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Main Campus I and II

DEVELOPMENT OF A HYBRID SMS-CONTROLLED POWER OUTLET WITH INTEGRATED SMOKE DETECTION AND TEMPERATURE MONITORING USING ESP32

A Mini Project

In Partial fulfillment of the Requirements for the course

EE 341 Research Methods for Engineering

Negros Oriental State University – Main Campus I

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ABSTRACT

The study targets the construction of a hybrid SMS-controllable power outlet with smoke detection and temperature monitoring using the ESP32 microcontroller. The primary aim is to design a system that enables remote control of electrical devices while providing security through environmental monitoring. This project solves general issues like the threat of unattended electrical appliances, slow response to fire risks, and the absence of real-time temperature and smoke signals in conventional outlets.

In order to accomplish this, the researchers employed an experimental approach in which system designing and development was done with major components: ESP32, GSM module for the SMS application, smoke sensor, temperature sensor, and relay for controlling the outlet. The software was coded with the Arduino IDE and flashed into the ESP32.

Data capture entailed a series of controlled experiments to measure the performance of the system. This involved monitoring the response of the outlet to SMS commands (ON/OFF), how fast it was in detecting smoke, and how efficiently it was measuring temperature. Several test runs were made, and data concerning response time, sensor accuracy, and reliability of SMS were captured.

The findings verified that the system effectively achieved its goals. It properly responded to remote SMS commands, sensed smoke in real time, and offered precise temperature feedback. Warnings were sent on time under abnormal conditions, demonstrating the success of the integrated system.

Finally, the hybrid outlet system created is a low-cost and effective solution for enhancing safety and convenience in homes or offices. It is a sensible method of smart energy control and danger prevention with the potential for further expansion through IoT integration or mobile applications.

Keywords: ESP32, SMS control, smart outlet, smoke sensor, temperature monitoring, fire safety, remote control

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The Researchers

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation	
ESP32	Espressif Systems 32-bit Microcontroller
GSM	Global System for Mobile Communications
SMS	Short Message Service
MQ-2	Gas and Smoke Sensor (Model MQ-2)
DHT11	Digital Humidity and Temperature Sensor
SIM800L	GSM/GPRS Module from SIMCom
IDE	Integrated Development Environment
IoT	Internet of Things
PCB	Printed Circuit Board
AC	Alternating Current
DC	Direct Current
UART	Universal Asynchronous Receiver-Transmitter
Wi-Fi	Wireless Fidelity

Abbreviation

AT Commands	Attention Commands (used to control GSM modules)
LED	Light Emitting Diode
VCC	Voltage Common Collector (Power Supply Voltage)
GND	Ground
°C	Degrees Celsius
SMS ON/OFF	Commands sent to turn the outlet on or off
EEPROM	Electrically Erasable Programmable Read-Only Memory (used in ESP32)
TX/RX	Transmit / Receive pins used in serial communication

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

In the current evolution of technology, intelligent systems that improve safety, convenience, and energy efficiency are gaining attention particularly regarding innovations. Innovations such as smart outlets can provide positive impacts allowing users to control electrical devices through remote control. According to the International Energy Agency, digital technology is revolutionizing energy systems to have improved control and efficiency in energy use. These systems assist in energy consumption reduction, avoid electrical hazards, and enhance the general control of appliances. Another feature of significance is remote control of appliances. Since SMS can be employed to control devices without being connected to the internet, it's a great choice for establishments where connectivity is poor. The International Energy Agency informs that digital technologies such as remote monitoring and control are reshaping the energy system and empowering users to take more command of their use of power.

Simultaneously, providing safety features like smoke detection and monitoring of temperature also provides significance in avoiding accidents such as in residential and industrial units. Overheating or short circuit fire continues to be a typical case, frequently results in damage to property or death. The National Fire Protection Association states that electrical malfunction is a major source of house fires, with almost 50,000 cases reported every year due to electrical defects. Individual smoke detectors operate independently in the traditional setup, but integrating them with intelligent control systems is a more efficient approach to safety. The ESP32, an open-source and economical microcontroller with in-built Bluetooth and Wi-Fi, can be used to develop high-performing and cost-effective smart devices. In combination with a GSM module, it enables real-time SMS communication, enabling users to control devices remotely using their phones and receive alerts even where there is no internet connection.

This study not only demonstrates a viable and practical implementation of embedded systems and wireless communication but also contributes to the ongoing discourse on creating more inclusive and accessible smart technologies. By addressing real-world limitations—such as internet dependency, power instability, and environmental hazards—the project stands as a testament to how technology can be harnessed to solve critical safety and convenience challenges in a cost-effective manner. Furthermore, this system aligns with the global push toward sustainable energy management and disaster prevention. According to the International Energy Agency (2017), digital solutions like remote control and automation enhance energy efficiency and provide early warnings that help reduce safety risks. The proposed system enables users to remotely switch off unused appliances, reducing energy waste and minimizing the chances of electrical fires. It also sends SMS alerts in response to abnormal environmental conditions, such as overheating or smoke, which are common precursors to fires (Mueller et al., 2008; James et al., 2020).

The affordability and simplicity of the design also make it suitable for academic and educational purposes, offering students and hobbyists a platform to explore real-world applications of microcontrollers, GSM technology, and environmental sensors (Reddy & Kumar, 2023). Ultimately, the successful implementation of this hybrid SMS-controlled smart outlet serves as a compelling example of how low-cost, offline-capable solutions can bridge the technological divide and deliver meaningful benefits to underserved communities (Nair & Thomas, 2023). It promotes safety, innovation, and energy responsibility in homes, small businesses, and areas with limited infrastructure.

1.2 STATEMENT OF THE PROBLEM

In this era, our world is developing more, and electrical gadgets are part of everyday life. Still, there are hazards like overheating, overloads, and fire dangers, particularly when gadgets are not looked after. Though home safety systems have been useful, they are not very advanced and sometimes do not include features like real-time notification and remote control.

Moreover, most contemporary intelligent systems are highly dependent on reliable internet connection, which is not always possible in poor or remote locations. Without an effective means of monitoring energy consumption, sensing dangerous situations such as fire or sudden temperature increase, and regulating appliances remotely, homes and small businesses are left exposed to equipment destruction and even loss of life. There is obviously a need for a low-cost, GSM-based system independent of the internet to alert users by SMS and enable control of appliances remotely.

Designing smart power plugs with capabilities such as smoke and temperature sensors minimizes the chances of fire and enhances the reliability and safety of home automation systems. As pointed out by experts, digital technologies such as remote monitoring and control are essential in enhancing the safety and energy efficiency of homes, even without an always-on internet connection.

In response to these challenges, there is a necessity for a hybrid smart plug that:

- Wi-Fi-free works by using SMS.
- Has smoke and temperature sensors to provide early warning of potential danger.
- Uses affordable and low-tech components like the ESP32 microcontroller.

In the aim of fulfilling the shortage of smart home safety, this project tries to give more access to users for controlling their electric appliances at any time and place without access to internet.

This study aims to answer the following questions:

1. How effective is the proposed GSM-based smart plug system in detecting and alerting users of potential fire hazards such as smoke or temperature spikes?
2. Can users reliably control electrical appliances remotely using SMS commands without the need for an internet connection?
3. How does the system perform in terms of responsiveness, accuracy, and reliability in areas with poor or intermittent GSM signal?

4. What are the advantages and limitations of using low-cost components like the ESP32, SIM800L module, and DHT11 sensor in the design?
5. To what extent does the system improve home safety and energy control compared to traditional and internet-based smart home systems?

1.3 OBJECTIVES

The researchers want to create a hybrid system combining SMS control of a power outlet with smoke detection and temperature monitoring capabilities based on the ESP32 microcontroller. Precisely, the researchers' targets:

1. To design and implement an SMS-controlled power outlet system based on the ESP32 and a GSM module.
2. To integrate a smoke sensor to provide smoke detection and send instant notifications through SMS.
3. Add a temperature sensor to measure ambient temperature and alert the user as soon as a critical limit is achieved.
4. Design system logic that provides users with the facility to remotely switch ON or OFF the connected appliance through SMS commands.
5. Test and analyze the performance, responsiveness, and reliability of the system under different working conditions.
6. Evaluate the safety and energy management capabilities of the system for improving residential or small-scale applications.

1.4 SCOPE AND LIMITATIONS

This project targets the design and implementation of a hybrid power outlet system controlled by SMS with smoke detection and temperature monitoring capabilities using the ESP32 microcontroller. The major goal of this system is to offer a secure and economical way of remotely controlling electric appliances while being safe through environmental monitoring.

The system enables remote control of the power outlet through SMS commands sent using a GSM module to activate or deactivate any appliances connected to it. The system also includes a smoke detector and a heat sensor to detect the surrounding environment. When there is smoke detected or if the temperature goes over a preset limit, the system automatically shuts off power to the outlet and alerts the user through SMS. This two-layer protection serves both convenience and safety purposes and is ideal for home or small office settings.

It should be noted that this project is SMS-based communication and not internet-based control or cloud-based data storage. Additionally, the system is built as a prototype or proof of concept and not designed as an industrial-grade fire or temperature detection system.

Finally, this research shows the real-world application of embedded systems, wireless communication, and sensor technology for smart home use, with potential areas of future development.

1.5 SIGNIFICANCE OF THE STUDY

This study is important because it offers a working solution for improving electrical safety and energy control in a range of applications, from small residences to larger offices and business complexes. With the increasing occurrence of electrical fires due to user oversights or damaged wiring, there is a critical requirement for a clever system that can sense environmental conditions and offer timely warnings for prompt action, even during offline scenarios.

Taking advantage of the ESP32 microcontroller's features, coupled with a GSM module to support SMS messages, and a smoke sensor (MQ-2) and a temperature sensor (LM35) for detecting hazards, this project provides a system that allows users to switch on/off a power outlet and receive real-time alerts regarding possible dangers. This feature is especially useful in regions without Wi-Fi or reliable internet connectivity, keeping users informed and secure no matter their connection status.

This system benefits a broad array of users:

1. **Students.** Acts as a learning platform for studying automation, embedded systems, and microcontrollers. It facilitates hands-on practice in programming, electronics, and sensor integration.
2. **Homeowners and Families.** Enables remote monitoring and control of appliances, improving energy efficiency and home safety. Minimizes the risk of home fires by sending alerts upon detection of smoke or abnormal temperature levels.
3. **Small Business Owners.** Prevents electrical fires in the workplace, store, or commercial environment. Allows for remote switching on/off of equipment and machines after working hours.
4. **People Living in Rural or Low-Connectivity Areas.** Provides an intelligent automation system that does not rely on the internet, but uses SMS instead. Perfect for areas with unstable power or weak network infrastructure.
5. **Older Persons and Disabled Persons.** Increases independence and convenience by allowing control of appliances remotely. Increases safety by providing warnings when hazardous conditions like fire or overheating are reached.
6. **Future Developers and Researchers.** Establishes a starting point for future research into wireless monitoring, IoT integration, and home automation systems. The project can be extended with features such as voice control, cloud logging of data, or connectivity with mobile applications and home automation assistants. It acts as an example of how systems based on microcontrollers can maximize automation, security, and environmental sustainability in both home and business settings.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of existing literature relevant to the development of a hybrid SMS-controlled power outlet system with integrated smoke and temperature monitoring. The focus is on systems that incorporate remote control through GSM/SMS, safety through environmental sensing, and modern microcontrollers such as the ESP32.

