1000);
  SMS.println("AT+CMGS=\"" + number + "\"\r"); //  x is your mobile number
  delay(1000);
  SMS.println("intruder Alert!!!");
  SMS.println("send ALARMON to activate the alarm or ALARMOFF to deactivate alarm");
  SMS.println("\r");
  delay(100);
  SMS.println((char)26);// ASCII code of CTRL+Z
  delay(1000);

}

void initialMsg()
'
```

**Figure 6:** Arduino IDE Code Snapshot

The following is the code written using the Arduino IDE that connects the Arduino to a GSM module, the Sim800L, to send SMS alerts. The program sets up a software serial communication between the GSM module and the Arduino using pins 4 and 3 for receiving and transmitting data, respectively. The program sets the baud rate for the serial communication to 9600 and sends several AT commands to the GSM module to configure it for text mode and set up message notifications. The code also defines the sendAlert() function to send an SMS alert and the initialMsg() function to send an initial message. The program also uses an ultrasonic sensor connected to pin 7, a buzzer connected to pin 8, and a variable sensor_value to hold the read sensor value. The variable sms_count keeps track of the number of SMS messages sent. In the setup() function, the program initializes the sensor, buzzer, and serial communication and sends the AT commands to configure the GSM module. A more detailed code implementation is presented in the appendix section.

