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كلية العلوم و التكنولوجيا

DEPARTMENT OF ELECTRICAL ENGINEERING

THESIS

PRESENTED FOR OBTAINING THE ACADEMIC MASTER'S DEGREE IN

Sector**: Automatic**

Specialty**: AUTOMATIC AND SYSTEMS**

TITLE

IoT based monitoring and control system for Home Automation

Presented by:

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In front of the jury:

- CHENIKHER Saleh	Prof	**President**
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- LOUDJANI Abdelhak	MAA	**Examiner**

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بسم الله الرحمن الرحيم

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Thanks to all my family.

Dedicated

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration and understanding. I dedicate this graduation to my ambitious self, to my family and my support system, to the one who was the light of my path and my strength, to the one who taught me without expecting anything in return, my dear father. And to my hope in life,

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BAKHOUCHE Chayma

Abstract:

The IoT-based monitoring and control system for home automation focuses on enabling users to remotely monitor and control their home appliances using Internet of Things (IoT) technology. This system allows users to interact with their appliances via smartphones, utilizing Wi-Fi as the communication protocol and Raspberry Pi as the server system. The design emphasizes a user-friendly approach, enabling direct interaction through a web-based interface over the internet. The system not only monitors sensor data but also triggers actions based on user requirements, enhancing flexibility and security in controlling electronic appliances within the home environment. Overall, this system offers globally accessible automation of electronic appliances by leveraging Raspberry Pi micro-controller boards, web connectivity, and relay switches to provide users with efficient and secure control over their home appliances.

الملخص

نظام المراقبة والتحكم القائم على إنترنت الأشياء لأتمتة المنزل يركز على تمكين المستخدمين من مراقبة والتحكم في الأجهزة المنزلية عن بُعد باستخدام تكنولوجيا إنترنت الأشياء. يتيح هذا النظام للمستخدمين التفاعل مع أجهزتهم عبر الهواتف الذكية، باستخدام بروتوكول الاتصال Wi-Fi ونظام خادم يعتمد على Raspberry Pi.يتميز التصميم بواجهة سهلة الاستخدام، مما يتيح التفاعل المباشر عبر واجهة ويب عبر الإنترنت. يقوم النظام بمراقبة بيانات المستشعرات وتنفيذ الإجراءات بناءً على متطلبات المستخدم، مما يعزز المرونة والأمان في التحكم في الأجهزة الإلكترونية داخل المنزل. بشكل عام، يوفر هذا النظام أتمتة شاملة للأجهزة الإلكترونية بفضل استخدام لوحات التحكم الدقيقةRaspberry Pi ، والاتصال عبر الويب، ومفاتيح التبديل، مما يتيح للمستخدمين تحكمًا فعالًا وآمنًا في أجهزتهم المنزلية، أينما كانوا.

Summary

Page

CHAPTRE I : Overview of Internet of Things

CHAPTRE II : IoT in Home Automation : Critical Operating Systems and Server Architectures

CHAPTRE III : Practical Applications of Home Automation Systems

List of figures

ChapterI :

ChapterII :

ChapterIII :

Abbreviations

IoT: Internet of Things

WIFI: wireless fidelity

Zigbee: Zonal Intercommunication Global-standard

RIOT: real-time operating system

MQTT: Message Queuing Telemetry Transport

PCB: Printed Circuit Board

SSID: service set identifier

General introduction

Smart home automation is a rapidly growing field that leverages the power of the Internet of Things (IoT) with advanced technologies to create intelligent and connected living spaces. By integrating a variety of devices, sensors, and systems, smart home automation enhances convenience, energy efficiency, security, and overall quality of life for homeowners [1].

At the core of smart home automation is the concept of IoT, which refers to the network of physical devices, vehicles, buildings, and other items embedded with sensors, software, and other technologies that enable them to connect and exchange data. These interconnected devices,ranging from smart lights and thermostats to security cameras and appliances, enable homeowners to monitor, control, and automate various aspects of their homes remotely [1].

A key components of smart home automation is the seamless integration and communication between different devices and systems. This is achieved using various protocols, such as Zigbee, Z-Wave, Bluetooth, and Wi-Fi, each with its own strengths and applications [2].

As smart home automation continues to evolve, new and innovative applications are emerging, such as intelligent lighting control, automated HVAC systems, and GSM- based pump control for water management. These practical applications highlight the versatility and potential of smart home automation in enhancing modern living [3].

This dissertation aims to provide a comprehensive overview of smart home automation, covering the fundamental concepts of IoT, the working principles and protocols involved, and the critical operating systems and server architectures that support thesesystems. Additionally, it will explore several practical applications of smart home automation, showcasing real-world examples and case studies [2].

By understanding the principles and potential of smart home automation, readers will be equipped with the knowledge to transform their homes into intelligent, efficient, and secure living spaces that adapt to their needs and preferences [4].

Chapter I:

Overview of Internet of Things

I.1 Introduction

A "smart house" is a residence equipped with Internet of Things (IoT) devices connected to mobile applications, allowing users to control various home elements such as appliances, security systems, and lighting. These IoT devices enable remote management of household items, providing users with the convenience of operating their home appliances from anywhere without needing to be physically present. The primary goal of this system is to offer a reliable web-based solution for managing everyday home appliances efficiently and conveniently. [2].

I.2 Internet of things

The Internet of Things (IoT) refers to a network of physical devices, vehicles, appliances, and other objects embedded with sensors, software, andnetwork connectivity, enabling them to collect and share data [5]. Figure 1.1 illustrates some examples of IoT applications:

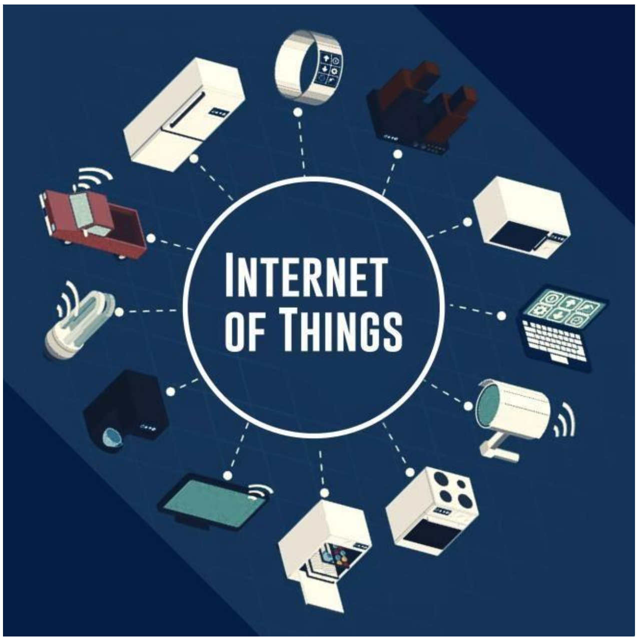


Fig.1.1: Some examples of IoT applications [6].

I.2.1 Working Principle:

IoT devices contain sensors and mini-computer processors that gather and collect data using machine learning. This data is collected through a Wi-Fi or secure LAN connection. For example, imagine a smart vacuum that cleans autonomously and can be controlled remotely through your phone, or a door equipped with a smart camera that alerts you when someone attempts to enter your home [7].

I.2.2 Applications:

The applications of the Internet of Things (IoT) are diverse and impactful across various industries. Some key applications of IoT include:

- Smart Agriculture: IoT technology enables the monitoring of crops, control of irrigation systems improvement of agricultural techniques, and enhancement of overall food production efficiency [8].
- Smart Farming: IoT assists farmers in monitoring fields, optimizing crop growth, minimizing waste, and increasing productivity through sensor-based technologies [8].
- Education: IoT offers multiple applications and platforms for education, providing educators with new tools to optimize classwork, improve the efficiency of the learning method, and improve connectivity with learners. [8].
- Healthcare: IoT applications in healthcare facilitate remote consultations, data sharing, and real-time patient monitoring, transforming medical systems from reactive to proactive [9].
- Traffic monitoring: With population growth, increased vehicle numbers, and city expansion, traffic monitoring has recently become a significant challenge in many countries. Researchers are now developing systems that utilize sensing technology and internet of things platforms to manage vehicle traffic. These systems enable users to verify conditions of various routes estimate travel times, and determine distances.[9].
- Industrial Automation: IoT enhances industrial processes by enabling machines to work together efficiently, monitor themselves, and optimize production processes [9].

I.3 Home automation

Home automation, as seen in figure 1.2, consists of a network of communication hardware, and electronic interfaces that connect everyday objects over the Internet. Each item is equipped with sensors and is connected to the internet through WiFi, allowing users to control them from a smartphone or tablet [10].

Three main elements are essential for constructing a home automation system: sensors, controllers, and actuators.

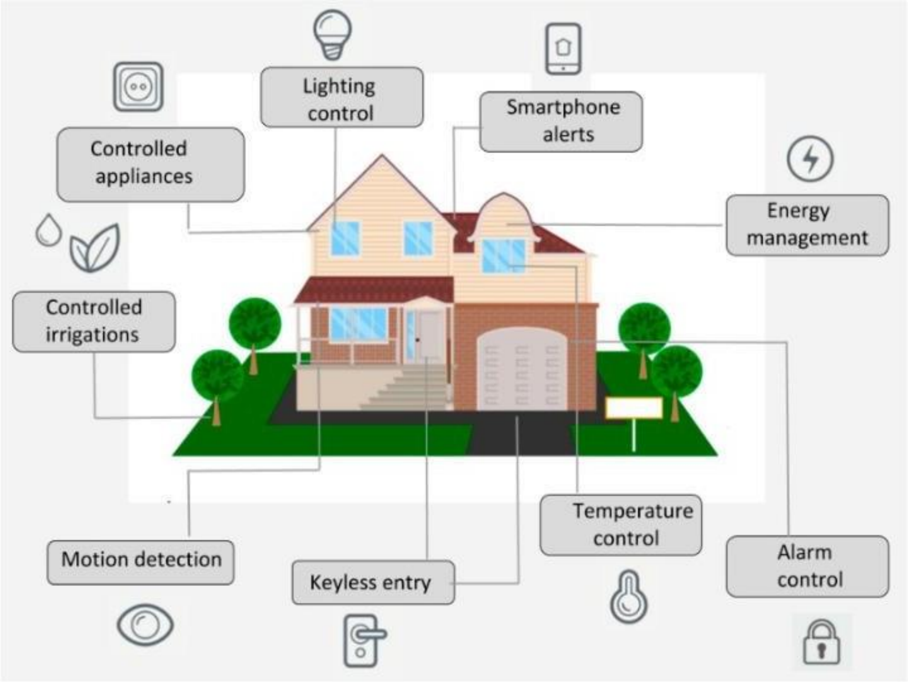


Fig. 1.2: Home automation system [11].

I.3.1 Working Principle:

Home automation operates on three levels:

- **Centralized Control:**

-A central control unit, often a smart home hub or a mobile app, acts as the brain of the home automation system.

-This control unit receives input from sensors, processes the data, and sends commands to the connected devices to perform specific actions [12].

- **Automation and Scheduling:**

-Home automation systems can be programmed to automate various tasks based on schedules, user preferences, or sensor inputs.

-For example, the system can automatically adjust the thermostat, turn on/off lights, or activate security systems based on pre-defined rules or user-defined schedules [12].

- **Remote Access and Monitoring:**

-Home automation systems enable remote access and monitoring through mobile applications or web-based interfaces.

-Users can control and monitor their home devices, receive alerts, and make adjustments from anywhere with an internet connection [12].

I.3.2 Most common protocols:

A home automation protocol, also known as home control technology, is a communication language used for sending and receiving instructions between devices via wired or wireless connection.

Short range wireless communication and low power consumption protocols are particularly suitable for home environments. Among these various wireless smart home protocols, the most popular, based on the number of the connected products, are highlighted in Figure 1.3. These include Wi-Fi, Bluetooth, Bluetooth BLE, ZigBee and Z-Wave, which are frequently referenced in the literature [13].

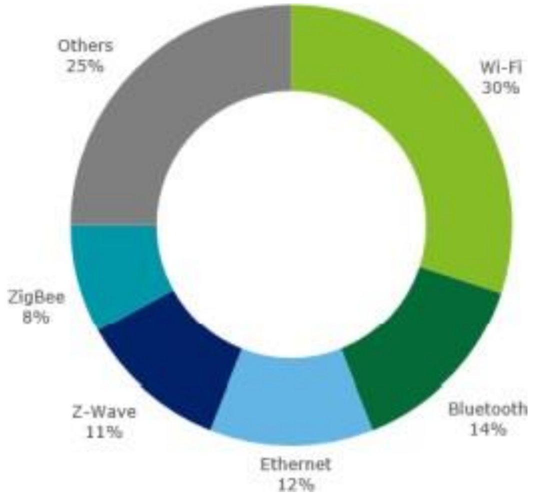


Fig. 1.3: Used Wireless Protocols for smart home [13].

Short-range wireless communication and low power consumption protocols are:

- **WIFI:**

Wi-Fi is a wireless communication technology that uses radio waves to link devices to a network. Adhering to the IEEE 802.11 standard, it functions across many frequency bands, ranging from 2.4 GHz to 5 GHz. One of the most widely used wireless protocols for smart homes is Wi-Fi.

Wi-Fi is highly versatile and widely supported, which makes it suitable for a broad range of smart home devices. It provides an extensive coverage, enabling devices to connect from different spots within home. Wi-Fi provides the bandwidth sufficient for data-intensive devices (e.g., video streaming).

Wi-Fi signal strength and coverage may be impacted by interference from other devices operating on different frequencies as well as obstructions like walls or furniture.

Furthermore, Wi-Fi is less appropriate for smart home devices that run on batteries since it uses more power than low-power protocols.

Wi-Fi runs on WPA2 and WPA encryption protocols to protect data transmitted over the network. However, the security of a Wi-Fi network also depends on factors like strong passwords and regular firmware updates that address vulnerabilities [14].

- **Bluetooth:**

Bluetooth and BLE are low-power device-specific wireless communication protocols. They allow short range wireless data transmission and reception between devices andfunction in the 2.4 GHz frequency spectrum.

Bluetooth and BLE are go-to communication protocols for battery-powered smart home devices due to their low energy consumption. They enable efficient data transferring and support direct device-to-device communication. Note that Bluetooth supports more features but consumes more power. You can use Bluetooth and BLE if you develop smart locks, sensors, and light bulbs.

The coverage area of Bluetooth and BLE is limited to the end user's house due to their short range. It works well for low-power applications, but not for devices that need high data transfer rates or wide coverage.

AES-CCM encryption is used by Bluetooth and BLE to secure data transfer. To fix any possible security flaws, it's essential to make sure that firmware and devices are up to current, just like with any wireless protocol [14].

- **Ethernet:**

Ethernet is a wired communication technology commonly used for local area networks (LANs). It operates via twisted pair and fiber-optic cables to transmit data at high speed. Ethernet follows the IEEE 802.3 standard and supports reliable and secure data transmission over a network.

An Ethernet connection offers a reliable and strong connection for smart home appliances. Ethernet's large bandwidth makes it ideal for local network operation and for gadgets like smart TVs, game consoles, and video streaming devices that need a dependable and quick Internet connection. Reliable communication between devices is ensured by Ethernet connections, which also remove the possibility of network interference.

Ethernet requires running cables throughout the home, which can be burdensome for end users. Therefore, Ethernet is the most suitable option when wired connections are already in place.

The smart home ecosystem is not well-secured when using Ethernet. Nonetheless, it guarantees safe data transfer through additional Ethernet-based protocols [14].

- **Z-Wave:**

Z-Wave is a wireless technology that offers dependable and secure communication between devices by operating in the sub-GHz frequency range, which is less than 1 GHz. By functioning as nodes in a mesh network, Z-Wave devices expand network coverage and keep connections intact in the event that a node fails.

Devices serve as repeaters in Z-Wave mesh networks, expanding the network's coverage. The network's range and dependability are improved by its self-healing topology. In order to maintain ongoing connection in the event of a device failure, the network reroutes signals over alternative pathways. Low-power Z-Wave protocols are utilized in smart thermostats, security systems, and lighting.

Z-Wave is a proprietary communication protocol, which means it may have limited compatibility with devices developed by third-party manufacturers.

Z-Wave operates on AES-128 encryption and supports two-way authentication between devices to ensure only authorized devices can join the network. Z-Wave ensures constant security via OTA updates [14].

