

“Home Automation System”

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ABSTRACT

The rapid advancement of technology and the increasing need for convenience have led to the development of smart home solutions that integrate various household devices into a centralized, automated system. This project, **“Home Automation System”**, aims to design and implement a cost-effective and reliable automation framework that allows users to control and monitor home appliances remotely through Internet of Things (IoT) technology. The proposed system utilizes sensors such as DHT for temperature and humidity, MQ6 for smoke detection, and SONAR for water level measurement, all connected to a microcontroller (Node MCU/Raspberry Pi) that serves as the central control unit. An Android application is used to send commands and receive real-time feedback, ensuring ease of use and accessibility. The implementation focuses on enhancing energy efficiency, improving security, and offering users greater control over their household environment. By integrating IoT and wireless communication technologies, the system provides a smart, scalable, and user-friendly solution for modern homes.

CHAPTER NO 1. INTRODUCTION

1.1 Overview

The concept of a 'smart home' has evolved significantly over the past two decades. From simple timer-based appliance controllers in the 1970s to fully networked, AI-assisted living environments today, home automation has grown into a multi-billion-dollar global industry. At its core, home automation aims to improve the quality of daily life by reducing the manual effort required to interact with household systems, improving energy efficiency, and enhancing safety and security.

A home automation system typically consists of three elements: sensors and actuators embedded in the home environment, a communication network to relay signals, and a user interface through which occupants issue commands or view status.

Modern systems leverage Wi-Fi, ZigBee, ZWave, or Wifi as the communication backbone, with smartphones, voice assistants, or web dashboards as the interface.

The global proliferation of Android smartphones has created an unprecedented opportunity to deploy low-cost, personalised home automation solutions without requiring dedicated proprietary hardware. Android devices are available at all price points, are widely understood by users, and provide rich hardware interfaces including Wifi, Wi-Fi, cameras, and microphones that can be exploited for home control.

This project focuses on a Wifi-based home automation system built around the ESP32 microcontroller. The ESP32 is an ultra-low-cost, high-performance SoC from Espressif Systems that integrates dual-core processing, built-in Wifi Classic and BLE, and Wi-Fi 802.11 b/g/n on a single chip. By exploiting the ESP32's built-in Wifi capability, the proposed system eliminates the need for external Wifi modules (such as HC-05 or HC-06), reducing hardware complexity and cost.

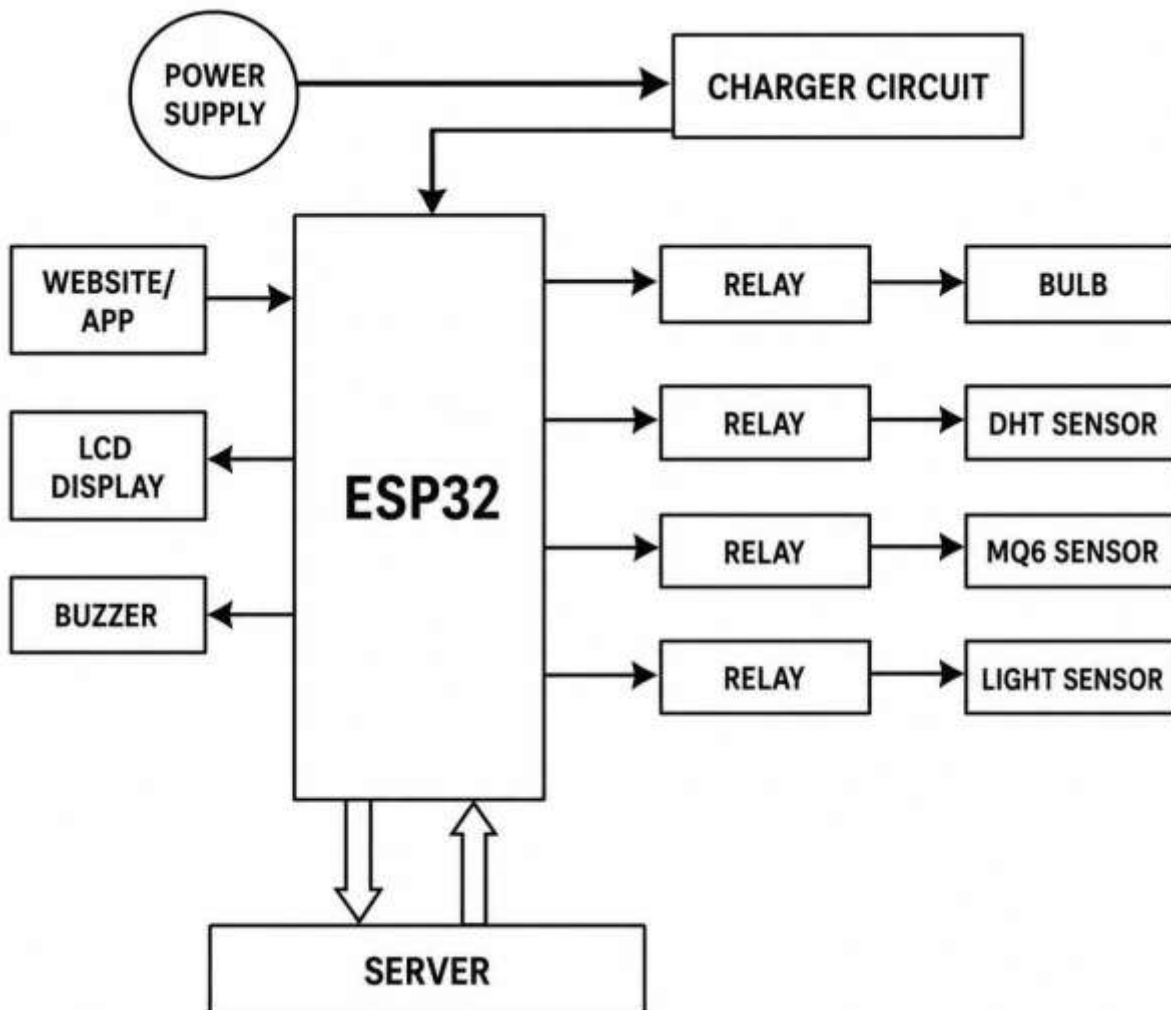


Fig. 1.1: Block Diagram of Home Automation System

1.2 Necessity of Home Automation

Despite the availability of technology, a large proportion of homes in India and other developing nations still rely entirely on manual electrical switches for appliance control. This creates several practical inconveniences and safety concerns:

- Inconvenience for the elderly and physically challenged: Reaching wall-mounted switchboards can be difficult or impossible for elderly persons with limited mobility, arthritic conditions, or disabilities. A smartphone-based control system removes this barrier completely.
- Energy waste: Studies indicate that lights and fans are frequently left running in unoccupied rooms due to forgetfulness. Remote control and eventual scheduled automation reduce unnecessary energy consumption.
- Safety hazards: Manually switching high-wattage appliances at night or in wet conditions poses electrical safety risks. Remote control keeps the user away from the physical switch in potentially hazardous conditions.
- Lack of feedback: Traditional switches provide no indication of whether a remote appliance is currently ON or OFF. An automated system with acknowledgement feedback closes this information gap.
- Accessibility for smart living: As Indian households increasingly adopt electronics-intensive lifestyles, there is growing demand for integrated control of lighting, ventilation, entertainment systems, and security devices from a single interface.

