

ZIBELINE INTERNATIONAL
PUBLISHING

ISSN: 2590-4043 (Online)

CODEN: AEMCDV



REVIEW ARTICLE

DESIGN AND DEVELOPMENT OF A LOW-COST SMART HOME SECURITY SYSTEM USING ARDUINO MICROCONTROLLER AND GSM TECHNOLOGYAdegboye, Oluwaseyi John^{a*}, Muhammad Uthman^b^aSheda Science and Technology Complex, (FMSTI), P.M.B 186, Abuja FCT, Nigeria^bDepartment of Electrical/Electronic Engineering, Faculty of Engineering, University of Abuja, Abuja, Nigeria*Corresponding Author E-mail: johnshei44@gmail.com

This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:

Received 20 July 2025

Revised 26 August 2025

Accepted 29 September 2025

Available online 15 October 2025

ABSTRACT

The increase in criminal activities has led to a growing demand for advanced smart home security solutions. Ensuring safety, especially when away from home, necessitates the integration of reliable, cost-effective security systems. This paper presents the design and implementation of a smart home security system that leverages an Arduino microcontroller and a GSM (Global System for Mobile Communications) module. The primary objective of the system is to enhance home security by promptly notifying homeowners of unauthorized entry or motion. The system integrates an Arduino UNO microcontroller with a PIR (Passive Infra-Red) motion sensor and a GSM module. Upon detecting motion or unauthorized access, the system uses the GSM module to send alerts to the homeowner's mobile phone, while simultaneously activating a buzzer and LED indicators. The solution is designed to be both affordable and accessible, utilizing basic, readily available components. This paper includes a detailed software implementation through Arduino programming and outlines the hardware configuration, including circuit diagrams and component specifications. The system's reliability and performance in detecting intrusions are validated through various testing scenarios.

KEYWORDS

Smart home security, Arduino Uno, GSM module, PIR sensor, home automation.

1. INTRODUCTION

The concept of smart homes has gained significant traction as one of the most promising applications of Internet of Things (IoT) technology (Lee, et al., 2014). Among the key features of smart homes, security is crucial in ensuring the safety of residents and the protection of personal belongings. The ability of security systems to monitor homes in real time is a prime example of their utility, especially in light of rising rates of home thefts and burglaries, which have prompted homeowners to become more vigilant. Traditional CCTV-based security systems, however, are not truly real-time, as alarms are typically triggered only after an incident occurs, with notifications often reaching homeowners after the crime has already been committed (Isa and Sklanos, 2017).

A "smart home" refers to a residence equipped with automated systems capable of responding to specific conditions, performing tasks in advance, and adapting to the occupants' needs. These homes are designed to manage various functions, including temperature control, lighting, entertainment, security, and emergency response (Isa and Sklanos, 2017). While all these functionalities contribute to an enhanced living experience, security remains a top priority. Smart home security involves the integration of advanced technologies to protect residences and their occupants against dangers such as burglary, gas leaks, and unauthorized access. For real-time monitoring and response, these systems make use of microcontrollers with Wi-Fi, Zigbee, or GSM modules. Automation and remote accessibility are enhanced via IoT technologies, leading to power efficient systems that also reduce energy usage making them both economical and environmentally friendly (Pandit, et al., 2019).

While high-end security systems are available on the market, they are often expensive and inaccessible to many homeowners. This research proposes a smart home security system that utilizes an Arduino microcontroller, PIR sensors, and a GSM module to provide an affordable, accessible, and scalable solution for real-time intruder detection and instant alerts. The system integrates IoT sensors and leverages GSM communication to enhance home security in a user-friendly manner (Hasan, et al., 2023). These components offer a cost-effective alternative to premium systems, ensuring reliability and scalability. The objectives of this research are to design a system that detects motion using the PIR sensor, initiates automated phone calls through a GSM module to alert homeowners instantly, reduces false alarms, ensures ease of installation, and provides scalability for future enhancements.