- **Zigbee:**

Zigbee is a low-cost, short-range wireless communication standard that uses little power. It has a mesh network topology and runs in the 2.4 GHz frequency range. Devices operate as nodes under the Zigbee protocol, expanding the network's scope. Mesh networks have the ability to automatically reconfigure and retain connectivity with other nodes in the event of a node failure.

Because of its mesh networking features and low power consumption, Zigbee is a good fit for smart home solutions. Devices can communicate with each other reliably thanks to this protocol. If you create sensors, thermostats, and smart lighting, you can use it.

Due to its short range, Zigbee is less appropriate for use in large homes and areas with substantial physical barriers. To expand the coverage, more Zigbee routers or repeaters might be needed, which would raise the network's total cost and complexity.

To secure communication, Zigbee relies on the AES-128 standard. The manufacturer regularly improves vulnerabilities and updates the firmware [14].

I.4 Conclusion:

A home automation system automates the majority of electrical, electronic, and technology-based tasks in a household, enabling control and management of household appliances and devices through a combination of hardware and software technologies. As technology advances, these systems are expected to continue evolving and expanding, introducing new devices and applications

IoT-based home automation solutions typically offer the tools necessary for remote monitoring, evaluation, and management of the system via a web browser or smartphone application. The lives of people are significantly impacted by these systems. These systems have a significant impact on people's lives, providing greater scalability and flexibility compared to traditional options.

Chapter II:

IoT in Home Automation: Critical Operating Systems and Server Architectures

II.1 Introduction

In the rapidly evolving landscape of home automation, the integration of Internet of Things (IoT) technology has fundamentally changed how we interact with our living spaces. At the heart of IoT-based home automation systems are the operating systemsand servers that drive these smart technologies. This chapter explores the critical role these components play in creating seamless, responsive, and secure smart home environments.

While a variety of operating systems and server solutions exist for IoT applications, this chapter specifically focuses on the Home Assistant operating system. It explores the system's unique features, advantages, and typical use cases. By examining Home Assistant in depth, we aim to provide a comprehensive understanding of the technological foundations that support modern home automation.

From its robust server platform that facilitates efficient communication and data management to its broad device compatibility and robust automation capabilities, this chapter highlights why Home Assistant stands out as a cornerstone in the smart home revolution [15].

II.2 Overview of Operating Systems and Servers for IoT-Based Home Automation

In this section, we will provide a brief overview of the leading operating systems and servers employed in IoT-based home automation. This sets the stage for our detailed exploration of Home Assistant [16].

II.2.1. Operating Systems

Contiki:

- Description: An open-source operating system for IoT, designed for resource-constrained devices.
- Key Features: IPv6 support, low power operation, and real-time capabilities.
- Use Case: Ideal for small sensors and devices in smart home networks [17].

FreeRTOS

- Description: A real-time operating system kernel for embedded devices, widely adopted in IoT applications.
- Key Features: Preemptive scheduling, small footprint, multi-tasking.
- Use Case: Suitable for managing multiple tasks in devices like smart thermostats and lighting systems [17].

RIOT OS

- Description: An open-source operating system focusing on modularity and energy efficiency.
- Key Features: Multi-threading, small memory footprint, extensive hardware support.
- Use Case: Best for low-power wireless devices within home automation networks [17].

Zephyr

- Description: A scalable, open-source real-time operating system backed by the Linux Foundation.
- Key Features: Cross-architecture support, strong security features.
- Use Case: Used in smart home hubs and security systems [17].

II.2.2 Servers

Mosquitto

- Description: An open-source message broker implementing the MQTT protocol.
- Key Features: Lightweight, supports MQTT version 5.0, authentication, and access control.
- Use Case: Facilitates communication between IoT devices and home automation systems [17].

Eclipse Kura

- Description: An IoT middleware framework providing gateway and edge computing services.

- Key Features: Device management, data management, cloud integration.
- Use Case: Suitable for smart home gateways that manage multiple devices and aggregate data [17].

OpenHAB

- Description: An open-source home automation platform integrating various systems and technologies.
- Key Features: Vendor-agnostic, supports numerous IoT protocols, unified interface.
- Use Case: Centralized control system for diverse smart home devices [17].

Home Assistant

- Description: An open-source home automation platform emphasizing local control and privacy.
- Key Features: Extensive device compatibility, powerful automation capabilities, user-friendly interface.
- Use Case: Control and automation of smart home devices, integrating a wide range of IoT products and services [15].

Google Home

- Description: A smart home platform powered by Google Assistant, integrating various smart devices.
- Key Features: Voice control, integration with Google services, compatibility with numerous IoT devices.
- Use Case: Managing and automating smart home devices via voice commands and Google Assistant [15].

Amazon Alexa

- Description: A smart home platform utilizing Amazon's voice assistant, Alexa, to control and automate devices.
- Key Features: Voice control, wide device compatibility, integration with Amazon services.

- Use Case: Voice-activated control of smart home devices and integration with a broad ecosystem of IoT products [17].

Blynk

- Description: An IoT platform providing tools to build web and mobile applications for the Internet of Things.
- Key Features: User-friendly interface, cloud connectivity, customizable dashboards.
- Use Case: Developing custom IoT solutions for home automation with an emphasis on app-based control and monitoring [17].

II.3 Home Assistant:

Home Assistant OS is an open-source home automation platform that emphasizes local control and privacy. It serves as a versatile integration platform and smart home hub designed to be independent of specific IoT ecosystems. This platform provides an embedded system experience akin to commercial off-the-shelf products, facilitating easy onboarding, configuration, and updates through a user-friendly interface.

The architecture of Home Assistant OS includes a minimal Linux environment to host Supervisor and Core components. The Supervisor manages the OS, while the Core interacts with users, Supervisor, and IoT devices/services. This modular setup allows Users to tailor the Home Assistant stack to their specific needs, offering flexibility in deployment.

Moreover, Home Assistant OS supports a wide range of hardware platforms and provides extensive integration capabilities, enabling the creation of a cohesive smart home ecosystem [18]

Home Assistant is renowned for its emphasis on local control, privacy, and extensive customization options, making it suitable for tech-savvy users willing to invest time in configuration. In contrast, platforms like Homey Pro offer a more intuitive and user-friendly experience straight out of the box, complete with cloud services, voice integrations, and dedicated customer support.

Users appreciate Home Assistant's robustness, configurability, and ability to integrate diverse devices and services, while acknowledging its steeper learning curve and hands-on maintenance requirements. Overall, the choice between Home Assistant and other platforms depends on users' programming experience, preferences for customization, and desired level of hands-on involvement in their smart home setup [19].

II.3.1 Key Features:

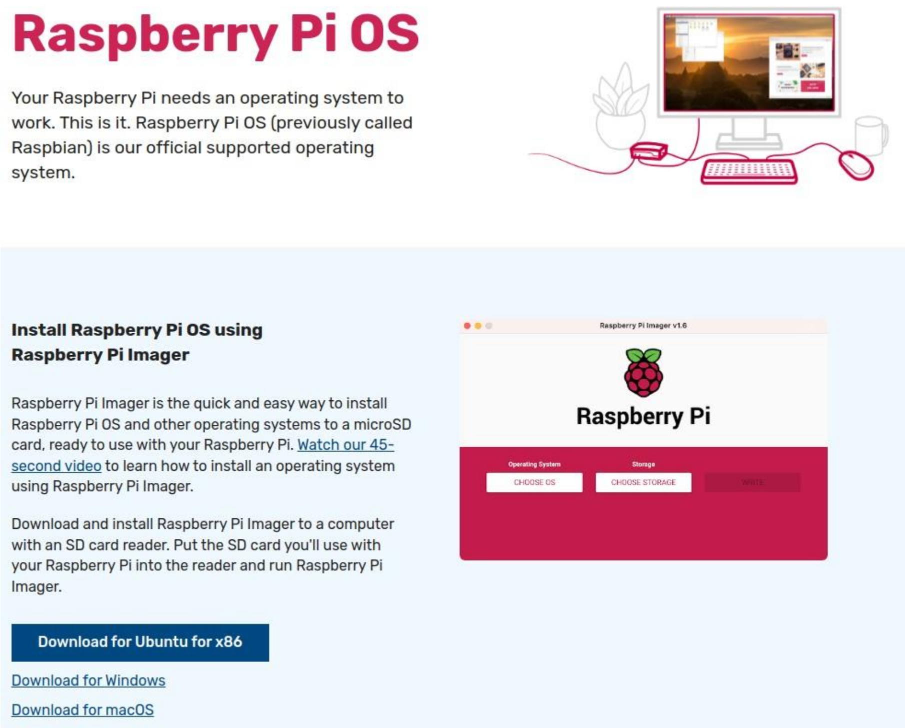
- Local Control and Privacy: Home Assistant operates locally on the user's device, with no remote access enabled by default. User data is stored solely on the device, ensuring privacy.
- Security: Home Assistant has security features like two-factor authentication and security ratings for add-ons. However, some security vulnerabilities have been discovered and addressed over time.
- Integrations: Home Assistant integrates with over a thousand different devices and services, allowing users to control a wide range of smart home products.
- Automation: Home Assistant's advanced automation engine allows users to create custom automations, such as turning on lights when the sun sets or receiving alerts when the garage door is left open.
- Ecosystem: Home Assistant is supported by a large, worldwide community of tinkerers and DIY enthusiasts, who contribute to the project and provide ongoing support.
- Platforms: Home Assistant can be run on a variety of platforms, including Raspberry Pi, ARM, and x86 devices, and is available as a software appliance or virtual appliance [20].

II.3.2 Installing Home Assistant OS

The process of installing Home Assistant OS involves several key steps:

- Write the image to you SD card

1. Download and install the Raspberry Pi Imager on your computer as described under.



Raspberry Pi OS

Your Raspberry Pi needs an operating system to work. This is it. Raspberry Pi OS (previously called Raspbian) is our official supported operating system.

Install Raspberry Pi OS using Raspberry Pi Imager

Raspberry Pi Imager is the quick and easy way to install Raspberry Pi OS and other operating systems to a microSD card, ready to use with your Raspberry Pi. Watch our 45-second video to learn how to install an operating system using Raspberry Pi Imager.

Download and install Raspberry Pi Imager to a computer with an SD card reader. Put the SD card you'll use with your Raspberry Pi into the reader and run Raspberry Pi Imager.

Download for Ubuntu for x86

Download for Windows

Download for macOS

Figure II.1.: Installing OS step01 [21].

2. Open the Raspberry Pi imager and select your Raspberry Pi device.

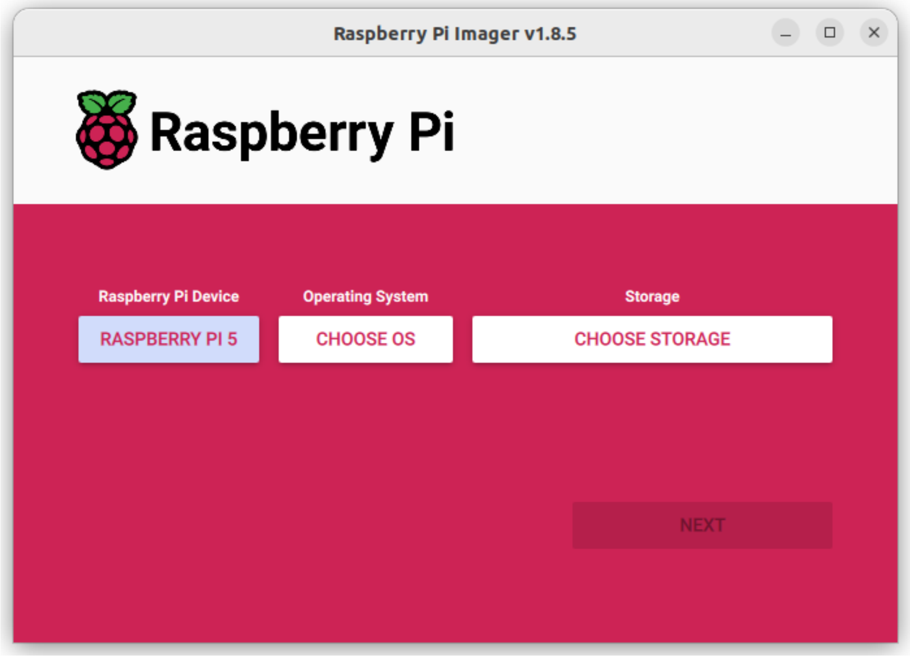
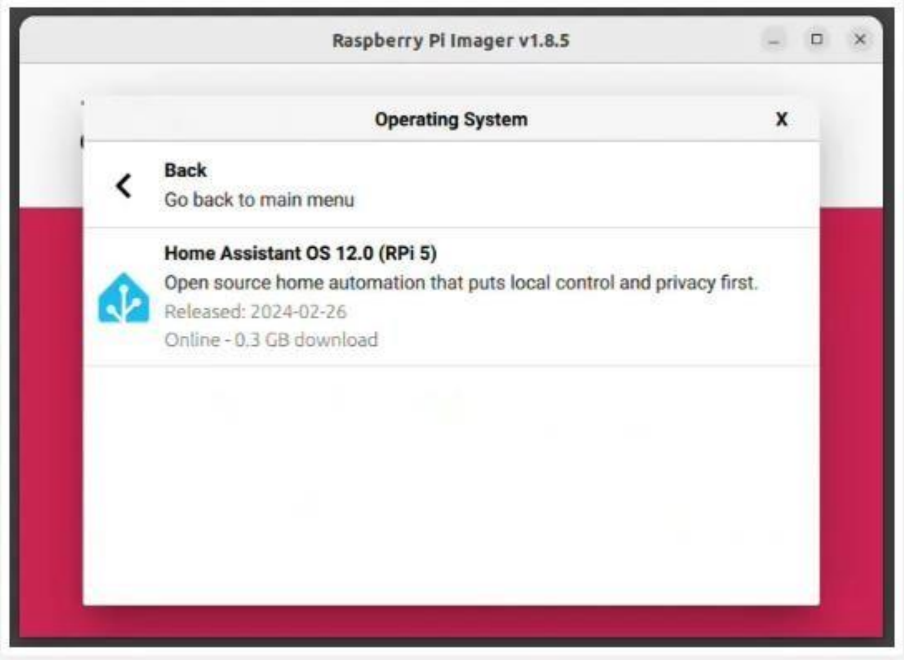


Figure II.2.: Installing OS step02 [21].

3. Choose the operating system:
    1) Select Choose OS.
    2) Select Other specific-purpose OS > Home assistants and home automation > Home Assistant.
    3) Choose the Home Assistant OS that matches your hardware (RPi 3, RPi 4, or RPi 5).



Raspberry Pi Imager v1.8.5

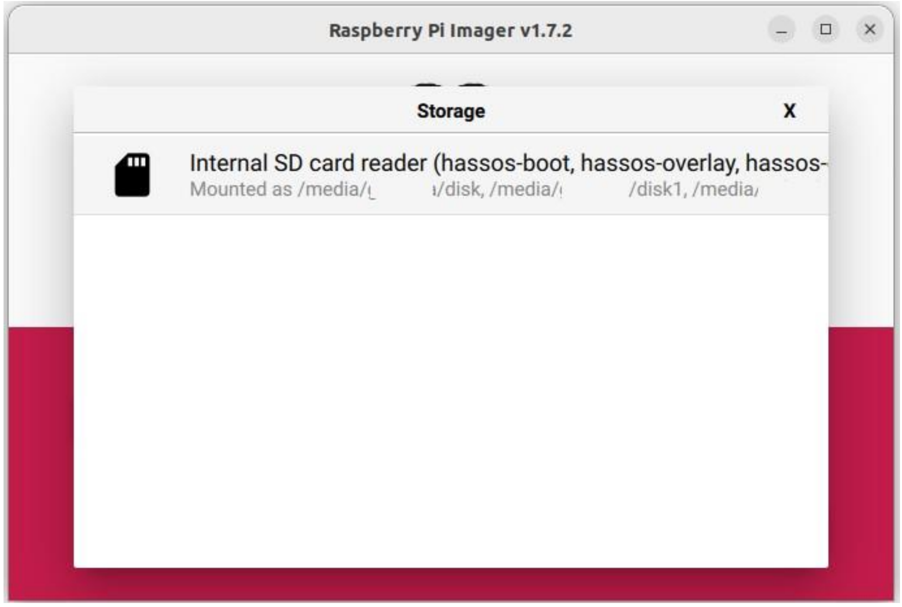
Operating System

Back
Go back to main menu

Home Assistant OS 12.0 (RPi 5)
Open source home automation that puts local control and privacy first.
Released: 2024-02-26
Online - 0.3 GB download

Figure II.3.: Installing OS step03 [21].