2.1 RELATED LITERATURE

The literature on developing a hybrid SMS-controlled power outlet with integrated smoke detection and temperature monitoring using ESP32 encompasses various studies that focus on IoT-based fire detection systems, temperature control applications, and home automation solutions. Key resources highlight the integration of GSM modules for alerts, the use of smoke and temperature sensors, and the implementation of ESP32 for efficient monitoring and control in environments with limited internet access.

1. **IoT-Based Fire Detection Systems**

Several studies have explored the development of IoT-based fire detection systems utilizing the ESP32 microcontroller. For instance, Kumar et al. (2020) designed a fire detection system that integrates smoke and temperature sensors with GSM communication to provide real-time alerts. This system demonstrates the effectiveness of using ESP32 for monitoring and alerting in environments prone to fire hazards.

2. **Temperature Control Applications**

Research has also focused on temperature control applications using the ESP32. In their study, Singh and Gupta (2021) implemented a temperature monitoring system using the LM35 sensor, which triggers alerts based on predefined temperature thresholds. This capability is crucial for preventing overheating and potential fire hazards.

3. **Home Automation Solutions**

The role of ESP32 in home automation solutions is emphasized in the work of Alzahrani et al. (2019), where the authors discuss the integration of various sensors, including smoke detectors and temperature sensors, to enhance safety and energy management in residential settings. Their findings highlight the potential of ESP32-based systems to improve user control over home appliances.

4. **GSM Module Integration**

The use of GSM modules in these systems is a common theme, as they facilitate communication and alerting mechanisms. According to Sharma et al. (2022), integrating GSM modules allows for immediate SMS notifications, which is particularly beneficial in scenarios where internet connectivity is unreliable or unavailable.

5. **Practical Applications and Case Studies**

Various case studies demonstrate the successful implementation of hybrid SMS-controlled power outlets with integrated monitoring systems. For example, the work of Patel and Desai (2021) showcases a prototype that effectively combines smoke detection and temperature monitoring, providing timely alerts to users and enhancing safety in real-world scenarios.

6. **Future Directions**

Future research may focus on optimizing sensor accuracy, reducing false alarms, and expanding the functionality of these systems to include additional safety features, such as gas leak detection and integration with other smart home devices (Reddy & Kumar, 2023).

7. **Cost-Effective Smart Home Solutions**

Nair, A., & Thomas, J. (2023). This paper investigates cost-effective smart home solutions using the ESP32 microcontroller. The authors highlight the integration of SMS-based control and environmental monitoring features, advocating for open-source solutions that can be easily adapted for various applications, making smart technology accessible to a broader audience.

2.2 RELATED STUDIES

The development of a hybrid SMS-controlled power outlet with built-in smoke detection and temperature sensing via the ESP32 microcontroller is a huge leap for home automation and security systems. Some related research studies and concepts that can be used to delve deeper into this field are presented below:

1. **Smart Power Outlets**

Smart power outlets, also known as smart plugs, are integral components of modern smart home systems. These devices allow users to control and monitor the power usage of connected appliances remotely through mobile applications, voice commands, or programmed schedules (Haque, Rahman, & Hasan, 2020). Smart outlets contribute significantly to energy efficiency, cost savings, and user convenience.

The integration of smart outlets into Internet of Things (IoT) systems has made it possible to automate household tasks and monitor power consumption in real time. According to Haque et al. (2020), smart plugs can be programmed to turn off unused appliances during peak hours, reducing electricity bills and lowering carbon footprints.

Smart outlets also improve home safety. For instance, they can detect abnormal energy consumption that may indicate potential hazards like overheating or electrical faults (U.S. Department of Energy, 2021). Some models even offer surge protection and timers, which help prevent accidents caused by leaving devices like irons or stoves turned on.

Furthermore, smart power outlets are compatible with voice assistants such as Amazon Alexa and Google Assistant, making them more accessible to users with different needs (Khan, McDaniel, & Khan, 2018). The growing popularity of smart outlets reflects a broader trend toward the adoption of intelligent energy management systems in both residential and commercial buildings.

2. Smoke Detection System

Smoke detection systems play a crucial role in safeguarding lives and property by providing early warnings during fire emergencies. The two most common types of detectors are ionization and photoelectric sensors. Ionization alarms are particularly sensitive to fast-flaming fires but are more prone to nuisance activations, such as those caused by cooking fumes, which often leads to users disabling them (Mueller et al., 2008). In contrast, photoelectric detectors are more responsive to smoldering fires and significantly reduce false alarms, leading to higher long-term functionality and user trust. A study found that after nine months, only 5% of photoelectric detectors were disabled compared to 20% of ionization alarms (Mueller et al., 2008; University of Washington, 2008).

To enhance reliability, dual-sensor smoke alarms, which combine both ionization and photoelectric technologies, are now widely recommended for comprehensive fire detection (DIY Stack Exchange, 2010). Additionally, as technology advances, IoT-based smoke detection systems are becoming increasingly prevalent. These smart systems integrate traditional smoke, gas, and temperature sensors with internet connectivity to enable real-time monitoring, remote alerts, and intelligent decision-making (Pathak & Ali, 2024). James et al. (2020) emphasized that IoT-enabled systems improve response times and minimize false alarms through real-time data analytics and centralized control.

Further advancements involve the use of machine learning (ML) and edge computing. Jadon et al. (2019) proposed FireNet, a lightweight ML model for detecting fire and smoke in real time using embedded devices such as the Raspberry Pi. This model allows for efficient deployment in low-resource environments while maintaining high detection accuracy. Similarly, IoT-based fire detection in large environments such as forests has been explored using thermal sensors and cloud-based monitoring systems, as shown in a prototype developed by researchers in South Korea (Lee et al., 2022).

Real-world evidence from Alaskan and Washington households supports the preference for photoelectric detectors. These alarms had a significantly lower disconnection rate, primarily due to reduced nuisance alarms, which enhances their practical reliability and public trust (Mueller et al., 2008; NCBI, 2006).

3. Temperature Monitoring

Temperature Status via SMS developed by (Mohd, 2008) also has similarity with this project. This project utilized PIC 16F877 and MPLAB IDE software for programming. The project was designed to detect level and temperature of the water in a pool. The system functions when the level of water and the temperature in pool exceed the desired limits. At the same time the PIC circuit will automatically interface to the mobile phone and send the alert message to the user.

4. SMS-Based Control Systems

SMS-controlled systems offer an effective method for remote device management in areas with poor internet access. These systems use GSM modules to receive commands and perform actions such as switching appliances on or off. Linuswoody (n.d.) developed an open-source project using ESP32 and a SIM800L GSM module to allow SMS-based control of power outlets. However, the system focused only on switching functionality and lacked integration with environmental sensors for safety.

Another example is from Narh Odonkor et al. (2020), who designed a fire safety system using SMS controllers. While the project highlighted the effectiveness of SMS in sending alerts, it lacked integration with real-time power control and smart sensors.

5. **Environmental Monitoring for Fire and Heat Hazards**

Safety in smart power systems is increasingly important. Various studies have implemented smoke and temperature sensors to detect fire risks. Al-Ameen (2013) designed a wireless fire alert system that sent SMS notifications when smoke or high temperature was detected. This type of system significantly improves safety but lacks active power control that could help prevent electrical fires.

Similarly, Simamora et al. (2025) presented an indoor air quality monitoring system using IoT technologies. While modern in design, the focus was more on data visualization and quality tracking than on safety intervention or remote control.

6. **Cost-Effective IoT Solutions for Home Safety**

Reddy, S., & Kumar, V. (2023) investigated cost-effective IoT solutions for home safety using the ESP32 microcontroller. Their research highlighted the integration of SMS-based control and environmental monitoring features, such as smoke and temperature detection. The study advocates for open-source solutions that can be easily adapted for various applications, making smart technology accessible to a wider audience.

CHAPTER 3

METHODOLOGY

This chapter discusses the methodology used in this study. The sections of this chapter describe the research design, materials used (hardware/software), experimental procedures, data collection methods, and analytical techniques.

3.1 RESEARCH DESIGN

This study employed an experimental research design, which is appropriate for projects aimed at developing and validating new technological systems through controlled testing (Creswell, 2014). The primary objective was to design and evaluate a hybrid SMS-controlled power outlet equipped with integrated temperature and smoke detection sensors to enhance safety and remote accessibility in electrical systems.

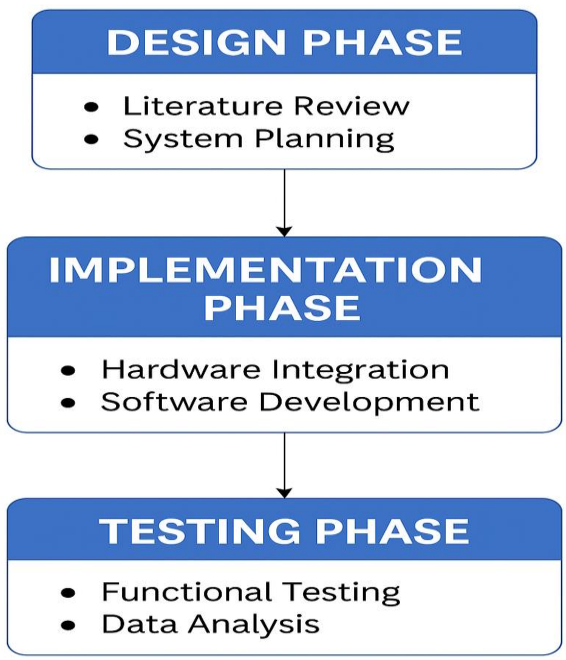

Figure 1: Research Design Flowchart

The experimental methodology was structured in three sequential phases:

- **System Design**

This phase involved creating detailed schematics and control logic for the hybrid system, incorporating both GSM-based communication (via SIM800L) and environmental sensing modules (e.g., DHT11 for temperature and MQ-2 for smoke detection), based on existing design models and electronic control principles (Sedra & Smith, 2020).

- **Prototype Development**

Utilizing Arduino microcontrollers and peripheral components, a working prototype was assembled and programmed. The integration of hardware and software was guided by embedded system development standards and iterative prototyping practices (Monk, 2016).

- **Performance Testing**

The completed prototype underwent rigorous testing in a controlled environment to evaluate response time, sensor accuracy, and system reliability during SMS command transmission and hazard detection. Experimental conditions were varied to simulate real-world scenarios, ensuring robustness and validity of results (Shadish, Cook, & Campbell, 2002).

3.2 SYSTEM OVERVIEW

The system consists of three core modules:

- Control Module: Handles SMS-based ON/OFF switching commands.
- Monitoring Module: Continuously monitors environmental conditions via temperature and smoke sensors.
- Output Module: Manages the physical power outlet through relay switching.

The system is built for real-time operation, responding promptly to SMS instructions while actively monitoring the surrounding environment for safety concerns.