Smart security system technologies encompass a wide range of solutions, including biometric authentication, motion detection, video surveillance, smart door locks, access control, IoT-based monitoring, AI-powered threat analysis, cloud-based management, and GSM-based alert mechanisms. Various systems have been developed using different platforms and technologies, but many face significant limitations in terms of cost, adaptability, and reliability (Sheshai, 2006). A group researcher developed an IoT based smart home automation system to enhance residential security, integrating features like automated door locks, gas leak detection, and fire alerts (Liang, et al., 2020). Building on this, the proposed system incorporates a PIR sensor and a GSM module for real-time intrusion detection and instant alert delivery. Some researchers introduced a Raspberry Pi-based surveillance system, integrating cameras and motion detectors for live streaming and intruder tracking (Prathaban, et al., 2019). However, the need for advanced image processing and reliable internet connectivity poses a barrier to widespread adoption. The

Quick Response Code



Access this article online

Website:

www.actaelectronicamalaysia.com

DOI:

10.26480/aem.02.2025.43.46

present work, by contrast, uses Arduino to achieve a simpler, more cost-effective, and internet-independent solution.

A Zigbee-based low-cost security system was developed to combat high burglary rates in Sarawak, incorporating a central hub and Firebase-based notifications (Rakib, et al., 2021). The proposed system improves on this by using GSM communication, thereby removing dependence on internet infrastructure. A group researcher developed an Arduino-based gas leak detection system was implemented using an MQ-5 sensor, buzzer, and SMS notifications via GSM (Muhammad, et al., 2021). The present research extends this by integrating intrusion detection through PIR sensors and phone call alerts.

According to a study, PIR-based systems have previously been used to trigger alarms and SMS messages when motion is detected (Baballe et al., 2021). The current work enhances this by configuring the GSM module to make real-time phone calls using ATD commands, offering a more attention-grabbing alert system. A group researchers proposed an ultrasonic sensor with a rotating mechanism to provide 360-degree surveillance (Yoannan, et al., 2013). While innovative, it is limited by mechanical complexity and environmental sensitivity. The proposed system replaces this with a PIR sensor to ensure faster, more reliable detection without mechanical parts.

The system developed by a group researcher employed motion detecting cameras and GSM-based SMS alerts (Arunkumar, et al., 2017). While useful, these systems remain either internet-dependent or limited in communication methods. The proposed design uses phone calls instead of SMS to increase user responsiveness. Some researcher introduced a vehicle security system that cut off the ignition upon detecting theft (Hutabarat, et al., 2018). While effective for vehicles, it lacks broader applicability. This research generalizes the concept for both home and vehicular use without relying on vehicle-specific components.

A group researcher discusses an IoT-based smart lock system that uses MQTT (Message Queuing Telemetry Transport) to notify users via a mobile app (Dinar et al., 2018). However, internet dependency and mobile app limitations reduce its applicability in areas with poor connectivity. The proposed system overcomes this by using GSM technology for call-based alerts. A researcher developed a GSM-PIR integrated system for intrusion detection and automatic door locking, sending SMS notifications (Faisal, 2024). The proposed work improves this by using phone calls for quicker homeowner engagement and a more modular design. A group researcher introduced a knock-based security system using Arduino and GSM which is able to send alerts upon incorrect knock patterns (Sai, et al., 2024). Though innovative, it is reactive and confined to door-based interactions. The proposed system employs a PIR sensor for proactive, continuous motion surveillance, offering broader and more effective coverage.

This research presents a novel approach to smart home security by integrating an Arduino microcontroller with a Passive Infrared (PIR) sensor and a GSM module configured to initiate real-time phone calls using ATD commands. Unlike existing systems that rely on internet connectivity, complex image processing, or high-cost platforms like Raspberry Pi or Zigbee, the proposed solution provides a cost-effective, user-friendly, and internet-independent alternative. This design makes the system particularly suitable for deployment in areas with limited technological infrastructure or unreliable internet services. Moreover, the use of voice calls rather than conventional SMS significantly enhances the likelihood of the alert being noticed and acted upon promptly by the homeowner.