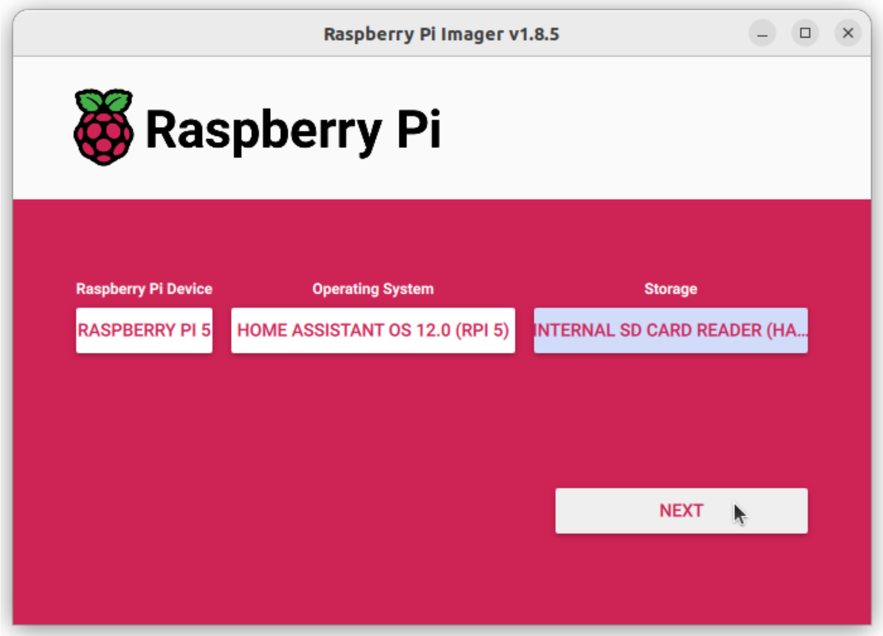
4. Choose the storage:
    1) Insert the SD card into the computer. Note: the contents of the card will be overwritten.
    2) Select your SD card.



Internal SD card reader (hassos-boot, hassos-overlay, hassos-
Mounted as /media/ /disk, /media/ /disk1, /media/

Figure II.4.: Installing OS step04 [21].

5. Write the installer onto the SD card:
   1) To start the process, select Next.
   2) Wait for the Home Assistant OS to be written to the SD card.



Raspberry Pi Device: RASPBERRY PI 5
Operating System: HOME ASSISTANT OS 12.0 (RPI 5)
Storage: INTERNAL SD CARD READER (HA...

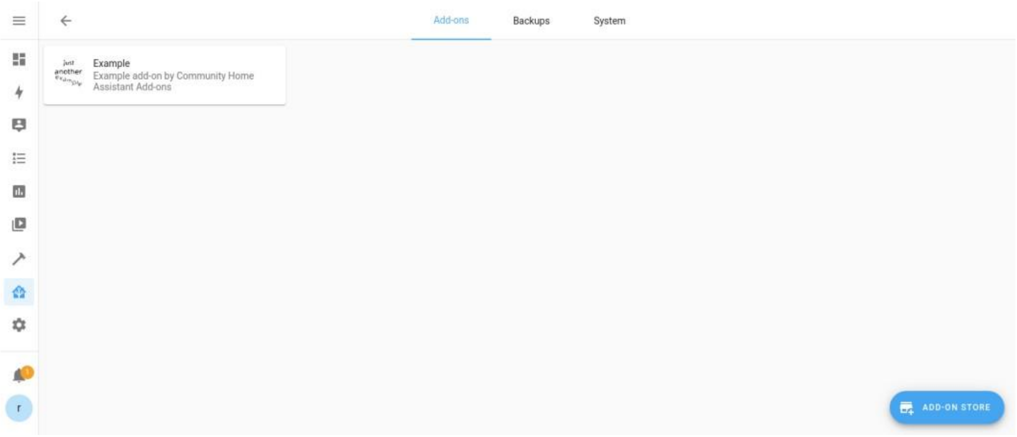
Figure II.5.: Installing OS step05 [21].

6. Eject the SD card.

- Start up your Raspberry Pi
  1) Insert the SD card into your Raspberry Pi.
  2) Plug in an Ethernet cable and make sure the Raspberry Pi is connected to the same network as your computer and is connected to the internet.
  3) Connect the power supply to start up the device [21].

II.3.3 Configuration:

The onboarding process takes care of the initial setup for Home Assistant, such as naming your home and selecting your location. After initial onboarding, these options can be changed in the user interface by clicking on Configuration in the sidebar and clicking on General, or by manually editing them in the Home Assistant configuration file called configuration.yaml. To make the first changes to the config.yaml file, we are going to install an add-on from the Home Assistant add-on store: the File editor. To get to the add-on store, go to Settings > Add-ons. On the new page, open the add-on store tab [22].



Example
Example add-on by Community Home Assistant Add-ons

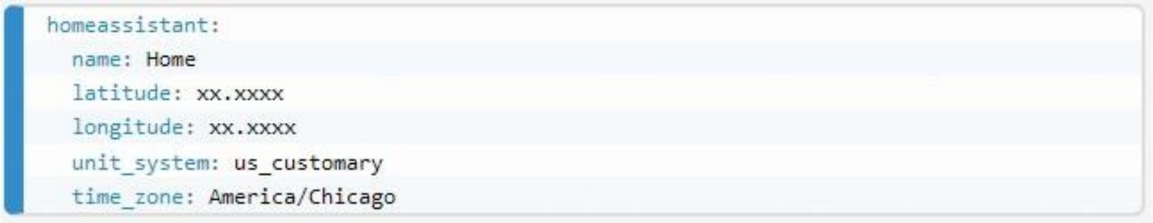
Figure II.6.: Configuration step01 [22].

Under the Official add-ons section, you will find the File editor add-on.

- Click on File editor and click on Install. When the installation is complete, the UI will go to the add-on details page for the file editor.
- Now start the add-on by clicking on Start.
- Open the user interface by clicking on Open Web UI.

Now let’s make a change using the file editor: we are going to change the name, location, unit system, and time zone of your Home Assistant installation.

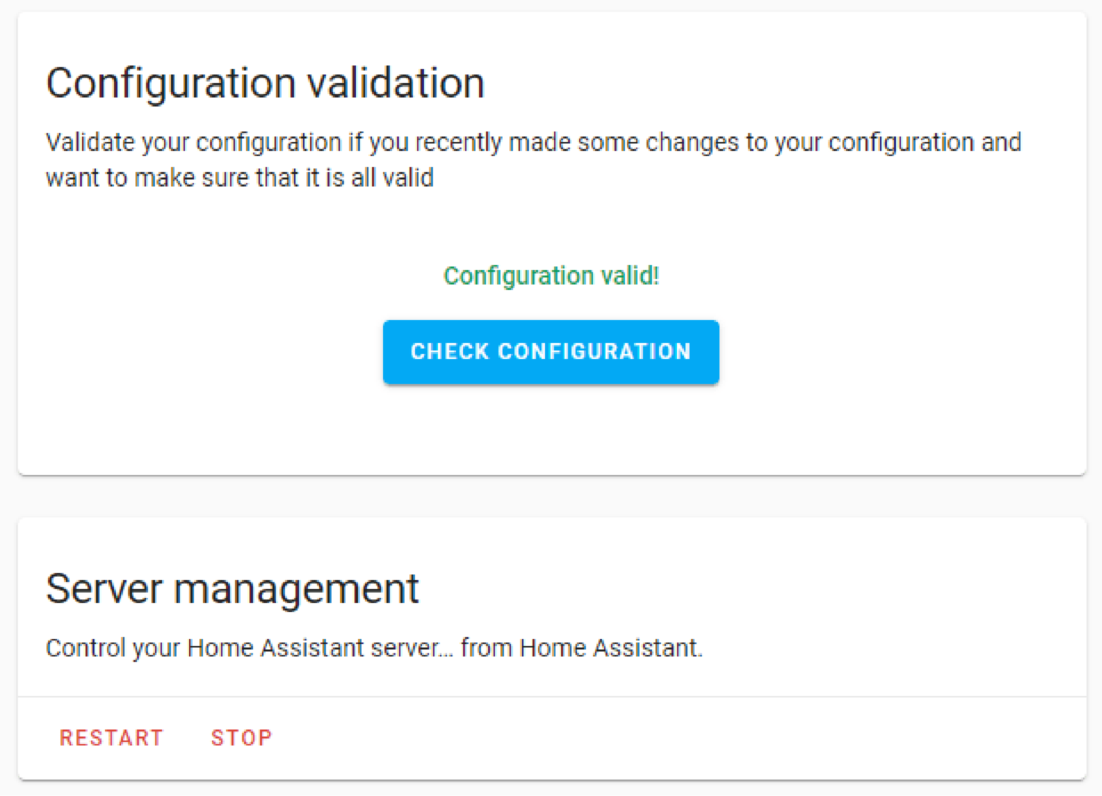
- Click the folder icon in the top left of the file editor window to open the file browser sidebar.
- Click the configuration.yaml file (in the /config/ folder) to load it into the main file editor window.
- Add the following to this file (preferably at the very top, but it ultimately doesn’t matter):



```
homeassistant:
  name: Home
  latitude: xx.xxxx
  longitude: xx.xxxx
  unit_system: us_customary
  time_zone: America/Chicago
```

Figure II.7.: Configuration step02 [22].

- Click the save icon in the top right to commit changes.
- Most changes in configuration.yaml require Home Assistant to be restarted to see the changes. You can verify that your changes are acceptable by running a configuration check. Do this by navigating to Developer Tools > YAML and then clicking on the Check configuration button. When it’s valid, it will show the text “Configuration valid!”. In order for the Check Configuration” button to be visible, you must enable Advanced Mode on your user profile.
- Now restart Home Assistant. You can do so by either using the Restart option in the ⚙ menu of the File Editor UI or by navigating to Settings > System and then clicking on the Restart button on the top right of the page [22].



Configuration validation

Validate your configuration if you recently made some changes to your configuration and want to make sure that it is all valid

Configuration valid!

Server management

Control your Home Assistant server... from Home Assistant.

Figure II.8.: Configuration step03 [22].

II.4 Blynk

Blynk is an iOS and Android platform for controlling Arduino, Raspberry Pi, and other Internet-connected devices. It has the ability to manage hardware remotely, show sensor data, store data, visualize it, and perform a variety of other fascinating things [23].

The platform is made up of three primary components:

- **Blynk App:** enables the user to create stunning interfaces for the projects by combining multiple widgets.
- **Blynk Server:** is in charge of all data transfers between the smartphone and the hardware.
- **Blynk Libraries:** enable communication with the server and process all incoming and outgoing commands for all popular hardware platforms [23].

II.5 Amazon Alexa

Amazon Alexa is a virtual assistant platform developed by Amazon that allows users to interact with devices and services using voice commands [24].

Alexa is Amazon's cloud-based voice service available on hundreds of millions of devices from Amazon and third-party manufacturers. Alexa can perform various tasks like playing music, setting alarms, creating to-do lists, providing weather and traffic updates, and controlling smart home devices [24].

- **Alexa App:** It allows users to discover new skills, control smart home devices remotely, and stay organized with lists and reminders.
- **Alexa-Enabled Devices:** Amazon offers a range of Alexa-enabled devices, including Echo smart speakers, Fire TV devices, and third-party devices from brands like Sonos, Lenovo, and Harman Kardon.

II.6 Google Home

Google Home is a comprehensive smart home platform that combines voice-controlled speakers, a mobile app, and a wide range of compatible devices to provide a personalized and helpful home experience for users, while also offering a robust developer ecosystem for building innovative smart home solutions [25].

- **Google Home App Features:**

- Provides a Favorites tab to quickly access frequently used devices, automations, and actions.

- Includes an Automations tab to create Routines for home automation.

- Shows home activity history, including camera events and device interactions [25].

- **Supported Devices:**

- Google Home supports a wide range of Google devices like Nest Mini, Nest Thermostat, Nest Cam, and Chromecast.

- It also works with many other compatible smart home products from various brands, including lights, locks, plugs, and Matter-enabled devices [25].

- **Privacy and Security:**

Google Home uses advanced security infrastructure to protect user privacy by default [25].

II.7 Apple HomeKit

Apple HomeKit is a software framework and communication protocol developed by Apple Inc. that allows users to configure, communicate with, and control smart home appliances using Apple devices [26].

- **Home App:**

- The Home app, introduced in iOS 10, unifies all HomeKit devices into one app for easy control.

- Supports automations using a home hub and pre-programmed "scenes" to control multiple devices with a single command [26].

- **Home Hubs:**

- Apple TVs (4th generation or newer) and HomePods can act as home hubs to control HomeKit devices remotely, grant guest access, and set up automations.

- HomePod Mini, 2nd gen HomePod, and Apple TV 4K (2nd gen and later) support Thread, a low-power mesh networking protocol for IoT devices [26].

II.8 Conclusion

IoT-based home automation systems enable remote monitoring and control of household appliances via smartphones, enhancing convenience and security. These systems are pivotal for real-time home security, automation, and remote system management.

Chapter III:

Practical Applications of Home Automation Systems

III.1 Introduction

Home automation represents a significant leap forward in how we control and interact with our living environments. At the forefront of this technological revolution is the ESP32 microcontroller, distinguished for its robust processing capabilities and integrated Wi-Fi and Bluetooth features. This chapter explores the diverse applications of the ESP32 in enhancing home automation systems, focusing on three distinct implementations: a SIM800L-based Home Automation Security System, a Smart Lighting System, and a SIM800L and MQTT-based Pump Control. Each of these applications illustrates the versatility and efficiency of the ESP32 in creating secure, energy-efficient, and user-friendly home automation solutions.

III.2 Application 1: Home Automation Security System

III.2.1 Introduction

The GSM-based Home Automation Security System is an innovative solution designed to enhance the security and convenience of modern homes. This system leverages the Global System for Mobile Communications (GSM) technology to provide remote control and monitoring of household appliances and security devices. By integrating GSM technology with home automation, users can control lights, doors, and other appliances via text messages or mobile applications, ensuring efficient energy usage and improved security.

Key security features include real-time alerts and notifications for potential intrusions or unauthorized access, sent directly to the homeowner's mobile device. This immediate response capability enables swift action, such as alerting authorities or activating in-home countermeasures. The combination of automation and security in a single system offers homeowners peace of mind and a higher degree of control over their living environment.

III.2.2 Description of the Proposed System

The GSM-based Home Automation Security System is designed to provide a comprehensive security solution for modern homes, utilizing advanced automation and GSM communication technologies. This system aims to enhance both security and convenience, allowing homeowners to monitor and control their home environment remotely and efficiently.

Core Components and Functionality: At the heart of the system are motion sensors strategically placed in various rooms throughout the home. These sensors are highly sensitive and capable of detecting any movement within their designated areas. Upon detecting movement, the system immediately initiates two key actions:

1. **Alarm Activation**: An audible alarm is triggered to alert anyone in the vicinity of the potential intrusion. This serves as a deterrent to intruders and provides immediate awareness to occupants.
2. **Emergency Calls**: Simultaneously, the system automatically dials two predefined phone numbers. These calls ensure that homeowners, security personnel, or emergency contacts are promptly informed of the detected movement, allowing for quick response and intervention.

Control Methods: To offer maximum flexibility and ease of use, the system can be activated and deactivated through three distinct methods:

1. **Physical Button**: Located on the control board, this button allows users to manually activate or deactivate the system. This method provides a straightforward and reliable means of control, particularly useful when the user is at home.
2. **SMS Message**: For remote control, the system can be operated via SMS messages. Users can send specific commands to activate or deactivate the system, providing control from virtually anywhere. This feature leverages GSM technology, ensuring that users can manage their home security even when they are far from home.
3. **Home Assistant Interface**: Integration with a home assistant interface adds a layer of digital control, allowing users to manage the system through a user-friendly platform. This interface can be accessed via smartphones, tablets, or computers, offering an intuitive and seamless control experience. Through this interface, users can also monitor sensor status, view system logs, and receive real-time notifications.