### 2.5    The System Flowchart

The system starts and the sensor begins to sense its environment. It sends a signal to the microcontroller every a signal is detected. Once a signal is received by the microcontroller, it processes this signal and sends an SMS

through the GSM module to the number programmed with the code. Figure 7 shows the system's operational flowchart.
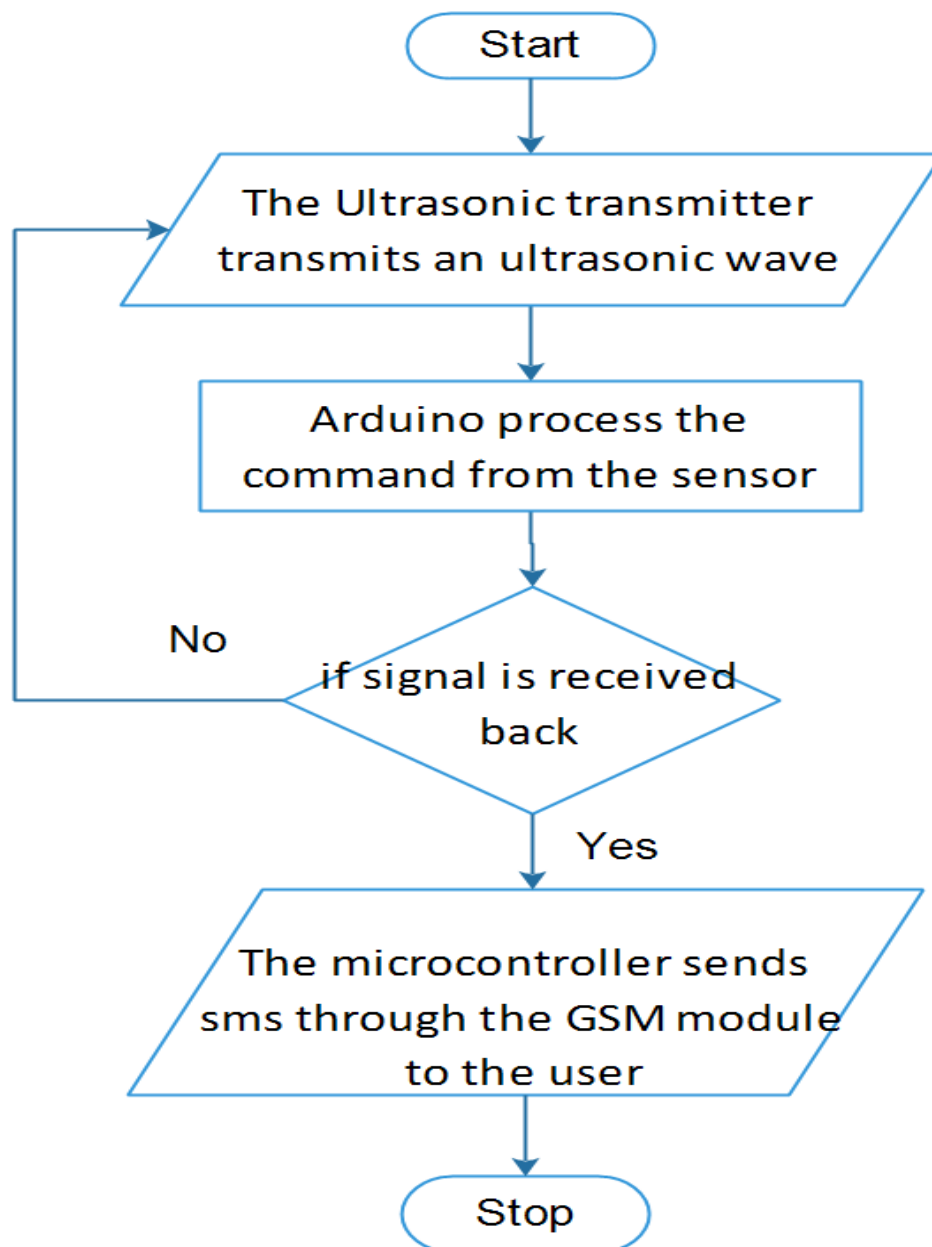


**Figure 7**: System's Flowchart

## 3. RESULTS AND DISCUSSION

### 3.1 Distance Test

The system's ability to mitigate stealth attacks within a range of 1cm to 70cm is evaluated through two tests. In the first test, a person is placed within the configured range, which causes the sensor to receive the reflected wave from the target. The sensor then sends a command to the microcontroller to notify it of its presence, and the microcontroller processes this signal and sends an SMS to the user via the GSM module. In the second test, a person is located at the borderline of the configured range (70-100cm) to assess the sensor's sensitivity to out-of-range movements. Figures 8 and 9 provide a visual representation of the device's internal structure and the testing process.
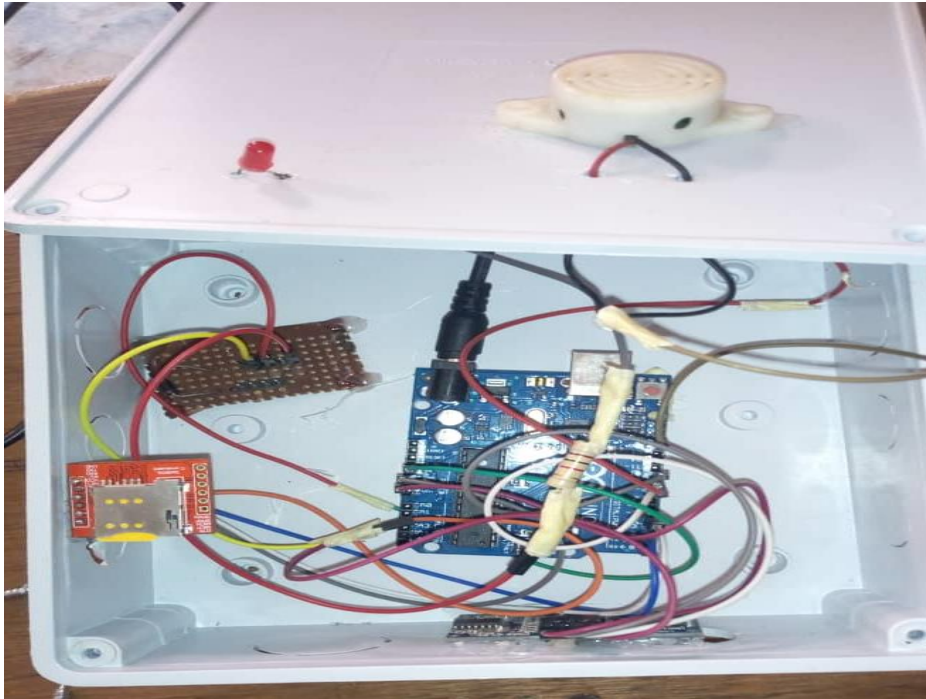
**Figure 8:** Device Internal View



**Figure 9**: Testing Process

**Test 1: Stealth attacks within the 1cm to 70cm range**
Result: The sensor successfully detected the presence of the human within the range of 1 to 70cm. The microcontroller processed the signal and sent an SMS to the user through the GSM module. The SMS received by the user reads: Someone is waiting at your door' as shown in Figure 10.