In addition, the system addresses limitations found in prior works, such as the environmental vulnerabilities and mechanical complexity of ultrasonic sensors and rotating modules. The PIR sensor offers faster response times and more consistent performance across varying conditions. Furthermore, by avoiding application-specific constraints such as systems tied to door mechanisms or vehicle ignitions the proposed solution offers a flexible and proactive framework for real-time surveillance. The integration of low-cost hardware components with effective GSM-based communication represents a meaningful advancement in smart home security, particularly for underserved or remote communities seeking accessible and reliable protection solutions.

2. MATERIALS AND METHODS

2.1 Hardware Components

The materials used in the design and construction of the proposed smart home security system are summarized in Table 1. Each component was selected based on its functionality, compatibility, and cost effectiveness for the intended application.

| Table 1: Components used in the construction of the smart home security system | | |
|--|---|---------------------------|
| Component | Specification/Model | Quantity |
| Arduino UNO R3 | ATmega328P | 1 |
| GSM module | SIM800L | 1 |
| PIR motion sensor | Detection range: 3–6 m (model dependent) | 1 |
| Voltage regulator module | LM2596 Buck DC-DC | 1 |
| Power Supply | 9V battery or adapter | |
| Resistors | 220 ohms, Power rating: 0.25W; Tolerance: ±5% | 1 |
| LED (Green and Red) | 5mm, indicating successful access and wrong input/lockout | 2 |
| Jumper wire | Male-to-male, male-to-female, or female-to-female | depending on wiring needs |
| Buzzer | 5V, ~85dB at 5V, 30mA to 50mA | 1 |

2.2 Block and Circuit Diagram

The design of the smart home security system is explained using two visual representations. Figure 1 shows the block diagram, which outlines the logical interaction among system components, while figure 2 presents the detailed circuit schematic illustrating the hardware connections and interfacing. The Arduino UNO microcontroller acts as the central control unit. Upon motion detection by the PIR sensor, it activates the buzzer and sends a signal to the GSM module to notify the user. LEDs provide visual alerts, and a voltage regulator ensures a stable power supply to the system.

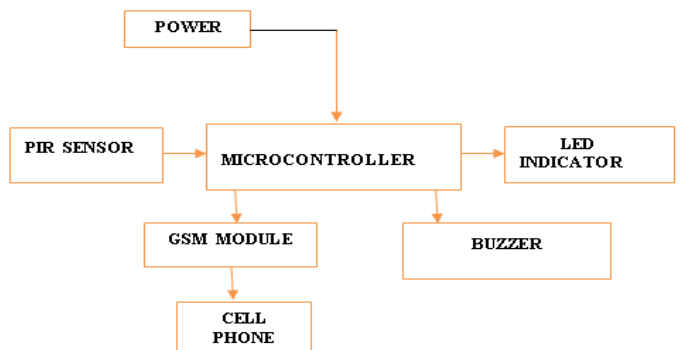


Figure 1: Block Diagram of the system

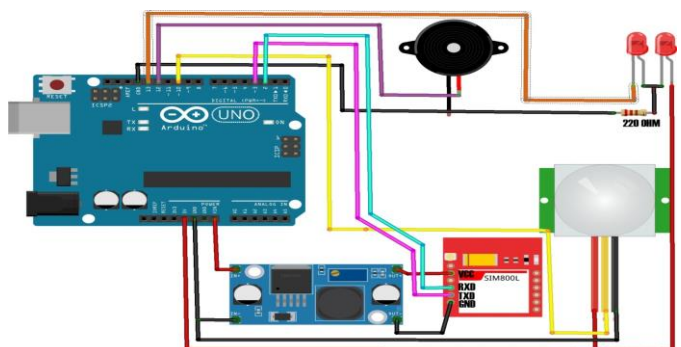


Figure 2: Circuit Diagram of the system

2.3 Working Principle

The smart home security system operates through a series of steps. The first step is the detection of motion using a Passive Infrared (PIR) sensor. This sensor generates a digital signal, which is then processed by an Arduino UNO microcontroller. If motion is confirmed, the Arduino activates a buzzer alarm and LED indicators to alert occupants. The Arduino also sends a communication signal to the SIM800L module, which initiates a real-time phone call to a predefined mobile number, enhancing home security through a low-cost, automated solution.