System Advantages: The proposed GSM-based Home Automation Security System offers several advantages:

- **Immediate Response**: The combination of alarm activation and emergency calls ensures rapid response to potential security threats.

- **Remote Control**: The ability to manage the system via SMS and home assistant interface provides unparalleled convenience and flexibility.
- **User-Friendly**: The straightforward control options and intuitive interface make the system accessible to users of all technical levels.
- **Enhanced Security**: Real-time monitoring and notifications enhance the overall security of the home, giving homeowners peace of mind.

In summary, the GSM-based Home Automation Security System integrates advanced motion detection, GSM communication, and user-friendly control methods to deliver a robust and reliable home security solution. This system not only safeguards the home but also offers convenient and flexible management options, making it an ideal choice for modern homeowners.

III.2.3 Mains elements of GSM based Home Automation

There are three main elements of a home automation system: sensors, actuators, and controllers. In this GSM based Home Automation Security System we have used IR sensor and esp32 Chip to control. Where ESP32 Chip is connected with IR sensor to detect human existence, Sim800L GSM module, and buzzer. The IR sensor is used along with the SIM 800L to automatically send a message to the phone when a human passes by and triggers the alarm.

1. **ESP32chip:** The ESP32 chip (FigIII.1) is a microcontroller developed by Espressif Systems, a Chinese company. It is a low-power, low-cost, and highly integrated chip that supports Wi-Fi, Bluetooth, and Zigbee protocols. The ESP32 chip is designed for IoT applications and is widely used in various devices such as smart home devices, wearables, and other IoT devices [27].

Figure III.1.: ESP32 Chip [28].

2. **IR Motion Sensor:** The IR (infrared) motion sensor, also known as a PIR (Passive Infrared) sensor, is a device that detects motion by measuring changes in infrared radiation. It is commonly used in security systems, lighting controls, and various IoT applications. The sensor works by detecting changes in infrared radiation, not just the presence of infrared, allowing it to differentiate between static heat sources and moving heat sources like people or animals. Key features of IR motion sensors include a detectionrange of up to 20 feet, adjustable sensitivity, low power consumption, and a digital pulse output when motion is detected. These sensors are essential components in creating motion-activated projects and enhancing automation and security applications in various systems [29].

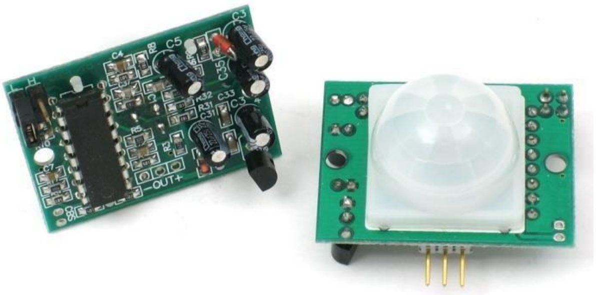


Figure III.2.: IR sensor [29].

3. **Relays:** Relays (Fig. III.3) are electrical devices that are typically used as inputs for controlling high voltages using very low voltages. This is constructed from two small metal flaps that seal the circuit and a coil wound around a pole. While one node is stationary, the other is movable. When electricity is delivered through the coil, it causes itto vibrate. It produces a magnetic field that pulls the moving node closer to the stationary node as a result the circuit gets completed. So, the circuit is ready for the high voltage to travel just by supplying a little voltage to start it up. Using a relay allows you to regulate AC appliances that need to be turned on and off at high voltage levels [30].

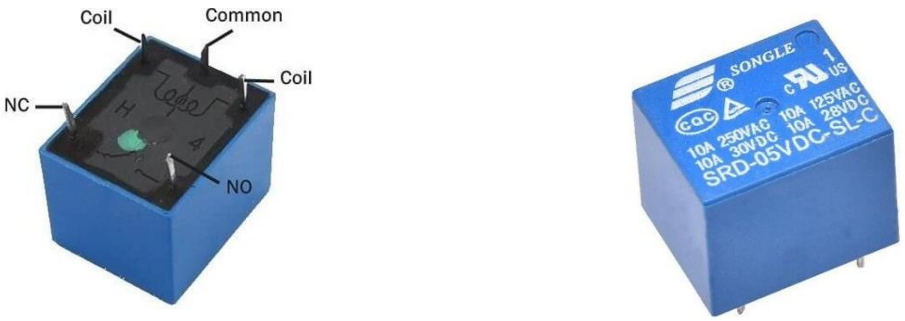


Figure III.3.: Relay srd-05vdc-sl-c [30].

4. **Buzzer and LEDs** (Fig. III.4 and Fig. III.5) have been used.

Figure III.4.: Buzzer [31]. **Figure III.5.**: Leds [32].

5. **SIM800L Module:** The SIM800L GSM/GPRS module is a miniature GSM modem that can be used in a variety of IoT projects. You can use this module to do almost anything a normal cell phone can do, such as sending SMS messages, making phone calls, connecting to the Internet via GPRS, and much more [33].

To top it all off, the module supports quad-band GSM/GPRS networks, which means it will work almost anywhere in the world [33].

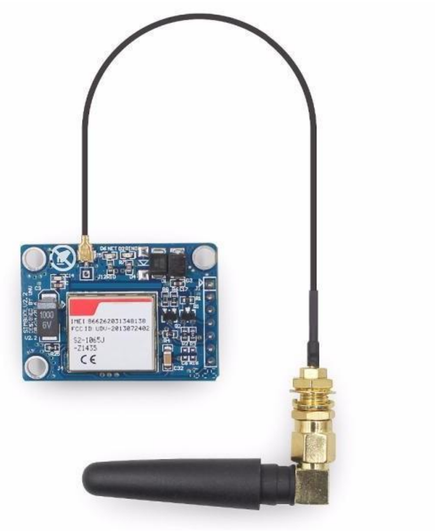


Figure III.6.: SIM800L module [34].

III.2.4 Designed Printed Circuit Board (PCB)

The designed Printed Circuit Board (PCB) for the GSM-based Home Automation Security System integrates various components to ensure efficient functionality and user-friendly operation. This section outlines the key elements and their roles within the system.

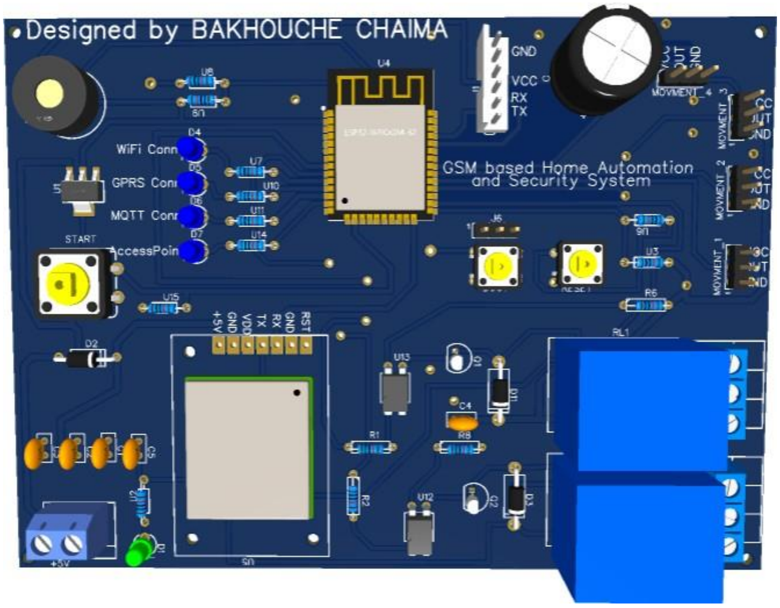


Figure III.7.: 3D Designed Printed Circuit Board (PCB).

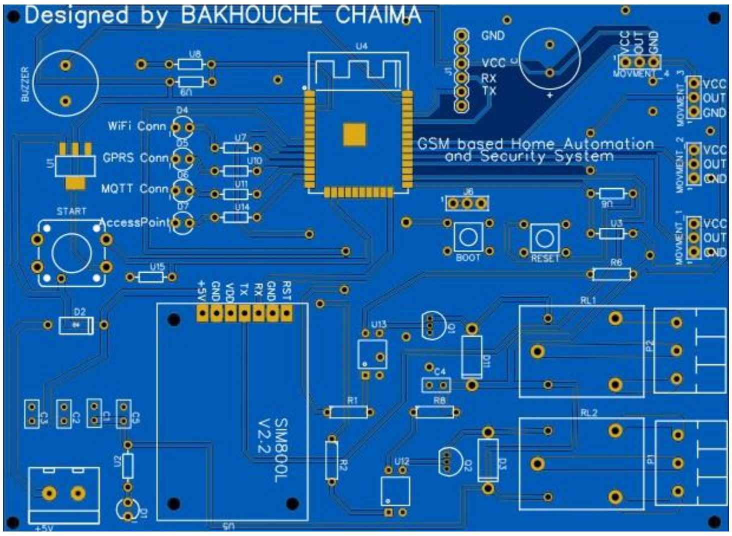


Figure III.8.: 2D Designed Printed Circuit Board (PCB).

Core Components

1. **ESP32 Chip**: At the heart of the PCB is the ESP32 chip, a powerful and versatile microcontroller with built-in WiFi and Bluetooth capabilities. The ESP32 handles the primary processing tasks, including sensor data management, communication with the GSM module, and user interface operations.
2. **LED Indicators**: Four LEDs are included on the PCB to provide visual feedback on the system's status:
   - **WiFi Connection LED**: Indicates the status of the WiFi connection. When lit, it confirms that the system is connected to a WiFi network.
   - **GPRS Connection LED**: Shows the status of the GPRS connection, ensuring that the system can communicate via GSM.
   - **MQTT Connection LED**: Reflects the status of the MQTT connection, indicating successful communication with the MQTT broker.
   - **Access Point Mode LED**: Lights up when the system is in Access Point mode, allowing direct connection for configuration or troubleshooting.
3. **Buttons**:
   - **Reboot Button**: This button reboots the entire system, useful for resetting the system or recovering from an error state.
   - **Programming Boot Button**: Used during the programming phase of theESP32 chip, this button enables the chip to enter boot mode for firmware updates.

  - **Activation/Deactivation Button**: Allows manual activation or deactivation of the security system, providing a quick and accessible control method for the user.

4. **SIM800L Module**: This GSM module facilitates communication over the GSM network, enabling the system to send SMS alerts and make emergency calls. It is crucial for remote monitoring and control features.
5. **Relays**: Two relays are incorporated to control the alarm siren. These relays are activated when a motion sensor detects movement, triggering the siren to alert occupants and deter intruders.
6. **5V Buzzer**: A buzzer is included on the PCB to provide audible feedback when an action is performed. This buzzer activates to confirm operations such as system activation/deactivation, providing an additional layer of user interaction.

PCB Layout and Design: The layout of the PCB is meticulously designed to ensure optimal performance and ease of use. Components are strategically placed to minimize signal interference and maximize operational efficiency. Key considerations in the design include:

- **Signal Integrity**: Careful routing of signal traces to avoid interference and ensure reliable communication between components.
- **Power Management**: Efficient power distribution to ensure stable operation of all components, with particular attention to the power requirements of the ESP32 and SIM800L module.
- **User Accessibility**: Placement of LEDs and buttons in accessible locations to provide clear and intuitive user feedback and control.

The designed PCB is a critical component of the GSM-based Home Automation Security System, integrating essential hardware to provide robust functionality and user-friendly operation. By combining the ESP32 chip, SIM800L module, relays, LEDs, buttons, and a buzzer, the PCB ensures seamless performance and effective control, enhancing the overall security and convenience of the system.

III.2.5 Home Assistant Configuration for the Security System

The lighting control system has been integrated with Home Assistant to create a unified interface for controlling all 14 channels. In Home Assistant, a section titled "Control Lights" was added, which includes controls for each of the 14 channels.

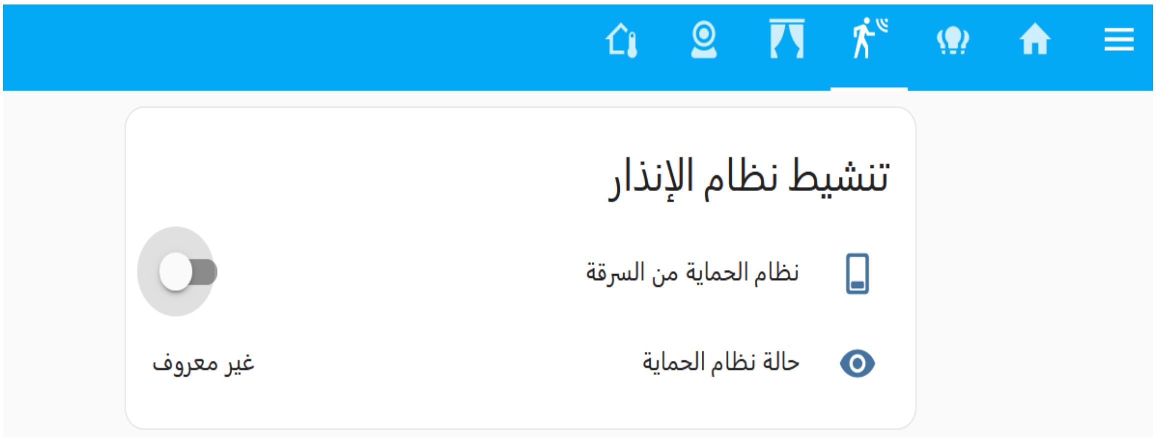
a) Home Assistant Settings

Adding MQTT Configuration:

- Home Assistant is configured to communicate with the ESP32 board using the MQTT protocol.
- MQTT topics are set up for each of the 14 channels for control and status updates.

b) Add Control Interface:

- Through the Home Assistant user interface, add a new control panel containing buttons for activation or deactivation of system and its state



تنشيط نظام الإنذار

نظام الحماية من السرقة

حالة نظام الحماية غير معروف

Figure III.9.: Home Assistant user interface.

c) Configuring WiFi and MQTT via Access Point Mode

The configuration of WiFi, MQTT username, and password is set using Access Point mode. Here’s how you can do it:

1. **Entering Access Point Mode**:
    - Press and hold the start button until you hear 10 beeps. The system will restart and enter Access Point mode.
2. **Connecting to Access Point**:
    - Open the WiFi settings on your device and connect to the network named "SecurtySystem".
    - No password is required for this connection.
    - Number phone
3. **Accessing the Configuration Page**:
    - Once connected, open a web browser and enter the IP address `192.168.4.1`.
    - This will open the HTML configuration page.
4. **Entering Configuration Details**:
    - The configuration page includes fields for:
        - **WiFi SSID and Password**: To connect the system to your home WiFi network.
        - **MQTT Broker Address**: The IP address of your MQTT broker.
        - **MQTT Username and Password**: Credentials for your MQTT broker.
        - **Phone Number**
5. **Saving the Configuration**:
    - After entering all the necessary details, click the "Submit" button to save the configuration to the ESP32 EEPROM.
6. **Exiting Access Point Mode**:
    - Press and hold the start button again for 10 beeps. The system will restart and exit Access Point mode, now ready to operate with the new settings.

III.3 Application 2: Lighting control system

III.3.1 Introduction

The Lighting Control System is a key component of the home automation project, designed to manage up to 14 separate lighting channels. Each channel can be individually controlled, providing a high degree of flexibility and customization for various lighting needs within the home.

III.3.2 System Overview

The Lighting Control System leverages the ESP32 microcontroller to manage 14 distinct lighting channels. This system allows users to control each lighting channel individually or in groups, either manually or remotely via a mobile application or web interface. This level of control enables users to create customized lighting scenarios to enhance comfort, convenience, and energy efficiency.

III.3.3 Main Components

a) ESP32 Microcontroller

The ESP32 serves as the central controller for the lighting system. It handles all the communication, processing, and control tasks, ensuring that each lighting channel operates as intended. The ESP32's built-in Wi-Fi and Bluetooth capabilities allow for seamless integration with mobile applications and other smart devices.

b) Relays

Each of the 14 lighting channels is controlled by an individual relay. These relays are responsible for switching the lights on and off based on the commands received from the ESP32. The use of relays ensures reliable and robust control over the lighting circuits.