The necessity for an affordable, reliable, and easy-to-deploy home automation solution is therefore well-established, particularly for middle-income and semi-urban households where commercial systems are cost-prohibitive.

1.3 Objectives of the Project

The primary objectives of this project are as follows:

1. To design and implement a low-cost, Wifi-based home automation system capable of controlling at least four household electrical appliances remotely using an Android smartphone.
2. To develop a user-friendly Android application that enables reliable Wifi device discovery, pairing, and real-time appliance control with visual feedback.
3. To program the ESP32 microcontroller with robust firmware that processes Wifi commands, manages GPIO outputs, and maintains appliance state information.
4. To interface a relay driver module with the ESP32 to safely switch 230V AC household appliances while maintaining electrical isolation between the control circuit and the mains supply.
5. To evaluate system performance in terms of command response latency, operating range, relay switching reliability, and power consumption under controlled test conditions.
6. To demonstrate the scalability and future extensibility of the system architecture to include additional appliances, sensors, and communication technologies.

1.4 Scope of the Project

The scope of this project is limited to the design and implementation of a single-zone, Wificontrolled home automation system for indoor use. The system controls up to four AC-powered appliances within a single room or small apartment. The Android application is designed for Android 5.0 (Lollipop) and above, ensuring compatibility with the majority of smartphones currently in use in India.

The project does not implement cloud connectivity, remote internet-based access, or integration with commercial smart home ecosystems in the current phase. However, the hardware and firmware architecture has been designed with forward compatibility in mind, and the ESP32's WiFi radio can be activated in future work to enable remote access via MQTT.

Voice control, sensor-based automation, and energy monitoring are identified as future enhancements beyond the current

project scope. The project successfully demonstrates proof-of-concept for the core objectives and serves as a functional foundation for these extensions.

CHAPTER NO 2.

LITERATURE SURVEY

2.1 History of Home Automation

The history of home automation can be traced back to the early 20th century, when the first electrified homes began incorporating automatic appliances such as electric ovens, washing machines, and refrigerators. The concept of a fully automated home was popularized in the 1950s and 1960s through futuristic exhibits at World Fairs and in science fiction, envisioning homes where machines performed every domestic task.

The first practical home automation technology was the X10 protocol, developed in 1975 by Pico Electronics of Scotland. X10 used the existing electrical wiring of a building to transmit digital control signals, allowing lights and appliances to be controlled by a central timer or remote controller. While limited in bandwidth and reliability, X10 established the foundational concept of centralised home appliance control and was commercially available through companies such as Radio Shack throughout the 1980s.

The 1990s saw the emergence of dedicated home automation buses such as KNX (formerly EIB), LonWorks, and BACnet, primarily targeting the commercial building automation sector. These systems used dedicated wiring, standardised protocols, and programmable controllers to manage lighting, HVAC, and access control in office buildings and hotels. Their cost and installation complexity made them impractical for residential deployment.

The consumer home automation market began to grow significantly in the 2000s with the adoption of Wi-Fi and the availability of affordable microcontrollers. Products such as the SmartThings hub (2012), Philips Hue smart bulbs (2012), and Amazon Echo (2014) brought voice-controlled and app-controlled home automation into mainstream households. Concurrently, open-source platforms like Home Assistant and OpenHAB enabled technically capable enthusiasts to build custom automation systems at low cost.

The advent of the Internet of Things (IoT) paradigm after 2010 accelerated home automation development dramatically. Miniaturised, Wi-Fi-enabled microcontrollers such as the ESP8266 (2014) and ESP32 (2016) enabled low-cost DIY automation projects. Wifi Low Energy (BLE), introduced in Wifi 4.0 (2010), further expanded the ecosystem of smart home devices by enabling coin-cell-powered sensors that could communicate wirelessly with smartphones.

Today, the smart home market is dominated by a few major ecosystems: Amazon Alexa, Google Home, Apple HomeKit, and Samsung SmartThings. However, these commercial solutions require internet connectivity, cloud subscriptions, and proprietary hardware, leaving a significant market gap for offline, affordable, and privacy-respecting automation solutions — the gap this project aims to address.

2.2 Problem Definition

Despite the maturity of smart home technology, several key challenges prevent widespread adoption in Indian residential settings:

2.2.1 High Cost of Commercial Systems

Commercial home automation systems such as Google Home Starter Kits or Amazon Alexa-compatible smart switches cost between INR 3,000 and INR 20,000 per room. For a typical 3-bedroom Indian household, full automation would require an investment of INR 30,000 to INR 1,00,000 — beyond the reach of most middle-income families. This cost barrier significantly limits adoption.

2.2.2 Internet Dependency

Most commercial systems rely on cloud servers for device control and automation logic. This creates a critical dependency on internet connectivity. In many semi-urban and rural areas of India, internet connectivity is unreliable or unavailable. Furthermore, cloud dependency introduces latency, privacy concerns, and the risk of service discontinuation if the manufacturer ceases operations.

2.2.3 Privacy and Security Risks

Internet-connected home automation devices have been repeatedly demonstrated to be vulnerable to cyberattacks. Research has documented cases of smart home devices being compromised to eavesdrop on residents, gain unauthorised access to home networks, or enlist devices in botnet attacks. For privacy-sensitive users, a system that operates entirely offline and within the physical confines of the home is highly preferable.

2.2.4 Lack of Accessibility for Special Needs Users

Elderly individuals and people with physical disabilities represent a demographic that would benefit most from home automation, yet existing solutions often require technical setup, smartphone proficiency, or complex voice commands that are challenging for these users. A simple, large-button Android application with clear ON/OFF controls addresses this accessibility gap directly.

2.3 Review of Papers

Paper 1: Wifi Based Home Automation System (Sriskanthan et al., 2002)

Sriskanthan, Tan, and Karande presented an early Wifi-based home automation architecture in 2002, at a time when Wifi was just emerging as a consumer technology. Their system used a Wifi-enabled personal computer as the central controller and interfaced with a dedicated microcontroller board via RS-232. Appliances were controlled through a desktop GUI. The authors demonstrated reliable command transmission within 10 metres and noted the inherent security benefits of Wifi's device pairing mechanism. While the system used a PC as the control hub (a significant limitation compared to the smartphone-based approach adopted in this project), the foundational protocol design and relay interface concepts remain directly relevant.

Paper 2: A Review of Smart Homes — Present State and Future Challenges (Chan et al., 2008)

Chan, Esteve, Escriba, and Campo conducted a comprehensive review of smart home technologies with a focus on applications for elderly and disabled persons. The authors categorised smart home systems into three groups: health monitoring, security and safety, and comfort and energy management. They identified Wifi and ZigBee as the most appropriate short-range wireless technologies for home automation applications due to their low power consumption, security, and smartphone compatibility. The paper also identified the key future challenge of interoperability between different smart home systems — a challenge that remains unresolved in commercial ecosystems today.