2.4 Implementation Methodology

2.4.1 Hardware Integration

The hardware components were assembled using jumper wires to ensure proper alignment and insulation. The buzzer was connected to digital pin 12 on the Arduino, while the ground terminal was connected to the Arduino's GND pin. The GSM module was connected to digital pin 3 and the voltage regulator to power it. The ground terminal was connected to the Arduino's GND via the voltage regulator. The PIR motion sensor was used to detect intrusions, with its Vcc pin connected to the Arduino's 5V output, GND pin to the Arduino GND, and signal output pin to digital pin 10. Two LED indicators were used to provide system status notifications, with each LED's cathode connected to a 220Ω resistor. The common cathode line was connected to the Arduino's GND.

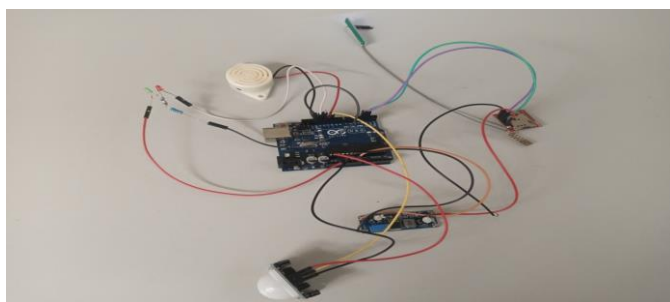


Figure 3: The System hardware Setup

2.4.2 Software Setup

The Arduino Uno was programmed using the Arduino Integrated Development Environment (IDE). The process involved installing the IDE on the host computer, developing control code in C/C++, connecting the Arduino board via USB cable, selecting the correct board model, and choosing the correct COM port. Finally, the compiled sketch was uploaded to the board.

3. RESULTS

The system underwent testing in controlled and uncontrolled environments to evaluate detection accuracy, response speed, alert success rate, and power consumption. Motion detection tests yielded a 96.7% success rate within a 3–5 meter range. The response time from motion detection to buzzer/LED activation averaged 0.6 seconds. The GSM module successfully initiated phone calls in 28 out of 30 test cases, resulting in a 93.3% success rate. Average power consumption was 115 mA, with a peak of 180 mA during call initiation and an idle current of 50 mA.

| Table 2: Performance Metrics of the Smart Home Security System | | | | |
|--|-------------|--------|---------|------------------------------|
| Parameter | Test Events | Result | Units | Remarks |
| Motion Detection Accuracy | 30 | 96.7 | % | High precision for PIR range |
| Call Success Rate | 30 | 93.3 | % | 2 calls failed |
| Average Response Time | 30 | 0.6 | seconds | From motion to buzzer/LED |
| Call Initiation Delay | 30 | 5.0 | seconds | Time to GSM call initiation |
| Idle Power Consumption | - | 50 | mA | In standby mode |

| Table 2 (Cont): Performance Metrics of the Smart Home Security System | | | | |
|---|-------------|--------|-------|-------------------------------|
| Parameter | Test Events | Result | Units | Remarks |
| Active Power Consumption | - | 180 | mA | During alarm and call |
| Average Power Usage | - | 115 | mA | Typical during full operation |

A low false alarm rate of 3.33% was achieved, attributed to effective placement and threshold calibration of the PIR sensor. System stability was validated with continuous operation over 10 hours, recording just one reset due to voltage fluctuation, which was corrected by upgrading the power supply regulation.