III.3.4 Control Interfaces

The system can be controlled through various interfaces:

1. **Manual Control**: Physical switches or buttons connected to the ESP32 can be used to manually control each lighting channel.
2. **Mobile Application**: A dedicated mobile app allows users to control the lighting remotely. The app communicates with the ESP32 via Wi-Fi or Bluetooth, providing a user-friendly interface for managing the lighting system.
3. **Web Interface**: Users can also control the lighting through a web browser by accessing the system's IP address. This interface offers similar functionalities to the mobile app, making it easy to adjust lighting settings from any device with internet access.

III.3.5 Functionality

1. Individual Channel Control

Each of the 14 channels can be individually controlled, allowing users to turn specific lights on or off according to their needs. This is particularly useful for creating customized lighting environments in different rooms or areas of the home.

2. Group Control

Channels can be grouped together to form lighting zones. Users can control these zones collectively, making it easy to implement lighting schemes for larger areas or entire floors of the house. For example, all living room lights can be grouped together and controlled with a single command.

3. Scheduling and Automation

The system supports scheduling and automation features, enabling lights to be turned on or off at specific times. This functionality is beneficial for enhancing security by simulating occupancy when the house is empty, as well as for energy savings by ensuring lights are only on when needed.

4. Dimming and Scene Creation

Advanced control options, such as dimming and scene creation, are also supported. Users can adjust the brightness of individual channels or groups of channels to create the perfect ambiance for any occasion. Scenes can be saved and recalled with a single command, making it easy to switch between different lighting setups.

5. Indicators and Feedback

The system includes visual indicators, such as LEDs, to provide feedback on the status of each channel. These indicators help users quickly identify which channels are active and ensure that the system is operating correctly.

The 14-channel Lighting Control System offers comprehensive and flexible lighting management for modern homes. With the ESP32 at its core, the system provides robust control, remote accessibility, and advanced features like scheduling and scene creation. This system not only enhances convenience and comfort but also contributes to energy efficiency and home security.

III.3.6 Designed Printed Circuit Board (PCB)

The designed Printed Circuit Board (PCB) for the Lighting System integrates various components to ensure efficient functionality and user-friendly operation. This section outlines the key elements and their roles within the system.

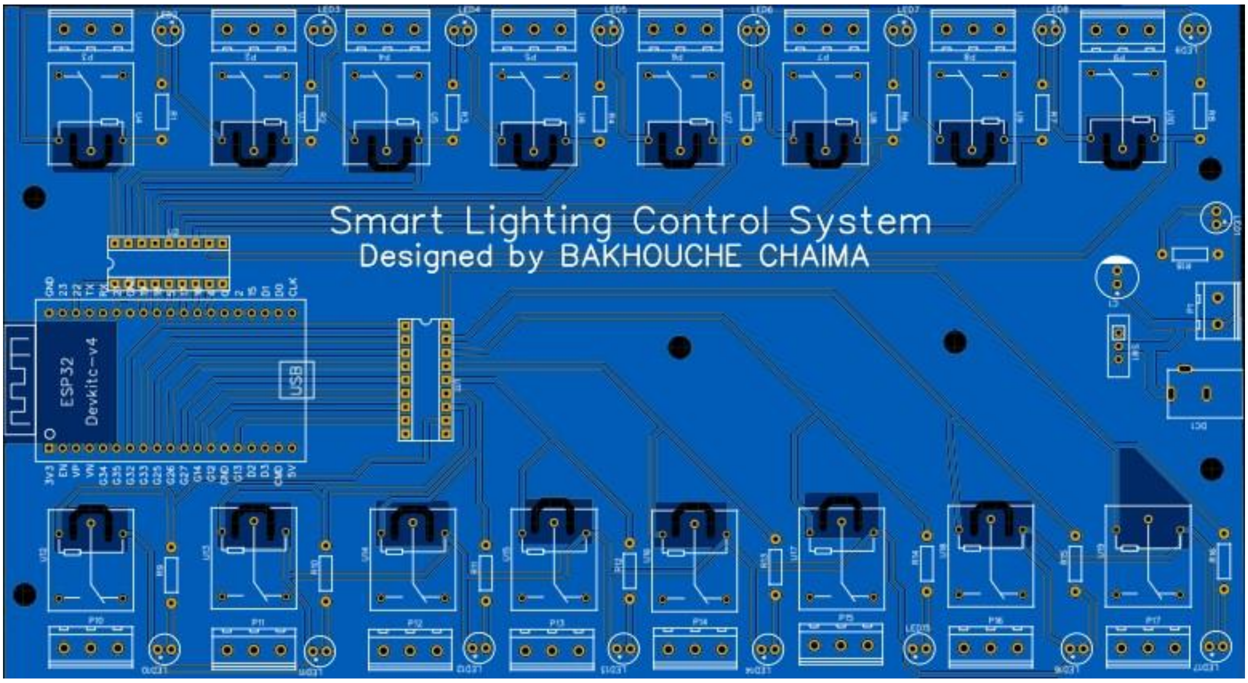


Figure III.10.:2D Designed Printed Circuit Board.

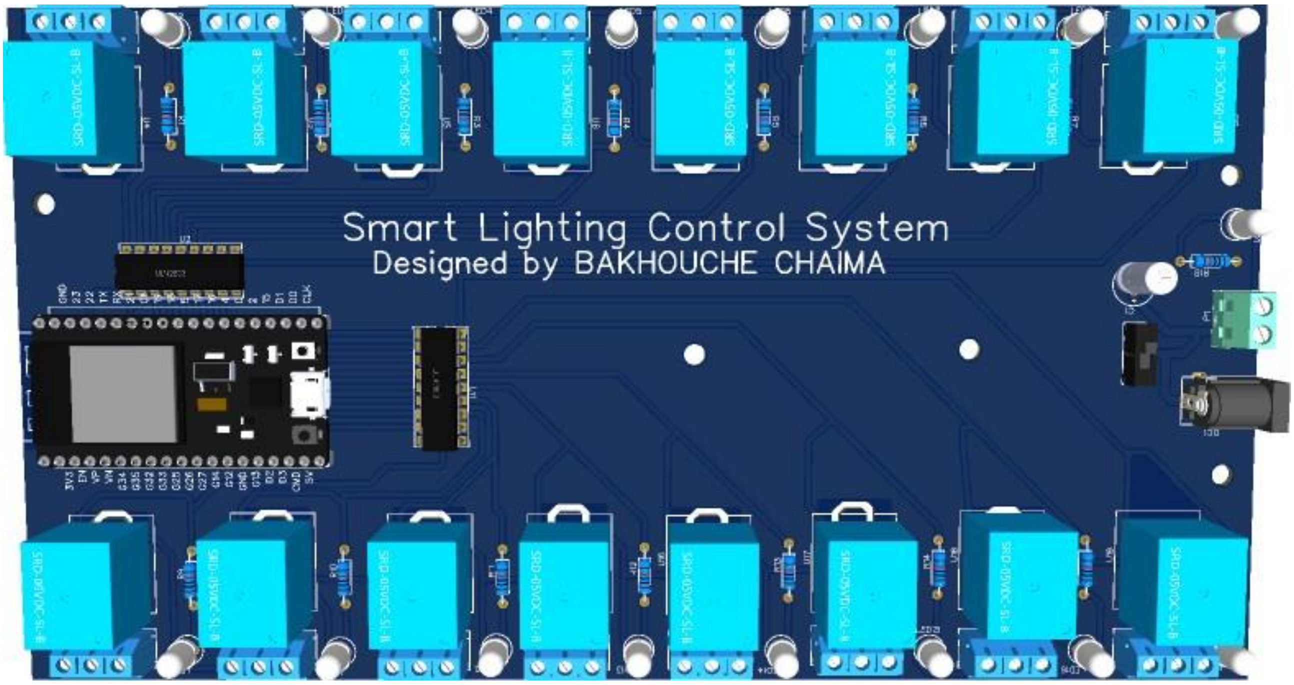


Figure III.11.:3D Designed Printed Circuit Board.

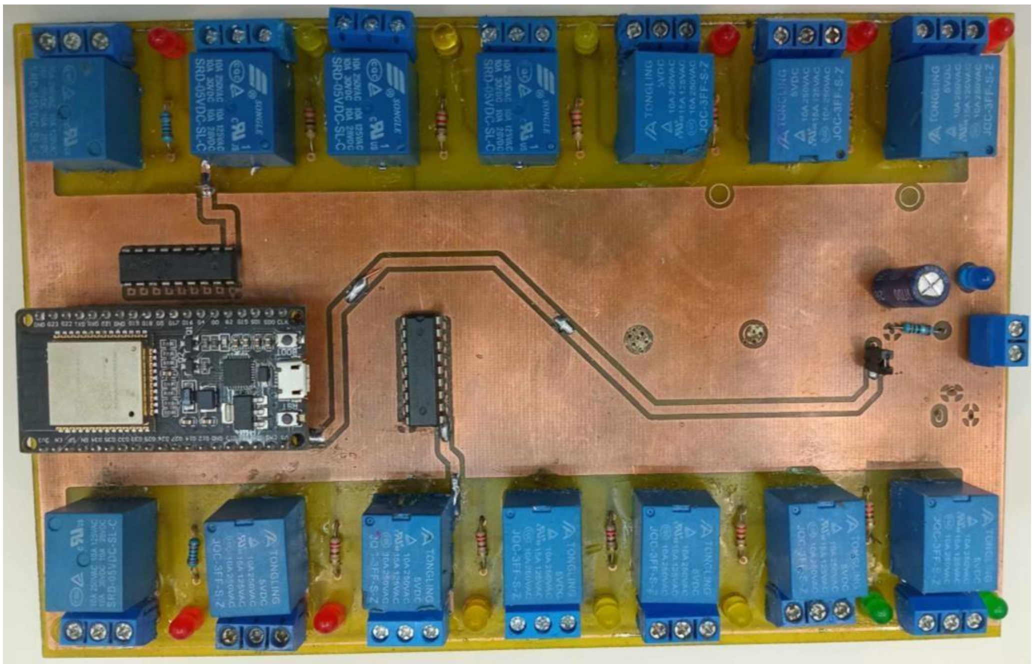


Figure III.12.: Real designed Circuit Board.

The PCB layout is carefully designed to minimize signal interference and ensure efficient operation. Key considerations in the layout include:

- **Separation of High and Low Voltage Areas**: High voltage components (relays) are physically separated from low voltage components (ESP32, control circuits) to prevent electrical interference.
- **Optimized Trace Routing**: Signal traces are routed to minimize cross-talk and electromagnetic interference.
- **Heat Dissipation**: Adequate spacing and heat sinks are provided for components that generate heat, ensuring the PCB operates within safe temperature limits.

Assembly and Testing

The PCB is assembled using high-quality components to ensure reliability. Each PCB undergoes rigorous testing to verify that all channels operate correctly, and that the ESP32 communicates effectively with the control interfaces. This testing ensures that the final product is robust and ready for deployment in home automation scenarios.

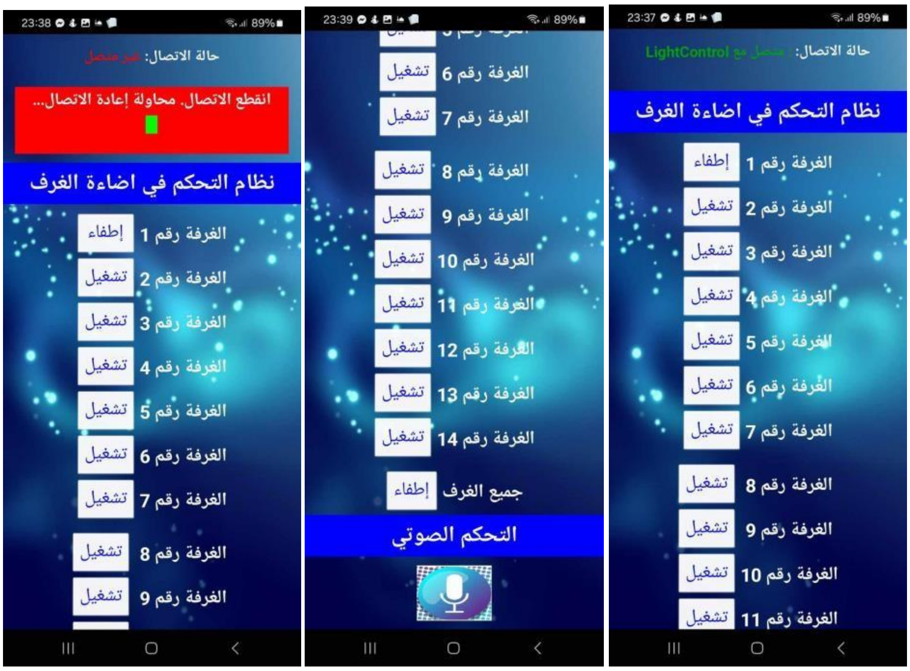
III.3.7 Android Application for 14-Channel Lighting Control

The Android application developed for the 14-channel lighting control system offers a user-friendly interface for managing the lighting in a home environment. The application uses Bluetooth for connecting to the control board, ensuring a seamless and efficient communication channel. One of the standout features of the application is its ability to automatically connect to the Bluetooth-enabled control board, simplifying the user experience.

Key Features of the Application

1. **Automatic Bluetooth Connection**:
   - The application is designed to automatically detect and connect to the Bluetooth module of the lighting control board upon launch. This eliminates the need for manual pairing and connection, providing a hassle-free user experience.
2. **Main Control Screen**:
   - The main screen of the application displays the status of all 14 lighting channels. Each channel can be individually controlled using intuitive on- screen buttons.

3. **Individual Channel Control**:
    - Users can turn each lighting channel on or off with a simple tap. The status of each channel (on/off) is visually indicated within the app.
4. **Group Control**:
    - Channels can be grouped together for collective control. This is useful for managing lighting in larger areas or specific zones within the home. Users can define groups and control them with a single command.
5. **Real-Time Status Updates**:
    - The application provides real-time updates on the status of each lighting channel. Any changes made manually or through the app are immediately reflected.



حالة الاتصال: غير متصل

انقطع الاتصال. محاولة إعادة الاتصال...

نظام التحكم في اضاءة الغرف

حالة الاتصال: متصل مع LightControl

نظام التحكم في اضاءة الغرف

Figure III.13.: Android Application for 14-Channel Lighting Control system.

The Android application for the 14-channel lighting control system leverages Bluetooth connectivity to provide a seamless and efficient user experience. With features such as automatic Bluetooth connection, individual and group control, scheduling, dimming, and scene creation, the application enhances the flexibility and functionality of the lighting control system. This ensures that users can easily manage their home lighting to suit their preferences and needs, contributing to a smarter and more comfortable living environment.

III.3.8 Home Assistant Configuration for the Lighting Control System

The lighting control system has been integrated with Home Assistant to create a unified interface for controlling all 14 channels. In Home Assistant, a section titled "Control Lights" was added featuring controls for each of the 14 channels.

a) Home Assistant Settings

1. **Adding MQTT Configuration**:
   - Home Assistant is configured to communicate with the ESP32 board using the MQTT protocol.
   - MQTT topics are set up for each of the 14 channels for control and status updates.
2. **Adding Control Panel**:
   - A control panel is added in Home Assistant containing 14 buttons, each representing a channel.
   - Each channel can be turned on or off individually through the control panel.
   - The status of each channel is displayed in real-time on the control panel.
3. **Add Control Interface**:

- Through the Home Assistant user interface, add a new control panel containing buttons for each channel.

