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Design and Implementation of a Smart Home Control System based on STM 32

Sustained le 02 /07/2022 Before the jury composed of:

Miloudi	Lalia	MCB	UMBB	Président
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Belhabchia	Malek	MCA	UMBB	Examiner

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Filière : Electronique

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Conception et mise en œuvre d'un control de maison intelligente basé sur STM 32

Soutenu le 02 /07 /2024 devant le jury composé de:

Miloudi	Lalia	MCB	UMBB	Président
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Abstract

In this work, we explore the design and implementation of a smart home system utilizing the STM32 microcontroller series, particularly focusing on the STM32F103C8T6 model. This project integrates various sensors, such as the DHT11 for temperature and humidity, the MQ-2 for gas detection, and RFID modules, to create a comprehensive home automation and monitoring solution.

The development involves both hardware and software components, with the latter programmed using STM32CubeIDE and the Android application developed via MIT's App Inventor. By leveraging these technologies, we aim to enhance safety, security, and efficiency in modern smart homes.

This system also provides scalability and user-friendly interfaces, ensuring adaptability to diverse home automation needs.

KEYWORDS: STM32 microcontroller, Sensors, Android application, Smart homes.

Résumé

Dans ce travail, nous explorons la conception et la mise en œuvre d'un système de maison intelligente utilisant la série de microcontrôleurs STM32, en nous concentrant particulièrement sur le modèle STM32F103C8T6. Ce projet intègre divers capteurs, tels que le DHT11 pour la température et l'humidité, le MQ-2 pour la détection de gaz et des modules RFID, pour créer une solution complète de domotique et de surveillance.

Le développement implique à la fois des composants matériels et logiciels, ces derniers étant programmés à l'aide de STM32CubeIDE et de l'application Android développée via App Inventor du MIT. En tirant parti de ces technologies, nous visons à améliorer la sûreté, la sécurité et l'efficacité des maisons intelligentes modernes.

Ce système offre également une évolutivité et des interfaces conviviales, garantissant l'adaptabilité aux divers besoins en matière de domotique.

Mots-clés: STM32 microcontroller, Capteur, Application android, Maisons intelligente
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الملخص

STM32 ، الملخص في هذا العمل، نستكشف تصميم وتنفيذ نظام منزل ذكي باستخدام سلسلة وحدات التحكم الدقيقة يدمج هذا المشروع بين العديد من أجهزة الاستشعار، مثل .STM32F103C8T6 مع التركيز بشكل خاص على نموذج DHT11 ، لإنشاء حل شامل لأتمتة ومراقبة RFID للكشف عن الغاز، ووحدات MQ-2لقياس درجة الحرارة والرطوبة، و المنزل.

وتم تطوير STM32CubeIDE يتضمن التطوير مكونات مادية وبرمجية، حيث تم برمجة الجزء الأخير باستخدام من خلال الاستفادة من هذه التقنيات، نهدف إلى تعزيز .MIT's App Inventor التطبيق على نظام أندرويد عبر السلامة والأمان والكفاءة في المنازل الذكية الحديثة.

يوفر هذا النظام أيضًا قابلية التوسع وواجهات سهلة الاستخدام، مما يضمن التكيف مع احتياجات أتمتة المنزل المتنوعة.

، واجهة برمجة (ANPR) ، التعرف التلقائي على لوحة الأرقام(OCR) الكلمات المفتاحية: التعرف الضوئي على الأحرف التطبيقات (API).

Dedication 1

I dedicate this thesis to the memory of my beloved father, who left us on December 25, 2023. Although you are no longer here to see the completion of this project, your love, wisdom, and support continue to inspire me every day. Rest in peace.

To my mother, my queen, who's unconditional love and unwavering support have been a constant source of strength for me. Thank you for everything you do.

To my three brothers, Islam, Amar, Ninoucha, and to my sister Serine, for their affection and unfailing encouragement. You have always been there for me, and I am deeply grateful.

My dear friends , especially Amel Gharnaout , Soumya Rebai and Amel Issolah , who hold a special place in my heart .I am grateful for your friendship, unwavering support , and the countless joyful moments we've shared.

Let this dedication be a humble expression of my everlasting gratitude to you. May our bond remain resilient as we navigate through challenges and grow together.

Bensifi Sarra

Dedication 2

Today, I would like to take a moment to thank you from the bottom of my heart. Your Support, your unconditional love and your constant presence have made me the person I am today.

To my parents, you are my heroes, my foundation, my source of strength and Comfort. Your dedication, sacrifice and unwavering support have been an endless source of infinite inspiration. You've always encouraged me to pursue my dreams, to believe in myself and to take on all the challenges that come my way. myself and to rise to any challenge that came my way. I am deeply grateful for everything you've done for me, and I'll carry you in my heart forever.

To my friends, you are my chosen family. You have shared with me moments of joy moments of joy, laughter and togetherness. Your sincere friendship and constant support have been sources of comfort and motivation. I am fortunate to have you by my side, and I know that our friendship will last a lifetime.

To my partner Sarra, thanks for your unwavering support, this thesis wouldn't be the same without you.

With all my love and gratitude.

Baouali Abderahmane

Acknowledgments

In the name of Allah the Most Powerful, Most Gracious, Most Merciful, I begin my acknowledgments.

First of all, I would like to thank God the Almighty and Merciful, who gave me the strength and the patience to accomplish this modest work.

Secondly, I would like to thank Mr.Kaouane for his support, his patience, his judicious and relevant advice, which help me carry out this dissertation with serenity. I would also like also to express our heartfelt gratitude to our friends, Khaled Bouabdallah and Hakim Ikhlef,for their unwavering support and expertise. Their insights and encouragement have been instrumental in the completion of this project. Without their contributions, this achievement would not have been possible. Thank you, Khaled and Hakim, for your steadfast companionship.

My sincere thanks also go to the members of the jury for their interest in this work by agreeing to examine it and enrich it with their proposals.

Finally, I would also like to thank all the people who participated directly or indirectly in the fulfilment of this work.

Hope you enjoy reading.

Contents

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Acronyms

GPIO General-Purpose Input/Output.

HSE High-Speed External.

HVAC Heating, Ventilation, and Air Conditioning.

I2C Inter-Integrated Circuit.

IoT Internet of Things.

PWM Pulse Width Modulation.

RFID Radio-Frequency Identification.

RH Relative Humidity.

SPI Serial Peripheral Interface.

Introduction

A smart home system integrates various sensors and devices to automate and enhance home management and security. This advanced system monitors environmental conditions, detects potential hazards, and allows for remote control of household appliances. Applications of smart home systems include energy management, security monitoring, and automated control of lighting, heating, and ventilation. With the increasing number of smart devices, the need for integrated home automation solutions is growing, making these systems essential for modern living.

Every smart home system relies on a network of sensors and actuators to gather data and respond to changes in the environment. This data is used for a variety of functions such as maintaining optimal temperature and humidity levels, detecting gas leaks, and controlling access to the home. The integration of these components ensures seamless operation and enhances the overall functionality of the home.

The integration of these sensors with the STM32 microcontroller forms the backbone of the smart home system. The STM32 is a versatile and powerful microcontroller that handles data collection, processing, and actuation, ensuring reliable performance and efficient operation. The system is designed to be controlled via a user-friendly mobile application developed using MIT App Inventor, providing seamless control and real-time notifications.

This smart home system automates various household functions, making them faster and more cost-effective. By integrating multiple sensors and leveraging the capabilities of the STM32 microcontroller, the system enhances home security, comfort, and energy efficiency.

Chapter 1

General Concept

1 Introduction

The concept of a ”smart home” has rapidly evolved from a futuristic vision to a reality in recent years, thanks to advancements in technology and the widespread adoption of Internet of Things (IoT) devices. Smart homes utilize interconnected devices, sensors, and systems to enhance comfort, convenience, security, and energy efficiency for homeowners. This chapter provides an overview of the fundamental concepts and technologies that form the basis of smart home systems, focusing on the integration of sensors, microcontrollers, and IoT technology.

The first section of this chapter explores the evolution and current state of smart home technology, highlighting the advantages and challenges associated with its implementation. It discusses how smart home systems have evolved from simple automation solutions to sophisticated, interconnected ecosystems that offer a wide range of functionalities and benefits for homeowners.

The second section delves into the role of Internet of Things (IoT) technology in home automation, providing an introduction to IoT, its applications in smart homes, and the benefits and challenges associated with its implementation. It discusses how IoT technology enables devices and systems within the home to communicate, collect data, and make intelligent decisions, leading to enhanced automation, monitoring, and control.

The third section provides an overview of the STM32 microcontroller, a versatile and flexible platform that forms the core of many smart home systems. It discusses the features, specifications, advantages, and applications of the STM32 microcontroller, highlighting its scalability, rich peripheral integration, advanced connectivity options, and comprehensive development ecosystem.

The final section focuses on the various types of sensors used in smart home systems, including temperature sensors, humidity sensors, light sensors, motion sensors, and more. It discusses the selection criteria for sensors and their role in smart home automation, highlighting how sensors provide the data that enables intelligent decision-making and control within the home.

By understanding the fundamental concepts and technologies discussed in this chapter, readers will gain insight into the key components of smart home systems and how they work together to create intelligent, interconnected living spaces.

2 Smart Home Technology

2.1 Definition and Overview

Smart home technology, also known as home automation or demotic, refers to the integration of various devices and systems within a home to automate and optimize functions such as lighting, heating, ventilation, air conditioning, security, and entertainment. These systems are interconnected and can be controlled remotely by the homeowner, typically through a mobile application or a centralized control panel.[1]
The figure Titled “smart Home” illustrates various components and functionalities of a smart home system.

Figure 1.1: Smart Home

The primary goal of smart home technology is to enhance convenience, comfort, energy efficiency, security, and accessibility for homeowners. By automating routine tasks and providing remote access and control over household devices and systems, smart homes offer a more convenient and efficient living environment.

2.2 Evolution and Current State of Smart Home Technology

The concept of smart homes has evolved significantly over the past few decades. Initially, smart home systems were expensive and complex, limited to high-end custom installations in luxury homes. However, advancements in technology, particularly in wireless communication, sensor technology, and microcontrollers, have made smart home technology more accessible and affordable for mainstream consumers.[1]

The evolution of smart home technology can be traced back to the introduction of basic home automation systems, such as programmable thermostats and remote-controlled lighting, in the late 20th century. These early systems laid the foundation for the development of more sophisticated and interconnected smart home systems.[2]

Today, smart home systems encompass a wide range of devices and technologies, including:[3]

2.2.1 Smart Thermostats

Devices that automatically adjust heating and cooling settings based on the homeowner's preferences and usage patterns, resulting in energy savings and increased comfort.

The Figure titled "Smart Thermostats" displays three different models of smart thermostats, showcasing their diverse designs and interfaces.

Figure 1.2: Smart Thermostats

2.2.2 Smart Lighting

Lighting systems that can be controlled remotely and programmed to adjust brightness, color, and schedule. Smart lighting solutions offer customizable lighting options, energy efficiency, and enhanced security by allowing homeowners to create the illusion of occupancy when away from home.

The following Figure represents "Smart Lighting" and its control with the phone.

Figure 1.3: Smart lighting

2.2.3 Home Security Systems

Integrated systems that include cameras, motion sensors, door and window sensors, and alarms, which can be monitored and controlled remotely. These systems provide homeowners with peace of mind by enabling real-time monitoring of their homes and immediate alerts in the event of security breaches or emergencies.

2.2.4 Voice Assistants

Devices that use natural language processing to enable users to control various smart home devices using voice commands. Voice assistants such as Amazon Alexa, Google Assistant, and Apple HomeKit provide hands-free control over smart home devices and enable seamless integration between different systems.

The figure bellow depicts voice assistants and their control various smart home devices.

Figure 1.4: Voice Assistants

2.2.5 Appliance Control

Systems that allow homeowners to monitor and control appliances such as refrigerators, ovens, washing machines, and dishwashers remotely. Smart appliances can provide energy usage data, maintenance alerts, and remote diagnostics, helping homeowners save time, money, and energy.

The figure “Appliance Control “displays how various household appliance can be managed through a smart home system.

Figure 1.5: Appliance Control

2.3 Advantages and Challenges

2.3.1 Advantages of Smart Home Technology

Convenience One of the primary advantages of smart home technology is the convenience it offers to homeowners. By automating routine tasks and providing remote access and control over household devices and systems, smart homes make daily life easier and more efficient.[2]

Energy Efficiency Smart home technology enables homeowners to optimize energy usage and reduce utility bills by automating energy-intensive processes and adjusting settings based on occupancy, time of day, and weather conditions. Smart thermostats, lighting systems, and appliances can help homeowners reduce energy consumption and minimize environmental impact.[2]

Security Integrated security systems with cameras, sensors, and alarms provide homeowners with peace of mind by enabling real-time monitoring of their homes and immediate alerts in the event of security breaches or emergencies. Smart home security systems can deter intruders, detect unauthorized access, and notify homeowners and authorities of potential threats.[3]

Accessibility Smart home technology can be customized to meet the specific needs of individuals with disabilities or mobility issues, enabling greater independence and autonomy. By providing remote access and control over household devices and systems, smart homes can enhance accessibility and improve quality of life for people with disabilities.[3]

3 Internet of Things (IoT) in Home Automation

3.1 Introduction to IoT

The Internet of Things (IoT) is a network of interconnected devices, sensors, and systems that communicate and exchange data over the internet without human intervention. IoT technology enables devices to collect, exchange, and analyze data in real-time, leading to new opportunities for automation, optimization, and innovation across various industries, including home automation.[1]

The figure bellow "Internet Of Things" illustrates the interconnected nature of various devices and systems through the internet.

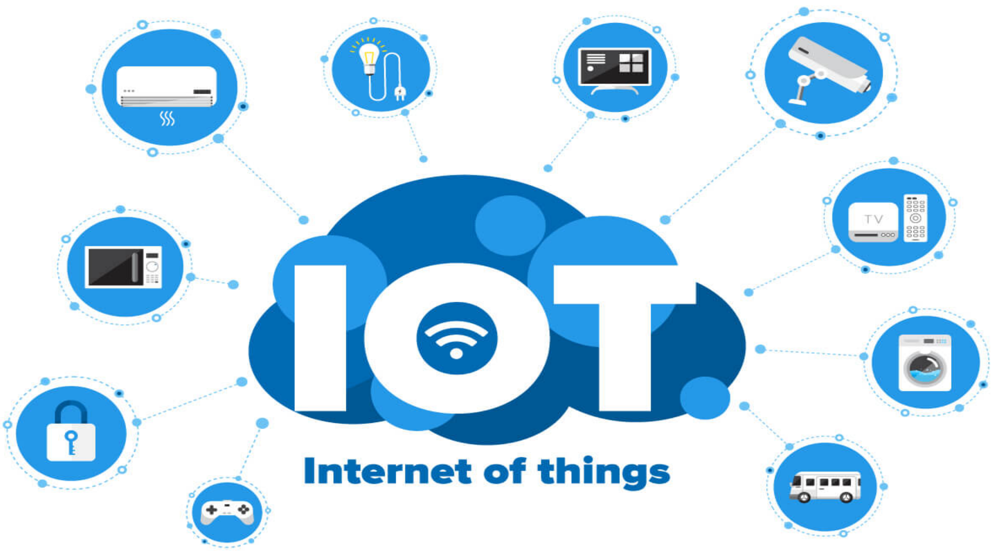

Figure 1.6: Internet Of Things

In the context of smart homes, IoT technology enables various devices and systems to communicate with each other, collect and analyze data, and make intelligent decisions to automate and optimize household functions. By connecting everyday objects to the internet and equipping them with sensors, actuators, and communication modules, IoT transforms ordinary homes into intelligent, responsive, and energy-efficient living spaces.[3]

The key components of an IoT system include:[2]

Sensors and Actuators: These are devices that collect data from the environment (sensors) and perform actions based on that data (actuators). Sensors can detect

changes in temperature, humidity, light, motion, sound, pressure, and other environmental variables, while actuators can control devices such as lights, thermostats, locks, switches, and appliances.
The picture depicts a collection of electronic components commonly used in internet of things (IOT) project.

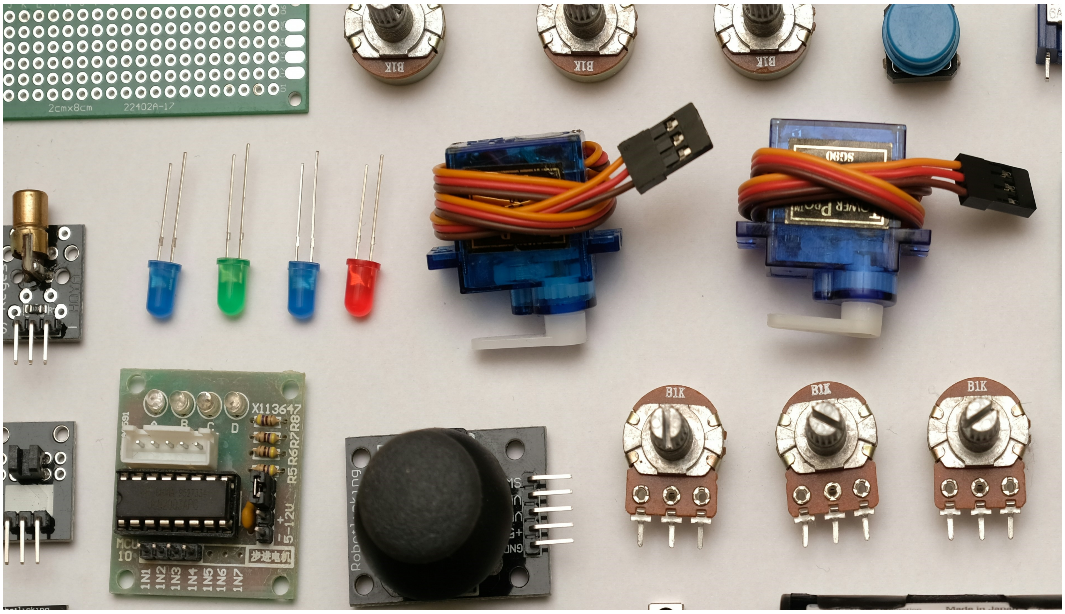

Figure 1.7: Sensors and Actuators

Connectivity: IoT devices are connected to each other and to the internet via wireless or wired networks, allowing them to exchange data and commands in real-time. Common communication protocols used in IoT systems include Wi-Fi, Bluetooth, Zigbee, Z-Wave, NFC (Near Field Communication), RFID (Radio Frequency Identification), and LoRaWAN (Long Range Wide Area Network).

Data Processing and Analytics: IoT devices generate large volumes of data that can be analyzed to extract valuable insights and make intelligent decisions. Cloud-based platforms and edge computing technologies are used to process, store, and analyze IoT data, enabling real-time monitoring, predictive maintenance, and data-driven optimization.

3.2 IoT Applications in Home Automation

The integration of IoT technology into smart home systems has revolutionized the way people interact with their homes and the devices within them. IoT-enabled smart home systems offer a wide range of applications and functionalities, including:

Remote Monitoring and Control: IoT technology enables homeowners to remotely monitor and control various devices and systems within their homes, such as thermostats, lighting, security cameras, door locks, window blinds, and appliances. This allows homeowners to adjust settings, receive notifications, and automate routine tasks from anywhere in the world using a smartphone, tablet, or web browser.[1]

The picture illustrates the concept of remote monitoring and control within the context of IOT (internet of things) technology.

Figure 1.8: Remote Monitoring and Control

Energy Management and Conservation IoT-enabled smart home systems can optimize energy usage, reduce utility bills, and minimize environmental impact by monitoring energy consumption, adjusting settings based on occupancy and usage patterns, and integrating with renewable energy sources such as solar panels and smart grids. Smart thermostats, lighting systems, and appliances can help homeowners save energy and money while reducing their carbon footprint.[4]
The image is a diagram titled "Energy Management and Conversation," illustrating a system for managing and conserving energy through various integrated components and technologies.