**Test 2: Stealth attacks outside the range of 70 to 100cm**
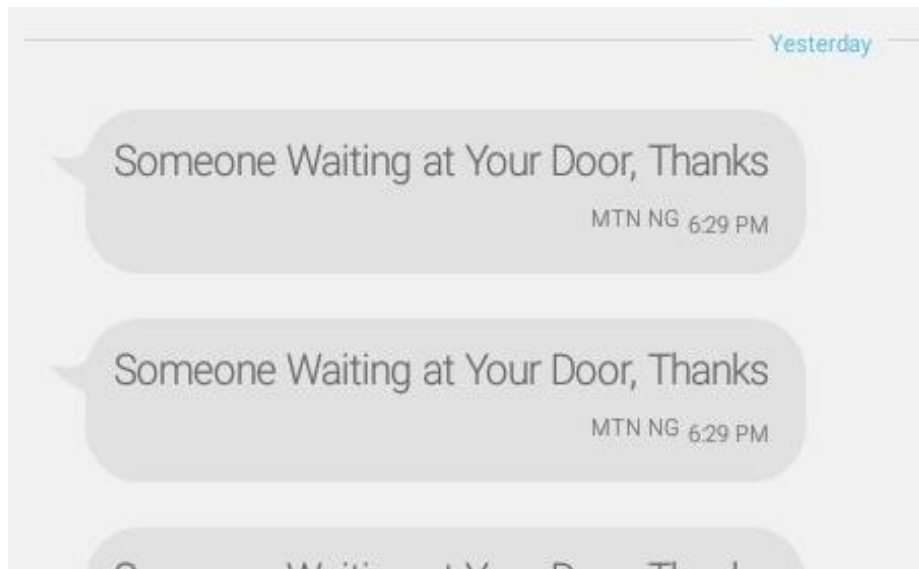Result: The sensor failed to detect any presence outside the range of 80cm.



**Figure 10**. SMS Received



**Figure 11**. Complete System

**3.2 Accuracy Test**

In order to assess the accuracy of the device, an experiment was conducted by placing the device in a fixed position with a measuring ruler of 80cm in length. The test involved moving a human hand closer and farther from the device at 5-cm intervals. The buzzer connected to the device emitted a beep sound upon detection. The test recorded every point of detection as (1) and every point of no detection as (0). Although the device was programmed to detect human presence within the range of 1cm-70cm, the experiment revealed that the device could detect human presence within the range of 1-80cm. Figure 12 illustrates the results of the experiment.