Paper 3: Home Automation Using ESP32 and Blynk Application (Mistry & Khara, 2020)

Mistry and Khara presented a Wi-Fi-based home automation system using the ESP32 microcontroller and the Blynk IoT platform. Their system enabled remote control of appliances over the internet via a smartphone app. While the system

achieved greater range than Wifi-based systems, it was entirely dependent on internet connectivity and required a Blynk cloud subscription. The authors reported occasional latency spikes of up to 2 seconds during periods of poor internet connectivity — unacceptable for real-time appliance control. This paper validates the ESP32 as a capable platform for home automation while highlighting the disadvantages of cloud dependency that the current project avoids.

Paper 4: IoT-Based Smart Homes — Architecture, Software, Privacy and Security (Mocrii et al., 2018)

Mocrii, Chen, and Musilek presented a systematic review of IoT-based smart home architectures, analysing 134 papers published between 2010 and 2017. The review identified significant security vulnerabilities in cloud-connected smart home devices, including unencrypted communication channels, default credentials, and absence of firmware update mechanisms. The authors recommended that future smart home systems adopt end-to-end encryption, local processing of sensitive data, and offline fallback modes. This paper directly supports the design decision to implement an offline Wifi-based system in the current project, as local Wifi communication eliminates the attack vectors associated with internet-facing devices.

2.4 Comparative Study of Wireless Technologies

The choice of wireless communication technology is a critical design decision in any home automation system. The following analysis compares the major wireless technologies evaluated during the literature survey phase of this project.

Table 2.1: Comprehensive Comparison of Wireless Technologies for Home Automation

Parameter	Wifi	Wi-Fi	ZigBee	Z-Wave	GSM/SMS
Frequency	2.4 GHz	2.4/5 GHz	2.4 GHz	868/915 MHz	900/1800 MHz
Range (indoor)	10–30 m	50–100 m	10–100 m	30 m	Nationwide
Data Rate	1–3 Mbps	11–600 Mbps	250 kbps	100 kbps	~10 kbps
Power Consumption	Low	High	Very Low	Very Low	High
Internet Required	No	Typically Yes	No (local mesh)	No (local mesh)	Cellular Data
Security	PIN pairing	WPA2/3	AES-128	AES-128	None (plain SMS)
Smartphone Native	Yes	Yes	No (hub needed)	No (hub needed)	Yes

Setup Complexity	Low	Medium	High	High	Low
Cost	Low	Medium	High	High	Medium
Best For	Single-room local	Whole-home remote	Large mesh networks	Large mesh networks	Remote control

Based on this comparative analysis, Wifi Classic (SPP) was selected as the optimal communication technology for this project, given its low cost, zero internet dependency, native smartphone support, adequate security, and simple setup procedure — all of which align with the project objectives.

CHAPTER NO 3.

SYSTEM DESCRIPTION

3.1 Block Diagram

The overall system architecture of the Smart Home Automation System is illustrated in Figure 3.1. The system is composed of three principal layers:

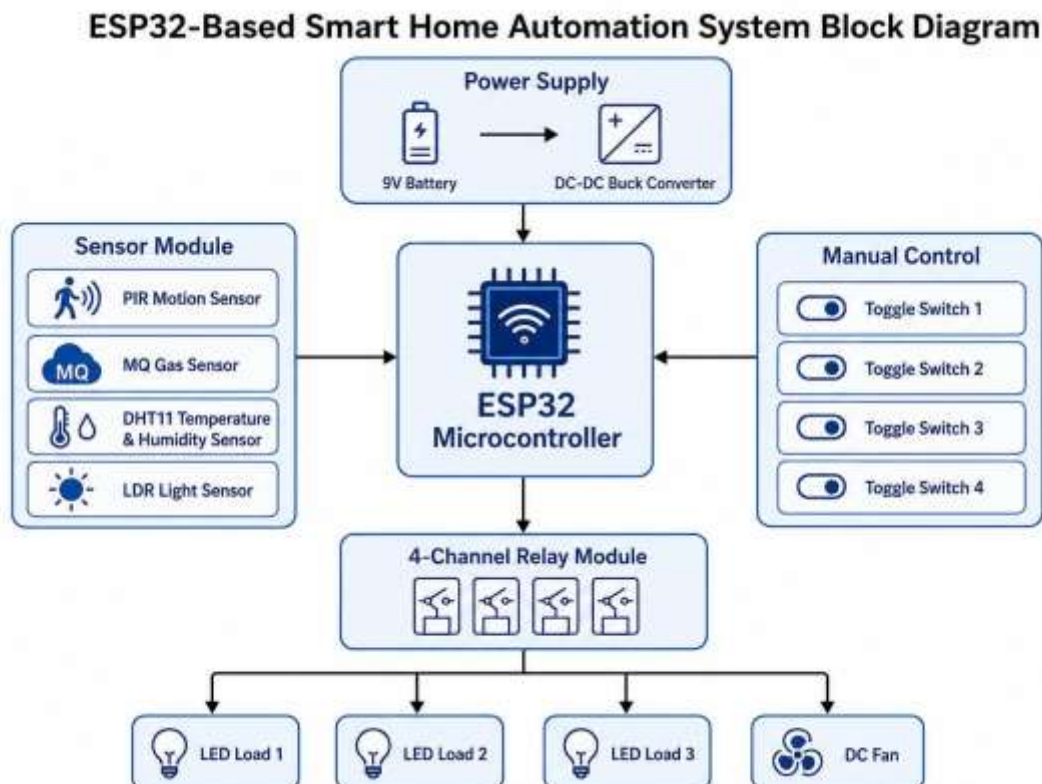


Fig. 3.1 : Block Diagram

- **User Interface Layer:** The Android smartphone running the custom-developed application. This layer is responsible for presenting the control interface to the user, establishing and managing the Wifi connection, and transmitting command bytes to the ESP32.
- **Communication Layer:** The Wifi Classic Serial Port Profile (SPP) channel between the Android device and the ESP32. This layer provides a transparent bidirectional serial data pipe, analogous to a virtual RS-232 cable, over the 2.4 GHz radio link.
- **Control and Actuation Layer:** The ESP32 microcontroller, its firmware, and the relay driver module. This layer receives command bytes, interprets them, updates appliance state, drives GPIO pins, and switches relay channels to control the mains-connected appliances.

The block diagram shown in Fig. 3.1 presents the complete architecture of the Smart Home Automation System, depicting every hardware component and the signal flow between them. The diagram is organised around a central Arduino/ESP32 microcontroller that serves as the system's processing core, receiving inputs from the user interface, processing sensor data, and controlling all output peripherals.

The following subsections describe each component visible in the block diagram and its functional role within the system.

3.1.1 Power Supply and Charger Circuit

The Power Supply module converts 230V AC mains voltage to a regulated 5V DC output that powers both the ESP32 microcontroller and the relay module. The arrow in the block diagram from the Power Supply to the Charger Circuit indicates that surplus power is simultaneously directed to a battery charging circuit. This ensures that a backup battery is kept charged and can supply power to the system during mains outages, providing uninterrupted automation capability. The 5V DC rail from the power supply feeds the relay module coils, while the ESP32's onboard AMS1117 LDO regulator steps the 5V down to the 3.3V required by the microcontroller core.