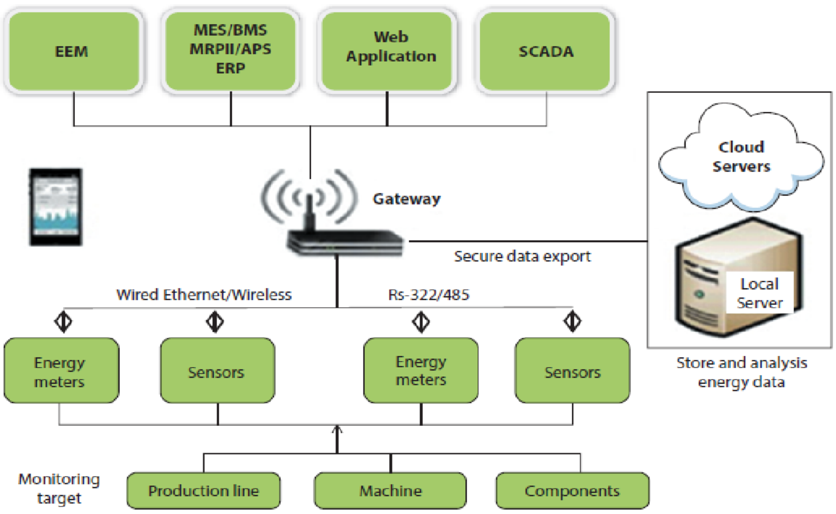

Figure 1.9: Energy Management and Conservation

Home Security and Surveillance IoT-based home security systems use cameras, motion sensors, door and window sensors, and alarms to detect intruders, monitor activity, and provide real-time alerts to homeowners and authorities. These systems can deter burglars, prevent break-ins, and provide homeowners with peace of mind knowing that their homes are secure and protected. Advanced features such as facial recognition, license plate recognition, and two-way audio communication enhance the security and surveillance capabilities of IoT-based home security systems.[4]

Environmental Monitoring and Automation IoT sensors can monitor environmental conditions such as temperature, humidity, air quality, water quality, and water leakage, allowing homeowners to detect and mitigate issues such as mold growth, water damage, and poor indoor air quality. Automated systems can control HVAC (heating, ventilation, and air conditioning) systems, irrigation systems, and smart appliances to maintain optimal conditions and conserve resources. For example, smart irrigation systems can adjust watering schedules based on soil moisture levels and weather forecasts, while smart HVAC systems can adjust temperature and humidity settings based on occupancy and usage patterns.[5]

The figure titled "Environmental Monitoring and Automation,"which outlines a system for monitoring various environmental parameters using sensors and network technologies.

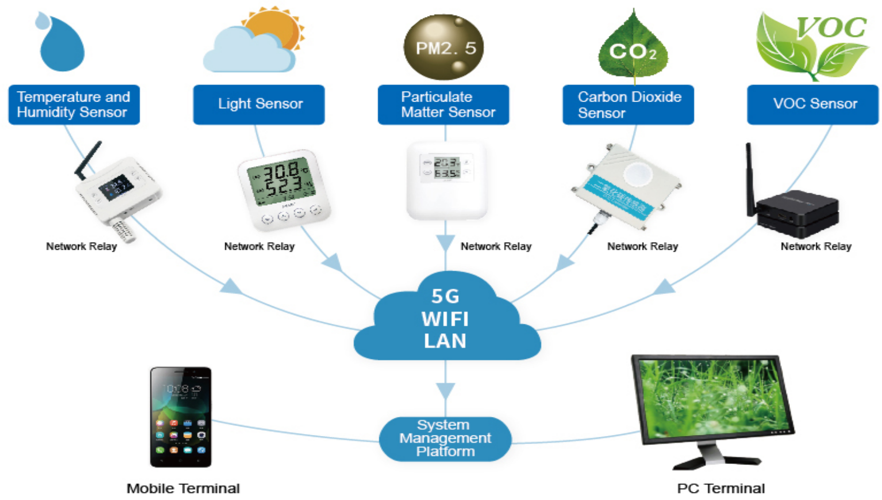

Figure 1.10: Environmental Monitoring and Automation

Health and Wellness Monitoring IoT-enabled smart home systems can monitor the health and wellness of occupants by tracking vital signs, activity levels, sleep patterns, and medication adherence. Wearable devices, smart sensors, and mobile apps can collect and analyze data to provide personalized insights and recommendations for improving health and wellness. For example, smart mattresses can monitor sleep quality and provide feedback on sleep patterns, while smart scales can track weight, body composition, and other health metrics.[1]

The figure is a diagram titled "Health and wellness Monitoring" illustrating a system that Leverages IOT (Internet of Things) technologies to monitor and manage health and wellness.

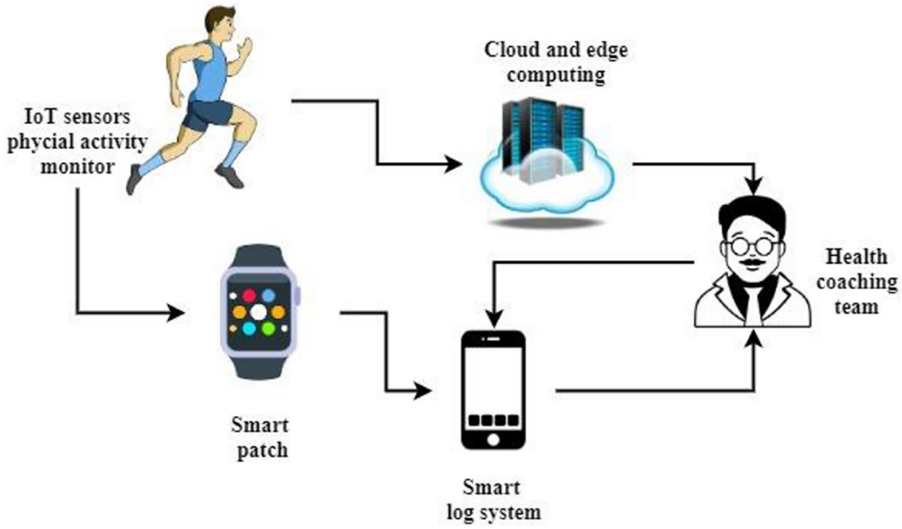

Figure 1.11: Health and Wellness Monitoring

3.3 Benefits and Challenges of IoT in Smart Homes

3.3.1 Benefits of IoT in Smart Homes

Convenience and Comfort IoT technology enables homeowners to automate routine tasks, control devices remotely, and create personalized settings to enhance convenience and comfort. By integrating various devices and systems within the home, IoT-enabled smart home systems provide a seamless and intuitive user experience. For example, homeowners can use voice commands, smartphone apps, or custom schedules to control lighting, temperature, music, and other aspects of their homes.[1]

Energy Efficiency and Cost Savings IoT-enabled smart home systems can optimize energy usage, reduce utility bills, and minimize environmental impact by monitoring energy consumption, adjusting settings based on occupancy and usage patterns, and integrating with renewable energy sources. Smart thermostats, lighting systems, and appliances can help homeowners save energy and money while reducing their carbon footprint. For example, smart thermostats can learn the occupants' preferences and adjust temperature settings accordingly, while smart lighting systems can adjust brightness and color temperature based on natural light levels and time of day.[3]

Enhanced Security and Safety IoT-based home security systems provide homeowners with peace of mind by enabling real-time monitoring of their homes, immediate alerts in the event of security breaches or emergencies, and remote access and control over security cameras, door locks, and alarms. These systems can deter intruders, prevent break-ins, and provide valuable evidence in the event of a crime. For example, homeowners can receive alerts on their smartphones when motion is detected outside their homes, or when doors or windows are opened or closed.[2]

Remote Monitoring and Management IoT technology enables homeowners to remotely monitor and manage their homes from anywhere in the world using a smartphone, tablet, or web browser. Whether they are at work, on vacation, or traveling abroad, homeowners can check on their homes, receive notifications, and take action as needed. For example, homeowners can use their smartphones to view live video feeds from their security cameras, adjust thermostat settings, turn lights on and off, and lock or unlock doors.[5]

3.3.2 Challenges of IoT in Smart Homes

Interoperability and Compatibility One of the significant challenges facing IoT in smart homes is the lack of interoperability and compatibility between devices and systems from different manufacturers. Incompatible protocols, standards, and communication protocols can lead to integration issues, limited functionality, and a fragmented user experience. For example, smart home devices that use different wireless communication protocols may not be able to communicate with each other, or may require additional hardware or software to bridge the communication gap.[1]

Privacy and Security Concerns The increased connectivity and data collection associated with IoT technology raise concerns about privacy and data security. Vulnerabilities in IoT devices and systems could potentially be exploited by hackers to gain unauthorized access to homes, compromise personal data, or launch cyber-attacks. To mitigate these risks, manufacturers should prioritize security by design, regularly update software and firmware, and implement strong encryption and authentication mechanisms. For example, smart home devices should use secure communication protocols, such as HTTPS (Hypertext Transfer Protocol Secure) and SSL/TLS (Secure Sockets Layer/Transport Layer Security), to encrypt data in transit and protect it from interception or tampering.[3]

Complexity and Usability Setting up and configuring IoT-enabled smart home systems can be complex and time-consuming, requiring technical expertise and troubleshooting skills. Additionally, the proliferation of smart devices and apps can lead to a cluttered and confusing user experience, making it difficult for homeowners to manage and control their smart home systems effectively. To address these challenges, manufacturers should focus on developing user-friendly, interoperable, and intuitive smart home solutions that meet the needs and preferences of a diverse range of consumers. For example, smart home devices should be easy to install, set up, and configure, with intuitive user interfaces and step-by-step instructions.[2]

4 STM32 Microcontroller

4.1 Introduction to STM32 Microcontroller

The STM32 microcontroller series, developed by STMicroelectronics, is a family of 32-bit ARM Cortex-M based microcontrollers designed for a wide range of applications, including industrial control, consumer electronics, automotive systems, and Internet of Things (IoT) devices. The STM32 series offers a scalable and flexible platform with a comprehensive set of peripherals, advanced connectivity options, and rich development tools, making it an ideal choice for embedded system designers and developers.[6]

The picture appears to be a page from a document discussing the STM32 microcontroller series, commonly used in embedded systems.

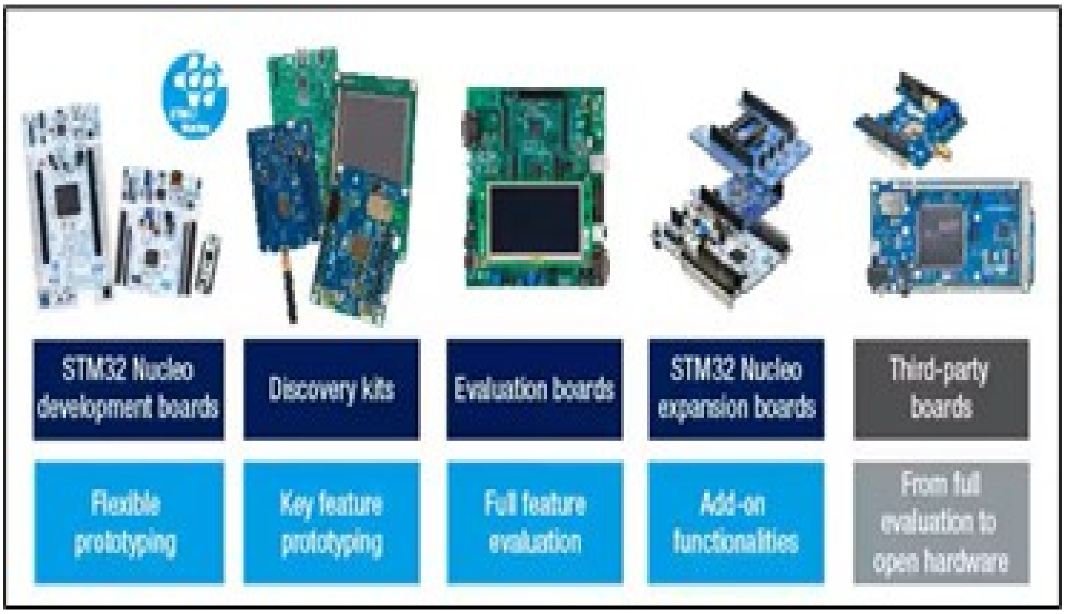

Figure 1.12: STM32 microcontroller series

4.2 Advantages and Applications

4.2.1 Advantages

The STM32 microcontrollers offer several advantages and are suitable for a wide range of applications, including:[6]

High Performance The STM32 microcontrollers feature high-performance ARM Cortex-M processors with clock speeds ranging from a few tens of megahertz to over 500 megahertz. This high-performance processing capability makes the STM32 microcontrollers suitable for applications requiring real-time processing, high-speed data acquisition, and complex control algorithms.

Low Power Consumption The STM32 microcontrollers are designed for low power operation, with multiple power-saving modes and features that help to minimize power consumption and extend battery life. This makes the STM32 microcontrollers suitable for battery-powered and energy-efficient applications such as portable devices, wearables, and IoT sensors.

Rich Peripheral Set The STM32 microcontrollers feature a comprehensive set of on-chip peripherals, including GPIO ports, timers, UARTs, SPI, I2C, ADC, DAC, PWM, USB, Ethernet, CAN, and more. This rich peripheral set provides the necessary functionality to interface with external sensors, actuators, displays, and communication devices, making the STM32 microcontrollers suitable for a wide range of embedded applications.

Advanced Connectivity The STM32 microcontrollers offer a range of connectivity options, including USB, Ethernet, CAN, SPI, I2C, UART, and wireless communication protocols such as Bluetooth, Wi-Fi, and Zigbee. This advanced connectivity enables seamless integration with external devices and networks, making the STM32 microcontrollers suitable for IoT and networked embedded systems.

Scalable Architecture The STM32 microcontrollers offer a scalable architecture with multiple product lines, each optimized for specific applications and offering a range of performance, power consumption, and peripheral options. This scalability allows developers to choose the STM32 microcontroller that best meets the requirements of their application, from cost-sensitive, low-power devices to high-performance, feature-rich systems.

4.2.2 Applications

The STM32 microcontrollers are widely used in a variety of applications, including:[6]

Industrial Control The STM32 microcontrollers are used in industrial automation and control systems, including PLCs (Programmable Logic Controllers), motor control systems, robotics, and factory automation.

Consumer Electronics The STM32 microcontrollers are used in a wide range of consumer electronics products, including smart appliances, home entertainment systems, wearable devices, and gaming consoles.

Automotive Systems The STM32 microcontrollers are used in automotive applications such as engine control units (ECUs), infotainment systems, dashboard displays, and advanced driver assistance systems (ADAS).

Internet of Things (IoT) Devices The STM32 microcontrollers are widely used in IoT devices such as smart sensors, actuators, gateways, and edge computing devices. They provide the processing power, connectivity, and flexibility required to enable intelligent, connected, and autonomous IoT systems.

Overall, the STM32 microcontrollers offer a versatile and flexible platform for embedded system design, with high performance, low power consumption, rich peripheral integration, advanced connectivity options, and a comprehensive development ecosystem.

5 Sensors used in a Smart Home

5.1 Types of Sensors Used in Smart Home Systems

Sensors are integral components of smart home systems, enabling the detection of changes in the environment, monitoring of conditions, and provision of data essential for intelligent automation and control. A diverse range of sensors is utilized in smart home systems to cater to various needs and requirements. Some common types of sensors used in smart home systems include:[6]

5.1.1 Temperature Sensors

These sensors measure ambient temperature and are crucial for controlling heating, ventilation, and air conditioning (HVAC) systems. They help optimize energy usage, ensure comfort, and prevent overheating or freezing. The figure depicts four different types of temperature sensors.

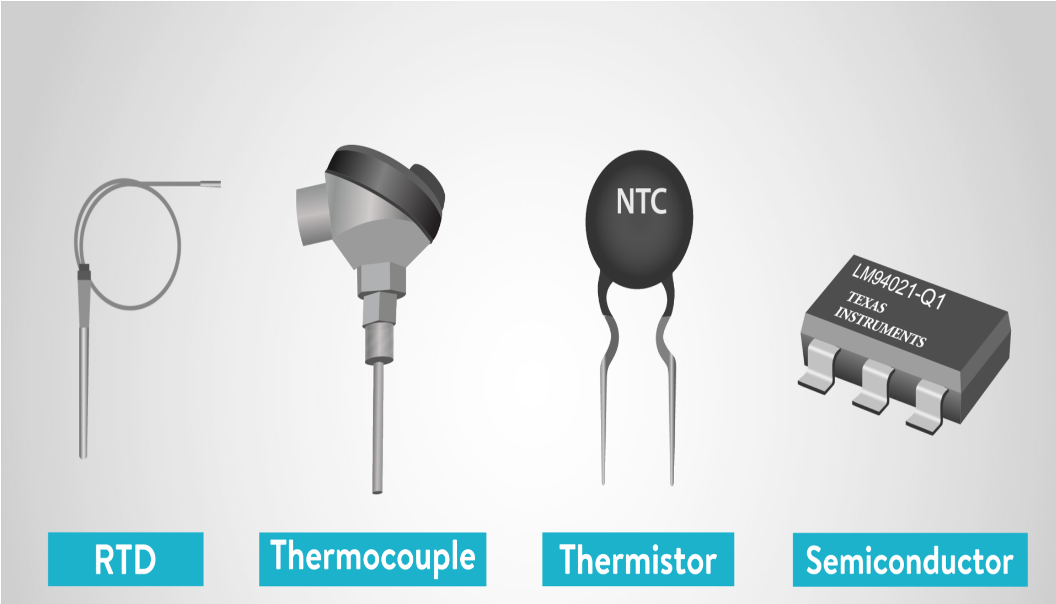

Figure 1.13: Temperature Sensors

5.1.2 Humidity Sensors

Humidity sensors measure ambient humidity levels and are vital for maintaining optimal indoor air quality. They are used to control HVAC systems, prevent mold and moisture damage, and ensure comfort and health. The image displays a humidity sensor, specifically a soil moisture sensor often used in agricultural and gardening applications.

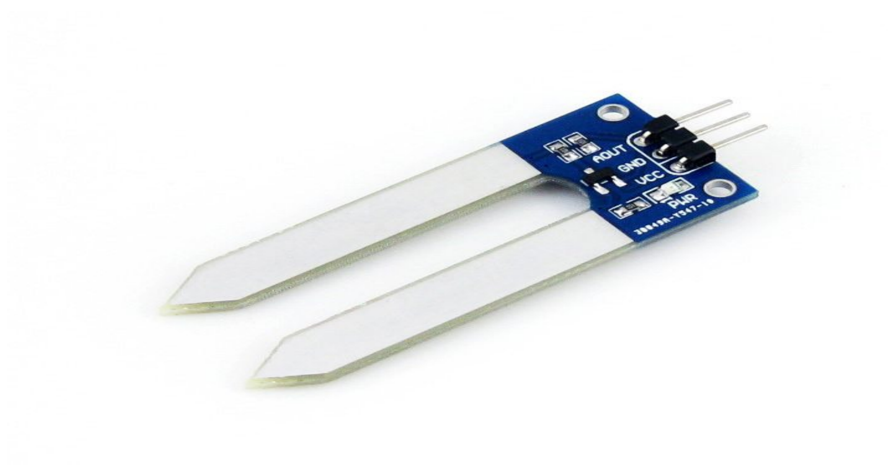

Figure 1.14: Humidity Sensors

5.1.3 Light Sensors

Light sensors measure ambient light levels and are used for controlling lighting systems, adjusting window blinds and shades, and optimizing energy usage. They enable smart lighting solutions that automatically adjust brightness and color temperature based on natural light levels and time of day.