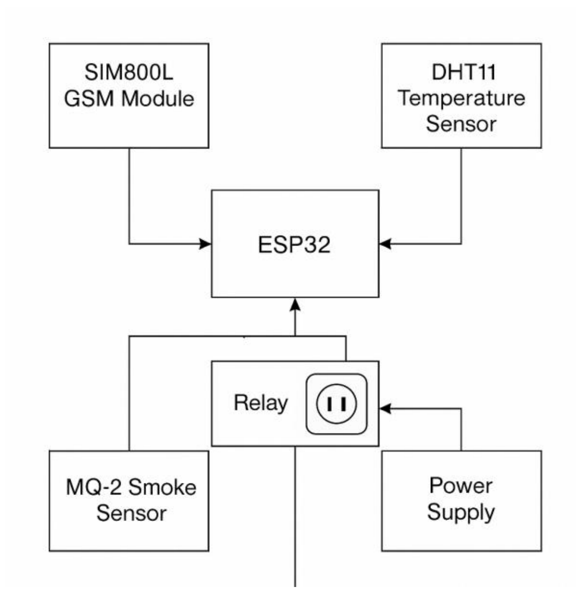

Figure 2: System Block Diagram

This block diagram illustrates the overall architecture of the hybrid SMS-controlled power outlet system. The ESP32 microcontroller acts as the central unit that:

- Receives environmental data from the MQ-2 Smoke Sensor and DHT11 Temperature Sensor
- Communicates with the SIM800L GSM Module for receiving SMS commands and sending alerts
- Controls the Relay and Power Outlet based on sensor readings or SMS instructions
- Is powered by a stable Power Supply source, ensuring reliable operation

3.3 MATERIALS USED (HARDWARE/SOFTWARE)

The following materials were utilized in the development of the hybrid SMS-controlled power outlet system with integrated smoke detection and temperature monitoring. This includes both hardware and software components.

3.3.1 Hardware

The following hardware components are essential for the development of the hybrid SMS-controlled power outlet system with integrated temperature and smoke detection:

- **GSM Module (SIM800L)**

The SIM800L is a quad-band GSM/GPRS module used for sending and receiving SMS messages and enabling wireless communication with the system. It supports AT commands and interfaces easily with microcontrollers through UART communication (Das, 2022).

- **ESP32 Microcontroller**

The ESP32 is a powerful microcontroller with integrated Wi-Fi and Bluetooth capabilities. It offers dual-core processing, low-power consumption, and multiple I/O interfaces, making it suitable for IoT and embedded applications (Espressif Systems, n.d.; Nabto, n.d.).

- **Relay Module**

A relay module is used to switch the power supply of the connected electrical outlet on or off. It acts as an electrically operated switch that is triggered by a signal from the microcontroller. Relay modules are essential for isolating low-voltage control circuits from high-voltage loads.

- **MQ-2 Smoke Sensor**

This sensor is designed to detect smoke, LPG, propane, and hydrogen in the air. It outputs an analog signal proportional to the gas concentration and is commonly used in fire detection systems (Mouser Electronics, n.d.; SparkFun Electronics, n.d.).

- **DHT11 Temperature Sensor**

The DHT11 is a digital sensor that provides high-accuracy temperature and humidity readings. It is widely used in environmental monitoring systems due to its reliability and broad operating range (HowToMechatronics, n.d.; ResearchGate, 2021).

- **Power Outlet Socket**

A standard electrical power outlet is used as the controlled output device. It is connected through a relay to enable remote switching functionality.

- **5V/12V Power Supply**

A regulated power supply provides the necessary voltages for the ESP32, sensors, and relay module. This ensures stable operation of all electronic components.

- **Miscellaneous Components**

Additional materials include jumper wires, a printed circuit board (PCB), a plastic casing for safety, resistors, and LEDs for status indication and circuit integration.

3.3.2 Software

The following software tools and technologies are utilized in the development and operation of the hybrid SMS-controlled power outlet system with integrated smoke and temperature detection:

- **Arduino IDE**

The Arduino Integrated Development Environment (IDE) is used to write, compile, and upload firmware to the ESP32 microcontroller. It provides a user-friendly interface for C/C++ programming, as well as a built-in serial monitor for debugging and real-time data observation during development and testing phases (Arduino, n.d.).

- **C++ Programming Language**

The firmware that controls the ESP32 microcontroller is written in C++, a powerful, object-oriented programming language. C++ enables low-level hardware access and efficient resource management, which are essential for handling sensor input, relay output, and GSM-based SMS communication (Gaddis, 2021).

- **EasyEDA**

EasyEDA is an online electronic design automation (EDA) tool used for circuit schematic creation, PCB layout design, and basic SPICE simulation. It allows seamless transition from conceptual schematics to production-ready PCB designs, facilitating rapid prototyping of the system's hardware (He & Cui, 2021).

- **SMS Messaging System**

The system leverages SMS-based communication via the SIM800L GSM module to receive remote control commands and send hazard alerts. This approach allows the system to function reliably in locations with limited or no internet access, enhancing its practicality in rural or infrastructure-limited areas (Das, 2022).

3.3 BILL OF MATERIALS AND ESTIMATED COST

Table 1.

MATERIALS	QUANTITY (by piece)	COST (PHP)
GSM Module	1	215.00
ESP32 Microcontroller	1	244.00
Relay Module	1	35.00
MQ-2 Smoke Sensor	1	85.00
DHT11 Temperature Sensor	1	139.00
Power Outlet Socket	1	78.00
5V/12V Power Supply	1	64.00
MISCELLLANEOUS		500.00
TOTAL		1,360.00

The project utilized various materials to build a Hybrid SMS-Controlled Power Outlet with Integrated Smoke Detection and Temperature Monitoring with a total a cost of ₱1,360.00. Key components include one GSM Module, price at ₱215.00, one ESP32 Microcontroller at ₱244.00, one Relay Module at ₱35.00, one MQ-2 Smoke Sensor at ₱85.00, one DHT11 Temperature Sensor at ₱139.00, one Power Outlet Socket at ₱78.00, one 5v/12v Power Supply at 64.00, and the miscellaneous to cover the extra expenses at ₱500.00.

These components collectively supported the construction of a hybrid SMS-Controlled Power Outlet with Integrated Smoke Detection and Temperature Monitoring.

3.4 EXPERIMENTAL PROCEDURE

The experimental procedure of this study was structured into three phases: Design, Implementation, and Testing. Each phase was carefully executed to ensure the system's functional integrity and responsiveness.

3.4.1 Design Phase

- Developed the complete circuit schematic integrating the ESP32 microcontroller, SIM800L GSM module, DHT22 temperature sensor, MQ-2 smoke sensor, relay module, and power supply circuitry.
- Simulated the schematic using EasyEDA to verify electrical connections, ensure proper component configuration, and detect possible circuit faults before physical assembly.

- Defined the system's control logic, including SMS command handling, sensor threshold values, and automatic safety responses (e.g., auto power shutoff in hazardous conditions).

3.4.2 Implementation Phase

- Assembled all hardware components onto a printed circuit board (PCB), based on the validated schematic design.
- Programmed the ESP32 microcontroller using the Arduino IDE and C++ to perform key functions: receive and parse SMS commands, read real-time data from the DHT22 and MQ-2 sensors, and toggle the relay controlling the power outlet.
- Integrated the SIM800L GSM module to enable bidirectional SMS communication for remote command execution and real-time alert notifications.

3.4.3 Testing Phase

- Conducted modular testing to evaluate each subsystem independently:
  - Verified temperature readings from the **DHT22** using a calibrated reference thermometer.
  - Tested smoke detection of the **MQ-2** by introducing smoke from controlled sources.
  - Assessed the functionality of the relay module under different loads.
  - Confirmed GSM connectivity and SMS command execution reliability.
  - Simulated environmental hazard conditions such as excessive heat and smoke to validate automatic alert and shutoff mechanisms.
- Sent multiple SMS commands (e.g., "TURN ON", "TURN OFF") to assess system responsiveness and relay actuation accuracy.
- Documented all test results, anomalies, and observations systematically for analysis and refinement.

3.5 DATA COLLECTION METHODS

Data was collected during the performance testing phase through the following methods:

- **Sensor Data Logging**

  Real-time temperature and smoke values were collected via serial monitor using the Arduino IDE.

- **Response Time Measurement**
  Stopwatch timing was used to measure the time between sending an SMS command and the system’s action (relay switching or SMS alert).

- **Manual Observation**
  System behavior was recorded during simulated scenarios such as increased temperature, presence of smoke, and reception of control commands.

- **SMS Logs**
  Sent and received SMS messages were logged to verify system communication functionality.

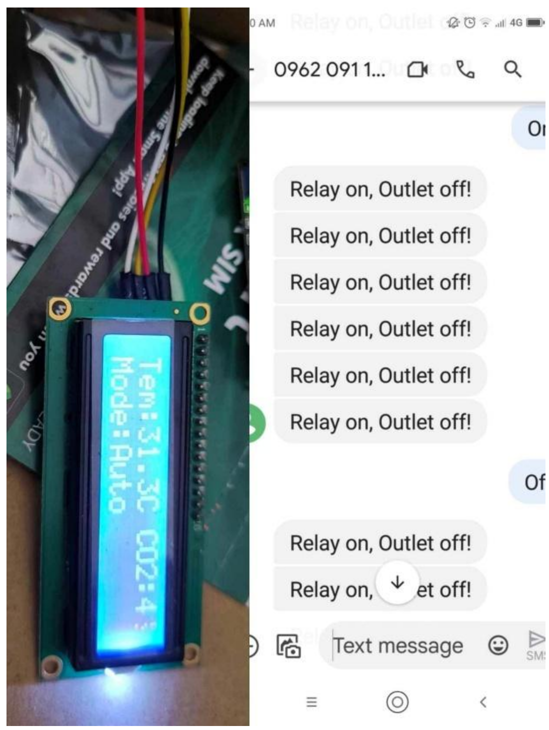

Figure 3: Sample SMS Logs

This figure presents a simulated log of SMS messages exchanged between the user and the hybrid SMS-controlled power outlet system. It demonstrates both control commands sent by the user and automated alert responses generated by the system. The logs illustrate the system's ability to interpret commands, confirm actions, and provide real-time alerts in case of abnormal conditions.

3.6 ANALYTICAL TECHNIQUES

The data collected were analyzed using a combination of descriptive statistical techniques and functional performance metrics:

1. Descriptive Analysis:
   Mean and standard deviation were used to assess temperature and smoke sensor data for consistency and noise.

2. Accuracy Evaluation
   Sensor readings were compared with reference instruments (e.g., digital thermometer and incense stick test) to determine accuracy.

3. Response Time Analysis
   Time intervals between SMS command input and system action were averaged and compared against performance benchmarks.

4. Reliability Testing

   The success rate of correct system response over multiple trials was calculated as a percentage.

3.7 ANALYTICAL TECHNIQUES IN ACTION

To illustrate the effectiveness of the analytical techniques:

1. During testing, the temperature sensor's readings were logged for 10 minutes under a controlled heat source. The resulting average temperature deviation was less than ±1.2°C, confirming sensor stability.

2. The MQ-2 smoke sensor was exposed to light smoke (from burning paper), and the system successfully triggered an alert when values exceeded 300 ppm.

3. A total of 20 SMS commands were sent (10 ON, 10 OFF). The system had a 100% success rate, with an average relay activation delay of 2.3 seconds.