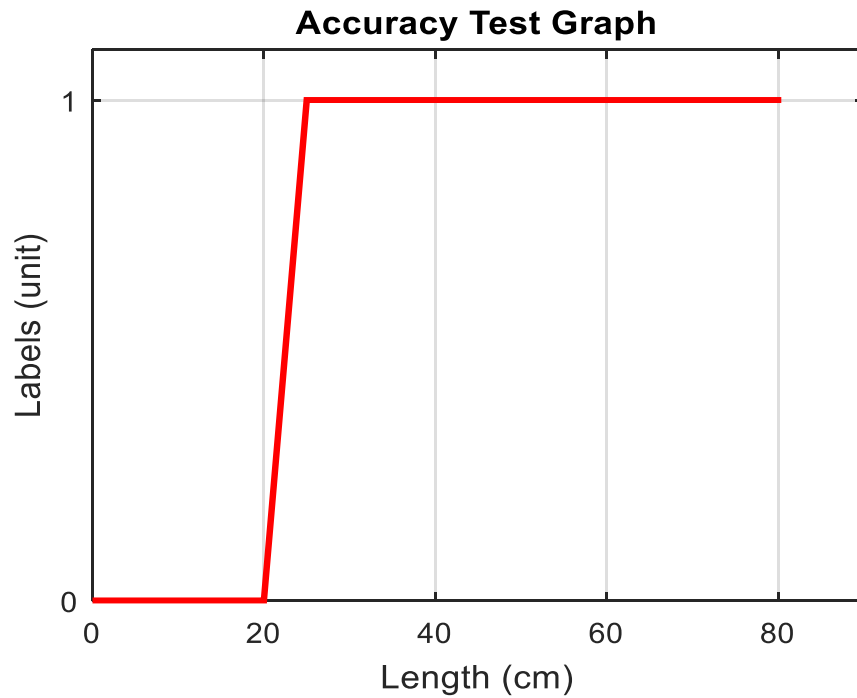
**Accuracy Test Graph**



**Figure 12**: Accuracy Test Graph

**3.3 Energy Consumption Test**

The Energy Consumption Test was conducted to measure the device's power consumption in both active and passive states. A 5V 16800mAh energy bank was used to power the device, and power readings were taken at 30-minute intervals for five hours. The device's energy usage was monitored while active and inactive, and the results were graphed in Figure 13. The device consumed only 25% of the energy in the bank while active and approximately 10% while passive. Figure 13 shows the device connected to the energy bank.
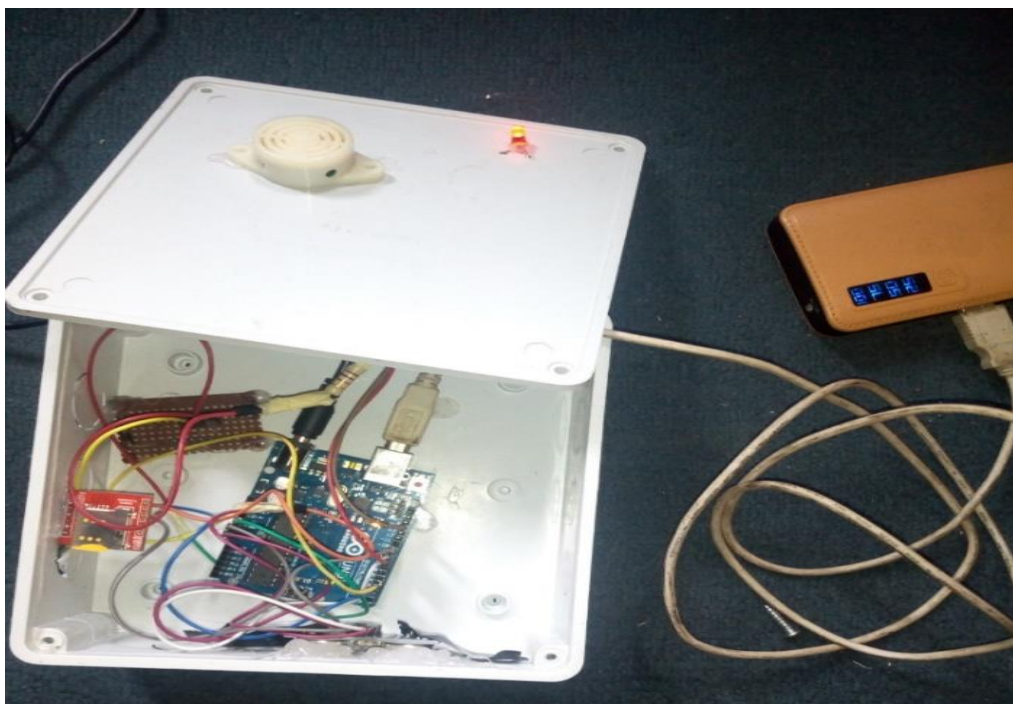


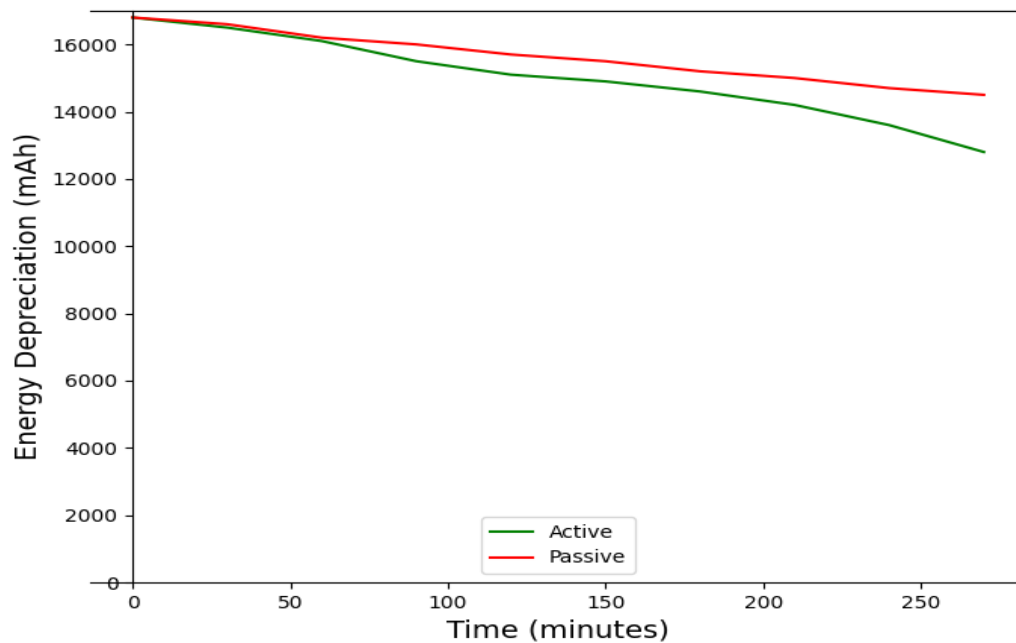**Figure 13:** Energy Consumption Test

**Figure 14:** Energy Consumption Graph for the two observed states

### 4. CONCLUSION

This paper presents the design and development of a smart doorbell system that detects human presence and notifies the homeowner. The system utilizes an ultrasonic sensor, a microcontroller, a GSM module, and software to detect and notify the homeowner of any human presence at the door. The system was tested for accuracy, distance, and energy consumption, and the results showed that it can detect human presence within the range of 1-80cm and consumes only a small percentage of energy from a 5v 16800mAh energy bank. The smart doorbell system presented in this paper addresses the problem of burglars using stealth and visitors spending time searching for doorbells around the house. With the increasing need for security and convenience, this system provides a reliable solution for homeowners and businesses.