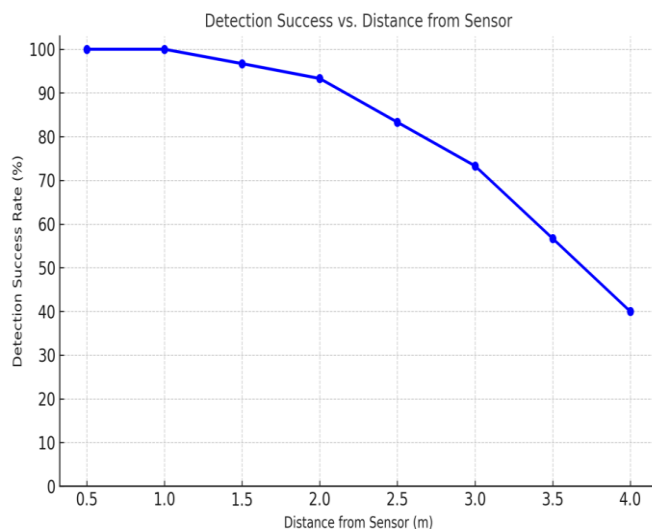


Figure 4: Detection Success vs. Distance from Sensor

Figure 4 illustrates the relationship between detection success rate and the distance from the PIR sensor. The PIR sensor achieves optimal performance at a distance of 3 to 5 meters, with success rates dropping outside this range.

4. DISCUSSION

The test results validate the system's reliability in detecting intrusion and notifying users in near real time. Compared to systems relying on internet services or SMS alerts, the phone call mechanism proved more effective at capturing user attention. This improves the likelihood of timely response, especially in high-risk areas. Additionally, the system's energy footprint is low enough to support battery-powered or solar-enhanced configurations for long-term use in remote locations.

Component modularity ensures easy expansion. For instance, adding door sensors or flame detectors can enhance the system's functionality without requiring major redesign. Further, code optimization or integration with RTC (Real-Time Clock) modules could support logging and time-based activation.

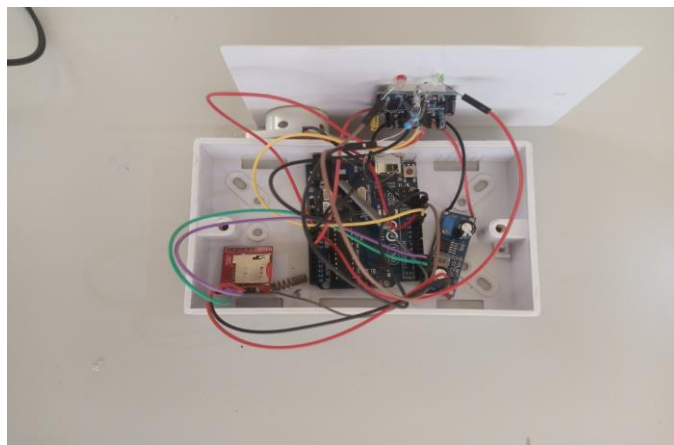


Figure 5: Interior View of the Completed system



Figure 6: External View of the Completed system

5. CONCLUSION

The Smart Home Security System was successfully designed and implemented, demonstrating its effectiveness, reliability, and energy efficiency as a practical solution for enhancing residential security. The system consistently detected intrusions and promptly notified users via automated phone calls, indicating its suitability for real-world applications. Furthermore, its low power consumption and operational stability confirm its appropriateness for continuous deployment in both typical and resource-constrained environments.

Several directions for future enhancements are proposed to improve the system's functionality and broaden its scope of application. Expanding sensor integration through the inclusion of additional modalities such as door/window contact sensors, surveillance cameras, or vibration detectors would enable more comprehensive environmental monitoring. The development of a dedicated mobile application could further enhance user interaction by enabling real-time alerts, system control, and remote diagnostics.

To ensure uninterrupted performance during power outages, incorporating a battery backup system is recommended, thereby improving the system's resilience. Enhancing energy efficiency through the implementation of low-power operational modes particularly during idle periods would reduce energy consumption and increase long-term sustainability. Finally, the system's modular architecture allows for scalability, supporting the integration of advanced features such as facial recognition and cloud-based analytics, which would extend its utility within a broader smart home ecosystem.