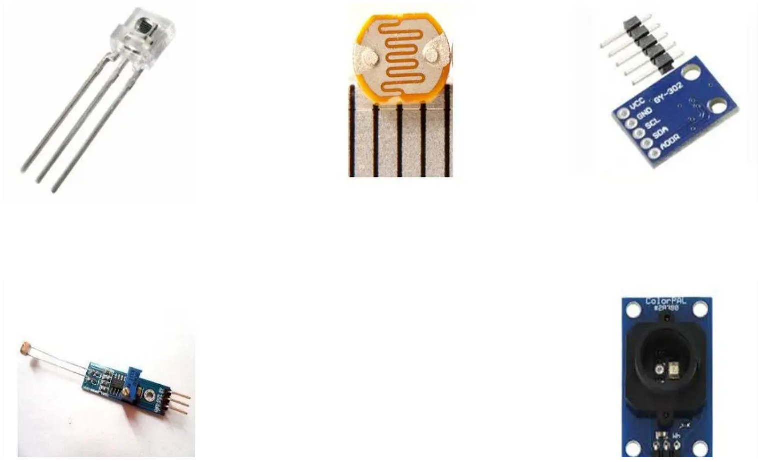

Figure 1.15: Light Sensors

5.1.4 Motion Sensors

Motion sensors detect movement within a specified area and are used for security, lighting control, and occupancy detection. They trigger automated responses such as turning on lights, sending notifications, or activating security alarms when motion is detected. The image “Motion Sensors” displays three motion sensors in different colors ,each with three pins protruding from the bottom.

Figure 1.16: Motion Sensors

5.1.5 Occupancy sensors

Occupancy sensors detect the presence of people within a specified area and are used for lighting control, HVAC control, and energy management. They help optimize energy usage by adjusting settings based on occupancy and usage patterns. The figure titled “Occupancy Sensors” shows various types of occupancy sensors , which include different designs and forms .

Figure 1.17: Occupancy Sensors

5.1.6 Door and window sensors

Door and window sensors detect the opening and closing of doors and windows and are used for security, access control, and automation. They trigger alarms and notifications when doors or windows are opened or closed, providing enhanced security and surveillance.

5.1.7 Contact sensors

Contact sensors detect the opening and closing of doors, windows, cabinets, and drawers and are used for security, access control, and automation. They provide real-time status information and trigger automated responses based on changes in status.

5.1.8 Water leak sensors

Water leak sensors detect the presence of water and are used to prevent water damage, monitor plumbing systems, and ensure safety and security. They trigger alarms and notifications when water is detected, enabling prompt action to mitigate damage. The figure labeled “Water Leak Sensors” shows a water leak sensor system , which includes a main unit mounted on the wall and a probe connected via a cable ,designed to detect the presence of water.

Figure 1.18: Water Leak Sensors

5.1.9 Gas Sensors

Gas sensors detect the presence of harmful gases such as carbon monoxide, methane, and propane and are used for safety, security, and environmental monitoring. They trigger alarms and notifications when gas leaks are detected, providing early warning and protection against hazards. The picture “Gas sensors” showcases a variety of gas sensors , each designed to detect specific gases in different environments

Figure 1.19: Gas Sensors

5.1.10 Vibration sensors

Vibration sensors detect mechanical vibrations and are used for security monitoring, and automation. They detect unauthorized entry, tampering, and attempts to force doors or windows, triggering alarms, notifications, and automated responses to enhance security and surveillance. The picture "Vibration Sensors" showcases three models of vibration sensors, each designed to measure and monitor vibrations in different settings.

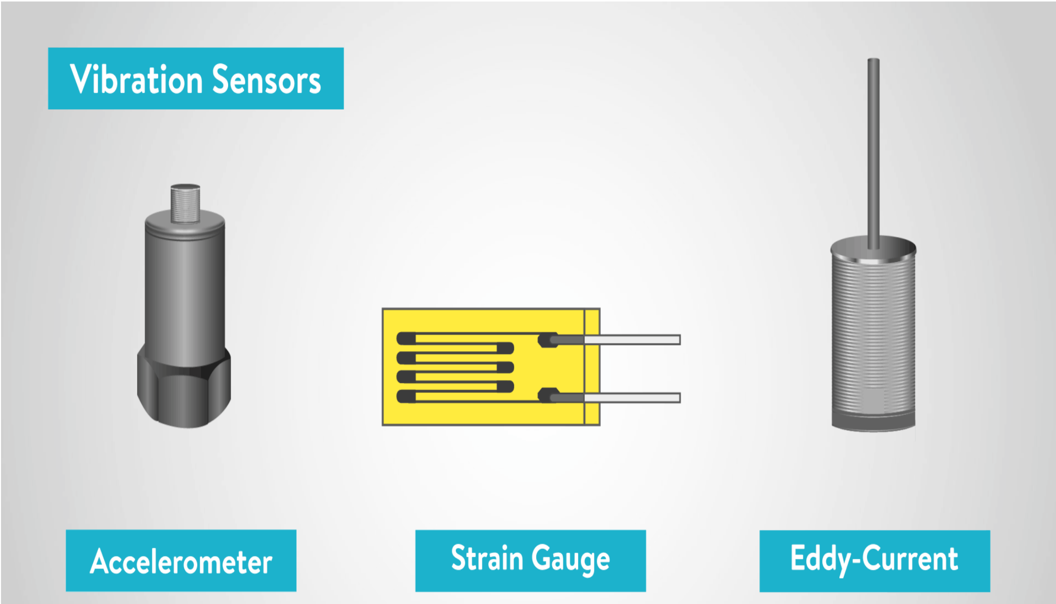

Figure 1.20: Vibration Sensors

5.2 Role of Sensors in Smart Home Automation

Sensors play a crucial role in smart home automation by providing data that enables intelligent decision-making and control. The data collected by sensors is used to detect changes in the environment, monitor conditions, and trigger automated responses. The role of sensors in smart home automation includes:[7]

5.2.1 Environmental Monitoring

Sensors detect changes in temperature, humidity, light, motion, sound, and other environmental variables, providing data that enables intelligent automation and control of HVAC systems, lighting systems, window blinds, and other devices.

5.2.2 Occupancy Detection

Sensors detect the presence of people within a specified area, enabling automatic lighting control, HVAC control, and energy management based on occupancy and usage patterns.

5.2.3 Security and Surveillance

Sensors detect motion, sound, vibration, and other security-related events, triggering alarms, notifications, and automated responses to enhance security and surveillance.

5.2.4 Safety and Health Monitoring

Sensors detect smoke, carbon monoxide, water leaks, gas leaks, and other safety-related events, triggering alarms, notifications, and automated responses to ensure safety and protect against hazards.

5.2.5 Energy Management

Sensors monitor energy usage, detect energy wastage, and optimize energy consumption based on occupancy, usage patterns, and environmental conditions, leading to energy savings and reduced utility bills.

5.2.6 Automation and Control

Sensors provide data that enables intelligent automation and control of smart home devices and systems, including lighting, HVAC, security, entertainment, and appliances, leading to increased convenience, comfort, and efficiency.

In summary, sensors are essential components of smart home systems, providing the data that enables intelligent automation, monitoring, and control. By selecting the right sensors and integrating them effectively into smart home systems, homeowners can achieve greater convenience, comfort, safety, and energy efficiency.

6 Conclusion

In This chapter, the fundamental concepts and technologies forming the basis of smart home systems are explored. The discussion begins with the evolution and current state of smart home technology,, highlighting its advantages and challenges. From simple automation solutions to sophisticated, interconnected ecosystems, smart home systems have transformed the way we interact with our homes, offering enhanced comfort, convenience, security, and energy efficiency for homeowners.

The role of Internet of Things (IoT) technology in home automation is then delved into, covering its applications in smart homes and the benefits and challenges associated with its implementation.. IoT technology enables devices and systems within the home to communicate, collect data, and make intelligent decisions, leading to enhanced automation, monitoring, and control.

Next, an overview of the STM32 microcontroller is provideda versatile and flexible platform that forms the core of many smart home systems. We discussed its features, specifications, advantages, and applications, highlighting its scalability, rich peripheral integration, advanced connectivity options, and comprehensive development ecosystem.

Finally, the various types of sensors used in smart home systems are explored,including temperature sensors, humidity sensors, light sensors, motion sensors, and more. We discussed the selection criteria for sensors and their role in smart home automation, highlighting how sensors provide the data that enables intelligent decision-making and control within the home. By understanding the fundamental concepts and technologies discussed in this chapter, we have gained insight into the key components of smart home systems and how they work together to create intelligent, interconnected living spaces.

In the following chapters, The following chapters will delve deeper into the hardware and software components of the smart home project ,exploring how we can leverage these technologies to create a fully functional and efficient smart home system.

Chapter 2

Hardware and Software Overview

1 Introduction

In this chapter, the focus is on the hardware and software components essential for the development of a smart home system using the STM32 microcontroller. The discussion begins with an introduction to the STM32 microcontroller, exploring its features, specifications, and advantages, along with its diverse applications. Following this, various types of sensors employed in smart home systems are discussed, along with the selection criteria and their pivotal role in smart home automation. This chapter provides a comprehensive overview of the hardware and software aspects crucial for the development and implementation of an efficient and intelligent smart home system.

2 Hardware Overview

2.1 STM32 Microcontroller

2.1.1 Introduction to STM32 Microcontroller

The STM32 microcontroller series, developed by STMicroelectronics, has emerged as a cornerstone in the embedded systems industry due to its exceptional versatility, high performance, and rich feature set. This chapter provides an in-depth look at the hardware and software aspects involved in building a smart home system using the STM32 microcontroller platform, with a particular focus on the STM32 Blue Pill development board, powered by the STM32F103C8T6 microcontroller. Its features, specifications, advantages, and applications are explored to understand how it can be leveraged effectively in smart home automation projects.[8]

The Figure displays STM 32 Blue Pill development board, a low-cost microcontroller board based on the ARM Cortex-M3 processor.

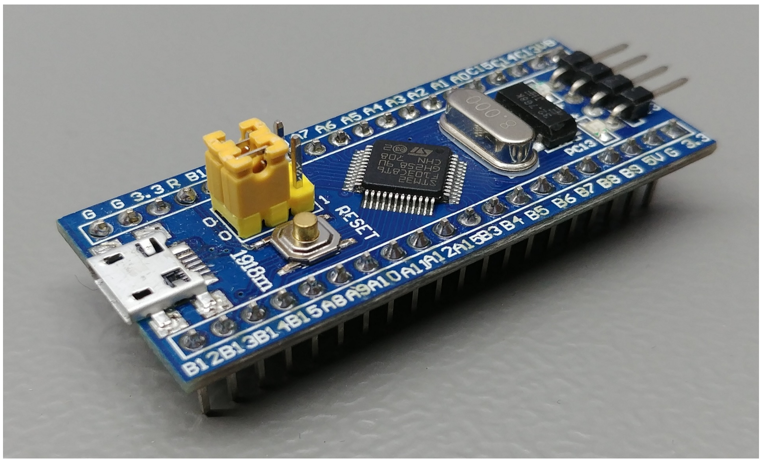

Figure 2.1: STM32 Blue Pill

2.1.2 Definition and Overview

The STM32 microcontroller series is based on the ARM Cortex-M processor architecture, offering a wide array of features and capabilities suitable for various embedded applications. The STM32F103C8T6 microcontroller, part of the STM32F1 series, is a 32-bit microcontroller known for its high performance, low power consumption, and rich set of integrated peripherals.[9]

2.1.3 Features and Specifications

The STM32F103C8T6 microcontroller boasts a comprehensive set of features and peripherals, making it an ideal choice for smart home automation and other embedded applications. Some key features and specifications of the STM32F103C8T6 microcontroller include:[10]

32-bit ARM Cortex-M3 Processor Powered by a 32-bit ARM Cortex-M3 processor running at up to 72 MHz, the STM32F103C8T6 offers high performance, efficient code execution, and real-time control. This processing capability makes it suitable for applications requiring real-time processing and complex control algorithms, ensuring optimal performance in various scenarios.

Scalable Architecture The STM32F1 series offers a scalable architecture with multiple product lines tailored to specific applications. The STM32F103C8T6, part of the mainstream STM32F1 series, strikes a balance between performance, power consumption, and peripheral integration, making it a versatile choice for a wide range of embedded applications. The Figure labelled "System Architecture" presents a block diagram detailing the architecture of the STM32F103C8T6 microcontroller.

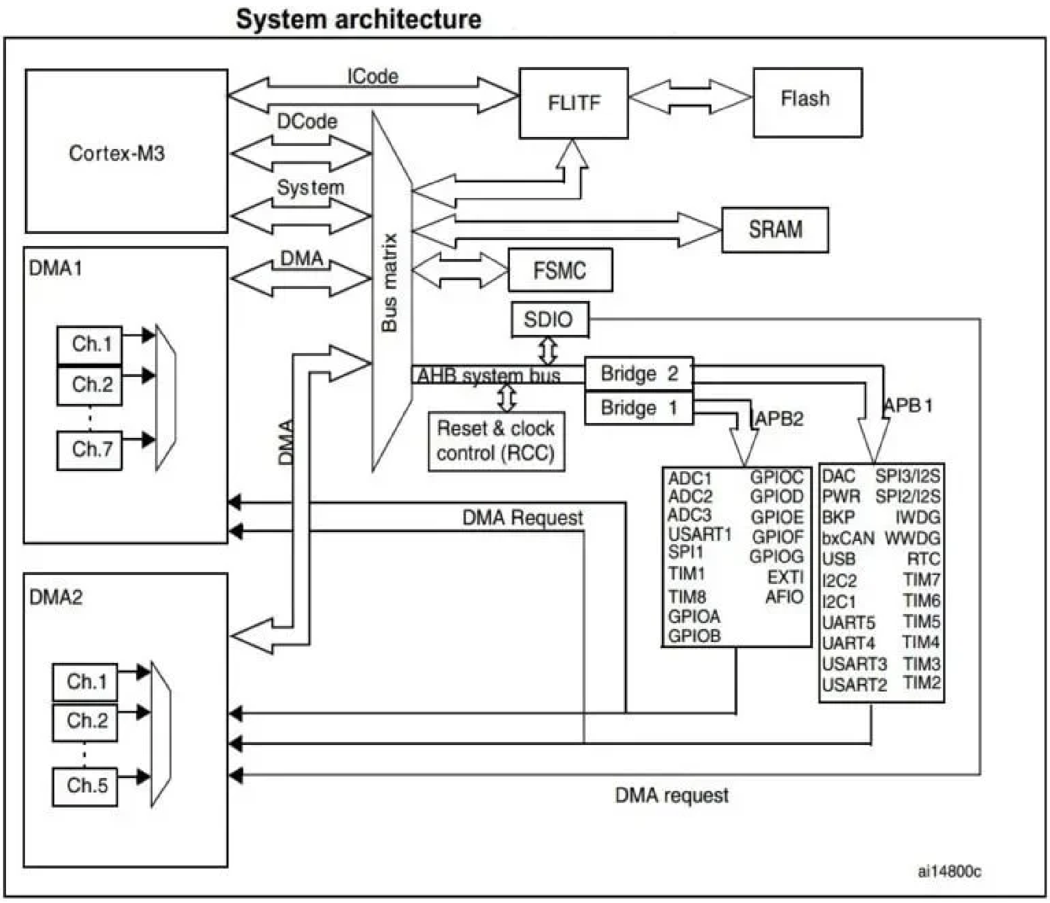

Figure 2.2: System Architecture

Comprehensive Peripheral Set The STM32F103C8T6 features a rich set of on-chip peripherals, including GPIO ports, timers, UARTs, SPI, I2C, ADC, DAC, PWM, USB, and more. These peripherals provide the necessary functionality to interface with external sensors, actuators, displays, and communication devices, enabling seamless integration and efficient operation in diverse embedded applications. The Figure below is a detailed pin out diagram of the STM32F103 microcontroller, often referred to as the "Blue Pill" due to its small size and blue PCB.

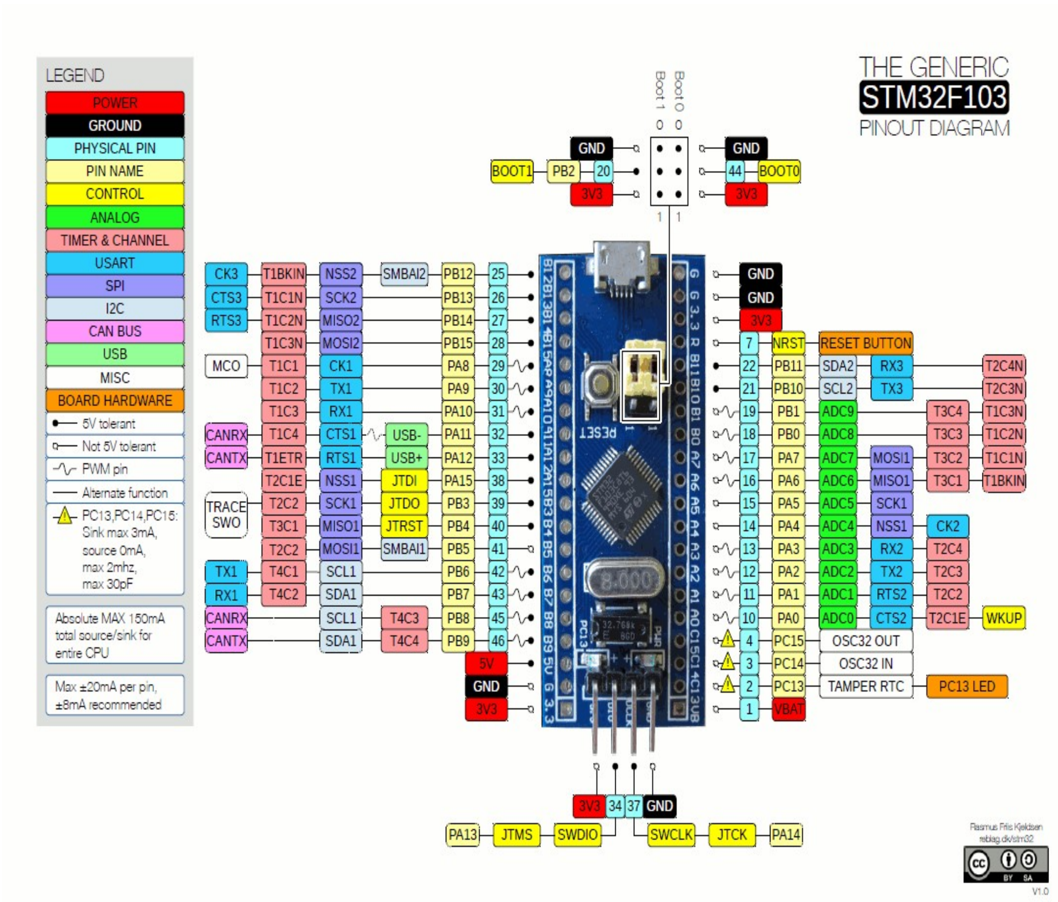

Figure 2.3: Peripheral Set of the STM32 Blue Pill

Advanced Connectivity Options The STM32F103C8T6 offers a range of connectivity options, including USB, UART, SPI, I2C, and CAN interfaces. These advanced connectivity options facilitate seamless integration with external devices and networks, making the STM32F103C8T6 well-suited for IoT and networked embedded systems.

Low Power Consumption Designed for low-power operation, the STM32F103C8T6 incorporates multiple power-saving modes and features such as dynamic voltage scaling, sleep modes, and peripheral clock gating. These features help minimize power consumption, making the STM32F103C8T6 an excellent choice for battery-powered and energy-efficient applications.

Rich Development Ecosystem The STM32F103C8T6 is supported by a robust development ecosystem, including a comprehensive set of development tools, software libraries, middleware, and application examples. STMicroelectronics provides free integrated development environments (IDEs) such as STM32CubeIDE and STM32CubeMX, along with third-party tools and open-source projects such as FreeRTOS, Mbed OS, and Arduino. This rich ecosystem facilitates the development and prototyping process, allowing developers to get started quickly and efficiently.

2.1.4 Advantages and Applications

Advantages The STM32F103C8T6 microcontroller offers numerous advantages, making it an ideal choice for smart home automation and other embedded applications. Some of these advantages include:

High Performance The STM32F103C8T6 is powered by a 32-bit ARM Cortex-M3 processor running at up to 72 MHz. This high-performance processor provides efficient code execution, real-time control, and the ability to handle complex control algorithms. Whether it's managing sensor data, controlling actuators, or processing user inputs, the STM32F103C8T6 delivers the performance required for demanding embedded applications.

The Figure labelled "32-bit ARM Cortex-M3 Processor" showcases a microcontroller from the STM32 series, specifically highlighting its ARM Cortex-M3 core.