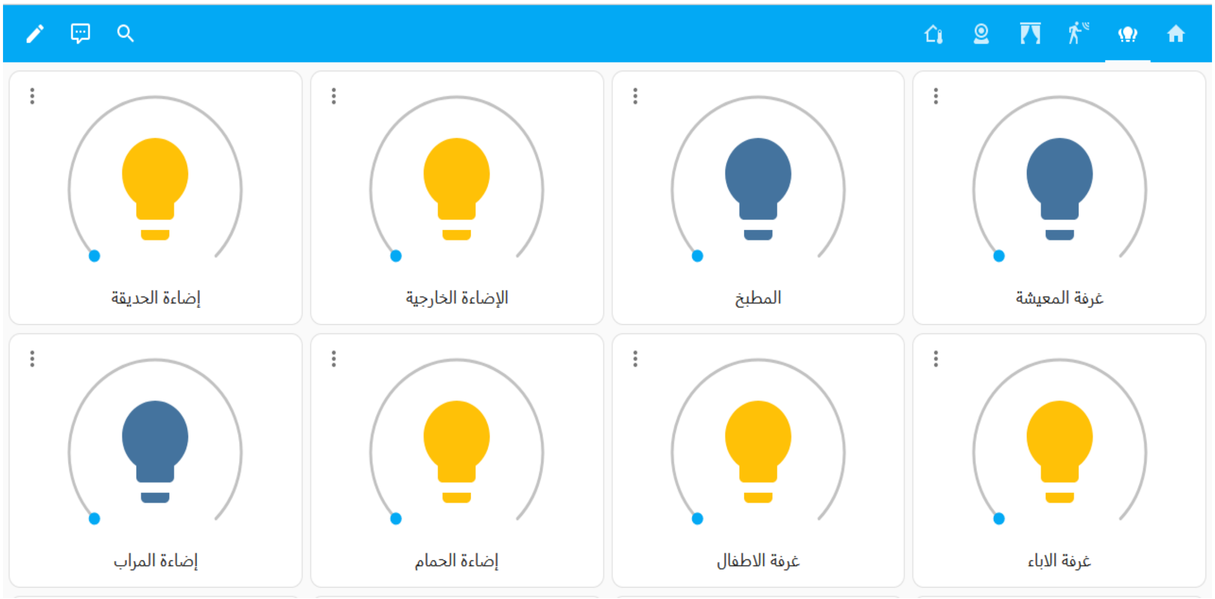


Figure III.14.: Home Assistant user interface.

4. Configuring WiFi and MQTT via Access Point Mode

Similar to the pump control application, the configuration of WiFi, MQTT username, and password is set using Access Point mode. Here’s how you can do it:

5. **Entering Access Point Mode**:

   ○ Press and hold the start button until you hear 10 beeps. The system will restart and enter Access Point mode.

6. **Connecting to Access Point**:

   ○ Open the WiFi settings on your device and connect to the network named "ControlLights".
   ○ No password is required for this connection.

7. **Accessing the Configuration Page**:

   ○ Once connected, open a web browser and enter the IP address `192.168.4.1`.
   ○ This will open the HTML configuration page.

8. **Entering Configuration Details**:

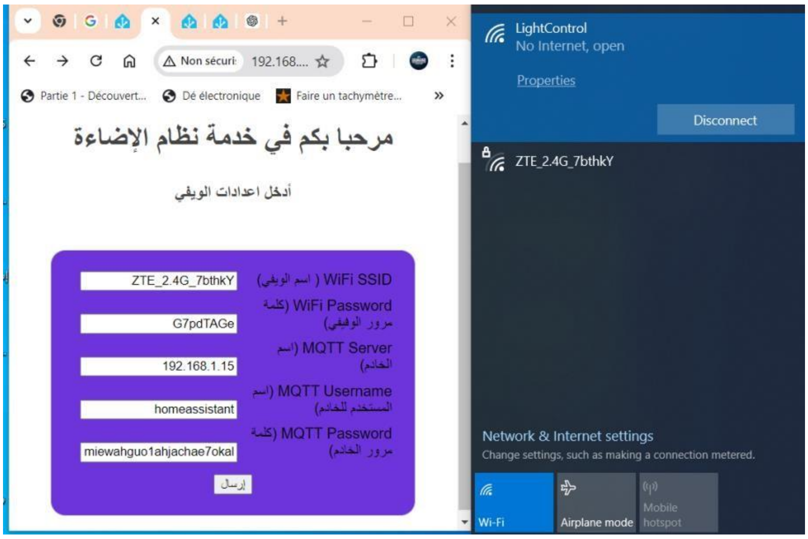
   - The configuration page includes fields for:
     - **WiFi SSID and Password**: To connect the system to your home WiFi network.
     - **MQTT Broker Address**: The IP address of your MQTT broker.
     - **MQTT Username and Password**: Credentials for your MQTT broker.

9. **Saving the Configuration**:

   - After entering all the necessary details, click the "Submit" button to save the configuration to the ESP32 EEPROM.

10. **Exiting Access Point Mode**:

    - Press and hold the start button again for 10 beeps. The system will restart and exit Access Point mode, now ready to operate with the new settings.



مرحبا بكم في خدمة نظام الإضاءة

أدخل اعدادات الويفي

WiFi SSID (اسم الويفي): ZTE_2.4G_7bthkY

WiFi Password (كلمة مرور الويفي): G7pdTAGe

MQTT Server (اسم الخادم): 192.168.1.15

MQTT Username (اسم المستخدم للخادم): homeassistant

MQTT Password (كلمة مرور الخادم): miewahguo1ahjachae7okal

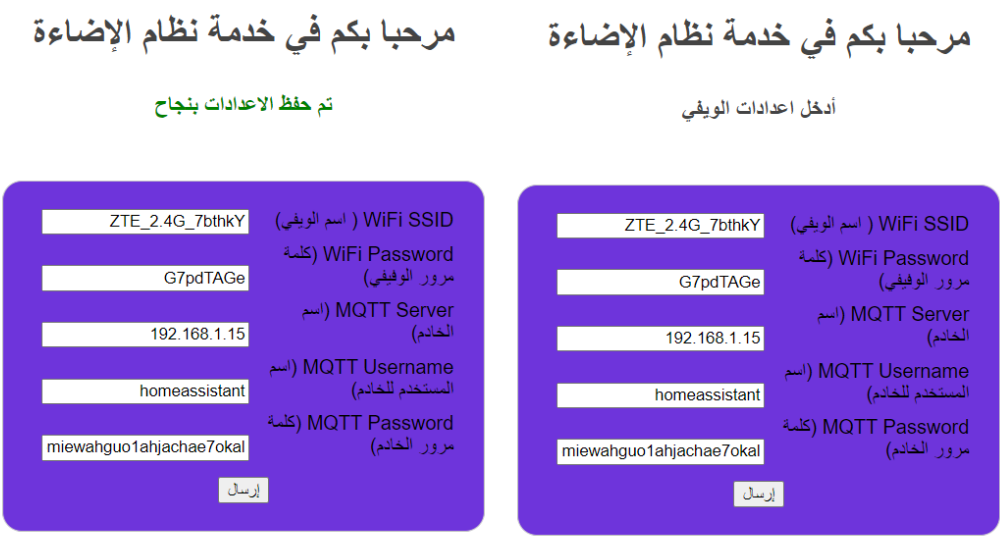
إرسال

LightControl
No Internet, open

ZTE_2.4G_7bthkY

Network & Internet settings
Change settings, such as making a connection metered.

Figure III.15.: Access point mode for Lighting Control system.



مرحبا بكم في خدمة نظام الإضاءة

تم حفظ الاعدادات بنجاح

WiFi SSID (اسم الويفي) ZTE_2.4G_7bthkY

WiFi Password (كلمة مرور الويفي) G7pdTAGe

MQTT Server (اسم الخادم) 192.168.1.15

MQTT Username (اسم المستخدم للخادم) homeassistant

MQTT Password (كلمة مرور الخادم) miewahguo1ahjachae7okal

إرسال

مرحبا بكم في خدمة نظام الإضاءة

أدخل اعدادات الويفي

WiFi SSID (اسم الويفي) ZTE_2.4G_7bthkY

WiFi Password (كلمة مرور الويفي) G7pdTAGe

MQTT Server (اسم الخادم) 192.168.1.15

MQTT Username (اسم المستخدم للخادم) homeassistant

MQTT Password (كلمة مرور الخادم) miewahguo1ahjachae7okal

إرسال

Figure III.16.: Access point mode parameters.

The lighting control system is part of an integrated home automation system that allows users full control over their home lighting via an Android application or through Home Assistant. This integration enhances convenience and efficiency in managing lighting, providing a smart and comfortable living environment. The system also allows easy configuration of WiFi and MQTT settings via Access Point mode, ensuring that setup and maintenance are user-friendly. Furthermore, using a Raspberry Pi 4 as the server for Home Assistant ensures reliable and efficient management of the entire system.

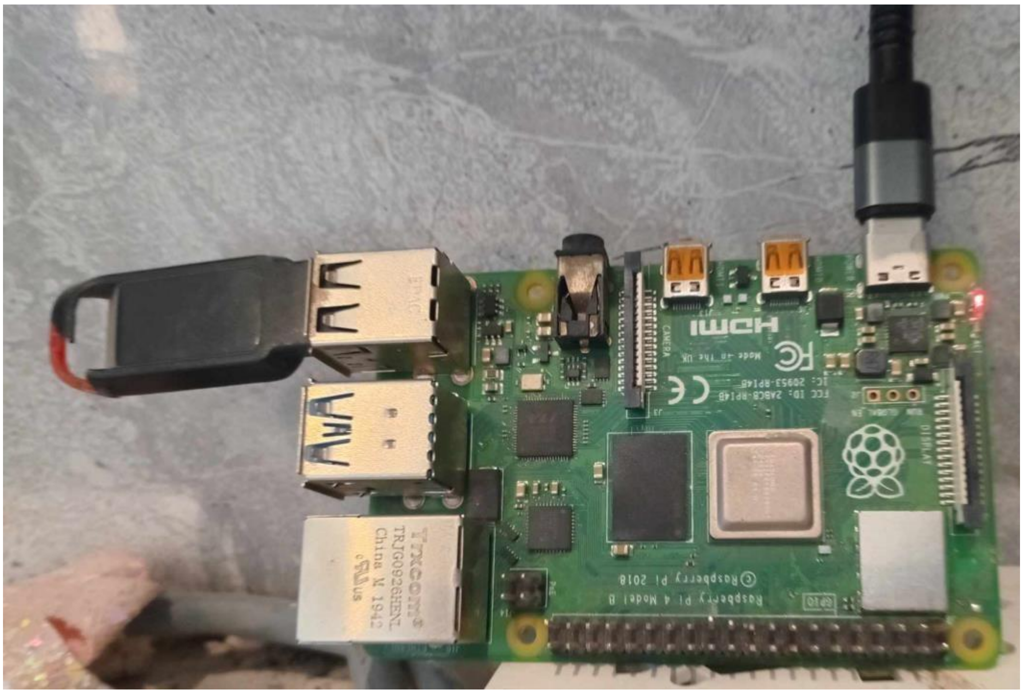


Figure III.17.: used ***Raspberry Pi 4*** as the server for Home Assistant.

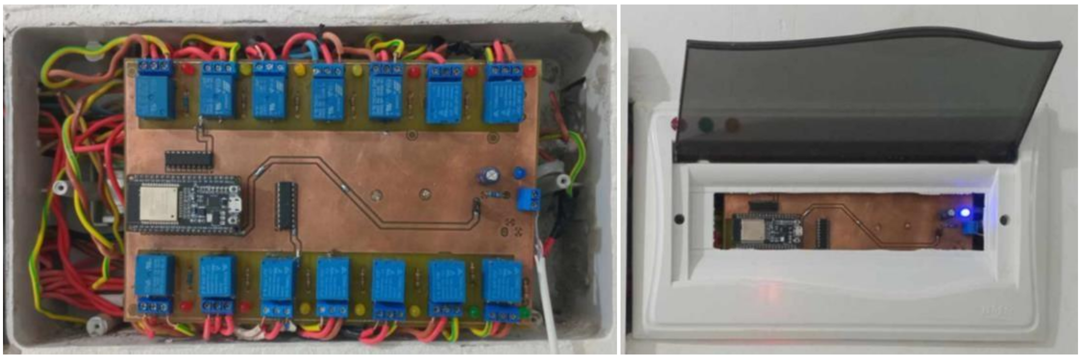


Figure III.18.: Lighting control board installed in the electrical switchboard.

III.4Application 3: GSM based pump Control

III.4.1Introduction

Efficient water management is crucial for both agricultural and residential applications. The GSM-based Pump Control system leverages the ESP32 microcontroller andthe SIM800L GSM module to provide remote control and monitoring of water pumps. To enhance user convenience, the system is equipped with an Android application that facilitates easy management and operation. Through GSM communication, users can control the pump via the app from any location, ensuring timely and precise irrigation. This integration optimizes water usage and enhances productivity, making it an invaluable tool for modern water management practices.

III.4.2 Description of the Proposed System

The GSM-based Pump Control system is designed to provide flexible and efficient management of water pumps, catering to both manual and remote operation. This system leverages the capabilities of the ESP32 microcontroller and the SIM800L GSM module, combined with an intuitive Android application, to offer robust and user-friendly control over pump operations. The core functionality of the system allows users to turn the pump on or off either manually or remotely. For manual control, users can directly interact with the physical interface connected to the ESP32, enabling straightforward and immediate operation of the pump. For remote control, the system utilizes GSM communication to receive commands sent via the Android application. This remote access ensures that users can manage the pump from any location, providing unparalleled convenience and flexibility.

To prevent overuse and ensure optimal water management, the system includes features that manage the pump's operating time. Users can set a default maximum run time for the pump through the Android application. If the pump is turned on, the system will automatically shut it off once this predefined time elapses, preventing any potential damage or water wastage due to prolonged operation.

Additionally, the system allows users to define a new stop time as needed. This customization ensures that the pump operates according to the specific requirements of the user, whether for irrigation schedules or other water management needs. By providing both preset and adjustable timing options, the system guarantees safe and efficient pump operation, aligning with user preferences and usage patterns.

The proposed GSM-based Pump Control system offers a comprehensive solution for managing water pumps, combining manual and remotecontrol capabilities with advanced time management features. This ensures efficient water usage, enhanced convenience, and reliable operation tailored to the user's needs.

III.4.3 Android Application for Pump Control

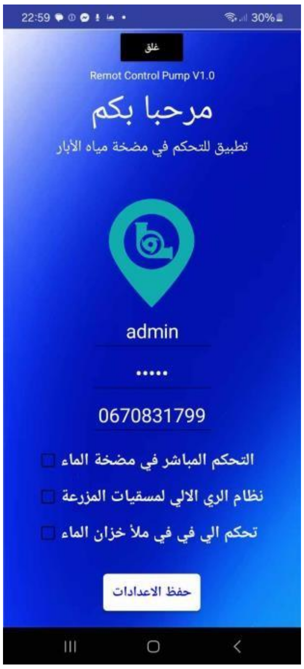
The Android application developed for the GSM-based Pump Control system provides a user-friendly interface to manage and monitor the pump operations remotely. The application is designed with simplicity and efficiency in mind, featuring two main screens that offer comprehensive control and monitoring functionalities.

a) First Screen: User Authentication

The initial screen of the application is dedicated to user authentication and configuration. It includes three text input fields:

1. **Username**: Allows the user to enter their unique username for authentication.
2. **Password**: A secure input field for the user's password to ensure authorized access.
3. **Phone Number**: The phone number of the SIM card located in the system board, which the application will use to communicate with the pump control system.
4. **Check Box**: An option to enable automatic water level control for a tank. When checked, this option allows access to additional controls for managing the water level.

These credentials ensure secure access to the pump control functionalities and establish a reliable communication link with the system.



Remot Control Pump V1.0

مرحبا بكم

تطبيق للتحكم في مضخة مياه الأبار

admin

•••••

0670831799

□ التحكم المباشر في مضخة الماء

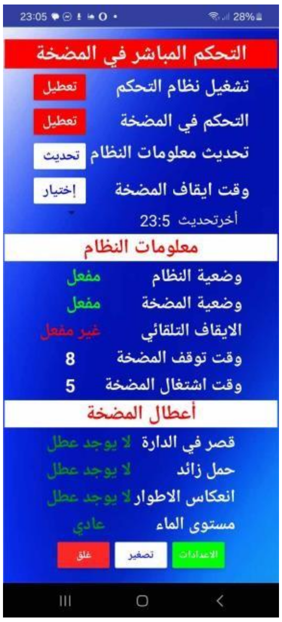
□ نظام الري الالي لمسقيات المزرعة

□ تحكم الي في في ملأ خزان الماء

Figure III.19.: First Android Application screen.

b) Second Screen: Pump Control and Monitoring

The second screen of the application is divided into three subsections, each serving a distinct purpose for control and monitoring.



التحكم المباشر في المضخة

تشغيل نظام التحكم تعطيل

التحكم في المضخة تعطيل

تحديث معلومات النظام تحديث

وقت ايقاف المضخة إختيار

أخرتحديث 23:5

معلومات النظام

وضعية النظام مفعل

وضعية المضخة مفعل

الايقاف التلقائي غير مفعل

وقت توقف المضخة 8

وقت اشتغال المضخة 5

أعطال المضخة

قصر في الدارة لا يوجد عطل

حمل زائد لا يوجد عطل

انعكاس الاطوار لا يوجد عطل

مستوى الماء عادي

Figure III.20.: Second Android Application screen.