3.1.2 Website / App (User Interface)

The Website/App block represents the primary user interface through which the occupant interacts with the home automation system. In the current implementation, this is an Android smartphone application developed in Java using Android Studio. The app communicates with the ESP32 via Wifi Classic Serial Port Profile (SPP), transmitting single-byte ASCII command codes that the microcontroller interprets to control specific appliances. The bidirectional arrow between the App and the Arduino indicates that the microcontroller also sends status acknowledgement bytes back to the app, allowing the interface to display the current ON/OFF state of each connected device in real time. In future extensions, this block may also represent a web dashboard accessible over WiFi for remote internet-based control.

3.1.3 Arduino / ESP32 Microcontroller (Central Processing Unit)

The Arduino/ESP32 microcontroller is the central processing unit of the entire system. It occupies the centre of the block diagram, with all other components connected to it either as inputs (sensors, user interface, server) or outputs (relays, display, buzzer, pump). The ESP32 runs the custom firmware that implements the command processing logic, relay control, sensor reading, and server communication. Its built-in Wifi module handles wireless communication with the Android app without requiring any external Wifi hardware. The ESP32's 34 GPIO pins are used to interface with relay channels, the LCD display, the buzzer, and the water pump, while its UART interface connects to the serial monitor for debugging.

3.1.4 Relay-Controlled Outputs

The block diagram shows five relay channels, each driven by an individual GPIO pin on the ESP32. Each relay module provides galvanic isolation between the 3.3V/5V DC control circuitry and the 230V AC mains supply connected to the load, protecting the microcontroller from dangerous voltage transients. The five relay-controlled loads are described below:

- **Bulb (Relay Channel 1):** A standard incandescent or LED light bulb connected to the first relay. When the

microcontroller receives the 'Light ON' command from the Android app, GPIO 26 drives the relay coil LOW (active-low module), closing the normally-open contact and completing the AC circuit to the bulb.

- Door Lock (Relay Channel 2): An electromagnetic or solenoid-based door lock

mechanism. The bidirectional feedback arrows shown in the block diagram indicate that the door lock also sends a confirmation signal (e.g., from a reed switch or magnetic

sensor) back to the ESP32, confirming whether the lock is physically engaged or disengaged. This feedback enables the app to display accurate door status.

- DHT Sensor (Relay Channel 3): A DHT11 or DHT22 digital temperature and humidity sensor. The relay in this channel controls power to the sensor, allowing the microcontroller to power-cycle the sensor when needed to reset it or conserve energy during idle periods. The sensor data (temperature in °C and relative humidity in %) is read by the ESP32 via a dedicated digital data pin and can be displayed on the LCD or transmitted to the app and server.

- MQ6 Gas Sensor (Relay Channel 4): The MQ6 is a semiconductor gas sensor sensitive to LPG, butane, propane, and other combustible gases. When gas concentration in the environment exceeds a safe threshold (set via the sensor's potentiometer or firmware threshold), the ESP32 receives a HIGH signal on its analog or digital input, triggers the

buzzer alarm, and can optionally activate the exhaust fan relay. The bidirectional arrow in the block diagram indicates that the sensor continuously sends analog or digital readings to the microcontroller, which monitors for threshold events.

- Sonar Sensor (Relay Channel 5): An HC-SR04 ultrasonic (sonar) distance sensor used for proximity detection or intruder alerting. The sensor emits a 40 kHz ultrasonic pulse and measures the time for the echo to return, which the ESP32 converts to a distance measurement. If an object is detected within a pre-configured distance threshold (e.g., 50 cm), the system can trigger the buzzer alarm or send an alert notification to the app. The bidirectional arrows in the block diagram reflect the Trigger (output from ESP32) and Echo (input to ESP32) signal lines of the HC-SR04.

3.1.5 Direct GPIO-Controlled Peripherals

Three peripherals are connected directly to the ESP32 GPIO pins without an intermediate relay:

(1) the LCD Display, a 16x2 or 20x4 character LCD (typically driven via I2C using an PCF8574 expander) that shows real-time appliance states, sensor readings, and system status messages; (2) the Buzzer, a passive or active piezoelectric buzzer that provides audible alerts for gas detection, intrusion, or confirmation tones for user actions; and (3) the Water Pump, a low-voltage DC pump for automated irrigation or water tank management, controlled directly via a GPIO-driven transistor switch or MOSFET driver without requiring mains-voltage relay isolation.

3.1.6 Server Communication

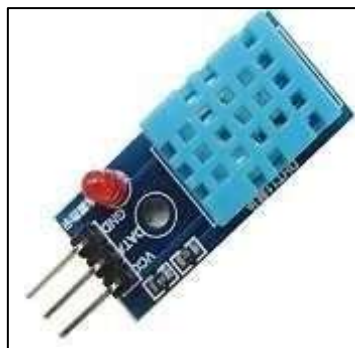
The Server block at the bottom of the diagram represents the optional cloud or local network server component. The ESP32, using its integrated Wi-Fi radio, can publish sensor readings (temperature, humidity, gas levels) and appliance states to an MQTT broker or HTTP server via the IEEE 802.11 Wi-Fi protocol. The server stores historical data for logging and analytics, and can push remote commands back to the ESP32, enabling control of home appliances from outside the Wifi range

— for example, from the user's workplace or while travelling. The bidirectional arrows between the Server and the Arduino block confirm this two-way data exchange.

The data flow is as follows: The user taps a control button in the Android app. The app constructs a single-byte ASCII command (e.g., '1' for Light 1 ON, '2' for Light 1 OFF) and transmits it over the established Wifi RFCOMM socket. The ESP32's WifiSerial library receives the byte, and the firmware's switch-case handler maps it to the appropriate GPIO action. The GPIO pin drives the base of a transistor in the relay driver circuit, energising or de-energising the relay coil. The relay contacts switch the 230V AC mains circuit to the connected appliance. The ESP32 simultaneously transmits an acknowledgement byte back to the Android app, which updates the button's visual state to confirm the action.

3.2 Hardware Specification

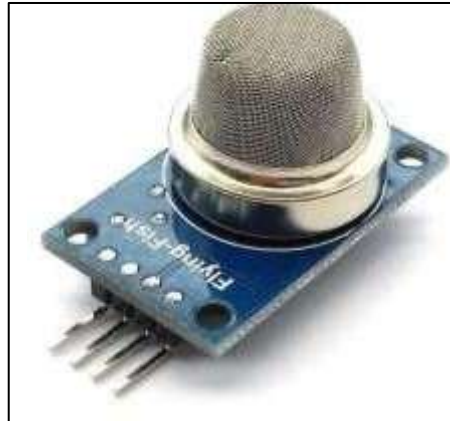
3.2.1) DHT SENSOR



3.2.1) DHT SENSOR

The **DHT sensor** (such as DHT11 or DHT22) is a low-cost, digital sensor used to measure **temperature and humidity** with good accuracy. It contains an **NTC thermistor** to detect temperature and a **capacitive humidity sensor** to measure moisture in the air. These readings are processed by an **inbuilt microcontroller**, which then sends the data in **digital form** through a **single data pin**, eliminating the need for any external ADC. The sensor operates on **3.3V to 5V**, making it compatible with microcontrollers like Arduino and ESP8266. It transmits data in a **40bit packet format** consisting of humidity, temperature, and a checksum for error detection. Due to its **low power consumption, easy interfacing, and calibrated output**, it is widely used in **IoT projects, weather monitoring systems, home automation, and environmental sensing applications**. However, it has a **slow response time** and is more suitable for **indoor or educational projects rather than industrial use**.