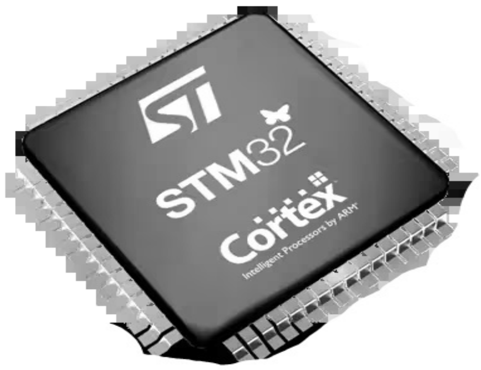

Figure 2.4: 32-bit ARM Cortex-M3 Processor

The Figure illustrates the architecture of the Cortex-M3 processor, which is commonly used in microcontrollers like the STM32F103C8T6.

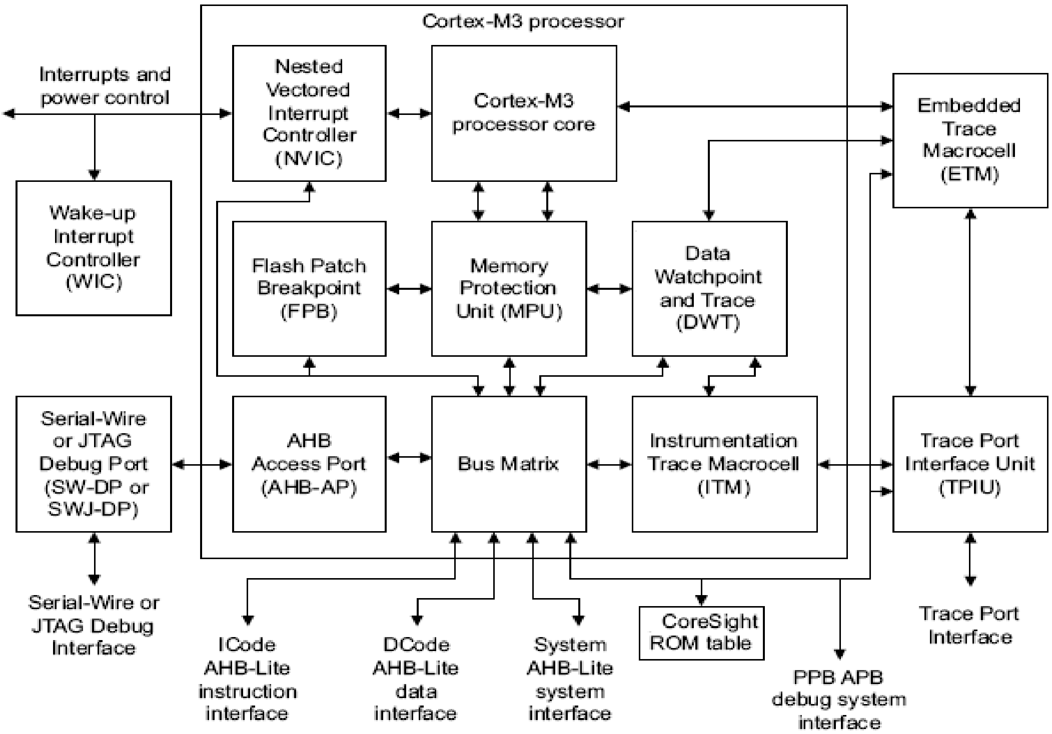

Figure 2.5: Processor Architecture

Availability One of the key advantages of the STM32F103C8T6 microcontroller is its widespread availability. It can be purchased from various distributors worldwide, ensuring easy access to the microcontroller for hobbyists, students, and professional developers alike. The availability of the STM32F103C8T6 from multiple sources also ensures a stable supply chain, reducing the risk of component shortages and project delays.[11]

Affordability Despite its advanced features and capabilities, the STM32F103C8T6 microcontroller remains highly cost-effective. It offers a rich set of features and peripherals at an affordable price point, making it accessible to developers working on projects with budget constraints. Whether you're a hobbyist working on a personal project or a professional developer working on a commercial product, the STM32F103C8T6 offers excellent value for money.[12]

This figure illustrates the affordability of the STM32F103C8T6 Blue Pill development board.

Figure 2.6: Price of the STM32 Blue Pill

Ease of Use: Another significant advantage of the STM32F103C8T6 microcontroller is its ease of use and programmability. STMicroelectronics provides a rich development ecosystem for the STM32 microcontroller series, including comprehensive documentation, software libraries, and development tools. The STM32CubeIDE and STM32CubeMX integrated development environments (IDEs) offer graphical configuration tools, code generators, and debugger support, simplifying the development process and allowing developers to get started quickly and efficiently. Additionally, the STM32 microcontroller series is supported by a vibrant online community, providing tutorials, forums, and open-source projects that further enhance the development experience.[10]

Applications The STM32F103C8T6 microcontroller is suitable for a wide range of embedded applications, including:

Smart Home Automation The STM32F103C8T6 is an excellent choice for smart home automation projects. It can control various home appliances, monitor environmental conditions, and communicate with other devices to create a seamless and intelligent home automation system.

Industrial Control Systems The high performance and real-time control capabilities of the STM32F103C8T6 make it well-suited for industrial control systems. It can be used to control machinery, monitor processes, and collect data for analysis, ensuring efficient and reliable operation in industrial environments.

This figure labelled as “industrial Control Systems” shows a person using a tablet to interact with and possibly control machinery in an industrial setting.

Figure 2.7: Industrial Control Systems

Consumer Electronics The STM32F103C8T6 is used in a wide range of consumer electronics products, including home entertainment systems, wearable devices, and gaming consoles. Its high performance, low power consumption, and rich set of peripherals make it an ideal choice for consumer electronics applications.

Automotive Applications The STM32F103C8T6 is used in automotive applications such as engine control units (ECUs), infotainment systems, dashboard displays, and advanced driver assistance systems (ADAS). Its real-time control capabilities and advanced communication interfaces make it well-suited for automotive applications.

Internet of Things (IoT) Devices The STM32F103C8T6 is widely used in IoT devices such as smart sensors, actuators, gateways, and edge computing devices. It provides the processing power, connectivity, and flexibility required to enable intelligent, connected, and autonomous IoT systems.

The Figure titled "Using stm32 in IOT Project" showcases various components and modules that can be integrated into an IOT project using The STM32 microcontroller .

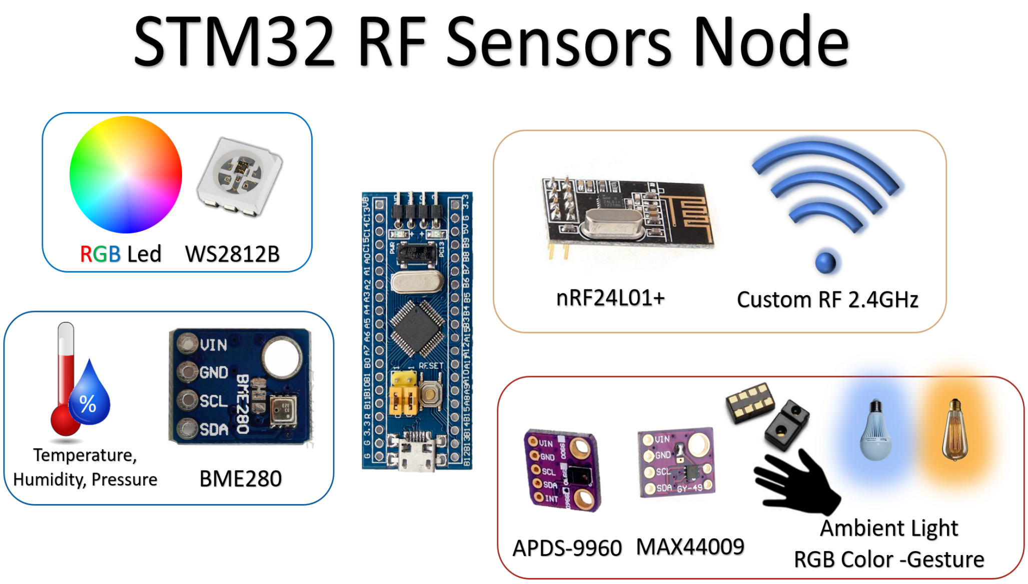

Figure 2.8: Using STM32 in IOT project

With its high performance, affordability, availability, and ease of use, the STM32F103C8T6 microcontroller is the perfect choice for developers looking to build innovative embedded systems for various applications. Whether you're designing a smart thermostat, a home security system, or an industrial automation solution, the STM32F103C8T6 provides the features and capabilities you need to bring your project to life.

2.2 Overview of Sensors and Modules

In the context of smart home automation, sensors play a pivotal role in monitoring environmental conditions, detecting presence, and ensuring security. For this project, we will be using the following sensors:

DHT11 A digital temperature and humidity sensor.

MQ-2 A gas sensor capable of detecting LPG, smoke, alcohol, propane, hydrogen, methane, and carbon monoxide.

RFID (Radio-Frequency Identification) Used for access control and security.

Light-Dependent Resistor is an electronic component whose resistance decreases as the intensity of light falling on it increases.

HC-05 The HC-05 is a Bluetooth module used for wireless communication between devices.

Oled SSd1306 The OLED SSD1306 is a popular type of organic light-emitting diode (OLED) display that is controlled by the SSD1306 driver.

2.2.1 DHT11 Sensor

[6] The DHT11 is a digital sensor used for measuring temperature and humidity, making it an essential component in various smart home applications, particularly those related to climate control and environmental monitoring. The Figure titled "DHT11 Sensor" illustrates the DHT11 digital sensor ,which is and commonly used for measuring temperature and humidity.[13]

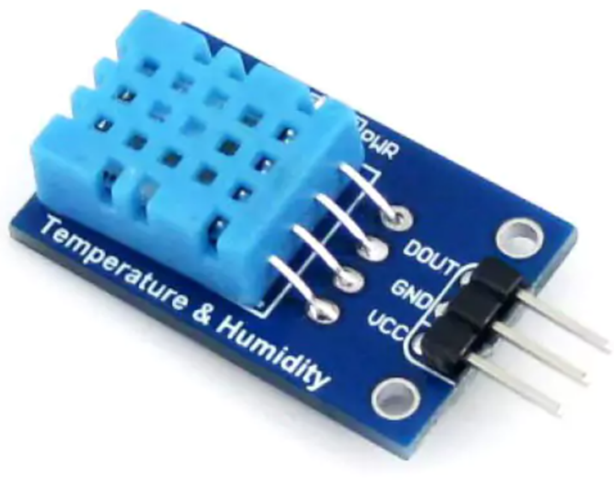

Figure 2.9: DHT11 Sensor

Overview The DHT11 sensor provides reliable readings of both temperature and humidity. It utilizes a capacitive humidity sensor and a thermistor to measure the surrounding air and outputs a digital signal on the data pin (no analog input pins needed).

Specifications

- HTemperature Range: 0°C to 50°C with an accuracy of ±2°C.
- Humidity Range: 20% to 90% RH with an accuracy of ±5% RH.

- Operating Voltage: 3.5V to 5.5V.comfortable indoor environments automatically.
- Signal Transmission: Digital signal output, simplifying the interface with microcontrollers like the STM32F103C8T6.

Applications

- HVAC Systems: Helps in maintaining optimal temperature and humidity levels.
- Greenhouses: Monitors and controls the microclimate to ensure the best conditions for plant growth.
- Weather Stations: Collects local temperature and humidity data.
- Home Automation: Integrates with systems to maintain comfortable indoor environments automatically.

Advantages

- Ease of Use: Simple interface with microcontrollers and straightforward data interpretation.
- Low Cost: Affordable solution for basic temperature and humidity monitoring.
- Compact Size: Easily fits into small devices and applications.

2.2.2 MQ-2 Gas Sensor

The MQ-2 is a versatile gas sensor that can detect a variety of gases including LPG, smoke, alcohol, propane, hydrogen, methane, and carbon monoxide. This makes it an invaluable sensor for ensuring safety and security in smart home environments.[14]

The Figure “MQ-2 Gas Sensor” depicts the MQ-2 gas sensor module, which is commonly used for detecting gases such as LPG ,methane ,alcohol ,propane ,hydrogen ,and smoke.

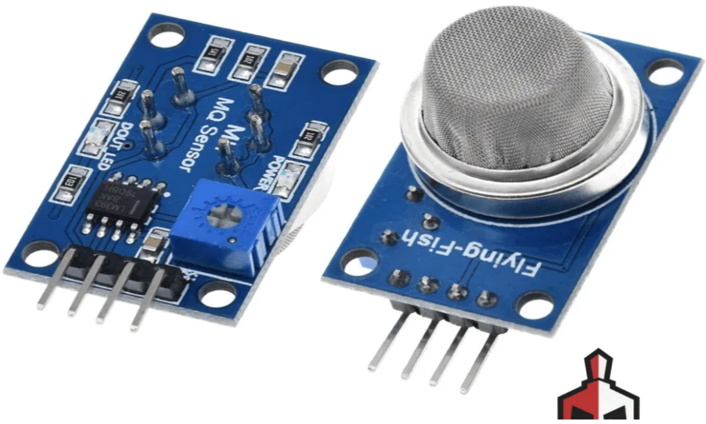

Figure 2.10: MQ-2 Gas Sensor

Overview The MQ-2 sensor operates by measuring the resistance change of the sensor's sensitive layer when exposed to target gases. It provides an analog output signal that can be converted to digital by the microcontroller.

Specifications

- Detectable Gases: LPG, Smoke, Alcohol, Propane, Hydrogen, Methane, and Carbon Monoxide.
- Operating Voltage: 5V.
- Sensitivity Range: 200-10000 ppm (parts per million) for various gases.
- Response Time: ¡10 seconds for target gases.

Applications

- Smoke Detection: Critical for fire safety systems.
- Gas Leak Detection: Monitors for leaks in LPG or natural gas systems to prevent accidents.
- Air Quality Monitoring: Ensures indoor air is safe by detecting harmful gases.
- Industrial Safety: Used in manufacturing environments to monitor gas levels and maintain safe working conditions.

Advantages

- Wide Range of Detection: Can sense multiple harmful gases.
- High Sensitivity: Capable of detecting low concentrations of gases.
- Cost-Effective: Affordable for broad deployment in safety applications.
- Ease of Integration: Compatible with various microcontroller platforms for data collection and processing.

2.2.3 RFID (Radio-Frequency Identification) Sensor

RFID technology is widely used for identification and access control, providing a convenient and secure method for managing entry and tracking objects.[15] The Figure shows an RFID (Radio-Frequency Identification) sensor ,specifically an RFID reader and a key for tag.

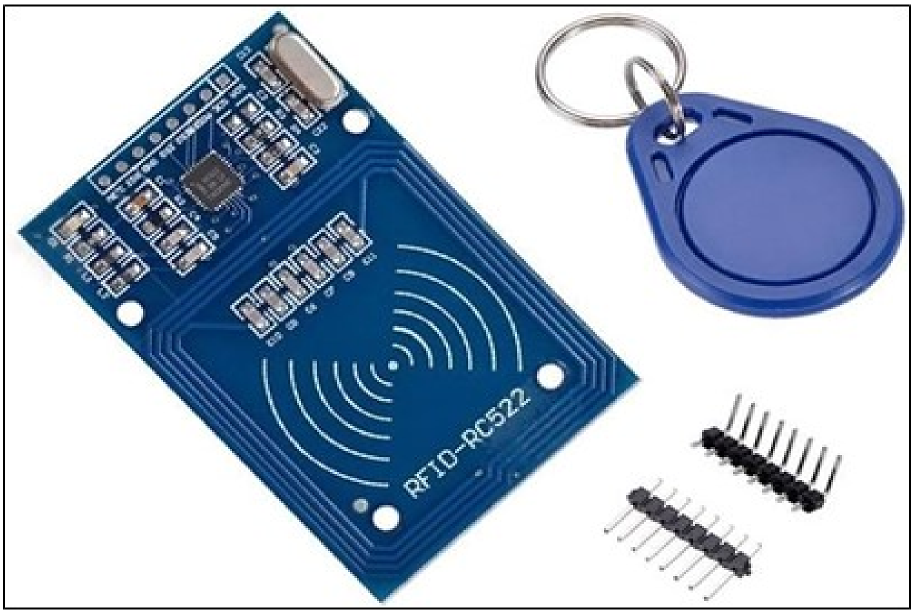

Figure 2.11: RFID

Overview RFID systems consist of a tag (transponder) and a reader. The reader emits radio waves and receives signals back from the tag, which carries a unique identification number. This technology is used for automatic identification and tracking of tags attached to objects.

Specifications

- Frequency Range: Commonly 125 kHz for low-frequency tags or 13.56 MHz for high-frequency tags.
- Reading Distance: Typically ranges from a few centimetres to several meters, depending on the system.
- Operating Voltage: Typically 3.3V to 5V for most RFID readers.
- Data Storage: Tags can be read-only or read-write, with varying storage capacities.

Applications

- Access Control: Manages entry to homes or specific rooms by recognizing authorized tags.
- Inventory Management: Tracks items within a smart home or other environments.
- Security Systems: Enhances security by ensuring only authorized personnel can access certain areas.
- Automation: Triggers actions or logs events when specific tags are detected.

Advantages

- Security: Provides a high level of security and control over access.
- Convenience: Allows for contactless interaction, which is fast and easy to use.
- Versatility: Can be used in a wide range of applications from security to inventory management.
- Scalability: Easy to expand systems by adding more tags and readers.

2.2.4 Light Dependent Resistor

A Light Dependent Resistor alternatively called: LDR, photoresistor, photocell or photoconductor, is a variable resistor whose value decreases with increasing incident light intensity.[16]

The Figure depicts a Light-Dependent Resistor (LDR), also known as a photoresistor , whose resistance decreases with increasing incident light intensity.

Figure 2.12: Light-Dependent Resistor

2.2.5

OLED SSD1306 Display The OLED SSD1306 is a small, high-contrast display used for visual output in embedded systems. It is commonly used for displaying text, graphics, and other visual information in smart home projects. Key features include:

- Display Size: Typically available in 0.96-inch size with 128x64 pixel resolution.
- Interface: Supports I2C or SPI communication interfaces.
- Low Power Consomption: Consumes minimal power, making it suitable for battery-operated devices.

- High Contrast: Provides clear and bright display output, even in low light conditions.

The image shows a small OLED display module based on the SSD1306 driver, commonly used in various electronics and microcontroller projects.

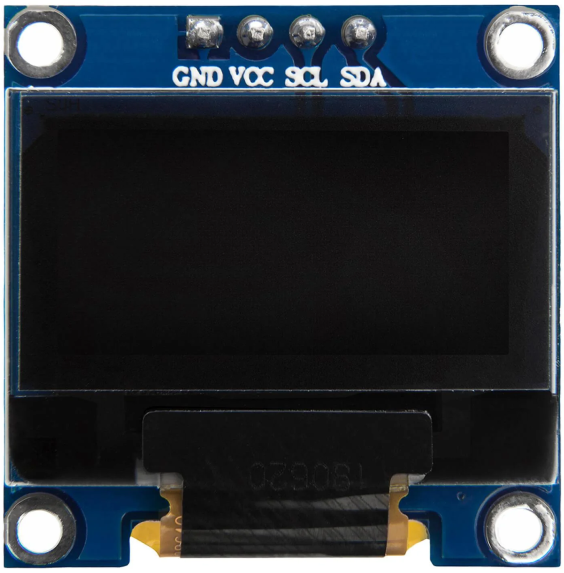

Figure 2.13: OLED SSD1306

2.3 Bluetooth Wireless Technology

2.3.1 Overview

Bluetooth wireless Technology is a low-cost cable-replacement method for connecting computer based devices in home and small office environments for exchanging data over short distances (using short-wavelength ultra-high frequency UHF radio waves in the Industrial, Scientific and Medical ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables.[17]

The image depicts the Bluetooth wireless logo, which is widely recognized and used to denote devices and technologies that support Bluetooth wireless communication.

Figure 2.14: Bluetooth Wireless Logo

2.3.2 HC-05 Bluetooth Module

The HC-06 module permits any microcontroller with a standard RS232 serial port to communicate with a PC or a Smartphone equipped with a Bluetooth Master module. Its main specifications are:[18]

- Bluetooth number: JY-MCU-HC-06, surface mounts with integrated antenna.
- Operating Voltage: 5 volts
- Default baud rate: 9600 bps
- Default pin: 1234
- Default name: HC-05
- Class: 2, with up to 10-meter coverage.