- **Control Pump**

This subsection provides four buttons for various control actions:

1. **Turn System On/Off**: This button allows the user to remotely turn the entire system on or off.
2. **Turn Pump On/Off**: This button enables the user to remotely start or stop the pump.
3. **Update System Information**: This button refreshes the system information displayed in the application, ensuring that the user has the most up-to-date data.
4. **Set Desired Running Time**: This button opens a selection list where the user can choose the desired running time for the pump, allowing for precise control over its operation.

- **System Information**

The second subsection displays critical information about the pump system:

1. **System Status**: Indicates whether the system is currently on or off.
2. **Pump Status**: Shows whether the pump is currently running or stopped
3. **Default Stop Time**: Displays the default maximum running time set for the pump.
4. **Actual Running Time**: Provides the current running time of the pump, helping users track how long the pump has been operating.

- **Pump Faults**

The third subsection is dedicated to monitoring and displaying any faults detected in the pump system:

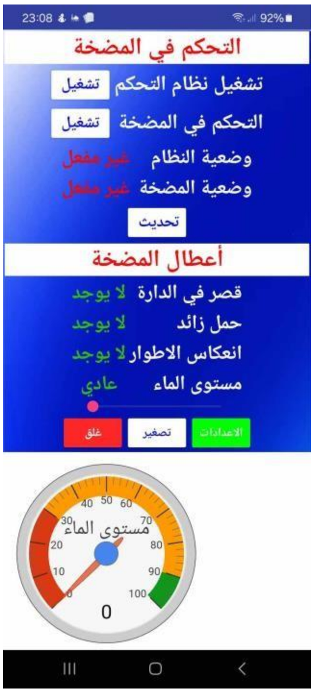
1. **Short Circuit**: Indicates if there is a short circuit in the pump's electrical system.
2. **Overload**: Alerts the user if the pump is experiencing an overload condition.
3. **Phase Change**: Detects and reports any phase changes in the pump's electrical supply.
4. **Water Level**: Monitors and displays the water level to prevent dry running or overflow conditions.

The application provides real-time feedback and notifications to keep the user informed about the pump's status and any faults that may occur. This ensures that the user cantake timely action to address any issues and maintain optimal pump operation. It offers a comprehensive and intuitive interface for managing the GSM-based Pump Control system. With secure authentication, remote control capabilities, real-time information updates, and fault monitoring, the application ensures efficient and effective management of water pump operations.

c) Third Screen: Automatic Water Level Control

When the check box for automatic water level control is selected on the first screen, the application provides access to an additional screen dedicated to managing the water level of a tank. This screen includes:

- **Water Level Monitoring**: Real-time display of the current water level in the tank.
- **Automatic Control Settings**: Options to set thresholds for water levels to trigger automatic pump operations, ensuring the tank maintains a desired water level without manual intervention.
- **Manual Override**: Allows the user to manually control the pump if needed, even when the automatic control is enabled.



التحكم في المضخة

تشغيل نظام التحكم تشغيل

التحكم في المضخة تشغيل

وضعية النظام غير مفعل

وضعية المضخة غير مفعل

أعطال المضخة

قصر في الدارة لا يوجد

حمل زائد لا يوجد

انعكاس الاطوار لا يوجد

مستوى الماء عادي

Figure III.21.: Third Android Application screen.

d) Fourth Screen: Automatic Water Level Control

The fourth screen of the application is divided into four subsections, each serving a distinct purpose for control and monitoring.

1. Main Control Panel

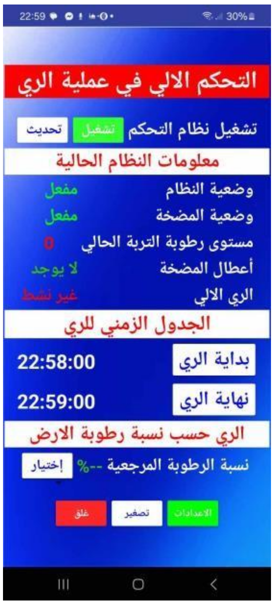
Buttons:

- Activate System: this button is used to turn on or turn off the system.
- Update System Information: this button is used to refresh and retrieve the latestsystem status and information.

2. System Information Display

This section shows real-time data about your irrigation system:

- **System State:** Displays whether the system is active or inactive.
- **Pump State:** Indicates whether the pump is currently running or stopped.
- **Soil Humidity Level:** Shows the current moisture level of the soil.
- **Pump Faults:** Displays any issues or faults detected in the pump.
- **Automatic Irrigation State:** Shows if the automatic irrigation feature is enabled ordisabled.



معلومات النظام الحالية

وضعية النظام مفعل

وضعية المضخة مفعل

مستوى رطوبة التربة الحالي 0

أعطال المضخة لا يوجد

الري الالي غير نشط

الجدول الزمني للري

بداية الري 22:58:00

نهاية الري 22:59:00

الري حسب نسبة رطوبة الارض

نسبة الرطوبة المرجعية --%

Figure III.22.: Fourth Android Application screen.

3. **Irrigation Scheduling**

Schedule Time of Irrigation:

- **Select Start Time:** It uses to set the beginning time for the irrigation operation.
- **Select End Time:** It uses to set the ending time for the irrigation operation.

4. **Irrigation Based on Reference Soil Humidity**

Reference Soil Humidity: It uses to choose the desired reference humidity level for the soil. The system will use this reference to determine when to activate the irrigation based on the current soil moisture level.

III.4.4 Android Application for MQTT-Based Pump Control

This section details the use of an Android application developed for controlling a pump system via MQTT. The application comprises four main screens, each designed to manage different aspects of the pump control system.

1. User Authentication

The first screen is dedicated to user authentication and configuration of MQTT settings. It includes the following elements:

- **Text Inputs:**
  - **Username:** Enter your username.
  - **Password:** Enter your password.
  - **MQTT Broker:** Specify the MQTT broker address.
  - **MQTT User:** Enter the MQTT username.
  - **MQTT Password:** Enter the MQTT password.
- **Checkboxes:**
  - **Direct Control of Pump Control:** Allows direct control of the pump.
  - **Automatic Irrigation System:** Enables the automatic irrigation system.
  - **Automatic Control of Water Tank Level:** Activates automatic water tank level control.

2. Pump Control and Monitoring

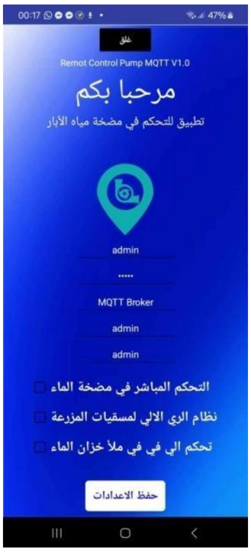
The second screen is titled "Pump Control and Monitoring" and is divided into three subsections:

Subsection 1: Control Buttons

- **System On/Off:** Remotely turn the system on or off.
- **Pump On/Off:** Remotely turn the pump on or off.
- **Update System Information:** Refresh the system status.
- **Set Running Time:** Choose the desired running time from a list.

Subsection 2: System Information

- **System State:** Displays the current state of the system.
- **Pump State:** Shows the status of the pump.
- **Default Stop Time:** Indicates the default stop time for the pump.
- **Actual Running Time:** Displays the actual running time of the pump.



Remot Control Pump MQTT V1.0

مرحبا بكم

تطبيق للتحكم في مضخة مياه الآبار

admin

•••••

MQTT Broker

admin

admin

□ التحكم المباشر في مضخة الماء

□ نظام الري الالي لمسقيات المزرعة

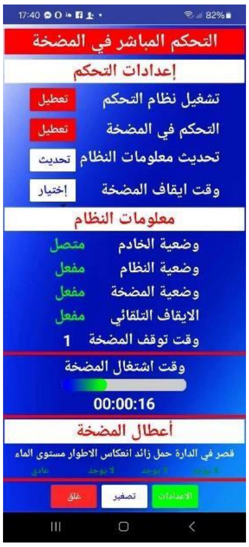
□ تحكم الي في في ملأ خزان الماء

Figure III.23.: First MQTT Android Application screen.

Subsection 3: Pump Faults

- **Short Circuit:** Indicates if there is a short circuit fault.
- **Over Load:** Shows if the pump is overloaded.
- **Phase Change:** Displays any phase change faults.

- **Water Level:** Indicates the water level status.



التحكم المباشر في المضخة

إعدادات التحكم

تشغيل نظام التحكم تعطيل

التحكم في المضخة تعطيل

تحديث معلومات النظام تحديث

وقت ايقاف المضخة إختيار

معلومات النظام

وضعية الخادم	متصل
وضعية النظام	مفعل
وضعية المضخة	مفعل
الايقاف التلقائي	مفعل
وقت توقف المضخة	1

وقت اشتغال المضخة

00:00:16

أعطال المضخة

قصر في الدارة	حمل زائد	انعكاس الاطوار	مستوى الماء
لا يوجد	لا يوجد	لا يوجد	عادي

Figure III.24.: Second MQTT Android Application screen.

3. Automatic Water Level Control

The third screen, titled "Automatic Water Level Control," is divided into four subsections:

Subsection 1: Control Buttons

- **Activate/Deactivate System:** Buttons to turn the system on or off.
- **Update System Information:** Button to refresh the system status.

Subsection 2: System Information

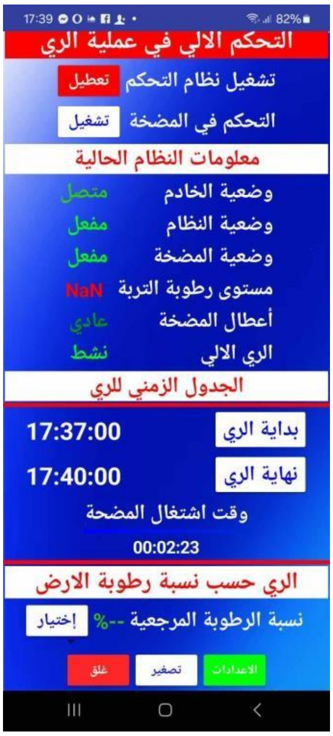
- **System State:** Displays the current state of the system.
- **Pump State:** Shows the status of the pump.
- **Soil Humidity Level:** Indicates the humidity level of the soil.
- **Pump Faults:** Lists any pump faults.
- **Automatic Irrigation State:** Shows whether the automatic irrigation is active.

Subsection 3: Irrigation Schedule

- **Start Time:** Button to select the start time of irrigation.
- **End Time:** Button to select the end time of irrigation.

Subsection 4: Reference Soil Humidity

- **Reference Selector:** Allows the user to choose the desired reference humidity level for irrigation.



17:39 82%

التحكم الالي في عملية الري

تشغيل نظام التحكم تعطيل

التحكم في المضخة تشغيل

معلومات النظام الحالية

وضعية الخادم متصل

وضعية النظام مفعل

وضعية المضخة مفعل

مستوى رطوبة التربة NaN

أعطال المضخة عادي

الري الالي نشط

الجدول الزمني للري

بداية الري 17:37:00

نهاية الري 17:40:00

وقت اشتغال المضخة

00:02:23

الري حسب نسبة رطوبة الارض

نسبة الرطوبة المرجعية --% إختيار

Figure III.25.: Third MQTT Android Application screen.

4. Automatic Tank Water Level Control

The fourth screen, titled "Automatic Tank Water Level Control," is divided into three subsections:

Subsection 1: Control Buttons

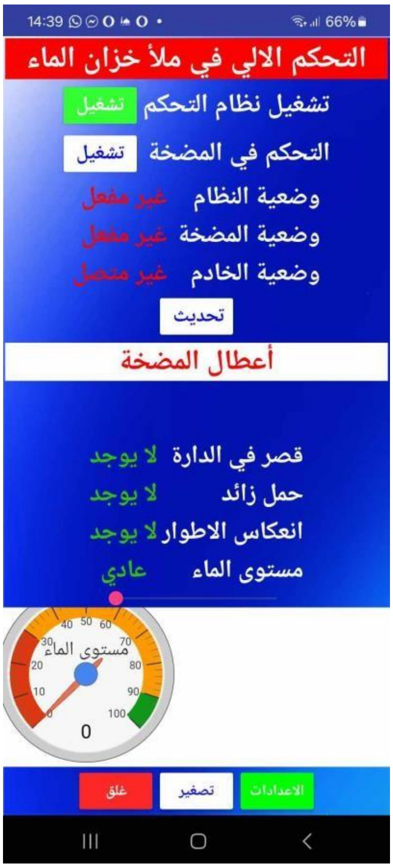
- **Activate/Deactivate System:** Buttons to turn the system and pump on or off.

Subsection 2: Pump Faults

- **Previous Pump Faults:** Displays a list of previous pump faults.

Subsection 3: Tank Water Level

- **Water Level Display:** Shows the current water level in the tank.



التحكم الالي في ملأ خزان الماء

تشغيل نظام التحكم تشغيل

التحكم في المضخة تشغيل

وضعية النظام غير مفعل

وضعية المضخة غير مفعل

وضعية الخادم غير متصل

أعطال المضخة

قصر في الدارة لا يوجد

حمل زائد لا يوجد

انعكاس الاطوار لا يوجد

مستوى الماء عادي

Figure III.26.: Fourth MQTT Android Application screen.

III.4.5 Designed Printed Circuit Board (PCB)

The designed Printed Circuit Board (PCB) for the GSM-based Pump Control system integrates various components to facilitate efficient and reliable pump management. Each component is selected to ensure optimal functionality, ease of use, and robust performance.

a) Main Components

1. **ESP32 Board:** At the heart of the system is the ESP32 microcontroller. Known for its powerful processing capabilities and integrated Wi-Fi and Bluetooth features, the ESP32 handles all control and communication tasks. It serves as the central unit that processes inputs from the user and sensors, and sends commands to other components.
2. **Relays:** The PCB includes two relays:

1. **Pump Activation Relay**: This relay is responsible for turning the pump on.
2. **Pump Deactivation Relay**: This relay is used to turn the pump off.

These relays are crucial for controlling the pump’s power supply, allowing for both manual and remote operation.

3. **Buttons:** There are two buttons on the PCB:
    - **System Activation/Deactivation Button**: This button allows the user to manually activate or deactivate the system.
    - **System Restart Button**: This button is used to restart the system, resetting all current operations and statuses.

These buttons provide a straightforward way to control the system manually when necessary.

4. **LEDs:** The PCB is equipped with four LEDs to indicate various system states:
    - **Wi-Fi Connection LED**: Indicates the status of the Wi-Fi connection.
    - **Network State LED**: Shows the state of the network connection.
    - **GPRS State LED**: Displays the status of the GPRS connection.
    - **Access Point/Activation System Status LED**: Indicates the system's status, including the access point state or general system health.

These LEDs provide visual feedback to the user, ensuring they are informed about the system's current operational status.

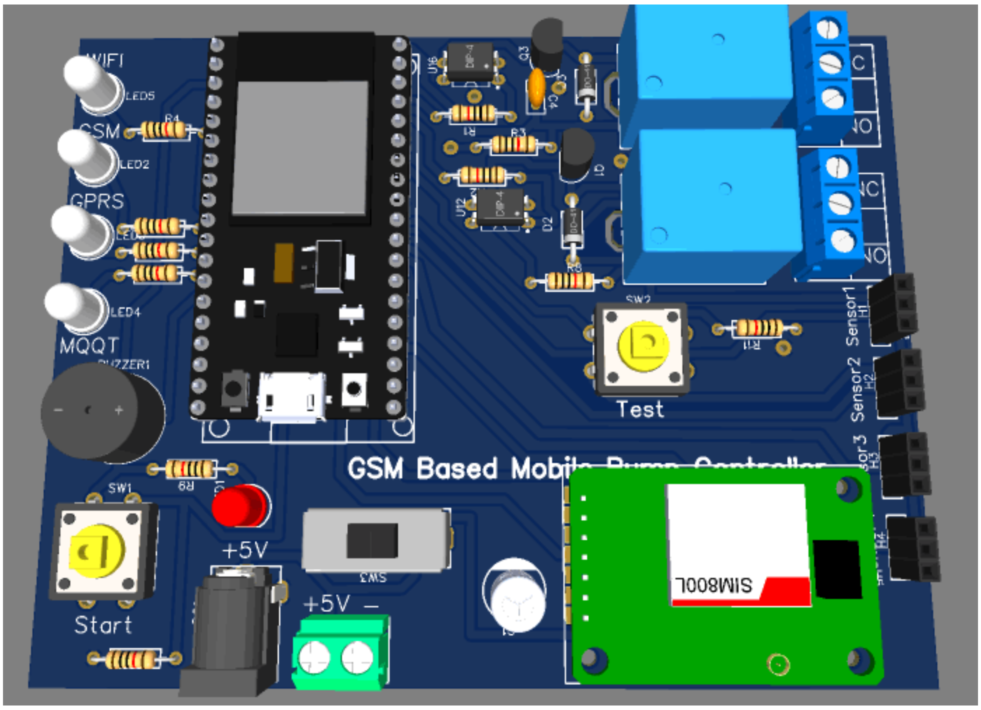


Figure III.27.: 3D Designed Circuit Board.