REFERENCE

Arunkumar, A., Maikkannan, P., Nitheiswaran, M., and Bagyalakshmi, N., 2017. Microcontroller based home security system using GSM Module. *International Journal of Innovation and Scientific Research*, 30 (3), Pp. 330–337. <https://ijisr.issr-journals.org/abstract.php?article=IJISR-17-123-02>

Baballe, A.M., Magashi, U.Y., Garko, B.I., Umar, A.A., Magaji, Y.R., and Surajo, M., 2021. Automatic gas leakage monitoring system using MQ-5 sensor. *Review of Computer Engineering Research*, 8 (2), Pp. 64–75. <https://doi.org/10.18488/journal.76.2021.82.64.75>

Dinar, R., and Sarno, R., 2018. Door automation system based on speech command and PIN using Android smartphone. In 2018 International Conference on Information and Communications Technology (ICOIACT) (pp. 667–672). IEEE. <https://doi.org/10.1109/icoiact.2018.8350715>

Faisal, A., 2021. Door security system using e-KTP RFID reading and passive infrared sensor. *Journal of Electrical and Electronics Engineering*, 3 (2), Pp. 93–98. <https://www.academia.edu/92043533>

Hasan, T., Abrar, M.A., Saimon, M.Z.R., Sayeduzzaman, M., and Islam, M.S., 2023. Constructing an integrated IoT-based smart home with an automated fire and smoke security alert system. *Malaysian Journal of Science and Advanced Technology*, 3 (1), Pp. 1–10. <https://doi.org/10.56532/mjsat.v3i1.125>

Hutabarat, D.P., Budijono, S., and Saleh, R., 2018. Development of home security system using ESP8266 and android smartphone as the monitoring tool. *IOP Conference Series: Earth and Environmental Science*, 195 (10), Pp. 012065. <https://doi.org/10.1088/1755-1315/195/1/012065>

Isa, E., and Sklanos, N., 2017. Smart home automation: GSM security system design & implementation. *Journal of Engineering Science and Technology Review*, 10 (3), Pp. 170–174. <https://doi.org/10.25103/jestr.103.22>

Lee, C., Zappaterra, L., Choi, K., and Choi, H.A., 2014. Securing smart home: Technologies, security challenges, and security requirements. In 2014 IEEE Conference on Communications and Network Security (pp. 67–72). IEEE. <https://doi.org/10.1109/CNS.2014.6997467>

Liang, C.B., Tabassum, M., Kashem, S.B.A., Zama, Z., Suresh, P., and Saravanakumar, U., 2020. Smart home security system based on Zigbee. *Advances in Intelligent Systems and Computing*, 1163 (5), Pp. 827–836. https://doi.org/10.1007/978-981-15-5029-4_71

Muhammad, B., Bello, M., Abubakar, B., and Tijjani, A., 2021. Implementation of security alarm using Arduino with P.I.R motion sensor and GSM module. *International Journal of Innovative Research in Emerging Sciences*, 2 (2), Pp. 1–7. https://acors.org/ijacoi/VOL2_ISSUE2_8.pdf

Pandit, S., Kamble, S.K., and Vasudevan, V., 2019. A project report on home security alarm system using OpenCV on Raspberry Pi 3. PDF4PRO. <https://pdf4pro.com/amp/view/a-project-report-on-home-security-alarm-system-using-69c302.html>

Prathaban, T., Thean, W., and Sazali, I., 2019. A vision-based home security system using OpenCV on Raspberry Pi 3. *AIP Conference Proceedings*.

Rakib, M.A.A., Rahman, M.M., Rana, M.S., Islam, M.S., and Abbas, F.I., 2021. GSM based home safety and security system. *European Journal of Engineering and Technology Research*, 6 (6), Pp. 69–73. <https://doi.org/10.24018/ejeng.2021.6.6.2580>

Reddy, R.S.C., Krishna, P.V., Chaitanya, M.K., Neeharika, M., and Rao, K.P., 2018. Security system based on knock-pattern using Arduino and GSM communication. *International Journal of Engineering and Techniques*, 4 (1), Pp. 154–157. <https://www.academia.edu/36679117>

Sheshai, S., 2006. Raspberry Pi based security system. University of Nairobi, Department of Electrical and Information Engineering. <https://eie.uonbi.ac.ke/sites/default/files/cae/engineering/eie/RASPBERRY%20PI%20BASED%20SECURITY%20SYSTEM.pdf>

Yoannan, S., Vaipicherry, V., Thankachan, D., and Tripathy, R., 2013. Security system based on ultrasonic sensor technology. *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*, 7 (6), Pp. 27–30. <https://iosrjournals.org/iosr-jece/papers/Vol7-Issue6/F0762730.pdf>