A red LED in the Bluetooth module indicates the status of the connection: when flashing, the module is in the phase of interconnection with other modules located in the same area. When the LED is always on, indicates that the module is already synchronized or ”paired” with another Bluetooth master module and therefore is ready to transmit and receive information.

The figure shows the HC-05 Bluetooth module, a popular Bluetooth to serial port module designed for wireless communication between microcontrollers and other devices.

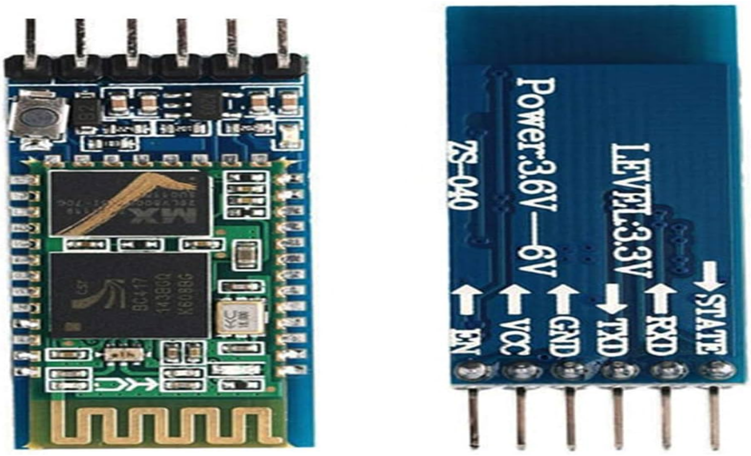

Figure 2.15: HC-05 Bluetooth Module

3 Software Overview

The software component of our smart home system is integral to its operation, providing the necessary tools for programming the STM32 microcontroller and designing the user interface for the smart home application. We utilized two primary software tools: App Inventor for designing the mobile application and STM32CubeIDE for programming the STM32F103C8T6 microcontroller.

3.1 App Inventor

App Inventor is an intuitive, visual programming environment developed by MIT that allows developers to build fully functional applications for Android devices. Its user-friendly drag-and-drop interface makes it accessible to both beginners and experienced developers.[19]

This figure includes a logo of the MIT App Inventor, which features a stylized bee with two hexagonal shapes in the background, this interface is highlighted for its use of block-based programming, which allows users to create complex applications by snapping together logical blocks .

Figure 2.16: App Inventor Logo

3.1.1 Key Features of App Inventor

Visual Programming Interface App Inventor uses a block-based programming language that simplifies coding by allowing users to snap together logical blocks like puzzle pieces. This makes it easy to create complex applications without extensive programming knowledge.

Component-Based Development App Inventor provides a wide range of built-in components, such as buttons, text boxes, sensors, and communication interfaces. These components can be easily added to the application and configured to perform various functions.

Real-Time Testing Developers can test their applications in real-time using the App Inventor Companion App, which runs on Android devices. This feature allows for immediate feedback and debugging, streamlining the development process.

Cloud-Based Storage Projects are stored in the cloud, making them accessible from any computer with internet access. This ensures that development work can be continued from multiple locations and devices.

Extensive Documentation and Tutorials App Inventor provides extensive documentation, tutorials, and a supportive community, making it easier for developers to learn and troubleshoot.

3.2 STM32CubeIDE

STM32CubeIDE is an integrated development environment provided by STMicroelectronics, tailored specifically for STM32 microcontrollers. It combines the STM32CubeMX graphical configurator and initialization code generator with the Eclipse-based development environment.

This picture illustrates a logo of the STM32Cube, which features a blue cube and a butterfly. The text highlights the integration of STM32CubeMX and the Eclipse-based development platform, the accompanying text outlines the features of STM32Cube

Figure 2.17: STM32CubeIDE Logo

3.2.1 Key Features of STM32CubeIDE

Integrated Development Environment Combines code editing, compilation, debugging, and project management in a single tool, providing a streamlined development workflow.

STM32CubeMX Integration Incorporates the STM32CubeMX configurator, which allows developers to visually configure peripherals, clock settings, and middleware, generating initialization code for the STM32 microcontroller.

Advanced Debugging Capabilities Offers a range of debugging tools, including breakpoints, watch variables, and real-time tracing, which help in identifying and fixing issues efficiently.

Code Generation Automatically generates initialization and peripheral setup code based on the user's configuration, saving time and reducing the potential for errors.

Comprehensive Documentation and Support Provides extensive documentation, example projects, and a large community of users, making it easier to find solutions and best practices.

4 Conclusion

This chapter has given a thorough overview of the essential elements and technologies needed to create an advanced smart home system. We have also looked at the features and uses of a variety of sensors, including the MQ-2 Gas Sensor, DHT11 Temperature and Humidity Sensor, RFID technology, Light Dependent Resistor (LDR), and OLED SSD1306 Display.

The advantages and specifications of each sensor were covered in detail, emphasizing their vital roles in improving the security, safety, and effectiveness of smart home environments. Moreover, we have looked at the integration and capabilities of software tools like the MIT App Inventor and STM32CubeIDE, highlighting their significance in managing and programming the STM32 microcontroller.
In summary, the chapter highlights how software tools and hardware components work together to create a smooth and functioning smart home system, opening the door to new applications and enhanced user experiences.

Going ahead, the knowledge acquired from this chapter will act as a basis for the use and enhancement of smart home technologies, guaranteeing that they satisfy the changing demands and standards of contemporary living.

Chapter 3

Hardware/Software System design

1 Overview

An embedded system comprises both hardware and software (firmware) components, each indispensable to the system's functionality. Following the construction of the hardware, the software assumes its crucial role in data manipulation and decision-making. This software can be scripted in assembly language or a high-level language, tailored for execution by the microprocessor. This project's software component is structured into two primary segments: -The Android application acts as the graphical user interface, developed with the JAVA programming language utilizing MIT App Inverter. -The firmware governs the behavior of the various system components and is coded in C/C++.

2 The Android Application Design Description

2.1 Android Tools

Android development using MIT App Inventor provides an intuitive, visual programming environment, making it accessible for users without extensive coding experience. The development process using MIT App Inventor involves setting up a simple yet powerful framework that allows for the creation and deployment of Android applications.

2.2 Design Description

The workflow to develop an Android application needs to follow a set of steps starting by creating an App Inverter project that gives the opportunity to create applications for various devices like TVs, Phones, Tablets, and Wear etc. Once done, a workspace space will appear containing three main areas; text editor area, gradle console area that contains a preview of the application, and the structure area that contains the hierarchy of the project which allows the programmer to navigate through multiple activity layout and java classes. The Android application of this project is made up with App Inverter with three main parts:

Communication part Set of activities that allow creating connection between the Smartphone and Bluetooth module by showing the nearby devices and allowing the user to pair with the HC-05 module.

Command part Set of activities representing a menu of rooms containing different toggle buttons dedicated for each device.

3 Sensor and modules Configuration

Importance of Sensor Configuration Proper sensor configuration in the STM32 Cube IDE is crucial for ensuring the accuracy, reliability, and efficiency of an embedded system. Sensors are responsible for collecting vital data from the environment, which is then used for decision-making and control processes. Correctly configuring these sensors allows for precise data acquisition, effective communication between hardware components, and optimal system performance. Misconfiguration can lead to incorrect data, system instability, and potential hardware damage. Therefore, it is essential to thoroughly understand and implement the appropriate initialization parameters, communication protocols, and calibration procedures to achieve the desired functionality and reliability of the embedded system.

3.1 Configuration procedure for each sensor

3.1.1 DHT11

DHT11 Humidity and Temperature Sensor / OLED with Blue Pill using STM32CubeIDE

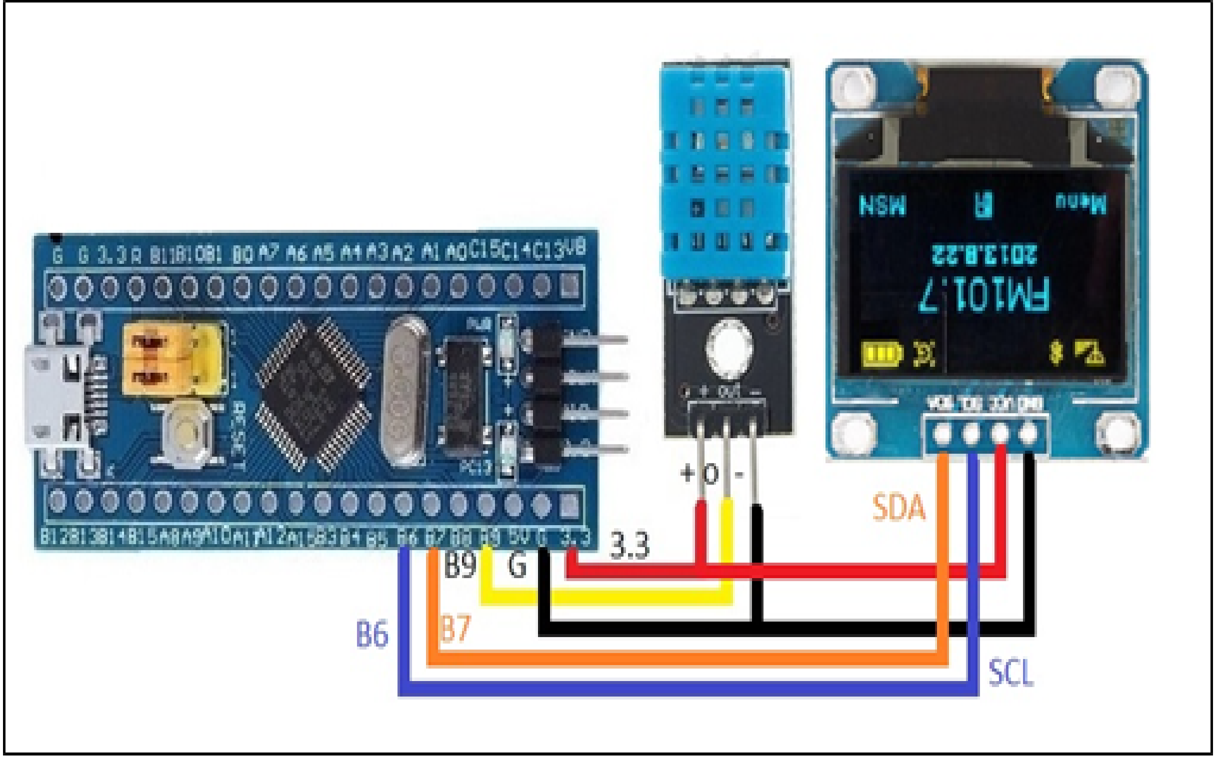

Figure 3.1: Wiring Diagram DHT11/Oled

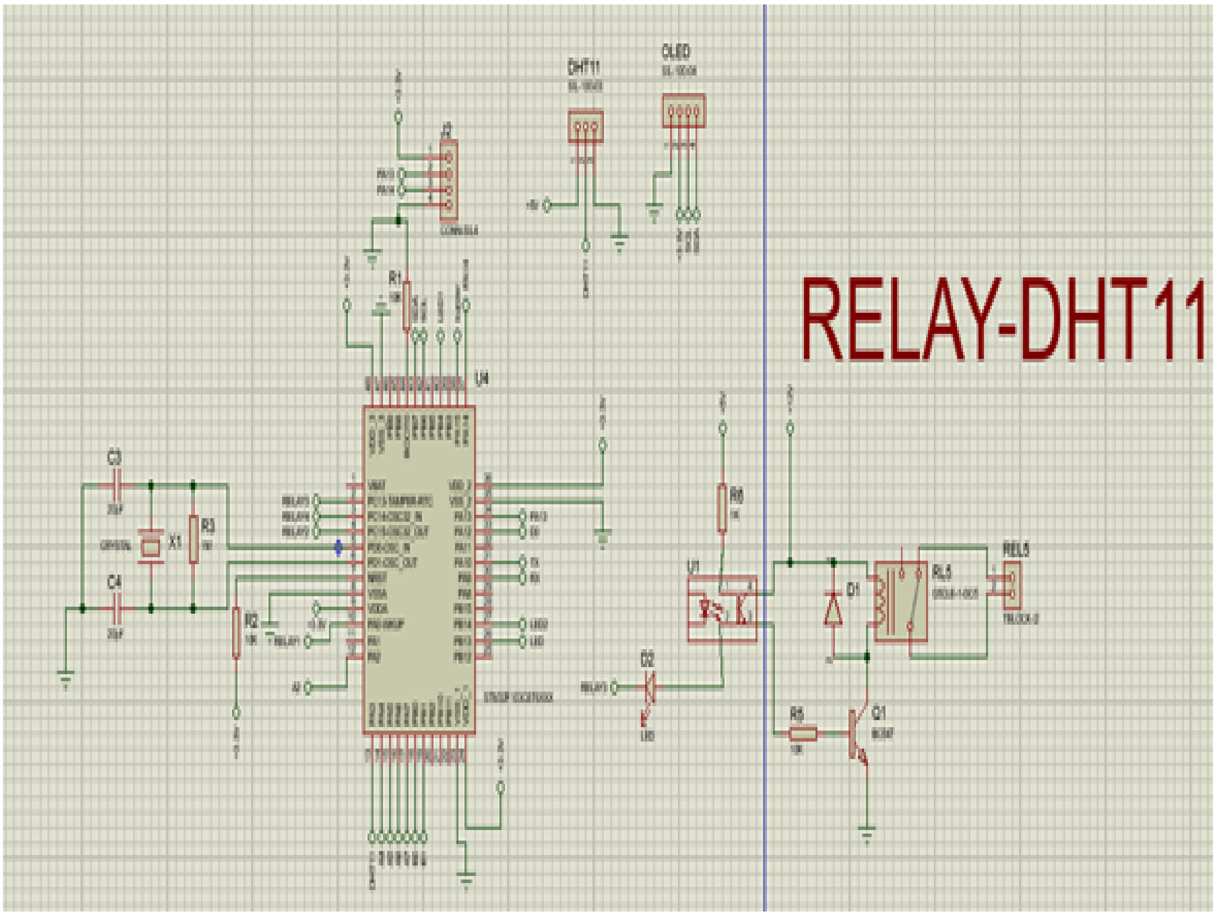

Figure 3.2: Wiring Diagram DHT11/Oled

STM32CubeIDE Settings Click RCC → High Speed Clock (HSE) to Crystal/Ceramic Resonator
Click Clock Configuration tab → HCLK (MHz) to 72
Click Pinout and Configuration tab
Click Timer → Click TIM1 → Clock Source set to Internal Clock Configuration → Parameter Settings → Prescaler set to 71
Set PB9 GPIO Output
Click connectivity –¿ Click I2C1
For I2C select I2C Configuration –¿ Parameter Settings
For I2C speed select Fast Mode