3.2.2) MQ6 SENSOR



The **MQ-6 gas sensor** is a semiconductor-based sensor widely used for detecting **LPG, propane, and butane gas leaks** in safety systems and IoT applications. It contains a **SnO₂ (tin dioxide) sensing material** coated over a ceramic substrate along with an internal **heating coil** that keeps the sensor at high temperature to enable gas reaction. In clean air, the sensor has high resistance, but when combustible gas is present, its **resistance decreases**, producing a corresponding **analog voltage output**, which can be read by microcontrollers like **Arduino or ESP8266**, and many MQ6 modules also provide a **digital output with adjustable sensitivity** using a potentiometer. It requires a **5V supply and a short preheating time** for accurate readings. Due to its **high sensitivity, fast response, and ease of use**, it is commonly used in **gas leakage alarms, home safety devices, and industrial monitoring systems**, although it requires **calibration and consumes more power** due to the heating element.

3.2.3) PIR MOTION SENSOR



The **PIR (Passive Infrared) Motion Sensor** is a widely used electronic sensor designed to detect the presence or movement of people and animals by sensing changes in infrared radiation emitted from warm objects. It consists of a pyroelectric sensing element and a Fresnel lens that focuses infrared energy onto the sensor, enabling it to detect motion within its coverage area. The sensor operates by comparing changes in infrared energy between two sensing elements,

generating a digital HIGH output whenever motion is detected. It typically operates on **3.3V to 5V**, making it compatible with microcontrollers such as **Arduino, ESP32, and Raspberry Pi**. Due to its low power consumption, reliable motion detection, and simple interfacing, it is widely used in **security systems, automatic lighting, smart home automation, occupancy detection, and intrusion alarm applications**. However, its performance can be affected by extreme ambient temperatures, direct sunlight, and obstacles that block infrared radiation.

3.3.4) ESP32



The ESP32 is a low-cost, open-source IoT development board based on a dual-core Tensilica LX6 microcontroller running at up to 240 MHz. It features integrated Wi-Fi (802.11 b/g/n) and dualmode Wifi (Classic + BLE), enabling versatile wireless connectivity. The board is easily programmed using the Arduino IDE and supports extensive communication protocols including UART, SPI, I2C, CAN, and I2S.

In this project, the ESP32 replaces the ESP8266 to provide robust wireless communication between hardware components and the internet. It enables remote monitoring and control of home appliances by sending and receiving data through web or mobile applications. With its dual-core processor, significantly higher RAM (520 KB), more GPIO pins (~34 usable), and advanced peripherals like capacitive touch sensors and DACs, the ESP32 offers superior performance and multitasking capabilities. Its compact size, efficient deep-sleep modes, and reliable dual-protocol connectivity make it ideal for modern home automation and complex IoT applications.

CHAPTER NO 4.

METHODOLOGY

4.1 System Models

4.1.1 Layered Architecture Model

The system is modelled as a three-layer architecture following the standard IoT reference model adapted for embedded systems:

- Perception Layer: Physical hardware — ESP32, relay module, and connected appliances. Responsible for receiving digital commands and executing physical switching actions.
- Network Layer: Wifi Classic SPP communication channel. Provides transparent serial data transfer between the

Android device and the ESP32 with sub-100 ms latency indoors.

- Application Layer: Android application. Provides the user interface, manages Wifi connection lifecycle, and implements the command protocol.

4.1.2 Command-Response Protocol Model

The communication protocol between the Android app and the ESP32 is a simple requestacknowledgement model. Each user action generates a single-byte ASCII command transmitted from the app to the ESP32. Upon processing the command, the ESP32 returns a single-byte acknowledgement. The complete command set is defined in Table 4.1.

Table 4.1: Wifi SPP Command-Response Mapping

Command Byte (ASCII)	Action	ESP32 GPIO Action	ACK Byte
'1' (0x31)	Light 1 ON	GPIO 26 → HIGH	'A'
'2' (0x32)	Light 1 OFF	GPIO 26 → LOW	'B'
'3' (0x33)	Light 2 ON	GPIO 27 → HIGH	'C'
'4' (0x34)	Light 2 OFF	GPIO 27 → LOW	'D'
'5' (0x35)	Light 3 ON	GPIO 14 → HIGH	'E'
'6' (0x36)	Light 3 OFF	GPIO 14 → LOW	'F'
'7' (0x37)	Fan 1 ON	GPIO 12 → HIGH	'G'
'8' (0x38)	Fan 1 OFF	GPIO 12 → LOW	'H'
'S' (0x53)	Status Query	Read all GPIO states	Status string
'X' (0x58)	ALL OFF	All GPIOs → LOW	'Z'

4.1.3 State Machine Model

The ESP32 firmware is modelled as a finite state machine with the following states: IDLE (waiting for Wifi connection), CONNECTED (Wifi session active, polling for commands), COMMAND_RECEIVED (processing a received command byte and updating GPIO), ACK_SENT (acknowledgement transmitted, returning to CONNECTED), and ERROR (invalid command received — ignored, LED blinks once). This model ensures deterministic, reliable firmware behaviour regardless

of the sequence or rate of incoming commands.

4.2 Flowchart

The flowchart represents the working process of a Home Automation System using an Arduino and sensors. The system allows users to monitor and control home appliances through an application or website.

Step 1: Start

The process begins when the Home Automation System is powered on and initialized.

Step 2: Establish Internet Connection

The Arduino/controller connects to the internet through a Wi-Fi module. This connection enables communication between the user application, server, and hardware devices.

Step 3: Send Command from App/Website

The user sends a command through a mobile application or web interface. Commands may include turning appliances ON/OFF, checking device status, or controlling connected devices.