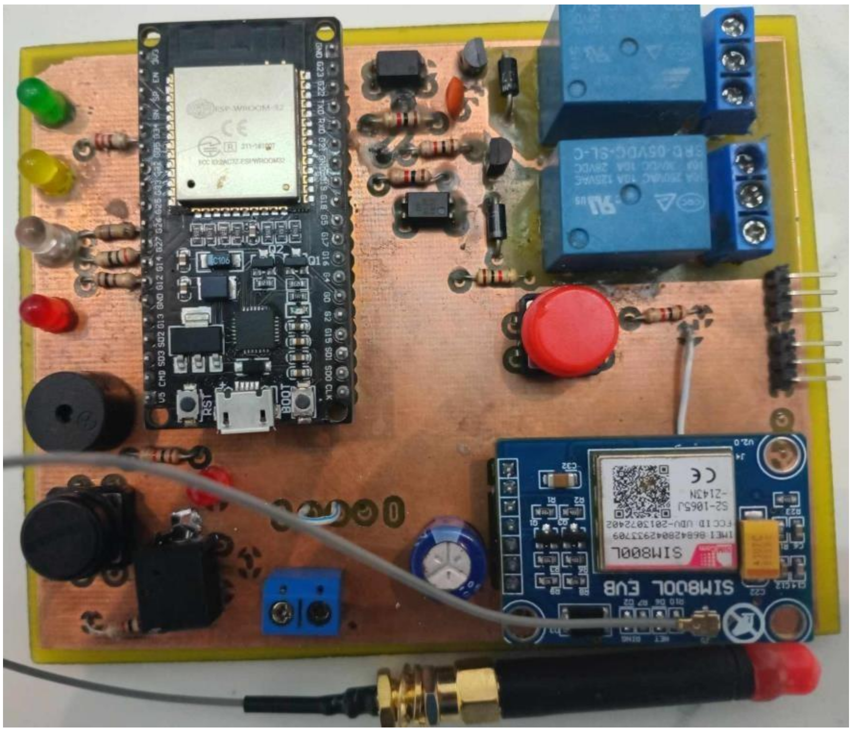


Figure III.28.: Real Designed Circuit Board.

5. **SIM800L Module:** The SIM800L GSM module is a key component for enabling remote communication. It allows the system to send and receive SMS commands,

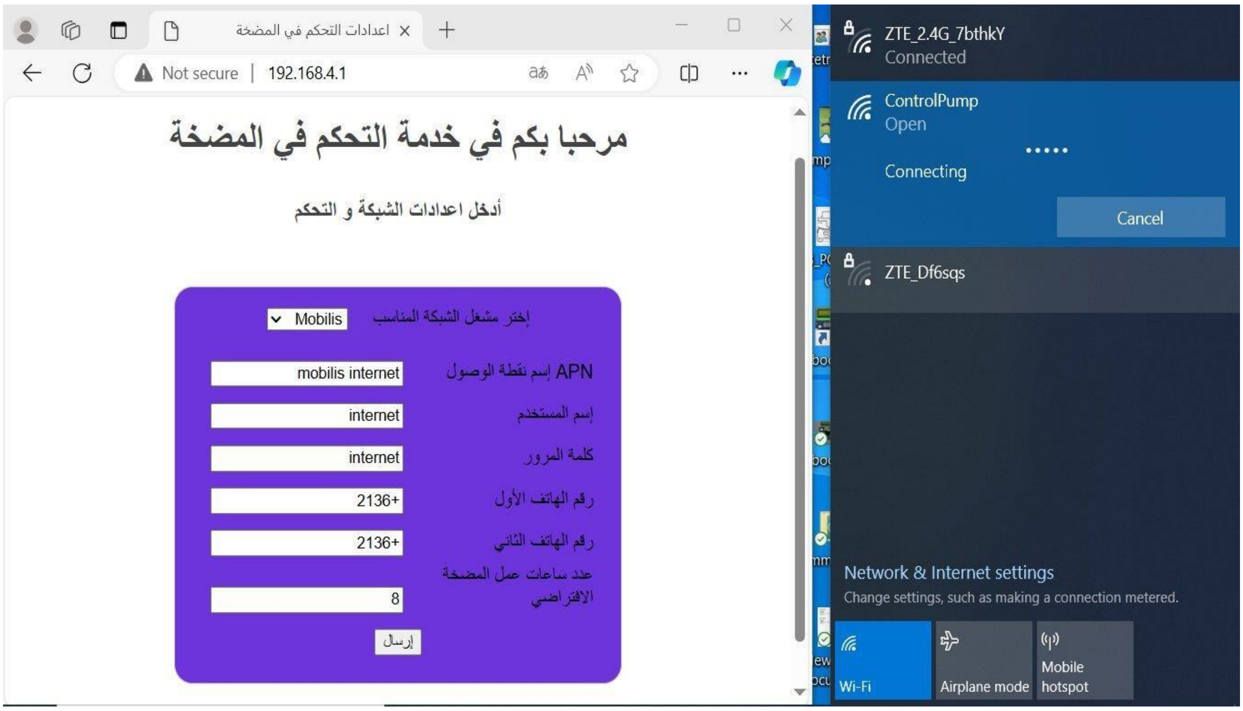
facilitating remote control and monitoring of the pump. This module ensures that the user can manage the pump from any location with GSM coverage.

6. **Buzzer:** It is included on the PCB to provide auditory feedback. It sounds to indicate that an action has been completed, such as turning the pump on or off, or updating system information. This feature ensures that the user receives immediate confirmation of their commands, enhancing the user experience.
7. **AC 220V Optocoupler Isolation Module:** To accurately monitor the pump's running state, an AC 220V Optocoupler Isolation Module is used as a sensor. This module detects whether the pump is running by sensing the AC voltage. The optocoupler provides electrical isolation, ensuring safe and reliable detection of the pump’s operational status. This information is then relayed to the ESP32, which can display the running state to the user and make decisions based on the pump's activity.

The designed PCB for the GSM-based Pump Control system integrates essential components to ensure efficient and reliable operation. The ESP32 board handles control and communication tasks, while the relays, buttons, LEDs, SIM800L module, and buzzer provide comprehensive functionality for both manual and remote pump management. This integration ensures a robust system that is user-friendly and effective in various operational conditions.

III.4.6 Access Point Mode

The Access Point (AP) Mode allows the user to enter and configure various settings required by the GSM-based Pump Control system. This mode is essential for initializing the system with necessary information such as network credentials and operational parameters.



اعدادات التحكم في المضخة

Not secure | 192.168.4.1

مرحبا بكم في خدمة التحكم في المضخة

أدخل اعدادات الشبكة و التحكم

إختر مشغل الشبكة المناسب: Mobilis

APN إسم نقطة الوصول: mobilis internet

إسم المستخدم: internet

كلمة المرور: internet

رقم الهاتف الأول: +2136

رقم الهاتف الثاني: +2136

عدد ساعات عمل المضخة الافتراضي: 8

ZTE_2.4G_7bthkY Connected

ControlPump Open

Connecting

ZTE_Df6sqs

Network & Internet settings

Change settings, such as making a connection metered.

Figure III.29.: Access point mode.

a) Entering Access Point Mode

To enter Access Point Mode, the user must follow these steps:

1. **Press and Hold the Start Button**: Keep pressing the start button.
2. **Wait for 10 Beeps**: Continue holding the button until the system emits 10 beeps.
3. **System Restart**: After the 10th beep, the system will automatically restart and enter Access Point Mode.

b) Connecting to the Access Point

Once in Access Point Mode, the system will broadcast a Wi-Fi network named `ControlPump`. The user should:

1. **Open Wi-Fi Settings**: Go to the Wi-Fi settings on their device (smartphone, tablet, or computer).
2. **Connect to ControlPump**: Select the `ControlPump` network from the list of available Wi-Fi networks.
3. **Access the Configuration Page**: Open a web browser and enter the IP address `192.168.4.1` to access the HTML parameters page.

1) Configuration Page

The configuration page includes seven text editors for entering necessary information:

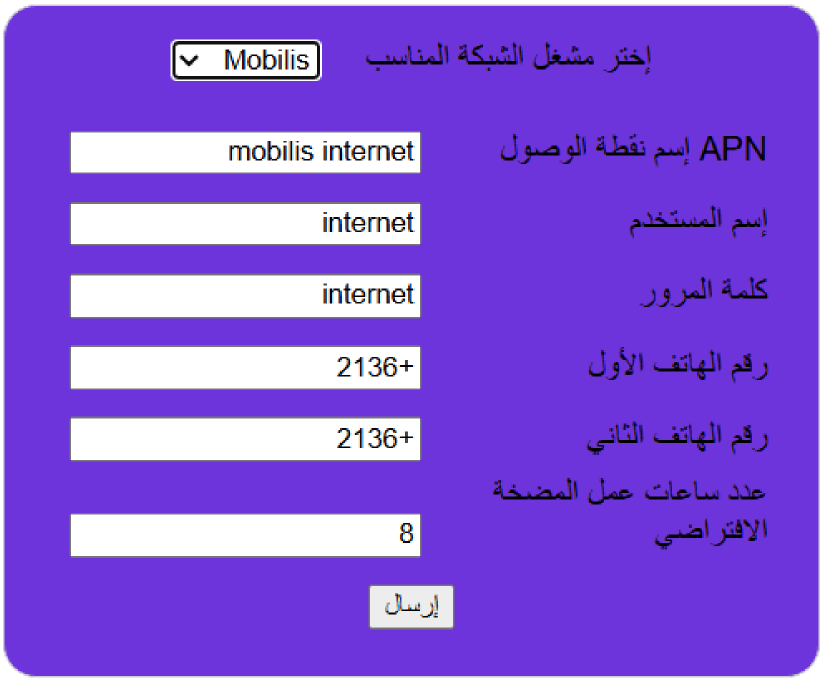
1. **Mobile Operator Selector**: A dropdown field to select the mobile operator (Mobilis, Djezzy, Ooredoo). Based on the selected operator, the fields for APN name, username, and password will be automatically populated.
   - **APN Name**: Automatically filled based on the selected mobile operator.
   - **Username**: Automatically filled based on the selected mobile operator.
   - **Password**: Automatically filled based on the selected mobile operator.
2. **Phone Numbers**: Two fields to enter the phone numbers that the system will communicate with. These numbers will receive notifications and allow remote control via SMS.
3. **Default Pump Running Time**: A field to set the default maximum running time for the pump.

c) Saving the Configuration

After entering all the required information:

1. **Submit the Information**: Click the "Submit" button on the configuration page to send the settings to the ESP32’s EEPROM.
2. **Exit Access Point Mode**: Press and hold the start button again until the system emits 10 beeps. The system will restart and exit Access Point Mode, returning to normal operation with the new settings saved.

By following these steps, the user can easily configure the system's parameters, ensuring it is set up correctly for efficient and reliable operation.



إختر مشغل الشبكة المناسب	Mobilis
APN إسم نقطة الوصول	mobilis internet
إسم المستخدم	internet
كلمة المرور	internet
رقم الهاتف الأول	2136+
رقم الهاتف الثاني	2136+
عدد ساعات عمل المضخة الافتراضي	8

Figure III.30.:HTML parameters page.

III.5. Project Status and Future Work

Due to time constraints, we were unable to complete the full implementation of the project. However, the groundwork laid by these individual systems provides a solid foundation for future development. Moving forward, we aim to integrate these systems, along with additional functionalities, into a comprehensive home automation interface. This unifiedsystem will offer seamless control and monitoring of various home automation tasks, further enhancing the convenience, security, and efficiency of smart homes.

Our future plans involve utilizing a home automation operator system to consolidate all individual systems into a single, cohesive interface. This operating system will enable centralized control, providing users with an intuitive and unified platform to manage all aspects of their home automation setup. By consolidating the various functionalities into one interface, users will benefit from streamlined operations and improved overall user experience.

III.6. Conclusion

The home automation systems discussed in this report represent significant advancements in enhancing the convenience, security, and efficiency of residential environments. By leveraging the capabilities of the ESP32 microcontroller, these systems provide robust solutions for managing various home automation tasks, each tailored toaddress specific needs and improve the quality of life for users.

SIM800L-based Home Automation Security System: The SIM800L-based Home Automation Security System offers a reliable and accessible means of securing homes. Utilizing GSM communication, this system allows users to monitor and control their home security remotely via SMS. Features such as real-time alerts and remote control enhance the safety and security of the home, providing peace of mind to homeowners.

Smart Lighting System: The Smart Lighting System, with its 14-channel control, demonstrates the potential of automation in optimizing energy usage and creating comfortable living spaces. By enabling individual and grouped control of lighting channels, users can customize their lighting environments to suit different occasions and preferences. The integration of manual, mobile, and web interfaces ensures that the system is both flexibleand user-friendly.

SIM800L and MQTT-based Pump Control: The GSM-based Pump Control system exemplifies the efficient management of water resources, crucial for both agricultural and residential applications. Through remote control capabilities facilitated by the SIM800L module and an intuitive Android application, users can manage their water pumps with precision and ease. Features like default running time settings and real-time status updates ensure optimal operation and water conservation.

Designed Printed Circuit Boards (PCBs): The designed PCBs for these systems play a crucial role in ensuring their functionality and reliability. By integrating essential components such as the ESP32 microcontroller, relays, buttons, LEDs, and communication modules, the PCBs provide a solid foundation for the systems' operations. Careful design considerations, including component layout, power management, and safety features, ensure that these PCBs meet the demands of modern home automation.

Access Point Mode and Configuration: The Access Point Mode facilitates easy configuration and setup of the systems, ensuring that users can input necessary parameters and customize settings according to their preferences. This user-centric approach enhances the usability of the systems, making them accessible even to those with minimal technical expertise.

Overall Impact: Together, these systems demonstrate the transformative potential of home automation technologies. They not only enhance convenience and comfort but also contribute to resource efficiency and security. By integrating advanced microcontrollers, communication modules, and user-friendly interfaces, these solutions pave the way for smarter, more connected homes.

In conclusion, the home automation systems based on the ESP32 microcontroller offer innovative solutions that address key aspects of modern living. Through continuous development and integration of new technologies, these systems can further evolve, providing even greater benefits and transforming the way we interact with our living spaces.

General conclusion

In conclusion, this comprehensive exploration into the Internet of Things (IoT) and home automation elucidates the profound impact of interconnected technologies on modern living. By delving into the foundational principles of IoT, we have established a clear understanding of how these systems collect, process, and communicate data to create smart, responsive environments. The discussion on home automation highlighted the seamless integration of IoT devices, allowing for efficient management and automation of household tasks through common protocols such as Zigbee, Z-Wave, and Wi-Fi. The examination of critical operating systems and server architectures provided insight into the software and hardware infrastructures essential for supporting IoT applications, emphasizing the roles of platforms like Home Assistant, Blynk, Amazon Alexa, Google Home, and Apple HomeKit. Furthermore, the practical applications showcased through case studies demonstrated the tangible benefits of IoT in enhancing security, lighting control, and water management systems, underscoring the versatility and transformative potential of these technologies.

This document not only underscores the theoretical underpinnings and critical technologies that drive IoT- based home automation but also illustrates their practical implementations, offering a holistic view of the future of smart living. As we move forward, the integration of IoT in home automation is poised to revolutionize our interaction with our living spaces, fostering environments that are not only more efficient and secure but also more intuitive and adaptive to our needs.

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