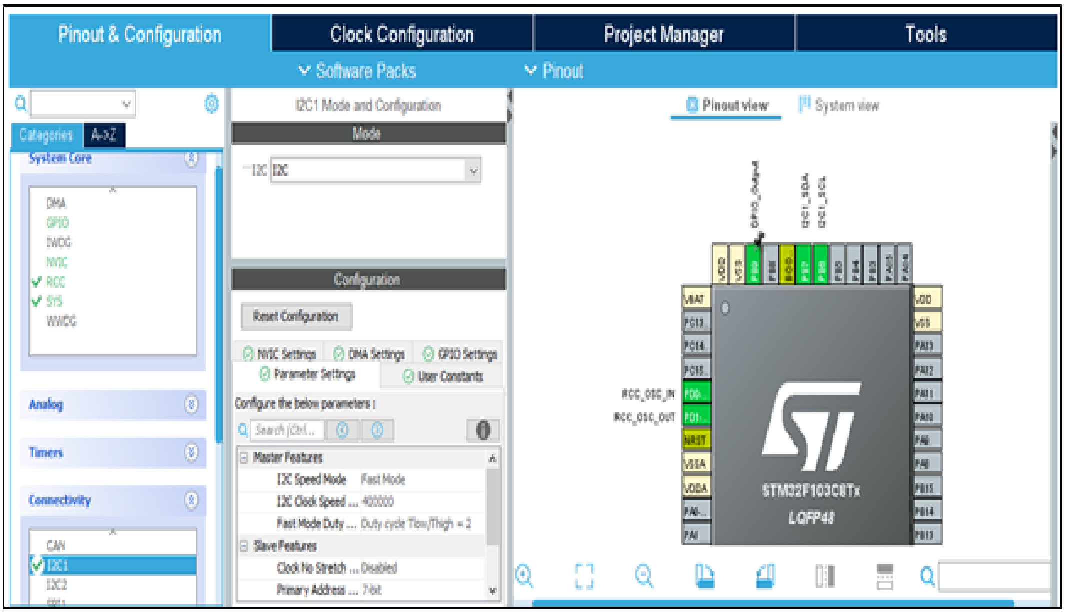

Figure 3.3: pin out and Configuration of DHT11/OLED

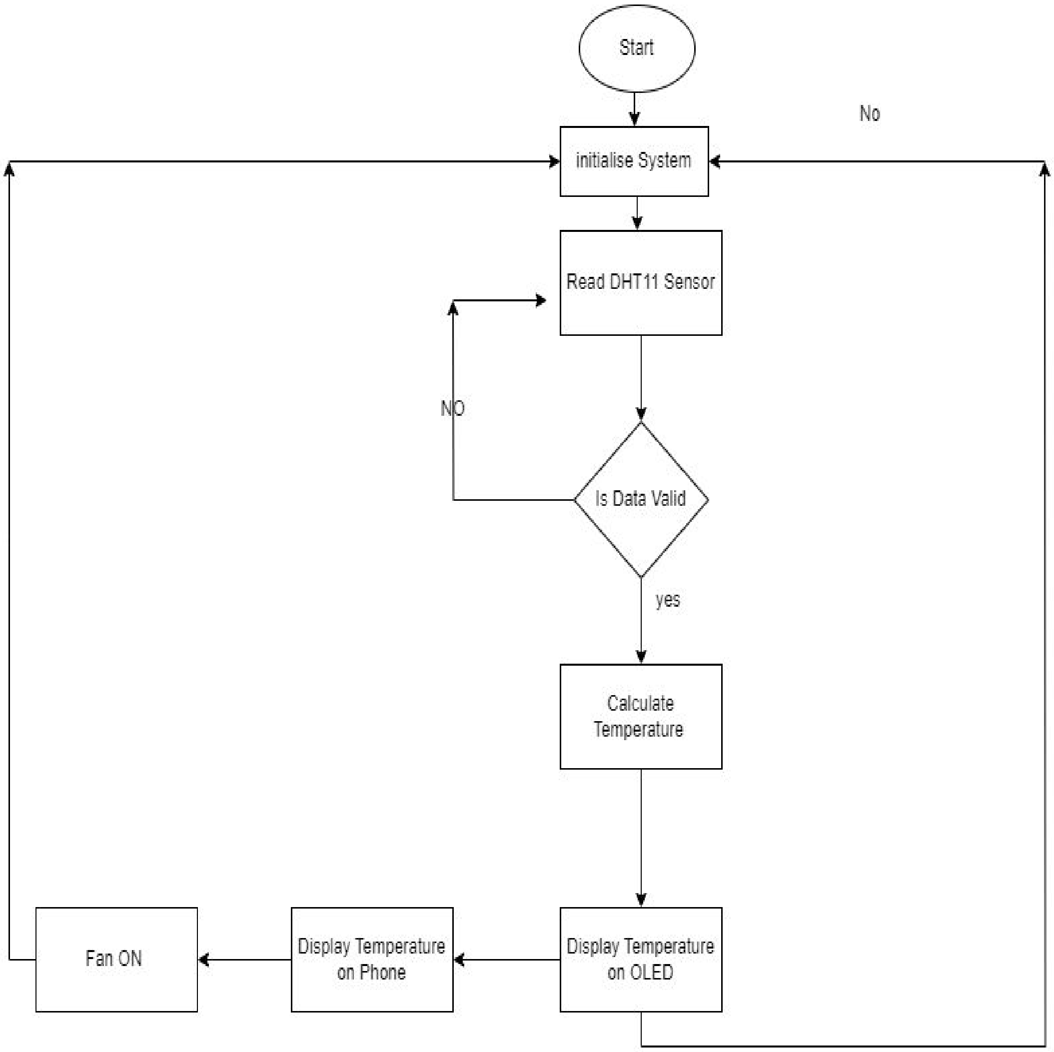

Figure 3.4: Process of DHT11

3.1.2 RFID (Radio-Frequency Identification)

RFID RC522 with Blue Pill using STM32CubeIDE

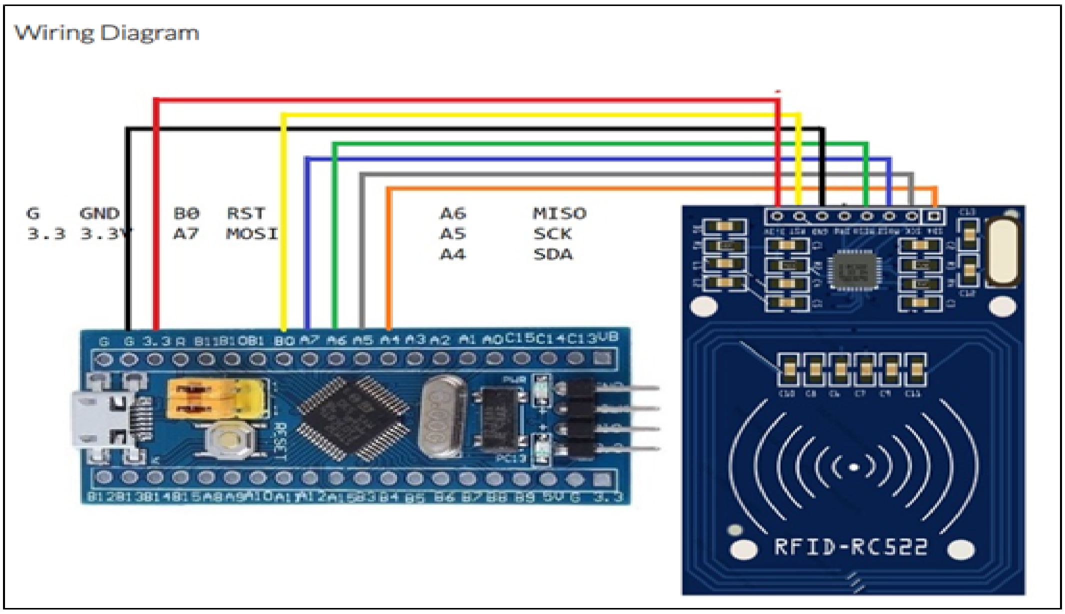

Figure 3.5: Wiring Diagram RFID

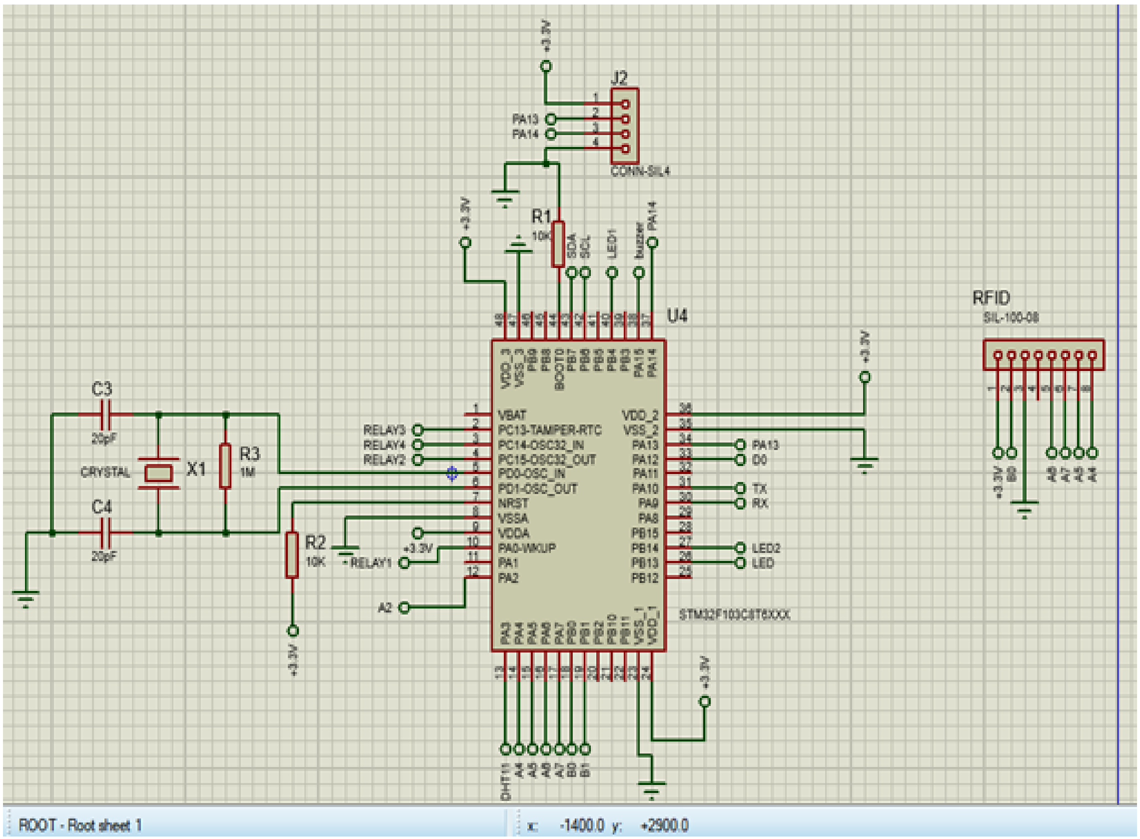

Figure 3.6: Wiring of the RFID

STM32CubeIDE Settings Click RCC → High Speed Clock (HSE) to Crystal/Ceramic Resonator
Click Clock Configuration tab → HCLK (MHz) to 72
Click Pinout and Configuration tab
Click connectivity → Click SPI1
For Mode select Full Duplex Master Configuration → Parameter Settings
Change prescalar (for Baud rate) to 8
Set PA4 to GPIO Output
Set PB0 to GPIO Output
Set PC13 to GPIO Output

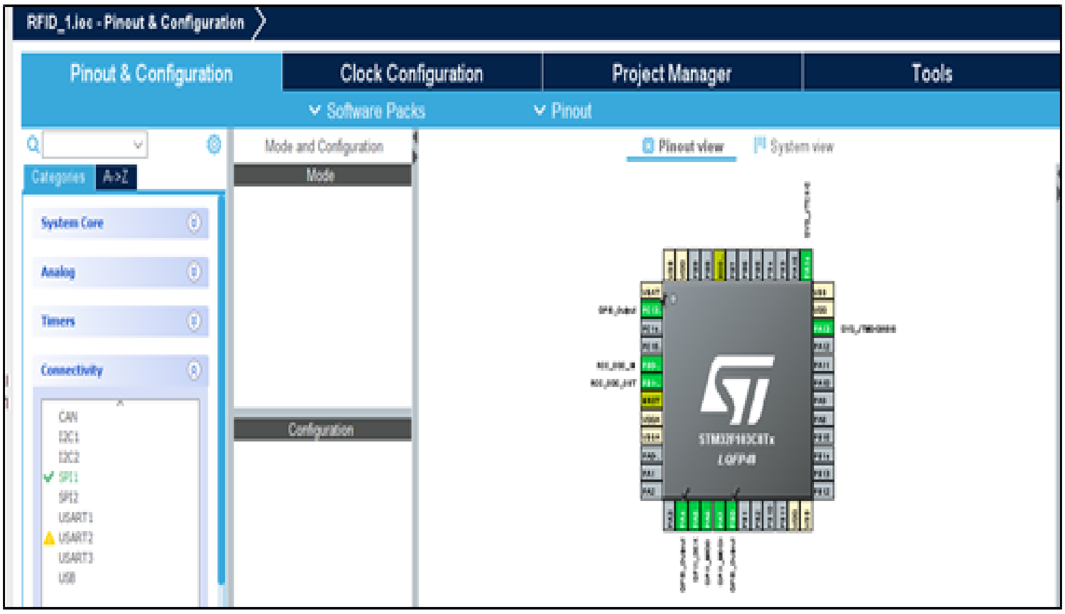

Figure 3.7: pin out and Configuration of RFID

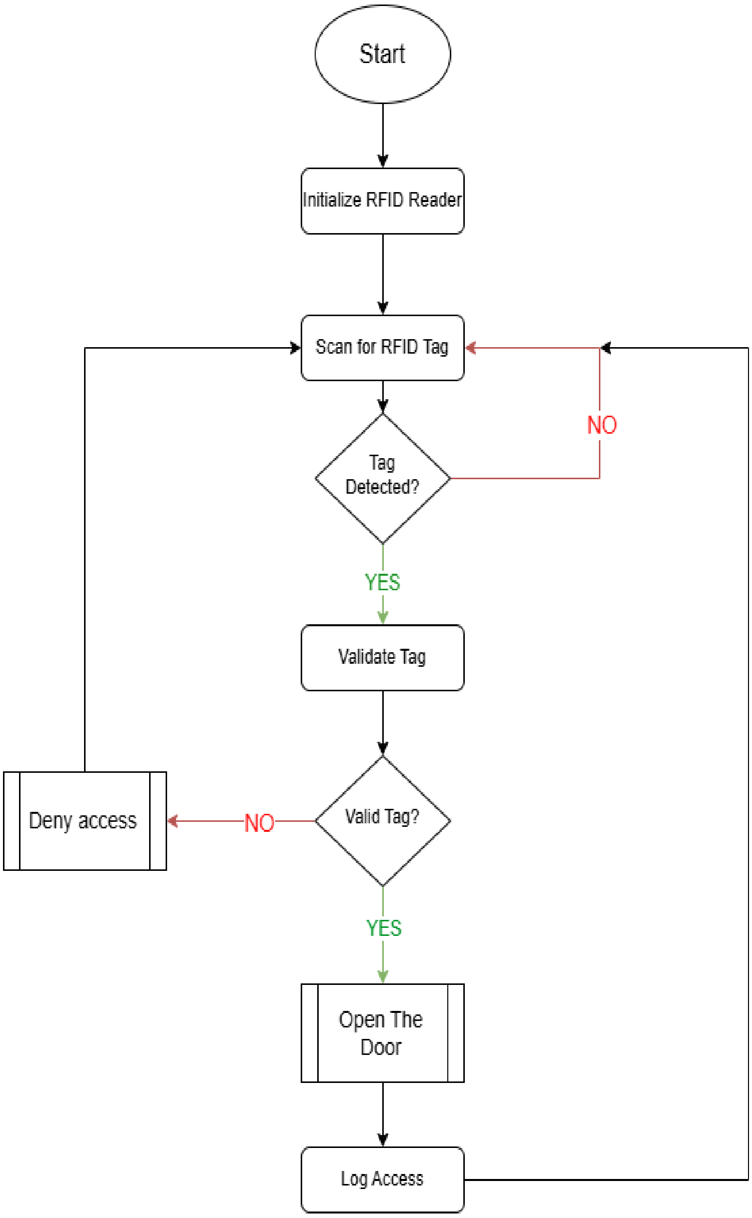

Figure 3.8: Process of RFID

3.1.3 Led

To turn on or off a lamp of a given room, the user should click on the lamp's icon on his phone to send the command to the digital controller; the latter cannot provide enough current from its output pins hence

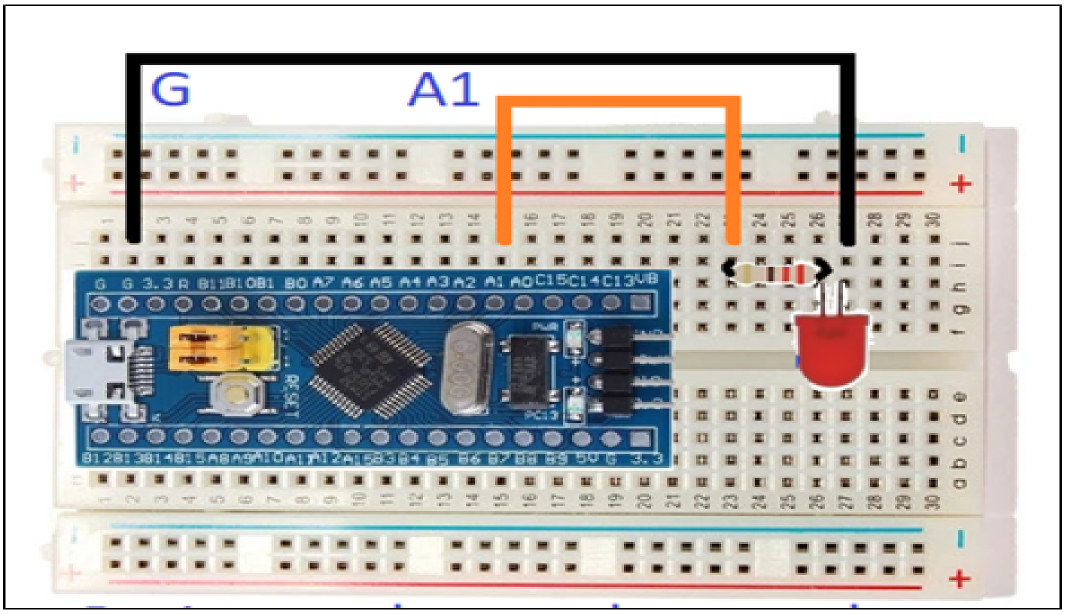

Figure 3.9: Basic wiring of Led

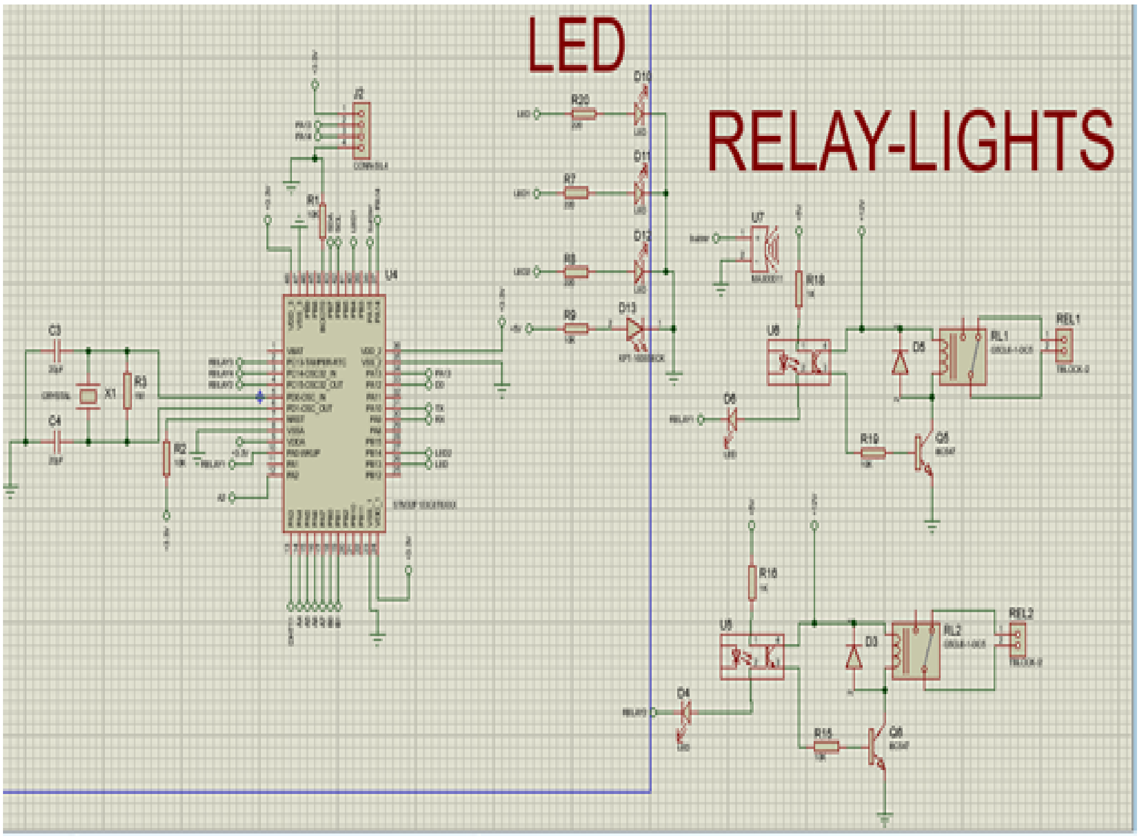

Figure 3.10: Wiring of the LEDs

STM32CubeIDE Settings

- Click Timer → Click TIM2 → Clock Source set to Internal Clock
- Channel2 set to PWM Generation CH2

- Configuration → Parameter Settings → Prescaler set to 127 Counter Period 625

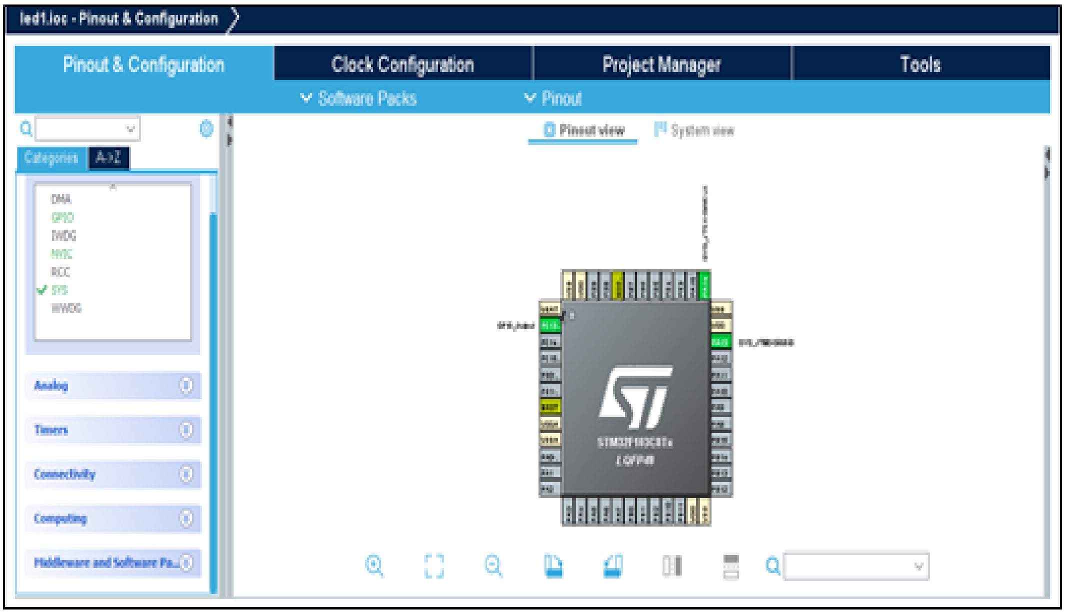

Figure 3.11: pin out and Configuration of LED

3.1.4 MQ-2 Gas Sensor

:

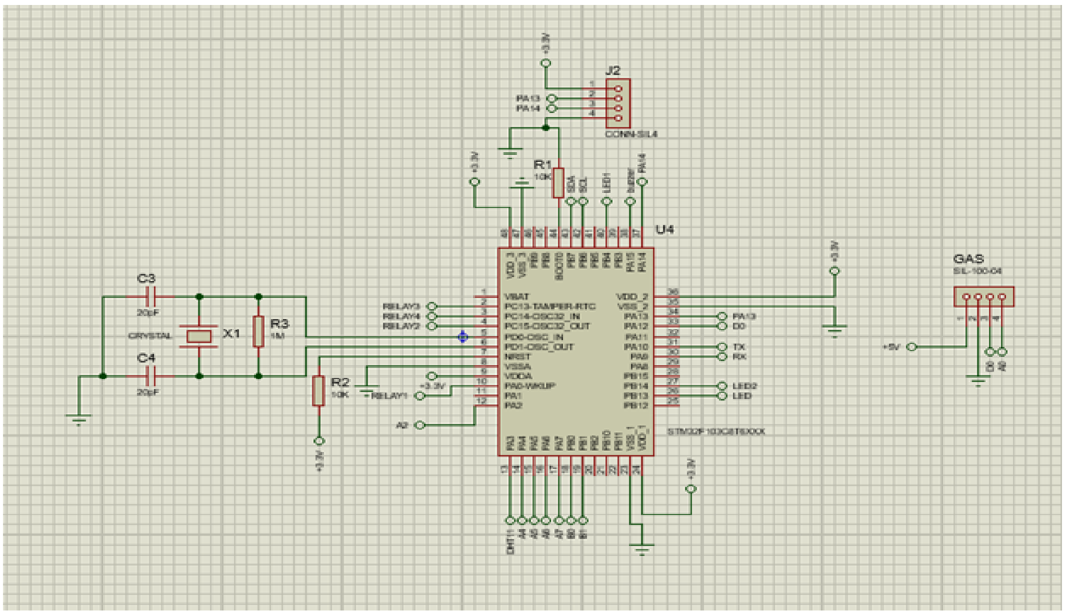

Figure 3.12: Wiring of MQ2

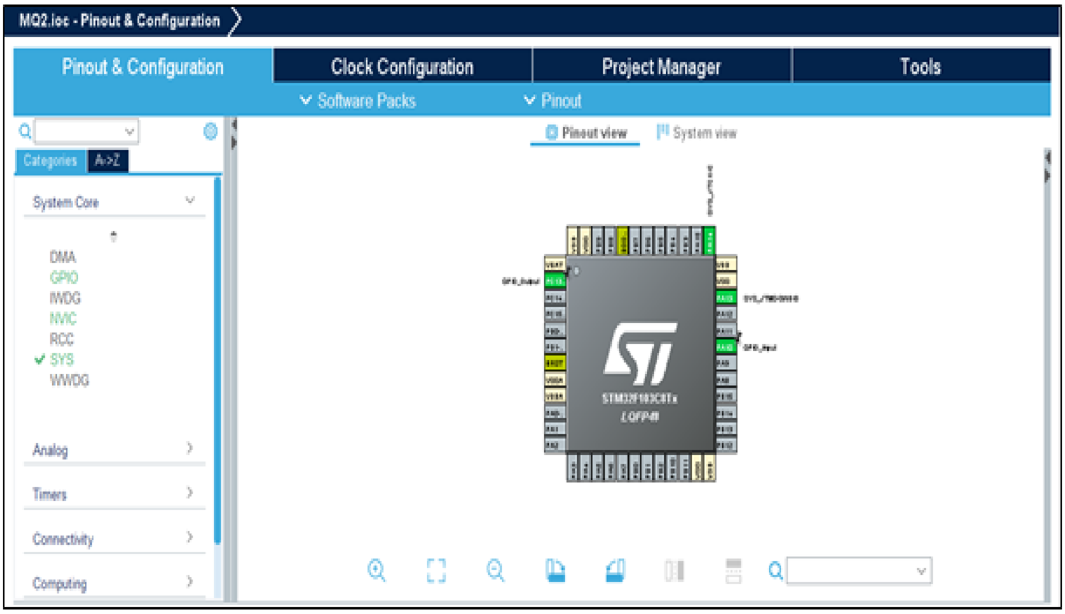

Figure 3.13: pin out and Configuration of MQ2

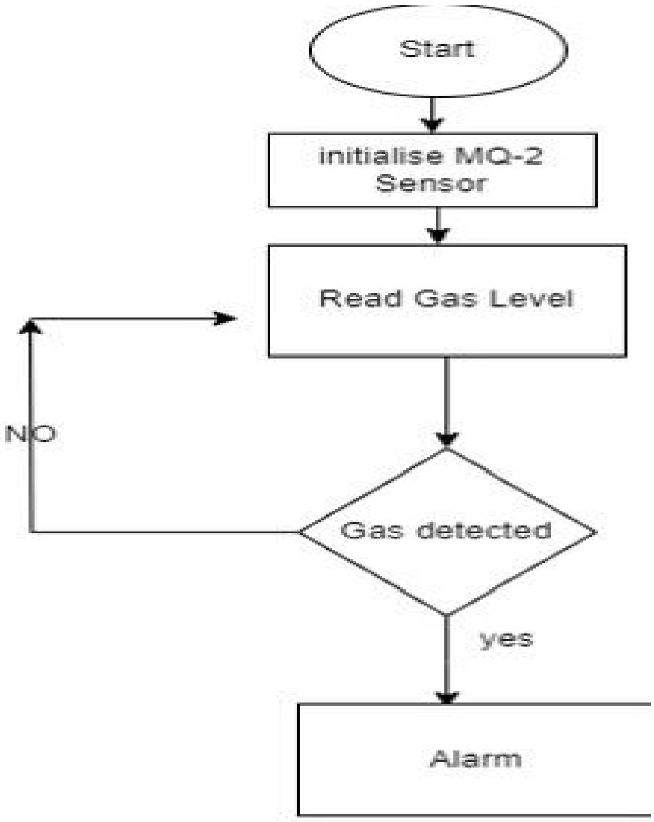

Figure 3.14: Process of the MQ-2

3.1.5 Alarm

The Android application enables user to activate the security mode; in this mode the user gets alerted in his phone whenever the car moves from its position. The latter is detected using a motion detector circuit as illustrated in the next figure. In addition, an internal alarm (involving a buzzer and a flashing lamp) gets triggered.

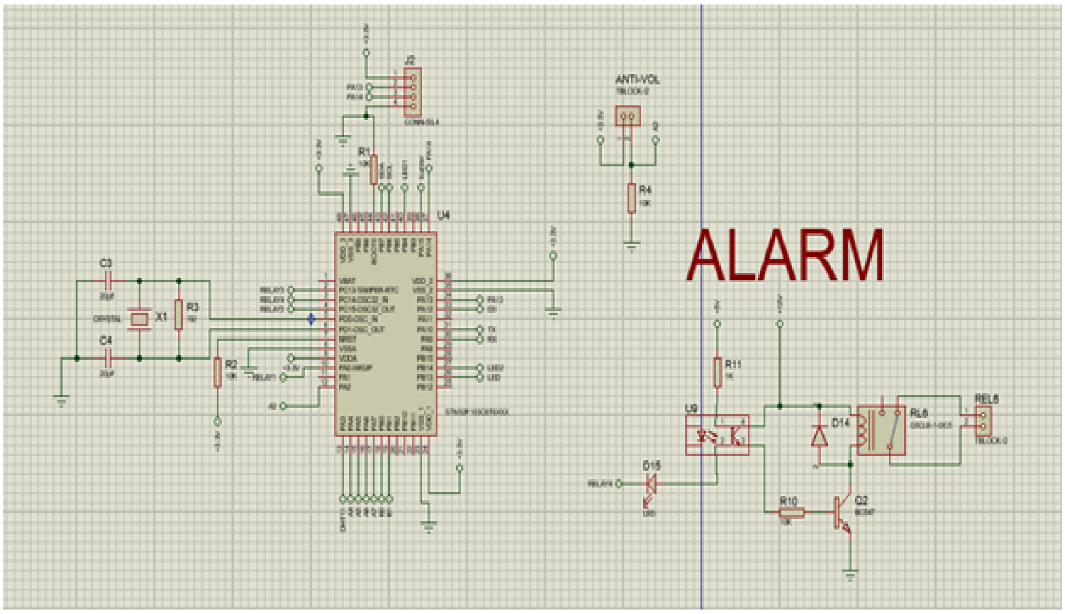

Figure 3.15: Anti-Flight Sensor and Alarm System Circuit

4 The firmware

The Firmware is the software that provides control, monitoring and data manipulation of the system. It is programmed using C/C++ language containing multiple routines shared between different tasks. The firmware of this project depends on the received data from the sensors or the user's Smartphone which generates an output that controls the house's features through the off-chip system.

4.1 The Main Program

At the runtime, the main program initializes the registers to be used in the body of the program and waits for the command sent by the user's phone or the sensors. Based on the received data, the execution of the program is then transferred to the code of the selected device. The next figure shows the work flow of the main program

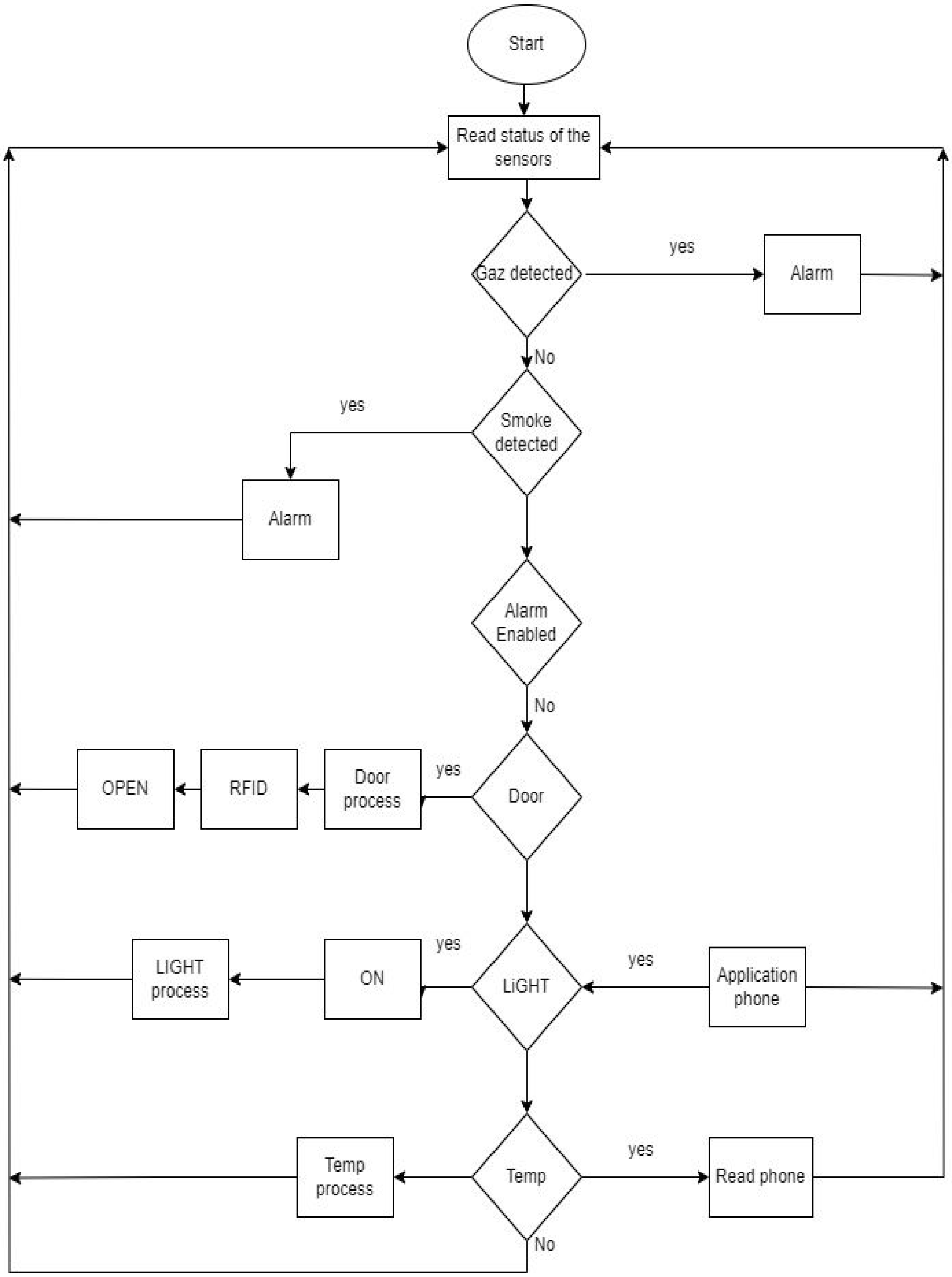

Figure 3.16: Workflow of the Main Program

5 Conclusion

This chapter has carefully described the hardware/software system's design and implementation, with an emphasis on the STM32CubeIDE-assisted integration of an Android application with a variety of sensors and modules. An review of the system's architecture opened the chapter, emphasizing the critical roles that software and hardware components play in attaining seamless functionality.

We looked at the Android application development process using MIT App Inventor and showed how it helps with accessible and user-friendly interface design. In-depth instructions were supplied for establishing crucial sensors, including the DHT11, RFID, and MQ-2, guaranteeing precise data gathering and dependable system functionality The chapter also covered the firmware's role in controlling system functions, including as data conversion procedures, gate routines, and the workflow of the main application. Wiring diagrams and configuration settings were used to demonstrate how various components were integrated, highlighting the significance of accurate initialization and calibration.

This chapter emphasizes the crucial interaction between software and hardware in embedded system architecture through this thorough analysis. The methods and insights offered show the possibilities for innovation in this quickly emerging subject and provide a basis for creating reliable, effective, and user-friendly smart home systems.

Chapter 4

Design and Implementation

1 Introduction

This chapter concludes the dissertation, we delve into the implementation phase of our smart home automation project, focusing on the practical aspects of integrating hardware and software components in which we present all the steps we have taken to create a reliable and automated system .The primary objective is to enable users to remotely control their home automation system in a seamless and efficient manner.

2 What is a prototype?

A prototype is a simple visualization of the product to test the concept.
There are thousands of new ideas that originate every day to solve a particular problem. Executing an idea can be a long and expensive process. Alongside this, no one can, with absolute certainty, say that their vision will work or that users will ultimately want and use their products. Sometimes even great ideas fail because they are overly complicated to use or understand.
Agile development pivots around faster time to market, learning, integration, and adaptability. A prototype is built on the principle of failing fast, freely experimenting, and learning while trying to reach the desired result. Finding failures propels learning and optimizes solutions to reach your goal.

3 Importance of the Prototype

Any project's development process must include the creation of a prototype, but it is especially important for PCB-based systems used in smart home environments. The prototype is crucial for the following main reasons:

Prototypes are essential in many fields because they provide concrete examples of ideas or notions. They are effective instruments for conveying and visualizing design intent, enabling users and stakeholders to offer early input and effectively hone requirements. Prototypes drastically lower development risks and related expenses by verifying viability and spotting possible problems early on.

Additionally, by allowing for numerous design iterations, they promote iterative improvement and guarantee that the finished product successfully satisfies customer needs. This iterative process promotes informed decision-making and consensus among stakeholders while improving the user experience and coordinating development activities with project goals. Prototypes are ultimately essential to the development process because they make it possible to create successful, functional, and user-centric products.

4 Smart Home Control PCB Design 3D

A PCB (Printed Circuit Board) for a smart home 3D is a specialized circuit board designed to facilitate the integration of electronic components within a smart home system, utilizing three-dimensional (3D) design principles

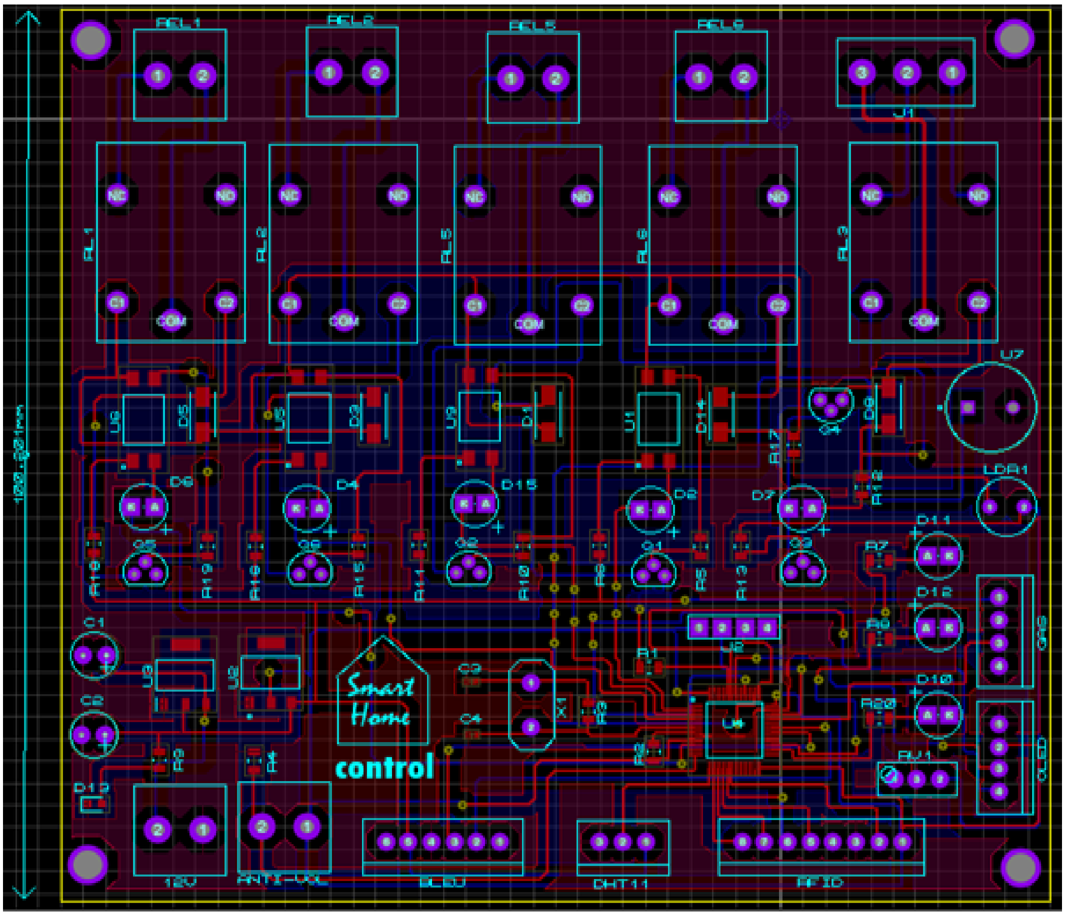

Figure 4.1: Smart Home Contrôle PCB design

5 Practical results

5.1 Secure access to the home function

a secure house access system employing RFID technology to regulate and authorize entry, enhancing convenience and security. Components include an RFID reader, tags for authorized users, an electronic door lock, visual status indicators, and a microcontroller for data processing. The system verifies RFID tag identifiers against a list of approved tags, triggering a red LED and maintaining locked status for unauthorized attempts, and a green LED to unlock for authorized access. It enables keyless entry, enhances security, and optimizes access control, supporting integration with other smart home systems for enhanced automation. Critical to its operation are considerations of data security, power supply reliability, and backup access strategies.

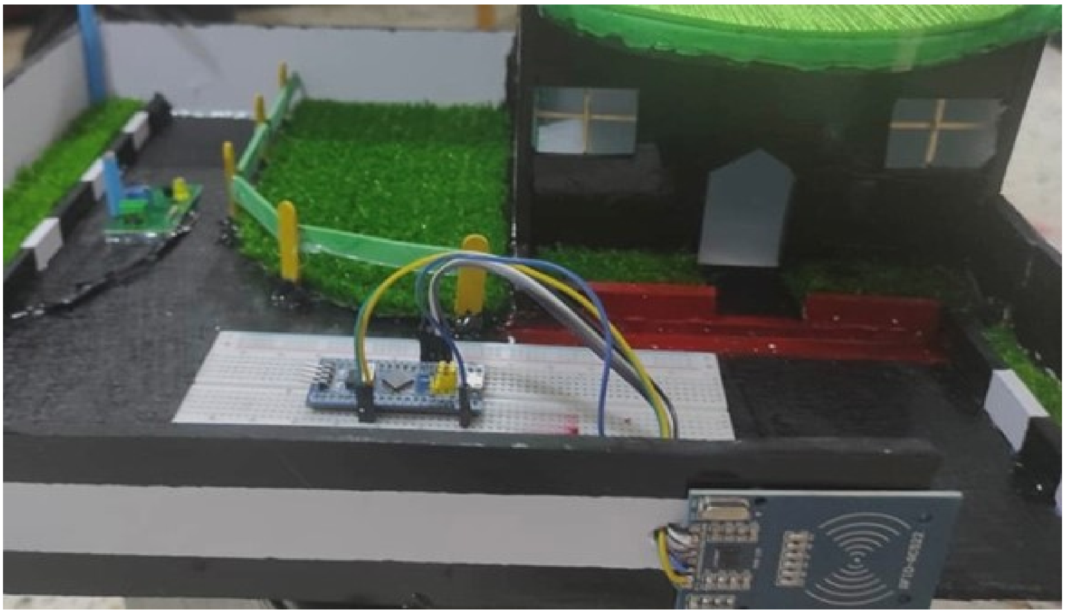

Figure 4.2: Smart Home Modele with RFID and Microcontroller integration

5.2 Temperature / Humidity acquisition function

The temperature and humidity acquisition function enables the acquisition of temperature and humidity values and humidity values within the home using the DHT11 sensor, the acquired values will be displayed on the ssd1306 oled display and also HTM page.