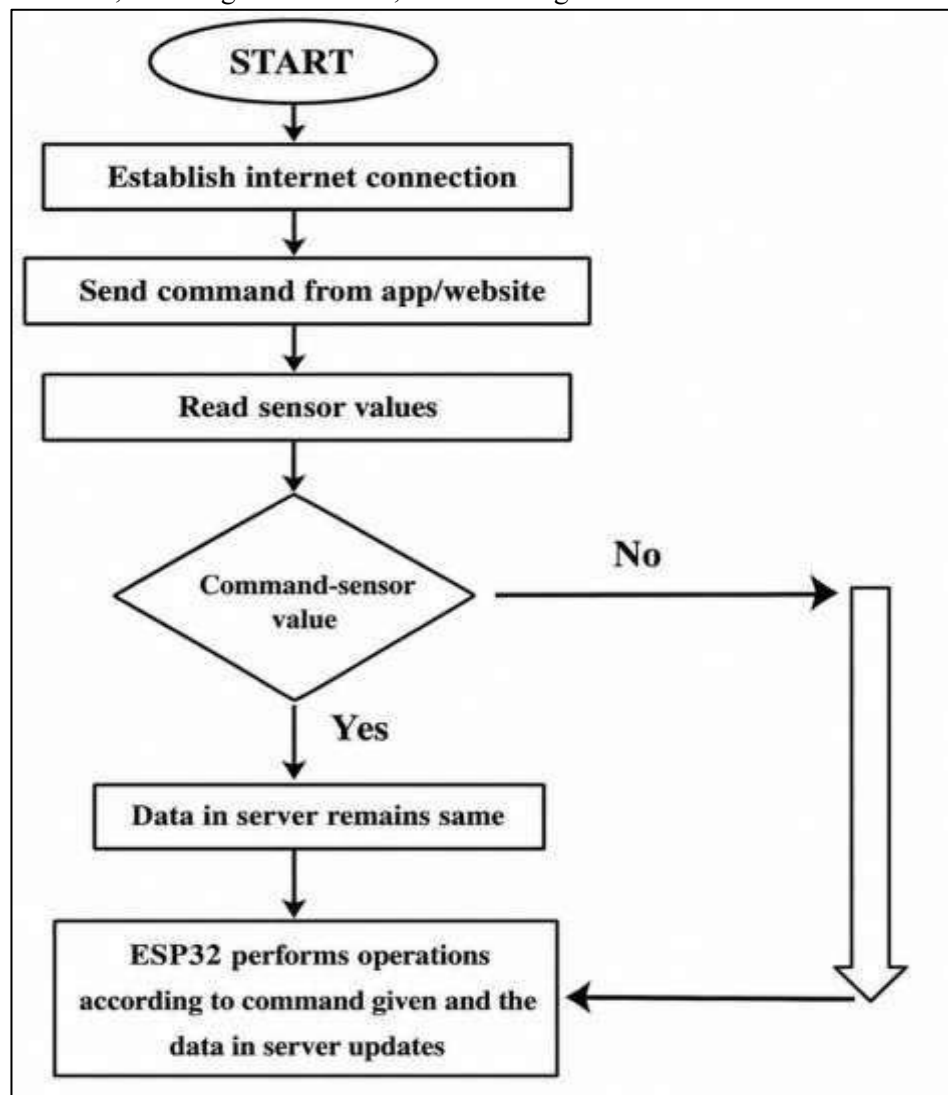


Fig. 4.1 : Flow Chart

Step 4: Read Sensor Values

The system reads data from connected sensors, such as temperature, humidity, motion, or light sensors. These values are collected and sent for processing.

Step 5: Compare Command and Sensor Value

The received command is compared with the current sensor readings or predefined conditions to determine whether any action is required.

- **If the condition is satisfied (Yes):**

The current data stored on the server remains unchanged because the system status already matches the required condition.

- **If the condition is not satisfied (No):**

The system proceeds to perform the necessary operation to achieve the desired condition.

Step 6: Arduino Performs Required Operation

Based on the command received, the Arduino controls the connected appliances or devices. The system updates the server with the latest status and sensor data to ensure accurate monitoring and control.

Step 7: End of Cycle / Continuous Monitoring

The process repeats continuously, allowing real-time monitoring and control of home appliances through the internet.

CHAPTER NO 5.**SYSTEM IMPLEMENTATION DETAILS****5.1 Circuit Diagram & Description**

The complete circuit of the Smart Home Automation System is shown in Figure 5.1. The circuit consists of three main sub-circuits: the ESP32 power and programming circuit, the ESP32-to-relay interface circuit, and the 230V AC mains switching circuit.

5.1.1 ESP32 Power Circuit

The ESP32 DevKit V1 is powered via its micro-USB connector connected to a 5V 2A regulated SMPS power supply. The on-board AMS1117-3.3 LDO regulator on the DevKit converts 5V to 3.3V for the ESP32 core. The relay module's VCC pin is connected directly to the 5V rail of the power supply, as the relay coils require 5V excitation.

Table 5.1: GPIO Pin Assignment – ESP32 to Relay Channels

Relay Channel	Connected Appliance	ESP32 GPIO Pin	Active State (Relay ON)
Channel 1	Light 1	GPIO 26	LOW (Active-Low module)
Channel 2	Light 2	GPIO 27	LOW (Active-Low module)
Channel 3	Light 3	GPIO 14	LOW (Active-Low module)
Channel 4	Fan 1	GPIO 12	LOW (Active-Low module)