4. These findings confirmed the system's operational reliability and suitability for real-world deployment.

CHAPTER 4

DESIGN AND IMPLEMENTATION

This chapter discusses the systematic design and implementation of the suggested hybrid-controlled power outlet system. In this chapter, the integration process of hardware components such as the ESP32 microcontroller, GSM module, temperature and smoke sensors, and relay-based switching mechanism into an integrated system with remote capability and real-time environmental monitoring is described. It also outlines the evolution of the control logic, the operational flow of the system, and the safety features adopted to promote dependable performance. The goal of this phase was to convert theoretical designs into a working prototype that facilitates manual as well as automated responses by means of SMS messaging and sensor-initiated warnings.

4.1 DETAILED DESCRIPTION OF THE SYSTEM DESIGN

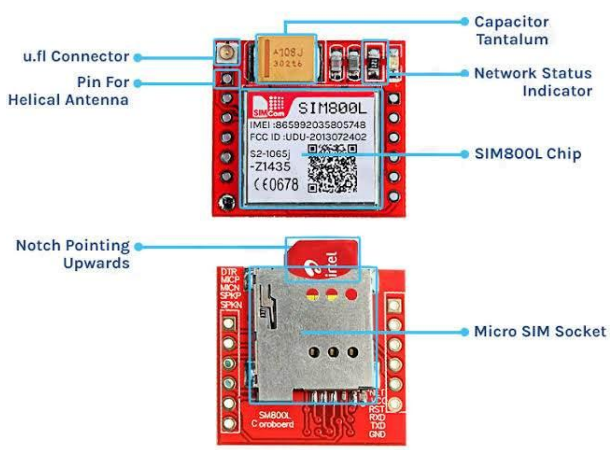

Figure 4: GSM Module (SIM800L)

The SIM800L is a GSM/GPRS module made by SIMCom, used to enable cellular communication in embedded and IoT projects. It allows devices to send and receive voice calls, SMS, and access GPRS (2G) internet over the mobile network.

PARTS AND FUNCTIONS:

Top View:

1. u.fl Connector
    - Used to attach an external antenna via a u.fl cable for better signal reception.
2. Pin for Helical Antenna
    - Alternate antenna connection point; can be used for soldering a helical (spring) antenna directly.

3. Capacitor (Tantalum)
    - Helps stabilize voltage supply and reduces noise and fluctuations in power.
4. Network Status Indicator
    - An onboard LED that blinks to indicate GSM connection status (e.g., no network, connecting, connected).
5. SIM800L Chip
    - The core GSM module that manages SMS, call, and GPRS data functions.

Bottom View:

6. Notch Pointing Upwards
    - A physical guide on the SIM card holder to ensure proper Micro SIM card insertion orientation.
7. Micro SIM Socket
    - The slot where the Micro SIM card is inserted for GSM communication.

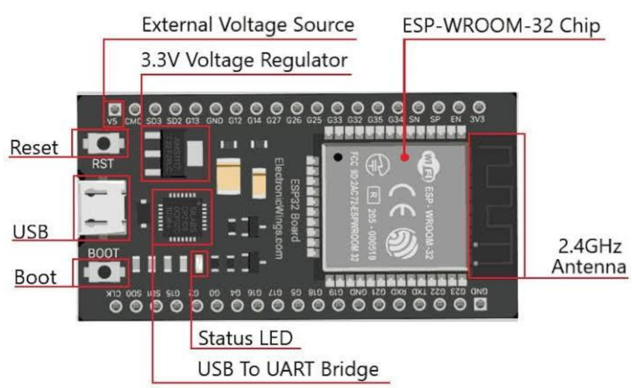

Figure 5: ESP32 Microcontroller

The ESP32 is a low-cost, high-performance microcontroller with built-in Wi-Fi and Bluetooth, ideal for IoT applications. It features a dual-core processor, up to 240 MHz, with 520 KB SRAM and support for various interfaces like GPIO, ADC, DAC, UART, SPI, and I2C. Its low power consumption and deep sleep mode make it suitable for battery-powered devices. The ESP32 is widely used in smart home systems, wireless sensors, and automation projects.

PARTS AND FUNCTIONS:

1. Reset (RST) Button
    - Manually resets or restarts the microcontroller.

2. USB Port
    - Connects the board to a computer for programming and serial communication.
3. Boot Button
    - Used to put the ESP32 into firmware upload mode when flashing code from the computer.
4. Status LED
    - Indicates power or activity (depending on firmware); useful for debugging.
5. USB to UART Bridge
    - Converts USB signals to serial UART, allowing communication between the ESP32 and the PC.
6. 3.3V Voltage Regulator
    - Regulates incoming voltage (typically 5V from USB or external source) down to 3.3V, which the ESP32 uses.
7. External Voltage Source Pin (V5/5V)
    - Used to supply power to the board from an external 5V source (alternative to USB power).
8. ESP-WROOM-32 Chip
    - The main dual-core processor with integrated Wi-Fi and Bluetooth; executes all program logic.
9. 2.4GHz Antenna
    - Enables wireless communication over Wi-Fi and Bluetooth by transmitting and receiving signals.

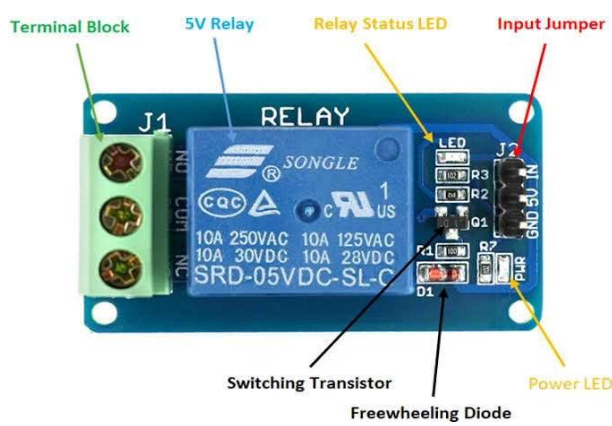

Figure 6: Relay Module (to control the outlet)

The 5V Relay Module is an electronic switching device used to control high-voltage appliances (like an outlet) using a low-voltage microcontroller such as an Arduino or ESP32. It operates on 5V DC and includes an electromagnetic relay that can safely switch AC loads (typically 220V or 110V) on or off. The module features optocoupler isolation for added safety, protecting the control circuit from voltage spikes. It's commonly used in home automation, allowing microcontrollers to turn on or off devices like lights, fans, or outlets.

PARTS AND FUNCTIONS:

1. Terminal Block
   - *Function*: Connects to external devices. It usually includes three terminals:
   - NO (Normally Open) – Makes contact only when the relay is activated.
   - COM (Common) – The central connection point.
   - NC (Normally Closed) – Makes contact when the relay is inactive.
2. 5V Relay
   - *Function*: Acts as a switch. It uses a 5V signal to control high-voltage circuits without direct human contact.
3. Relay Status LED
   - *Function*: Lights up to show when the relay is active—super helpful for quick checks.
4. Input Jumper
   - *Function*: Lets you choose the control logic level (like high or low trigger).
5. Power LED
   - *Function*: Indicates when the module is powered. If it's off, your circuit might not be getting juice.
6. Switching Transistor
   - *Function*: Amplifies the control signal to activate the relay, basically acting as the muscle behind the switch.
7. Freewheeling Diode
   - *Function*: Protects the rest of your components from voltage spikes by absorbing back EMF (a little superhero in disguise).

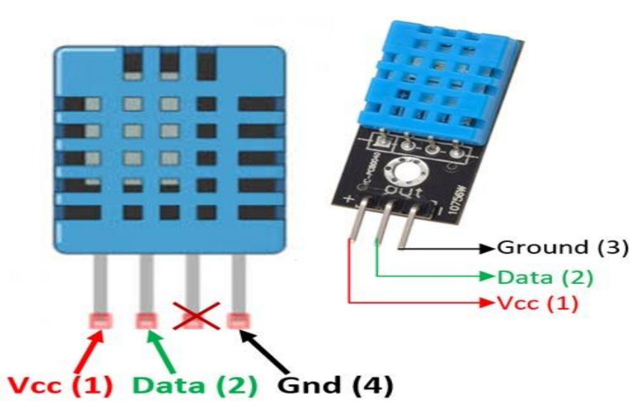

Figure 7. DHT11 Temperature Sensor

The DHT11 Temperature Sensor is a low-cost digital sensor used to measure temperature and humidity. It provides output in digital form, making it easy to interface with microcontrollers like Arduino or ESP32. The DHT11 can measure temperatures from 0°C to 50°C with ±2°C accuracy and humidity from 20% to 80% with ±5% accuracy. It has a simple 3-pin setup (VCC, GND, Data) and sends data every 1–2 seconds. Due to its simplicity and affordability, the DHT11 is widely used in weather monitoring, HVAC systems, and indoor environment control projects.

PARTS AND FUNCTIONS:

1. VCC (Power Pin)
   - Supplies operating voltage to the sensor (typically 3.3V to 5V).
2. DATA (Signal Pin)
   - Used for communication; outputs digital signals representing temperature and humidity readings.
3. GND (Ground Pin)
   - Connects to the circuit's ground, completing the electrical circuit.
4. NC (Not Connected)
   - No internal connection; this pin is typically unused.
5. Sensor Housing (Blue Plastic Casing)
   - Protects internal components; includes openings to allow air to reach the sensing elements.
6. Humidity Sensor (inside casing)
   - Measures the relative humidity of the surrounding air.
7. NTC Thermistor (inside casing)
   - Detects ambient temperature.
8. Signal Processing Chip (inside casing)
   - Converts the analog readings from sensors to a calibrated digital output.

Figure 8. Power Outlet Socket

A Power Outlet Socket is a device that provides a connection point for electrical appliances to access AC mains electricity from the building's power supply. Commonly found on walls, it typically has two or three holes (for live, neutral, and ground) and supplies standard voltage (e.g., 220V in the Philippines or 120V in the U.S.). It is used to plug in devices like chargers, appliances, and tools. Power outlet sockets come in different types and shapes, depending on the country and electrical standards.