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## Appendix

```
#include <SoftwareSerial.h>
// rx(9-arduino) connect to tx(gsm module)
// tx(10-arduino) connect to rx(gsm module)
SoftwareSerial SMS(4, 3);// rx(9) and tx(10)
String inputString;
String number = "xxxxxxxxxxx";
int sensor = 7; //The output of the Ultrasonic sensor connected to pin 7
int buzzer = 8; // buzzer connected at pin 8
int sensor_value; //variable to hold read sensor value
int sms_count = 0;
 void sendAlert()
{
  SMS.println("AT+CMGF=1"); //AT command for text mode of gsm module
  delay(1000);
  SMS.println("AT+CMGS=\"" + number + "\"\r");
  SMS.println((char)26);// ASCII code of CTRL+Z
  delay(1000);
}
void initialMsg()
{
  SMS.println("AT+CMGF=1"); //AT command for text mode of gsm module
  delay(100);
  SMS.println("AT+CMGS=\"" + number + "\"\r"); //  x is your mobile number
  delay(100);
  SMS.println((char)26);// ASCII code
  delay(1000);
}
void setup()
{
  pinMode(sensor, INPUT);
  pinMode(buzzer, OUTPUT);
  SMS.begin(9600);      // baud rate for gsm module
  Serial.begin(9600);    // baud rate for serial monitor
  delay(100);
  SMS.println("AT");
  delay(100);
  SMS.println("AT+CMGF=1");
  delay(100);
  SMS.println("AT+CNMI=1,2,0,0,0");
  delay(100);
  SMS.println("AT+CNMI=2,2,0,0,0");
  delay(1000);
  initialMsg();
```