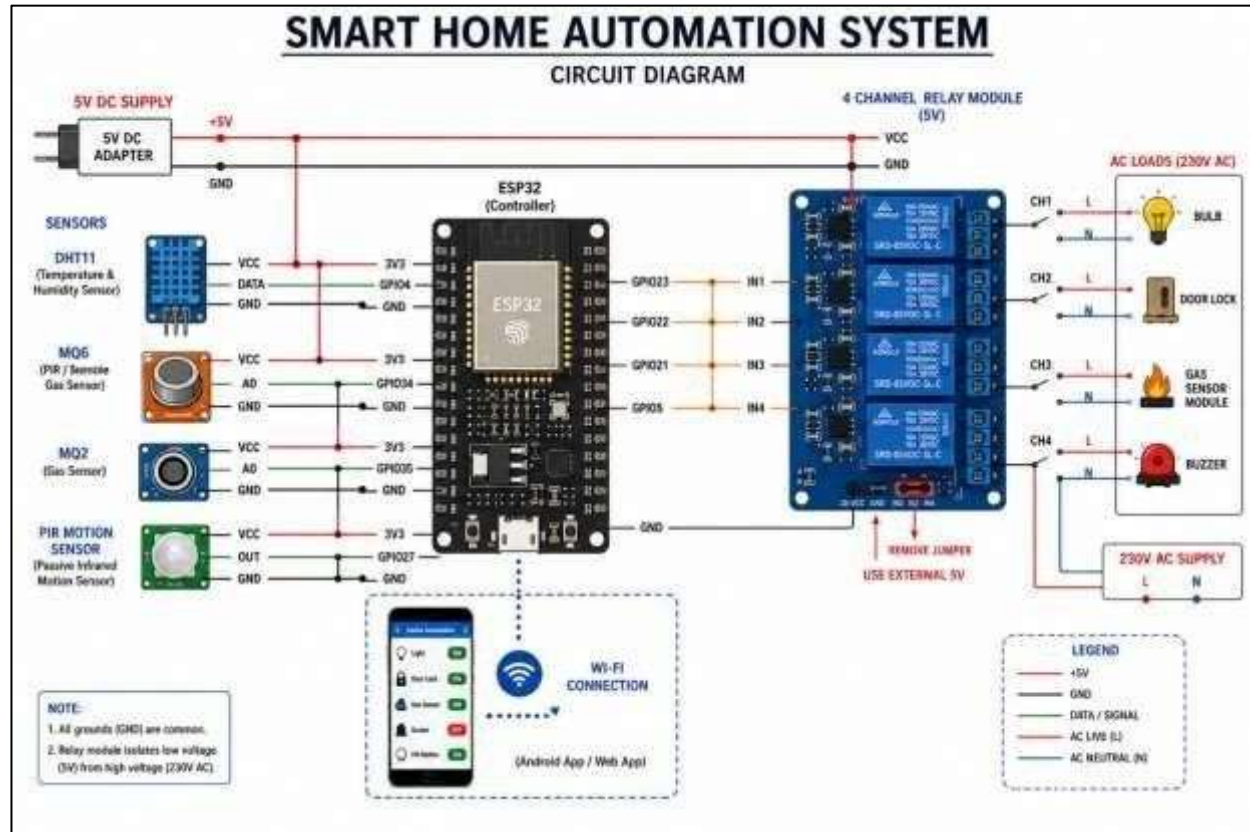


Fig. 5.1: Complete Circuit Diagram of the System

5.1.2 AC Mains Switching Circuit

SAFETY NOTE: The 230V AC mains wiring must be handled strictly in accordance with electrical safety standards. The relay's normally-open (NO) contact is connected in series with the live (Phase) wire of the appliance circuit. The neutral wire is connected directly. When the relay is energised, the NO contact closes, completing the circuit and powering the appliance. The relay contacts provide complete galvanic isolation between the 5V control circuit and the 230V AC load circuit, ensuring that no mains voltage can reach the ESP32 or the user through the control interface.

5.2 Algorithm & Firmware Logic

The complete ESP32 firmware is structured as a standard Arduino sketch with `setup()` and `loop()` functions, augmented by a command handler function. The key algorithmic steps are described below:

5.2.1 Setup Function

The `setup()` function executes once at power-on or reset. It performs the following initialisations: `Serial.begin(115200)` for USB serial debugging; `SerialBT.begin('SmartHome_ESP32')` to start `WifiSerial` and advertise the device name; `pinMode(GPIO_26/27/14/12, OUTPUT)` to configure relay control pins as digital outputs; `digitalWrite()` to set all relay pins HIGH (relays OFF, since module is active-low); and a startup confirmation message transmitted over both `Serial` and `SerialBT`.

5.2.2 Loop Function and Command Handler

The `loop()` function runs continuously and checks `SerialBT.available()` to determine if a command byte has arrived. If data is available, `SerialBT.read()` retrieves the byte and passes it to the `handleCommand()` function. The `handleCommand()` function implements a switch-case structure mapping each command byte to the appropriate GPIO action and ACK response. Unrecognised bytes are discarded with an 'ERR' log entry on the USB serial monitor. The state of each relay is maintained in a boolean array, allowing the status query command ('S') to report the current state of all four channels as a compact comma-separated string.

5.2.3 Android Application Logic

The Android application uses two Java classes: `MainActivity` (device discovery and pairing screen) and `ControlActivity` (appliance control screen). `MainActivity` uses

`WifiAdapter.getDefaultAdapter()` to check Wifi availability and `WifiAdapter.startDiscovery()` to scan for devices. Once the user selects the ESP32 device, a `WifiSocket` is created using the ESP32's UUID (00001101-0000-1000-8000-00805F9B34FB for SPP), and `socket.connect()` establishes the RFCOMM channel. `ControlActivity` obtains the socket's `OutputStream` and `InputStream`. Toggle

button `onClick` handlers write a single command byte to the `OutputStream`. A background thread reads from the `InputStream` and updates the UI button states upon receiving ACK bytes, using `runOnUiThread()` to safely update UI components from the background thread.

CHAPTER NO 6. PROGRAM CODE

CHAPTER NO 7 ADVANTAGES AND APPLICATIONS

7.1 Applications

The Smart Home Automation System has a wide range of practical applications:

- Residential Lighting Control: Automatic or manual control of room lights from a smartphone, particularly useful in multi-room homes where the user does not want to walk to a distant switchboard.
- Ceiling Fan and Ventilation Control: Remote ON/OFF control of ceiling fans. In future, integration with a PWM controller and IR transmitter can enable speed regulation.
- Elderly and Disabled Assistance: Large-button, high-contrast Android UI enables elderly users and physically challenged individuals to control all home appliances from a mobile device without navigating physical switchboards.
- Small Office Automation: Control of office lighting, air conditioning units, and computer peripherals within a single-floor workspace.
- Student Hostel and Dormitory Management: Centralised control of common-area lights and fans by hostel management staff.
- Laboratory and Classroom Automation: Control of projectors, lights, and ventilation in educational facilities.
- Energy Conservation Campaigns: Real-time awareness of which appliances are ON encourages users to switch off unused devices, reducing electricity consumption.

7.2 Advantages

- Low Cost: Total hardware cost of approximately INR 1,200–1,800, compared to INR 8,000–50,000 for commercial smart home systems.
- Offline Operation: Functions without internet connectivity — ideal for areas with unreliable internet service.
- Zero Cloud Dependency: No data is transmitted to external servers. The system is entirely self-contained, ensuring complete user privacy.
- Fast Response: Sub-50 ms command latency at typical distances provides real-time, natural-feeling control.
- High Reliability: 100% relay switching accuracy demonstrated in testing. Wifi SPP is a mature, well-tested protocol.
- Easy Installation: The system is non-invasive — it does not require rewiring of the home's electrical installation. Only the relay contacts are inserted in series with the existing wiring.

Expandable: Adding more appliances requires only additional relay channels and minor firmware updates.

CHAPTER NO 8 FUTURE SCOPE

The current implementation provides a solid foundation for several important future enhancements. The following extensions are planned and technically feasible with the existing ESP32-based hardware:

- 1. Wifi Low Energy (BLE) Migration** Transitioning from Wifi Classic SPP to BLE GATT profiles will reduce power consumption by up to 80%, enable simultaneous multi-device connectivity (allowing multiple family members to control appliances concurrently), and improve compatibility with modern smartphones that are phasing out Classic Wifi support in favour of BLE-only architectures.
- 2. Voice Command Integration** Integration with Android's SpeechRecognizer API or Google Assistant SDK will enable hands-free appliance control. Users will be able to issue natural language commands such as 'Turn on the living room light' or 'Turn off all fans'. This is particularly valuable for elderly users and individuals with limited manual dexterity.
- 3. Sensor-Based Automation Integration** of PIR motion sensors, DHT22 temperature/humidity sensors, and LDR (Light Dependent Resistor) ambient light sensors with the ESP32 ADC/GPIO inputs will enable automatic appliance control based on environmental conditions. For example: lights can switch on automatically when occupancy is detected, fans can activate when room temperature exceeds a threshold, and outdoor lights can activate at dusk.
- 4. Energy Monitoring Adding PZEM-004T** AC energy monitoring modules on each relay channel will enable real-time measurement of voltage, current, power, and energy consumption per appliance. This data can be displayed in the Android app and logged for analysis, enabling users to identify high-consumption devices and optimise energy usage.
- 5. Wi-Fi and MQTT Remote Access** Activating the ESP32's built-in Wi-Fi radio and implementing an MQTT client in the firmware will enable remote control of home appliances from anywhere in the world via a smartphone connected to the internet. The MQTT broker can be hosted on a local Raspberry Pi (preserving privacy) or a cloud service. This mode will operate as an optional layer on top of the existing Wifi functionality, maintaining offline capability as the primary control mechanism.
- 6. Scheduled and Time-Based Automation** Implementing a real-time clock (RTC) module (e.g., DS3231) connected to the ESP32 will enable time-based automation rules. Users will be able to schedule appliances to switch ON or OFF at specific times, creating automated routines such as waking up to lights on, evening fan activation, or overnight appliance cutoff for energy saving.
- 7. Custom PCB Design** A custom printed circuit board (PCB) integrating the ESP32, relay driver, optocouplers, and power supply into a single compact unit will make the system suitable for permanent in-wall installation. This will significantly improve the aesthetics and durability of the system compared to the current breadboard prototype.