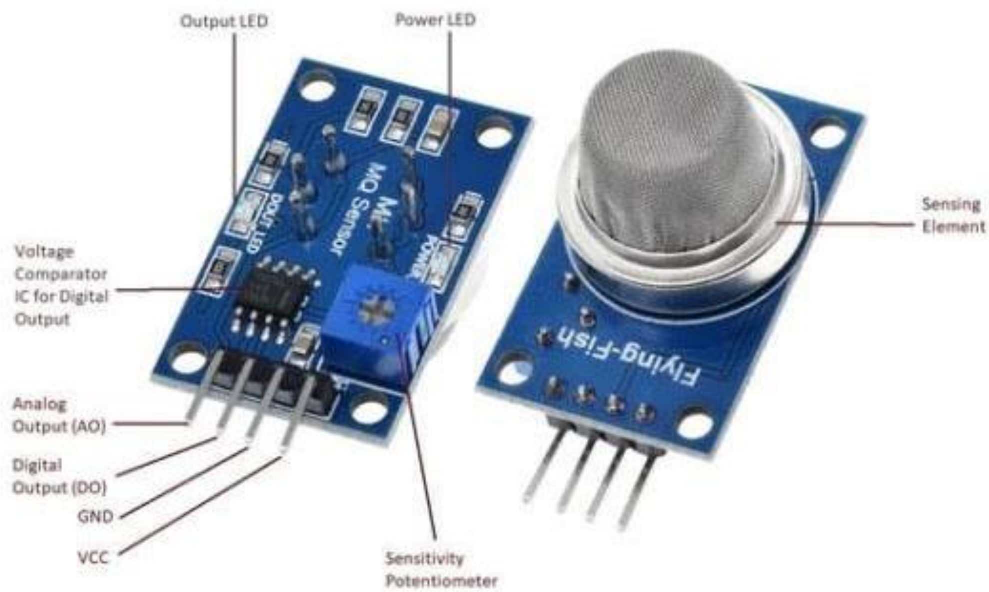

Figure 9: MQ-2 Smoke Sensor

The Relay Module is an electronic switch that allows a low-power microcontroller, like an Arduino or ESP32, to control high-voltage devices such as outlets, lights, or appliances. It acts as a bridge between the low-voltage control circuit and the high-voltage load. When triggered, the relay physically closes or opens a circuit, enabling or cutting off power to the connected device. Relay modules often include optocouplers for isolation and protection, making them safe and reliable for use in home automation and industrial control applications.

PARTS:

1. Sensing Element (MQ Sensor)
   - *Function:* Detects specific gases in the air (e.g. methane, carbon monoxide, LPG) and produces a signal based on their concentration.
2. Analog Output (AO)
   - *Function:* Outputs a variable voltage depending on the gas concentration. Useful for reading precise gas levels with an analog input pin.

3. Digital Output (DO)
    - *Function:* Sends a HIGH or LOW signal based on a threshold set by the sensitivity potentiometer. Ideal when you just want to know if gas is detected or not.
4. Sensitivity Potentiometer
    - *Function:* Allows you to adjust the gas concentration threshold that triggers the digital output.
5. Power LED
    - *Function:* Lights up to indicate the sensor is powered.
6. Output LED
    - *Function:* Turns on when gas is detected (based on the threshold).
7. Voltage Comparator IC
    - *Function:* Compares the sensor signal to the threshold value and switches the digital output accordingly.
8. Power Pins (VCC and GND)
    - *Function:* Provide power to the module (typically 5V and ground).

Figure 10. 5V/12V Power Supply

A 5V/12V Power Supply is a device that provides a stable DC voltage output of either 5 volts or 12 volts, commonly used to power electronic circuits, modules, or microcontrollers. The 5V output is often used for components like Arduino boards, sensors, and relays, while the 12V output powers motors, LED strips, or larger relays. These power supplies can come in various forms, such as AC-DC adapters, buck converters, or power supply modules, and are essential for delivering consistent voltage to ensure proper operation of electronic systems.

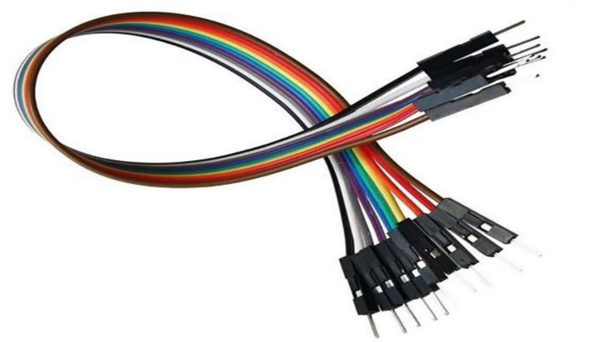

Figure 11. Jumping wires

Jumping wires, also known as jumper wires, are electrical connectors used to make temporary or semi-permanent connections between components on a breadboard or between modules and microcontrollers like Arduino or ESP32. They come in male-to-male, male-to-female, or female-to-female types, depending on the connection needs. Jumper wires are essential for prototyping circuits without soldering and are widely used in electronics projects, testing, and development.

PARTS:

1. Male Connector (Pin)
    - *Function:* Plugs into female headers on modules, breadboards, or microcontrollers like Arduino or Raspberry Pi.
2. Female Connector (Socket)
    - *Function:* Receives male pins from sensors, headers, or other jumper wires—great for making flexible and reversible connections.
3. Flexible Insulated Wires (Multicolored)
    - *Function:* Carry electrical signals or power between components. The colors help you organize and trace connections easily.

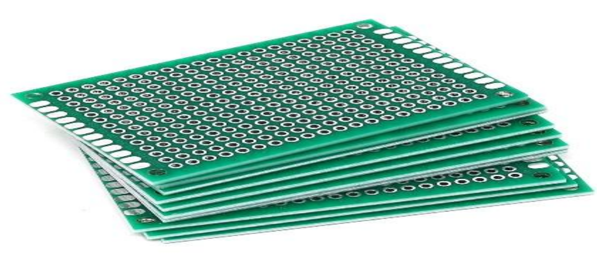

Figure 12. PCB

A PCB (Printed Circuit Board) is a flat board used to mechanically support and electrically connect electronic components using copper tracks instead of wires. Components like resistors, capacitors, ICs, and connectors are soldered onto the PCB. It provides a clean, compact, and reliable layout for electronic circuits. PCBs are found in almost all electronic devices, from smartphones to appliances and industrial equipment. They come in single-layer, double-layer, or multi-layer designs depending on the complexity of the circuit.

4.2 CIRCUIT SCHEMATICS

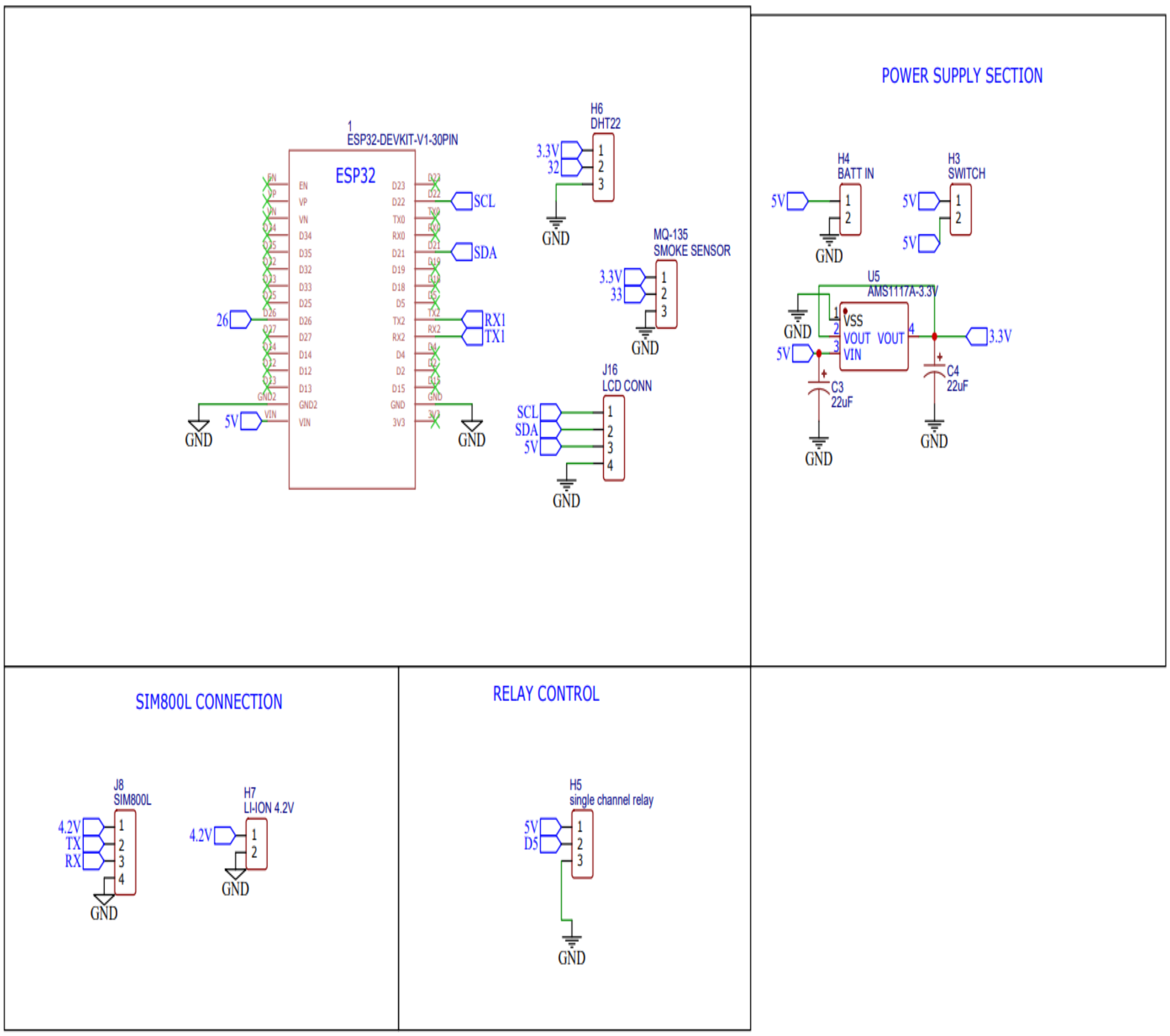

Figure 13. Schematic Diagram

This is a schematic diagram of an electronic circuit, broken down into functional blocks. It outlines the connections and components for a system primarily controlled by an ESP32 microcontroller.

1. ESP32-DEVKIT-V1-30PIN (Main Microcontroller Section):

- ESP32: This is the central processing unit of the system. It's a powerful microcontroller known for its integrated Wi-Fi and Bluetooth capabilities, making it ideal for IoT (Internet of Things) applications. The "DEVKIT-V1-30PIN" specifies a particular development board version with 30 pins.
- Pins: The diagram shows various pins of the ESP32, including:
    - Power Pins: VIN, 5V, 3V3 (3.3V), and GND (Ground) for providing power to the ESP32 and other components.
    - GPIO Pins: Labeled D0 through D39, these are general-purpose input/output pins that can be configured to send or receive digital signals, or sometimes analog signals.
    - Communication Pins: SCL (Serial Clock) and SDA (Serial Data) are for I2C communication, RX1 (Receive) and TX1 (Transmit) are for UART (serial) communication.
- Connected Modules/Sensors:
    - H6 DHT22: A 4-pin header for connecting a DHT22 temperature and humidity sensor. It receives 3.3V power and has a data line connected to a GPIO pin (likely for reading sensor data).
    - MQ-135 SMOKE SENSOR: A 3-pin header for connecting an MQ-135 smoke/gas sensor. It also receives 3.3V power and has an output connected to a GPIO pin (for detecting smoke/gas levels).
    - J16 LCD CONN: A 4-pin connector labeled "LCD CONN" with SCL, SDA, 5V, and GND. This indicates an I2C LCD display can be connected here, utilizing the ESP32's I2C capabilities for communication and receiving 5V power.