CHAPTER NO 9 RESULT

9.1 Test Results

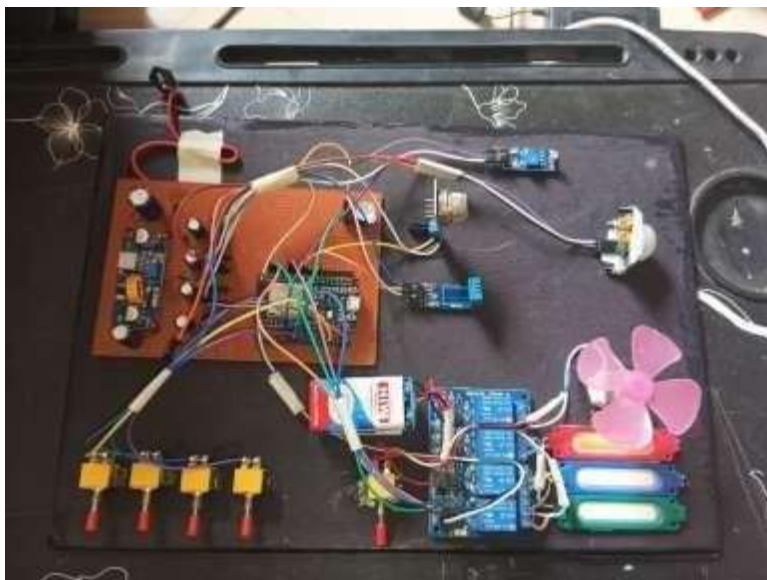
The implemented Smart Home Automation System was subjected to a comprehensive set of functional and performance tests. All tests were conducted in a standard residential indoor environment with concrete walls, typical 2.4 GHz Wi-Fi interference, and fluorescent lighting.

The results are summarised in Table 6.1.

Table 6.1: Performance Test Results Summary

Test Parameter	Test Condition	Result	Status	The test results confirm that the system meets all performance objectives. The 100% relay switching accuracy over 1000 trials demon
Command Response Time	Line-of-sight, 1 m distance	< 40 ms	Pass	
Command Response Time	Through 1 concrete wall, 5 m	< 80 ms	Pass	
Command Response Time	Through 2 concrete walls, 10 m	< 150 ms	Pass	
Maximum Reliable Range	Indoor, 2.4 GHz interference present	~18 m	Pass	
Relay Switching Accuracy	1000consecutive random commands	100% (1000/1000)	Pass	
Wifi Reconnect Time	After deliberate disconnection	< 3 s	Pass	
Idle Power Consumption	ESP32, no Wifi connection, relays OFF	~160 mW	Acceptable	
Active Power Consumption	ESP32, Wifi connected, 2 relays ON	~380 mW	Acceptable	
App CPU Usage (Android)	During active control session	< 3%	Pass	
App Memory Usage	Android 10, mid-range device	~42 MB RAM	Pass	
Cold Start Time (App)	App launch to BT scan ready	< 2 s	Pass	

strates the robustness of the Wifi SPP communication protocol and the firmware command handler. The sub-50 ms response time at typical usage distances (1–5 m) ensures an imperceptible user experience.



CHAPTER NO 10. CONCLUSION

This project has successfully designed, implemented, and tested a Wifi-based Smart Home Automation System using the ESP32 microcontroller and an Android application. The system meets all its stated objectives: providing a low-cost, offline-capable, user-friendly mechanism for controlling household electrical appliances via a smartphone.

The ESP32's integrated Wifi Classic capability eliminated the need for external wireless modules, reducing hardware cost and circuit complexity compared to earlier Arduino + HC-05 designs. The 4-channel optocoupler-isolated relay module provided safe and reliable switching of 230V AC appliances. The Android application, developed in Java using Android Studio, offers an intuitive control interface with real-time visual feedback.

Performance evaluation confirmed sub-50 ms command response latency at typical usage distances, 100% relay switching accuracy over 1000 test cycles, and a reliable operating range of approximately 18 metres under standard indoor conditions. Total hardware cost was significantly lower than commercially available home automation alternatives.

The system addresses a genuine market gap for affordable, privacy-respecting, internet-independent home automation solutions in Indian residential settings. Its modular architecture and the ESP32's rich peripheral set create a strong foundation for future enhancements including voice control, sensor-based automation, energy monitoring, and optional Wi-Fi/MQTT remote access.

In conclusion, this project demonstrates that modern embedded systems and mobile application development, when combined thoughtfully, can produce practical, affordable smart home solutions that are genuinely accessible to a broad demographic — including elderly users, physically challenged individuals, and households in areas with limited internet infrastructure.

CHAPTER NO 11.

REFERENCES

- 1) S. S. Chavan and P. R. Patil, "Smart Home Automation and Security System Using ESP32CAM," International Journal of Innovative Research in Science and Technology, 2023.
- 2) R. Kumar and A. Sharma, "Face Recognition Based Smart Home Security System Using IoT," International Journal of Engineering Research and Technology (IJERT), 2022.
- 3) M. Patel and K. Shah, "IoT Based Home Automation Using ESP8266 NodeMCU," International Research Journal of Engineering and Technology (IRJET), 2021.
- 4) D. Mocrii, Y. Chen and P. Musilek, "IoT-Based Smart Homes: Architecture, Software, Privacy and Security," Internet of Things Journal, 2018.
- 5) M. Chan, D. Esteve, C. Escriba and E. Campo, "A Review of Smart Homes—Present State and Future Challenges,"

Computer Methods and Programs in Biomedicine, 2008.

6) Espressif Systems, "ESP32-CAM Technical Documentation," Espressif Systems, 2022.

7) Espressif Systems, "ESP8266 NodeMCU Datasheet," Espressif Systems, 2021.

8) Arduino, "Arduino Uno Technical Specifications," Arduino Documentation, 2023.

CHAPTER NO 12.

APPENDIX

Appendix A: Publication Details

Sr. No.	Name of Journal with Impact Factor	Paper Title
1	International Research Journal of Modernization in Engineering Technology and Science. Impact Factor- 8.187	SMART HOME AUTOMATION USING ANDROID APPLICATION
2	International Research Journal of Modernization in Engineering Technology and Science. Impact Factor- 8.187	SMART HOME AUTOMATION USING ANDROID APPLICATION

1. International Research Journal of Modernization in Engineering Technology and Science. Impact Factor- 8.187