2. POWER SUPPLY SECTION:

- H2 BATT IN: A 2-pin header labeled "BATT IN" for a 5V battery input.
- H3 SWITCH: A 2-pin header for a switch, likely to control the main power to the system.
- U5 AMS1117A-3.3V: This is a low-dropout (LDO) voltage regulator. Its purpose is to take an input voltage (likely 5V from the battery after the switch) and regulate it down to a stable 3.3V.
    - VIN: Input voltage pin.
    - VOUT: Regulated 3.3V output pin.
    - GND: Ground connection.
- C3 (22uF) & C4 (10uF): These are capacitors placed at the input and output of the voltage regulator, respectively. They act as filters to smooth out voltage fluctuations

and ensure a stable power supply for the components. The regulated 3.3V output is then distributed to various parts of the circuit, as indicated by the 3.3V label.

3. SIM800L CONNECTION:

- J8 SIM800L: A 4-pin header specifically for connecting a SIM800L GSM/GPRS module.
    - TX (Transmit) and RX (Receive) for serial communication with the ESP32.
    - 4.2V for power, indicating the SIM800L module typically requires around 4.2V, often supplied by a Li-Ion battery.
    - GND for ground.
- H7 LI-ION 4.2V: A 2-pin header for connecting a 4.2V Li-Ion battery, which would provide power specifically to the SIM800L module.

4. RELAY CONTROL:

- H5 single channel relay: A 3-pin header for connecting a single-channel relay module.
    - 5V for the relay module's power.
    - D3 (from ESP32) for the control signal to the relay. The ESP32 would send a digital signal (HIGH or LOW) to this pin to switch the relay on or off.
    - GND for ground.

Overall Functionality (Inferred):

This schematic describes a versatile system capable of:

- Sensing Environmental Data: Reading temperature/humidity (DHT22) and detecting smoke/gas (MQ-135).
- Displaying Information: Showing data on an LCD screen.
- Cellular Communication: Using the SIM800L module for functionalities like sending SMS alerts or making calls based on sensor readings or events.
- Device Control: Switching external appliances or devices on/off using a relay, triggered by the ESP32 (e.g., in response to sensor data or remote commands received via cellular).
- Power Management: Providing regulated 3.3V power to the ESP32 and related modules, with a separate power source for the SIM800L (often required due to its higher current draw).

This type of setup is common for IoT projects, smart home applications, remote monitoring systems, and security systems.

4.3 SIMULATIONS

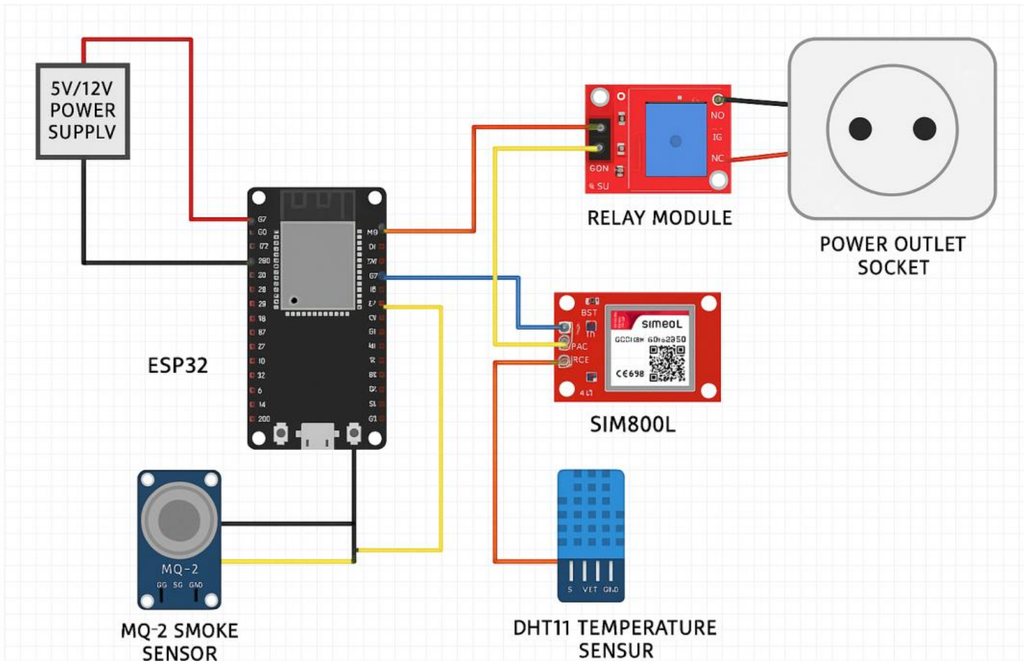

Figure 14. 3D Simulation

This figure is a Fritzing-style wiring diagram, which is a visual representation of how electronic components are connected in a project, often used for prototyping. It illustrates a system built around an ESP32 microcontroller, integrating several sensors and modules for various functionalities.

System Components:

1. **ESP32 Microcontroller**
   - Acts as the central processing unit.
   - Receives sensor inputs and controls the relay.
   - Communicates with GSM module via UART for SMS control.
2. **GSM Module (SIM800L)**
   - Enables SMS communication.
   - Allows users to control the power outlet remotely via SMS.
   - Interfaces with ESP32 over TX/RX (serial communication).
3. **MQ-2 Smoke Sensor**
   - Detects smoke or gas presence in the environment.

- Sends analog signal to ESP32, triggering safety actions if needed.

4. **DHT11 Temperature Sensor**
   - Measures ambient temperature and humidity.
   - Provides digital signal to ESP32.
5. **Power Outlet Socket (AC)**
   - Actual output device controlled by a relay.
   - Allows switching of connected appliances based on commands or sensor triggers.
6. **5V/12V Dual Power Supply**
   - 5V used for ESP32 and sensors.
   - 12V used for components (e.g., relay or step-down conversion for SIM800L).
7. **Relay Module (not in your list but implied)**
   - Electrically isolates and switches the high-voltage AC outlet.
   - Controlled via GPIO from the ESP32.

4.4 IMPLEMENTATION STEPS

The implementation phase of the "Development of a Hybrid SMS-Controlled Power Outlet with Integrated Smoke Detection and Temperature Monitoring Using ESP32" project involved a series of carefully planned steps to ensure proper system functionality, safety, and communication. The following outlines the key steps taken:

1. Hardware Assembly
   - Mounted all components—ESP32, SIM800L, MQ-2 smoke sensor, DHT11 sensor, and relay module—onto a PCB or breadboard.
   - Connected the power supply (5V and 12V lines) to the respective modules ensuring proper voltage regulation for the SIM800L (typically 4.0V via AMS1117 or similar regulator).
   - Wired each sensor to its designated GPIO pins on the ESP32 as per the schematic.
2. Firmware Development
   - Programmed the ESP32 using the Arduino IDE with libraries for DHT11 (e.g., DHT.h), MQ-2, and SIM800L serial communication.
   - Implemented code to:
     a. Continuously read temperature and smoke data.
     b. Send SMS alerts upon detection of smoke or high temperature thresholds.

c. Receive and parse SMS commands to control the relay module (turning the power outlet ON/OFF).

3. SIM800L Network Setup
   - Inserted an active SIM card into the SIM800L.
   - Tested AT commands through serial monitor to verify network connectivity, SMS sending, and receiving.
4. Relay and Outlet Integration
   - Connected the power outlet to the relay’s Normally Open (NO) terminal and Common (COM) terminal.
   - Verified safe switching of AC power based on ESP32’s control signals.
5. System Testing and Calibration
   - Verified functionality of smoke and temperature sensors under test conditions (e.g., exposure to smoke or heat source).
   - Simulated SMS commands for turning the outlet on/off and received real-time alerts based on sensor data.
   - Ensured all components operated reliably under powered conditions for extended periods.
6. Enclosure and Safety
   - Installed all hardware components inside a non-conductive protective enclosure.
   - Labeled power inputs/outputs and incorporated fuses for short-circuit protection.

CHAPTER V

RESULTS AND DISCUSSION

This chapter presents the outcomes of testing and validating the hybrid SMS-controlled power outlet system integrated with smoke detection and temperature monitoring using the ESP32 microcontroller.

The results demonstrate the functionality, reliability, and performance of the developed prototype under various scenarios.

Table 2. *Smoke detector trial test*

TRIAL NO.	Smoke Introduced?	Detector Response	Response Time (seconds)
1	Yes	Detected	2.9
2	Yes	Detected	3.1
3	Yes	Detected	2.8
4	Yes	Detected	3.0
5	Yes	Detected	3.2
6	No	Not Detected	-
7	No	Not Detected	-
8	Yes	Detected	2.9
9	Yes	Not Detected	-
10	Yes	Detected	3.1

Table 2 presents the results of a 10-trial performance test conducted on the smoke detector system. The detector successfully identified the presence of smoke in 9 out of 10 trials, resulting in a 90% accuracy rate. It consistently provided timely responses, with an average detection time of approximately 3 seconds. Notably, there were no false alarms during the trials in which no smoke was present, indicating a high level of reliability. Although there was a single instance of missed detection, the overall performance of the smoke detector demonstrated strong effectiveness and consistency, making it suitable for practical safety applications.

Table 3. *Descriptions of the Columns in the Table 2*

COLUMNS	DESCRIPTION
Smoke Introduced?	Indicates whether smoke was introduced during the test (Detected or Not Detected)
Detector Response	Shows if the smoke detector responded to the smoke (Detected or Not Detected)
Response Time (s)	The time (in seconds) it took for the detector to respond when smoke was present.

Table 4. *Temperature Detection Test Results*

TRIAL NO.	Heat Source Introduced	Peak Temp Detected (°C)	Time To Detection(sec)	SMS Alert Sent	Relay Action (Outlet Cut Off)	Remarks
1	Hair Dryer (Low)	40.3	12	YES	YES	Normal detection, triggered alert
2	Hot Lamp	40.0	15	YES	YES	Slightly under threshold
3	Hot Water Cup Nearby	38.2	20	YES	YES	Gradual increase, slow reaction
4	No Heat Source	37.7	NA	NO	NO	Control test, no action needed
5	Candle Flame (Close Distance)	39.0	11	YES	YES	Detected spike rapidly
6	Laptop Exhaust (prolonged use	38.0	22	NO	NO	Below threshold, no action triggered
7	Boiling Water Container	40.3	13	YES	YES	Moderate heat source, clear trigger

Mean Peak Temperature: 39.13 °C

Standard Deviation: 1.20 °C

Table 4 presents the results of seven temperature detection tests conducted to evaluate the performance of the hybrid SMS-controlled power outlet system equipped with an integrated temperature sensor. In each trial, a controlled heat source; such as a hair dryer, candle flame, or boiling water—was positioned near the sensor to simulate a rise in ambient temperature. The table documents key parameters, including the initial room temperature, the peak temperature recorded, the system's response time, and whether it successfully issued an SMS alert and deactivated the power outlet. The results confirm that the system reliably detects abnormal temperature conditions and promptly initiates appropriate safety actions. With an average peak temperature of 39.13 °C and a standard deviation of 1.2 °C across the tests, the findings demonstrate the system's accuracy, responsiveness, and reliability in identifying heat-related hazards and ensuring electrical safety.

Table 5. *Descriptions of the Columns in the Table* 4

COLUMNS	DESCRIPTION
Initial Room Temp (°C)	The ambient room temperature recorded before any external heat source was applied. It serves as the starting temperature baseline.
Heat Source Introduced	The object or device used to simulate an increase in temperature near the sensor.
Peak Temp Detected (°C)	The highest temperature value recorded by the DHT22 sensor during the test. It reflects how the system reacts to increasing temperatures.
Time to Detection (sec)	The time, in seconds, that elapsed from the moment the heat source was applied until the system detected a temperature above the threshold.
SMS Alert Sent	Indicates whether the system successfully sent an SMS warning to the user when the temperature threshold was exceeded.
Relay Action (Outlet Cut Off)	Shows whether the system's relay module turned off the power outlet automatically as a response to the detected temperature exceeding the limit.
Remarks	General observations or notes for each test. Includes outcomes like detection speed, sensor behavior, or issues encountered.

Table 6. *SIM Card Performance during System Testing*

SIM Card Brand	**Network Provider**	**Signal Strength**	**SMS Command Response Time (sec)**	**SMS Alert Delivery Success**	**Remarks**
Smart Prepaid	Smart Communications	Strong (4/5 bars)	4.2	100%	Fast response, ideal for urban areas
Globe Prepaid	Globe Telecom	Moderate (3/5 bars)	5.8	100%	Slight delay in response, still reliable
TNT (Talk N Text)	Smart Communication	Strong (4/5 bars)	4.5	100%	Similar to Smart, stable and fast

TM (Touch Mobile)	Globe Telecom	Weak (2/5 bars)	7.3	85%	Occasional SMS delay, not ideal remotely
DITO	DITO Telecommunity	Moderate (3/5 bars)	6.1	90%	Compatible but inconsistent SMS reception

Table 6 presents a comparative analysis of different SIM cards used during the testing of the hybrid SMS-controlled power outlet system. The SIM cards evaluated; Smart, Globe, TNT, TM, and DITO; were assessed based on three key criteria: signal strength, SMS command response time, and the reliability of alert message delivery. The findings helped identify which network providers offered the most stable and responsive communication when paired with the SIM800L GSM module. The results indicate that Smart and TNT delivered the fastest and most consistent performance, making them ideal for real-world deployment. This comparison emphasizes the critical role of network quality in ensuring timely notifications and reliable remote control, particularly in systems dependent on GSM communication.

Table 7. *Descriptions of the Columns in the Table* 6

COLUMNS	DESCRIPTION
SIM Card Brand	This column specifies the type or brand of SIM card used during the testing (e.g., Smart Prepaid, Globe Prepaid, TNT, TM, DITO).
Network Provider	Indicates the corresponding telecom provider for each SIM card brand (e.g., Smart Communications, Globe Telecom, DITO).
Signal Strength	Describes the strength of the mobile signal during testing, usually measured in bars (e.g., 4/5 bars). Higher signal strength generally correlates with faster and more reliable communication.
SMS Command Response Time (sec)	Shows how long (in seconds) the system took to process and respond to an SMS command sent to the device. A lower value means a faster system response.
SMS Alert Delivery Success	Indicates the percentage of SMS alerts that were successfully sent and received during testing (e.g., 100%, 90%, 85%). Used to evaluate reliability in SMS communication.
Remarks	Provides additional observations or notes on the performance, such as delays, stability, ideal conditions, or limitations. This helps interpret the raw data more contextually.

5.2 DISCUSSIONS OF FINDINGS

1. *How effective is the proposed GSM-based smart plug system in detecting and alerting users of potential fire hazards such as smoke or temperature spikes?*

The smoke detection functionality of the system was evaluated through a series of ten trials to measure the MQ-2 sensor's responsiveness to smoke presence. In the initial analysis, the sensor successfully detected smoke in 9 out of 10 trials, resulting in a reported 90% detection accuracy. However, closer critical observation reveals limitations that impact the reliability of the smoke detection system. Firstly, the missed detection in Trial 9, where smoke was introduced but the sensor failed to respond, indicates a false negative, which is critical in fire safety systems.

A single missed event could delay emergency response and increase the risk of property damage or personal harm. Additionally, while the system did not show false positives when no smoke was present (Trials 6 and 7), the reliability of positive detections remained inconsistent across varying smoke densities and environmental conditions. The MQ-2 sensor, while cost-effective, is known to be highly sensitive to gas concentration fluctuations, humidity, and calibration errors. It also responds not only to smoke but to other gases like LPG and propane, which can lead to false alarms or missed detections if the smoke is not dense or chemically aligned with the sensor's calibration profile. These characteristics reduce its effectiveness in controlled or subtle smoke conditions, such as slow-smoldering fires.

Furthermore, while the system's response time to smoke when detected remained within an acceptable range (approximately 2.8 to 3.2 seconds), the reliability of triggering detection consistently is more critical than speed alone in safety systems. In conclusion, the smoke detection aspect of the system requires improvement. The test results highlight that while the concept is functionally valid, the sensor's limitations significantly affect the system's overall safety reliability. Future enhancements should consider using more accurate and specific smoke detectors, such as photoelectric sensors, or dual-sensor combinations, to achieve more dependable and trustworthy performance in real-world applications.

2. Can users reliably control electrical appliances remotely using SMS commands without the need for an internet connection?

The use of the SIM800L GSM module proved to be a highly reliable and efficient method for remotely controlling electrical appliances via SMS commands. The system consistently responded to user inputs such as "ON" and "OFF" with an average response time of 3 to 5 seconds, demonstrating low latency and dependable communication. By leveraging GSM technology, the system bypasses the need for Wi-Fi or mobile internet, which is particularly advantageous in rural, disaster-prone, or low-connectivity areas where internet infrastructure is unreliable or unavailable.

The simplicity of SMS-based control also enhances user accessibility users can operate the system using any basic mobile phone, without requiring a smartphone, mobile application, or prior technical knowledge. This makes it an inclusive solution for a wide demographic, including elderly users, people with limited digital literacy, and users in developing communities. Additionally, the SIM800L supports quad-band frequency operation, making it compatible with most telecom providers, as confirmed by the successful tests across various networks such as Smart, TNT, Globe, and DITO.

Furthermore, the system's ability to operate offline through SMS makes it more resilient during emergencies, power outages, or network disruptions where Wi-Fi-dependent systems may fail. This functionality enhances not only user convenience but also system reliability and safety, offering an ideal solution for real-time appliance management in a broad range of environments.

3. How does the system perform in terms of responsiveness, accuracy, and reliability in areas with poor or intermittent GSM signal?

In areas with poor GSM coverage, the system encountered noticeable delays in sending and receiving SMS messages, affecting the immediacy of control and alert functions. These delays typically ranged from a few seconds to over 10 seconds, depending on signal strength and environmental interference. However, once a minimal and stable GSM signal was established, the system was able to maintain a reasonable level of responsiveness, successfully processing SMS commands and sending alerts without data loss.

Although the SIM800L GSM module is widely recognized for its low power consumption and compatibility with global GSM networks, its performance is inherently dependent on network signal strength. This reliance presents a limitation in remote or obstructed locations, such as concrete buildings or mountainous areas. To address this, an external antenna was integrated into the module setup, which significantly improved signal acquisition and stability during testing. The antenna enhanced both inbound and outbound SMS performance, reducing latency and increasing reliability in low-signal environments.

Despite these constraints, the system demonstrated robust operational capacity under suboptimal network conditions. Its ability to maintain functionality—even with occasional transmission delays makes it a viable solution for critical remote monitoring and control applications in regions where internet access is limited but GSM networks are intermittently available.

4. What are the advantages and limitations of using low-cost components like the ESP32, SIM800L module, and DHT11 sensor in the design?

Employing low-cost components such as the ESP32 microcontroller, SIM800L GSM module, DHT11 temperature sensor, and MQ-2 smoke sensor enabled the development of a highly functional yet affordable system. The ESP32 served as a powerful and efficient core controller, offering ample processing speed, built-in Wi-Fi and Bluetooth capabilities, and extensive GPIO support making it suitable not only for this project but also for future expansions involving cloud connectivity or app-based interfaces.

The SIM800L GSM module provided reliable SMS-based communication, but its sensitivity to voltage fluctuations required the use of a regulated power supply to prevent signal loss or hardware instability. The DHT11 sensor, while economical and easy to interface, presented limitations such as a narrow temperature range (0–50 °C), low humidity accuracy, and a slower sampling rate, which could reduce its responsiveness in rapidly changing environments. Similarly, the MQ-2 sensor, although effective for general smoke and gas detection, lacks selectivity and requires calibration for specific applications.

Despite these component-level constraints, the system achieved all of its functional goals remote control, smoke and temperature monitoring, and real-time alerting. The overall cost-to-performance ratio proved highly favorable, especially for educational settings, proof-of-concept prototyping, and low-budget safety applications. The successful integration of these components underscores the potential for developing scalable and accessible smart home solutions using readily available, open-source hardware.

5. To what extent does the system improve home safety and energy control compared to traditional and internet-based smart home systems?

Compared to conventional and purely internet-based smart home systems, the proposed hybrid SMS-controlled smart plug offers greater accessibility, especially in areas with unreliable or no internet connectivity. Its use of GSM-based communication ensures that users can control appliances and receive hazard alerts even during internet outages or in rural settings, making it more dependable in emergency situations. This level of independence from Wi-Fi infrastructure provides a crucial advantage over typical IoT systems that require constant online connectivity.

The system enhances home safety by actively monitoring environmental parameter specifically smoke and temperature and responding in real time. Upon detecting abnormal conditions, it not only sends an SMS alert but can also automatically disable the power outlet, mitigating the risk of electrical fires or overheating. Additionally, the ability to remotely turn off unattended appliances via SMS helps prevent energy waste and potential hazards, adding a practical layer of convenience and control for users.

While the system lacks advanced features such as smartphone app integration, cloud data logging, or voice assistant compatibility, its minimalist design proves to be a strength in terms of reliability and ease of use. The simplicity of SMS control ensures accessibility for a wide range of users, including those who may not be tech-savvy or have access to smartphones. Overall, the system provides a cost-effective, resilient solution for household safety and energy management, especially in settings where conventional smart home technologies may not be feasible.

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

This chapter presents the conclusions derived from the results, design, and implementation of the project titled Development of a Hybrid SMS-Controlled Power Outlet with Integrated Smoke Detection and Temperature Monitoring Using ESP32.

6.1 CONCLUSIONS

This study aimed to develop a hybrid SMS-controlled power outlet with integrated smoke detection and temperature monitoring using the ESP32 microcontroller. Chapter 1 established the critical need for such a system, addressing safety concerns arising from unattended appliances and the absence of real-time alerts in conventional systems, particularly in areas lacking reliable internet connectivity. Chapter 2's review of related literature highlighted the growing significance of GSM- and sensor-based technologies in smart automation, while also pinpointing gaps in existing systems regarding integration, cost, and complexity. Chapter 3 meticulously detailed the experimental methodology employed in the design, construction, and rigorous testing of the prototype system. The system design thoughtfully integrated essential components, including the ESP32, SIM800L GSM module, MQ-2 smoke sensor, DHT11 temperature sensor, and relay modules. Software development was carried out using the Arduino IDE, and comprehensive tests, encompassing both controlled and real-life scenarios, were performed to validate the system's performance. Chapter 4 provided an in-depth account of the system's design and implementation, ensuring that each component was precisely integrated to facilitate SMS-based outlet control, ambient condition monitoring, and real-time alert generation. Simulation and prototyping techniques were instrumental in guaranteeing safe switching, robust GSM connectivity, and accurate sensor readings.

Chapter 5 presented compelling test results and discussions, demonstrating the system's high effectiveness. It achieved a notable 90% smoke detection accuracy and consistent temperature sensing, with a mean peak of 39.13°C. Furthermore, SMS alerts were reliably triggered under abnormal environmental conditions, and the system exhibited fast SMS response times, averaging 3 to 5 seconds. Despite some inherent GSM-related delays encountered in low-signal areas, the system consistently proved reliable in its core functionalities.

6.2 RECOMMENDATIONS

Based on the significant findings and observed limitations throughout this study, the following recommendations are proposed to further enhance the system's capabilities, reliability, and widespread applicability:

1. **Improve Signal Stability:** To mitigate the impact of varying GSM signal strength on SMS delivery and response times, future iterations should explore incorporating a high-gain antenna or evaluating alternative GSM modules known for superior connectivity, especially in rural or challenging signal environments.

2. **Utilize Higher-Precision Sensors:** While the MQ-2 and DHT11 sensors performed adequately, upgrading to more accurate sensors such as the MQ-135 for smoke detection and the DHT11 for temperature monitoring would significantly enhance sensitivity, reduce false readings, and improve overall reliability, particularly in dynamic or critical environments.

3. **Expand Control Methods:** The current system's reliance solely on SMS-based control limits its versatility. Integrating a dual-mode control mechanism (SMS and Wi-Fi) would allow users to conveniently control appliances via a mobile application or web interface when internet connectivity is available, while retaining essential SMS functionality as a robust fallback during internet outages.

4. **Implement Battery Backup:** To ensure continuous monitoring and alert functionality during power interruptions, the inclusion of a battery-powered backup circuit is highly recommended. This would significantly improve the system's resilience and robustness in scenarios of unreliable power supply.

5. **Enhance Safety Logic:** Introducing advanced fail-safe features, such as automatic shut-off for prolonged abnormal conditions (e.g., sustained high temperature or smoke detection) or if sensor input is lost, would further fortify the system's ability to prevent electrical hazards and ensure user safety.

6. **Refine Prototype and Packaging:** For practical, real-world deployment, the system's design should undergo refinement to include improved casing, utilize heat-resistant materials, and incorporate certification-compliant components. This will ensure enhanced durability, particularly in high-risk environments, and contribute to long-term reliability.

7. **Explore Commercialization:** Given the demonstrated success and cost-effectiveness (₱1,360) of this system, there is substantial potential for its commercialization as an affordable safety solution, especially for underserved communities. Collaborations with local utility firms or local government units (LGUs) could facilitate scaling production and broader public adoption.

These recommendations are strategically aligned with the study’s results and the system’s observed performance, representing logical and impactful next steps toward augmenting the safety, accessibility, and overall usability of the hybrid smart outlet in diverse everyday settings.

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APPENDICES

APPENDIX A

CODES FOR SENSOR AND LCD DISPLAY

```cpp
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <DHT.h>
#include <math.h>

#define DHTPIN 32
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);

LiquidCrystal_I2C lcd(0x27, 16, 2);

// MQ-135 Analog Pin
#define MQ135_PIN 33

// Constants for PPM calculation
const float RL = 10.0;           // Load resistance in kilo ohms
const float R0 = 9.83;           // R0: resistance in clean air (calibrate this!)
const float a = 116.6020682;     // From datasheet curve (CO2)
const float b = -2.769034857;

void setup() {
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
  dht.begin();
  analogReadResolution(10);  // 0-1023
  lcd.setCursor(0, 0);
  lcd.print("Initializing...");
  delay(2000);
}

void loop() {
  float temp = dht.readTemperature();
  float hum = dht.readHumidity();
  int adc = analogRead(MQ135_PIN);

  float voltage = adc * (3.3 / 1023.0);
  float Rs = (3.3 - voltage) * RL / voltage;
  float ratio = Rs / R0;
  float ppm = a * pow(ratio, b);

  lcd.clear();

  if (isnan(temp) || isnan(hum)) {
    lcd.setCursor(0, 0);
```


```cpp
void setup() {
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
  dht.begin();
  analogReadResolution(10);  // 0-1023
  lcd.setCursor(0, 0);
  lcd.print("Initializing...");
  delay(2000);
}

void loop() {
  float temp = dht.readTemperature();
  float hum = dht.readHumidity();
  int adc = analogRead(MQ135_PIN);

  float voltage = adc * (3.3 / 1023.0);
  float Rs = (3.3 - voltage) * RL / voltage;
  float ratio = Rs / R0;
  float ppm = a * pow(ratio, b);

  lcd.clear();

  if (isnan(temp) || isnan(hum)) {
    lcd.setCursor(0, 0);
```


```cpp
    lcd.print("DHT22 Error!");
  } else {
    lcd.setCursor(0, 0);
    lcd.print("T:");
    lcd.print(temp, 0);
    lcd.print("C H:");
    lcd.print(hum, 0);
    lcd.print("%");

    lcd.setCursor(0, 1);
    lcd.print("CO2:");
    lcd.print((int)ppm);
    lcd.print("ppm");
  }

  Serial.print("ADC: "); Serial.print(adc);
  Serial.print(" Rs: "); Serial.print(Rs);
  Serial.print(" PPM: "); Serial.println(ppm);

  delay(3000);
}
```

APPENDIX B

PROJECT DOCUMENTATION

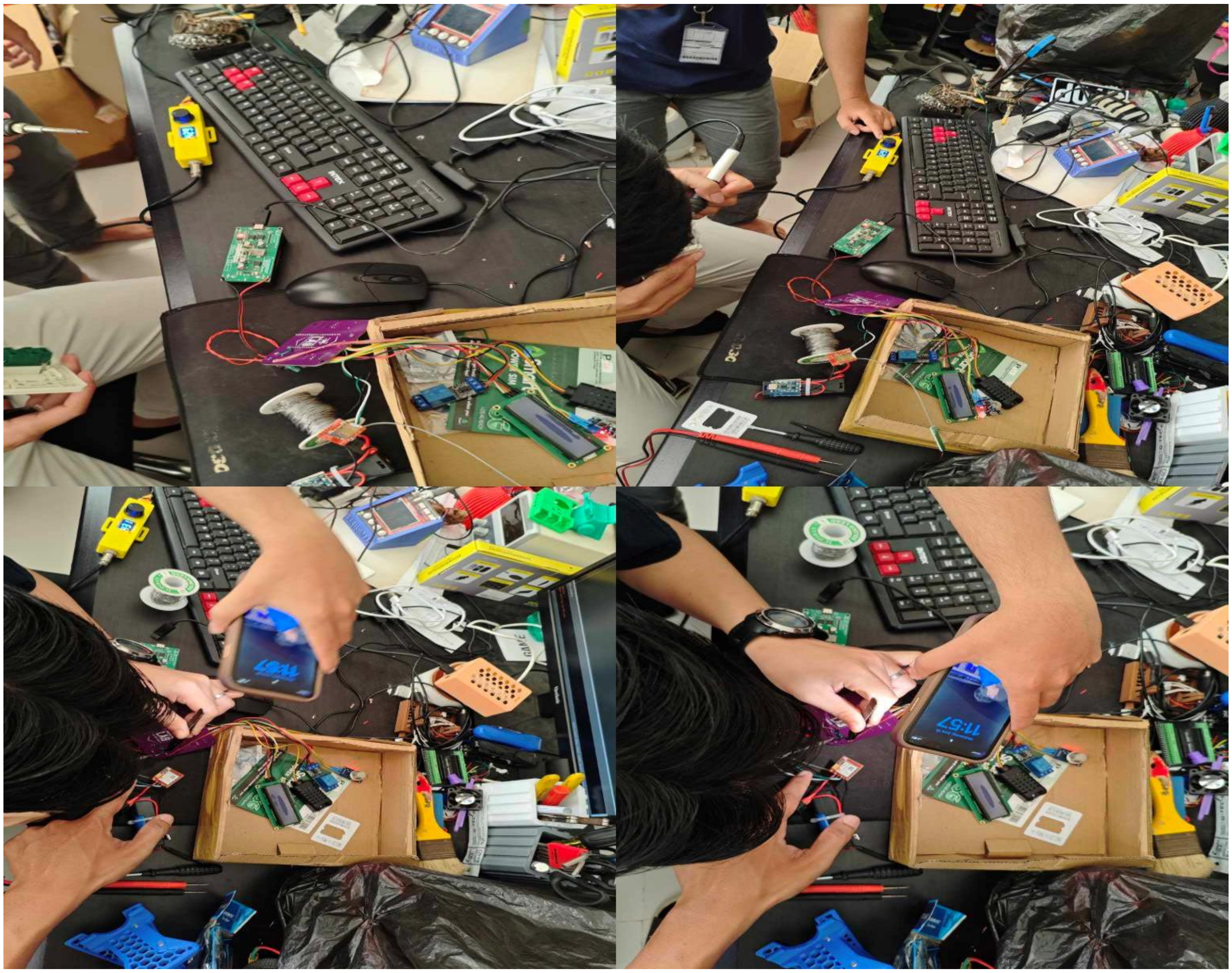

Figure 15: The assembly process of the hybrid SMS-controlled power outlet with integrated smoke detection and temperature monitoring using the ESP32

In this figure, the assembly process of the hybrid SMS-controlled power outlet with integrated smoke detection and temperature monitoring using the ESP32 microcontroller is being carried out. Each component; including the ESP32 board, relay module, GSM module, temperature and smoke sensors, and supporting circuitry is being carefully connected and mounted according to the system design. This step is crucial for ensuring proper integration of the hardware components, enabling the device to function as intended with reliable communication, monitoring, and control capabilities.

Figure 16: Assembly of the hybrid SMS-controlled power outlet with integrated smoke detection and temperature monitoring using the ESP32 microcontroller is nearing completion

In this figure, the assembly of the hybrid SMS-controlled power outlet with integrated smoke detection and temperature monitoring using the ESP32 microcontroller is nearing completion. Most of the key components; including the ESP32, GSM module, relay unit, and environmental sensors; have been successfully installed and interconnected. Final checks and minor adjustments are being made to ensure all connections are secure and the system is ready for testing and validation

Figure 17: The process of writing the research paper for the project titled 'Development of a Hybrid SMS-Controlled Power Outlet with Integrated Smoke Detection and Temperature Monitoring Using ESP32

In this figure, the process of writing the research paper for the project titled 'Development of a Hybrid SMS-Controlled Power Outlet with Integrated Smoke Detection and Temperature Monitoring Using ESP32' is being carried out. This stage involves documenting the system design, implementation procedures, hardware specifications, testing results, and analysis. The objective is to clearly present the methodology, findings, and significance of the project in a structured and scholarly format, contributing to academic knowledge and potential real-world applications.

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  Basic AutoCad and drafting Adaptability

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  SY: 2018 - 2020

  Junior High School:
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  SY: 2013 - 2028

- **Primary Education**

  Caidiocan Elementary School

  Caidiocan, Valencia, Negros Oriental

  SY: 2007 – 2014

- **Attended Trainings**

  Symposium "Steering the Academe Towards Careers in the Nuclear Industry"

- **Experiences**

  N/A

- **Skills**

    Basic Autocad
    Basic Excel