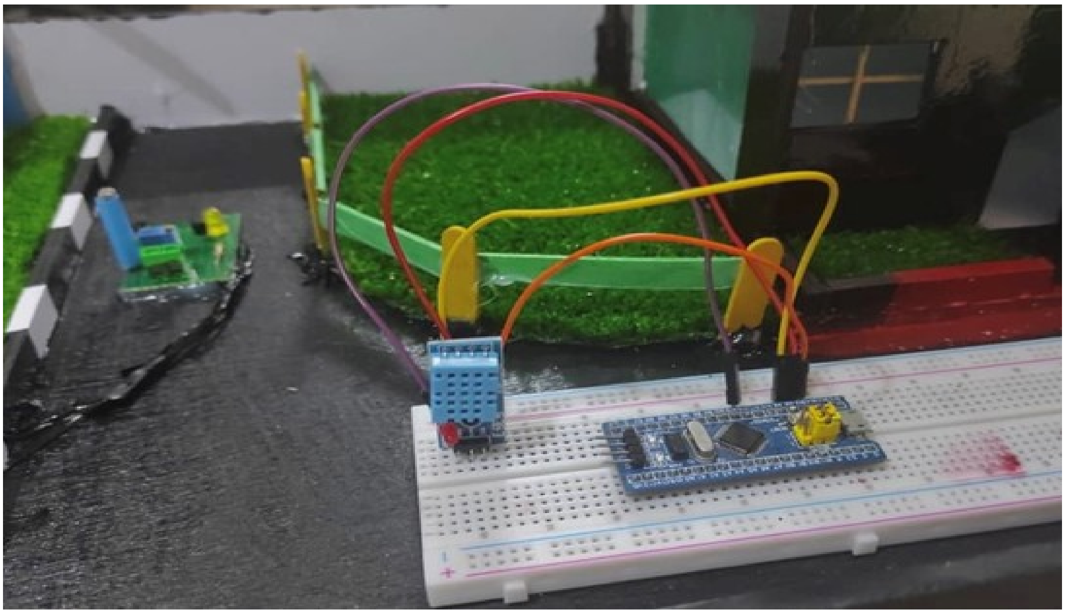

Figure 4.3: Smart Home Prototype Temperature Sensor and STM32

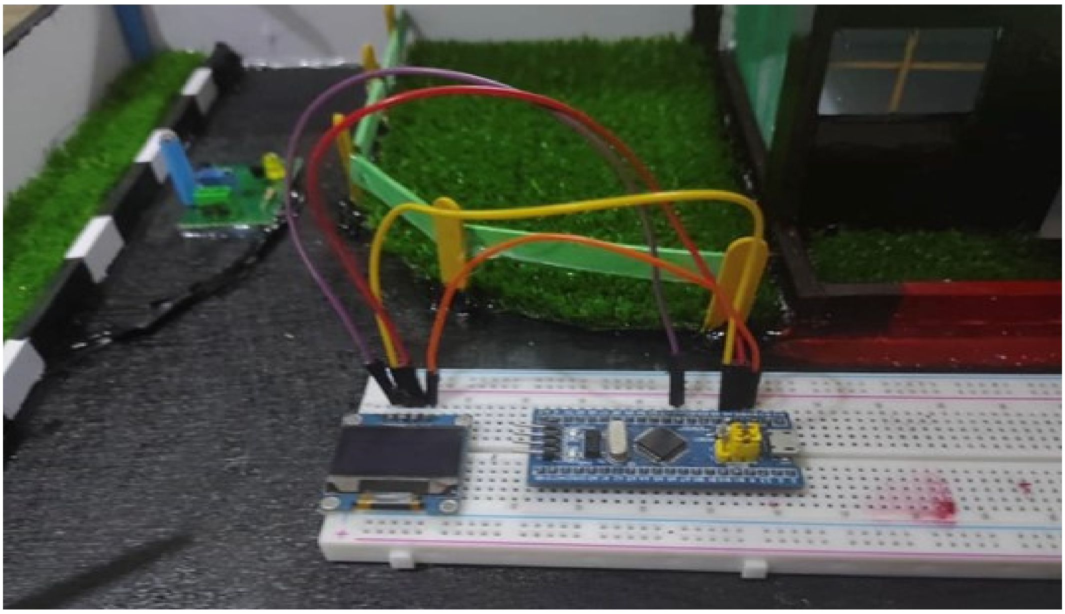

Figure 4.4: Oledssd1306 with Stm32

5.3 Gas leak detection function

This function detects gas leaks in the kitchen using the MQ-2 sensor to initiate an alarm to inform the user in case of danger.

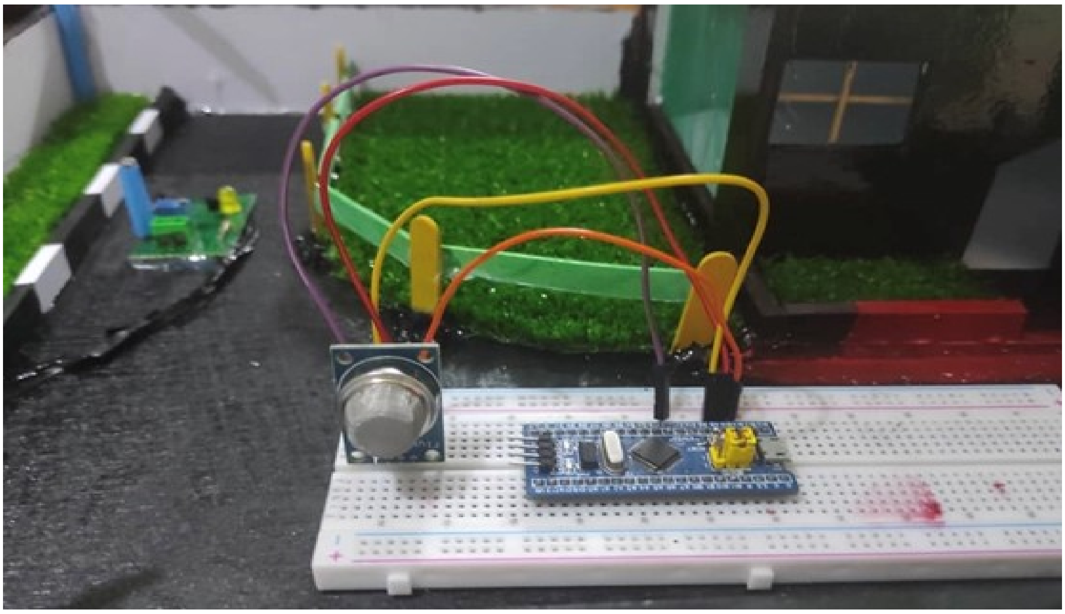

Figure 4.5: Smart Home prototype gas sensor with Stm32

5.4 Final Result

The realization of this prototype involved close coordination between different disciplines, architectural design, and electronic engineering, was required to realize this prototype. Intelligent sensors, remote control systems, and user-friendly interfaces are examples of technological choices that have been considered and supported based on their suitability for the project's goals and their potential benefits.

5.4.1 Commentary

In this project, we have successfully implemented a comprehensive smart home control system utilizing an STM32 microcontroller. The system integrates various sensors and modules, including an LED control, DHT11 temperature sensor, LDR (Light Dependent Resistor), RFID access control, anti-theft alarm, and MQ-2 gas sensor, all controlled via an Android application.

Key Functionalities:

1. LED Control: Users can control the LED lights through the Android application, providing convenience and enhancing home automation.

2. Temperature Monitoring: The DHT11 sensor accurately measures temperature and humidity. When the temperature exceeds 30 degrees Celsius, the system automatically activates the fan, maintaining a comfortable environment.

3. Light Intensity Control: The LDR sensor monitors ambient light levels, allowing for automatic adjustment of lighting conditions to save energy and enhance comfort.

4. RFID Access Control: The RFID module provides secure access control to the home, enhancing security by allowing only authorized individuals to enter.

5. Anti-theft Alarm: The system includes an anti-theft feature that activates an alarm if the door is opened without authorization, thereby deterring intrusions.

6. Gas Detection: The MQ-2 sensor detects harmful gases and triggers an alarm, ensuring the safety of the inhabitants by alerting them to potential gas leaks.

5.4.2 The smart home

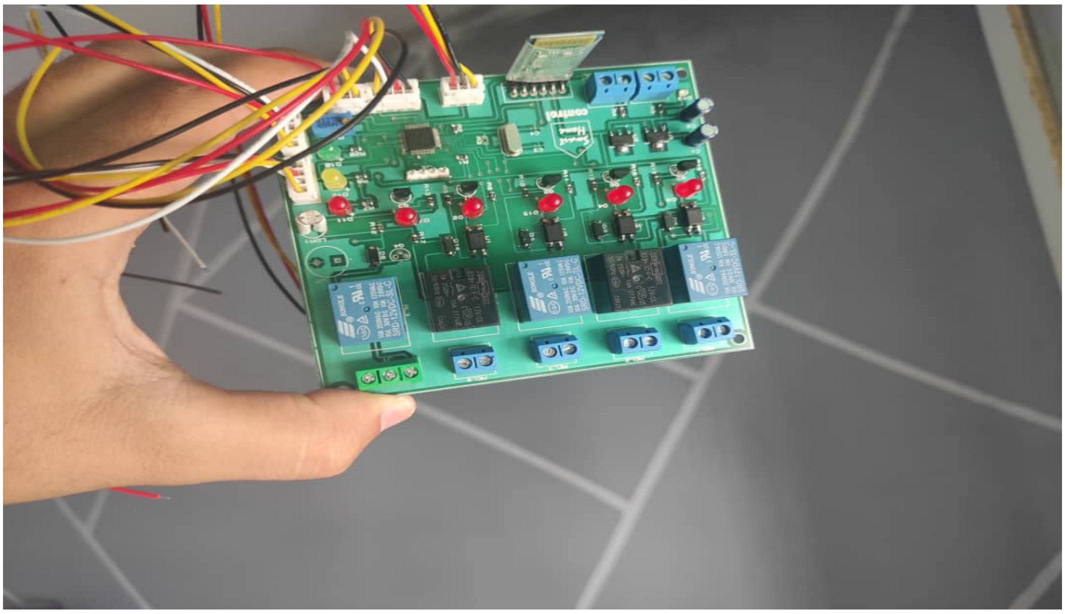

Figure 4.6: Smart Home

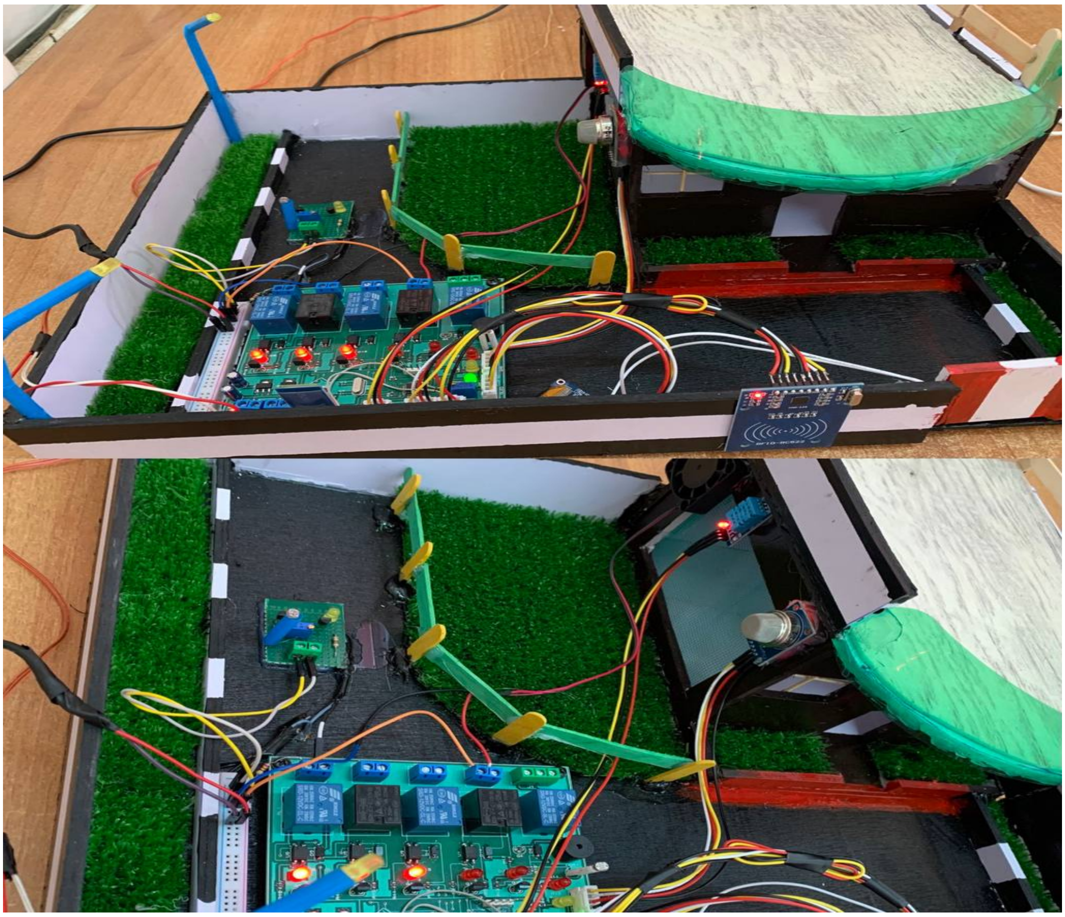

Figure 4.7: Smart Home prototype

5.4.3 The application

Figure 4.8: Securing the connection

Figure 4.9: Selecting the room

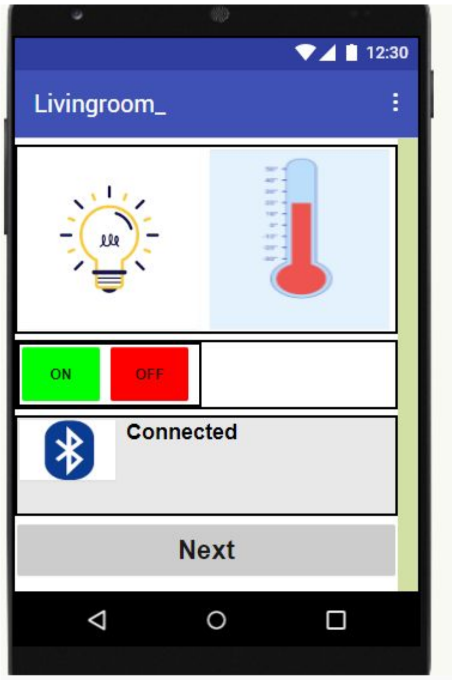

Figure 4.10: The Living Room

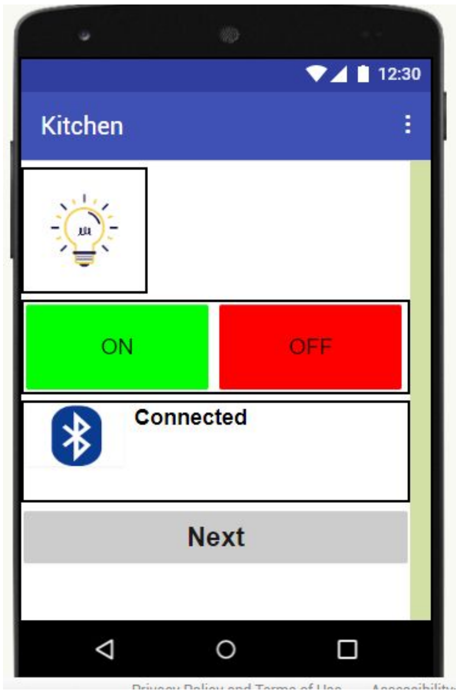

Figure 4.11: The Kitchen

6 Conclusion

This chapter emphasizes the value of interdisciplinary cooperation and ongoing innovation in addition to the technical and methodological aspects of designing and constructing the prototype. The smart home that is being showcased here is a big step towards the housing of the future since it satisfies modern living requirements while combining energy efficiency, comfort, and safety.

General Conclusion

The development of the smart home system detailed in this project demonstrates the significant potential of integrating modern sensor technologies with robust microcontrollers and user-friendly mobile applications. By leveraging sensors such as the DHT11 for temperature and humidity monitoring, the MQ-2 for gas detection, RFID for access control, and the LDR for lighting management, we have created a comprehensive home automation solution that enhances safety, security, and convenience.

Throughout this project, the STM32 microcontroller has proven to be a reliable and efficient platform for processing sensor data and executing control commands. Its versatility and processing power ensure that the system can respond promptly to environmental changes and user inputs, thereby maintaining optimal home conditions and ensuring the safety of the occupants.

The mobile application, developed using MIT App Inventor, provides a user-friendly interface that allows homeowners to monitor and control various aspects of their home remotely. This integration of hardware and software ensures that users can receive real-time alerts and take immediate action, further enhancing the functionality and appeal of the smart home system.

Key accomplishments of this project include:

- Enhanced Home Security: The use of RFID for access control and the integration of gas detection sensors significantly improve home security and safety.

- Efficient Home Management: Automated control of lighting and environmental conditions ensures energy efficiency and convenience.

- User-Friendly Interface: The mobile application provides an intuitive platform for monitoring and controlling the smart home system, making advanced home automation accessible to all users.

This project highlights the practical applications of IoT (Internet of Things) in everyday life, demonstrating how technology can be harnessed to create more secure, efficient, and comfortable living environments. The successful implementation of this smart home system serves as a foundation for further advancements in home automation, with potential for expansion and integration with other smart devices and systems.

Future work could involve the incorporation of additional sensors and devices, exploring advanced data analytics for predictive maintenance and energy management, and enhancing the mobile application's functionality. Moreover, integrating AI (Artificial Intelligence) could enable more intelligent and adaptive home automation, offering personalized experiences and further improving the system's efficiency.

In conclusion, this project illustrates the transformative impact of smart home technologies and sets the stage for future innovations in this rapidly evolving field. By continuing to explore and develop these technologies, we can look forward to a future where our homes are not only more connected but also smarter and more responsive to our needs.

Bibliography

[1] M. Mohammadi M. Aledhari M. Ayyash A. Al-Fuqaha, M. Guizani. Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials*, 17(14):2347–2376, 2015.

[2] Ahmed A. Kazmi S. Ahmed E. Gani A. Imran Yaqoob, Hashem. Internet of things forensics: Recent advances, taxonomy, requirements, and open challenges. *Future Generation Computer Systems*, 78(1):658–676, 2017.

[3] X. Jin D. Zhu. Smart home energy management systems based on iot technologies. *Energies*, 13(7):1590, 2020.

[4] G. P. Hancke M. R. Chowdhury, M. H. Uddin. A smart home energy management system using iot and big data analytics approach. *IEEE Transactions on Consumer Electronics*, 63(14):426–434, 2017.

[5] Morabito G Atzori L, Iera A. The internet of things: A survey. *Computer Networks*, 54(15):2787–2805, 2010.

[6] N.D. Stm32 32-bit arm cortex mcus. `https://www.st.com/en/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus.html`.

[7] M Johnson. Advancements in sensor technology for smart buildings. *Journal of Building Automation*, 25(2):45–63, 2019.

[8] Team STMicroelectronics. Stm32 microcontroller overview. `https://www.st.com/en/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus/documentation.html`.

[9] Team Arm Developer. Cortex-m3. `https://developer.arm.com/ip-products/processors/cortex-m/cortex-m3`.

[10] N.V STMicroelectronics. *Medium-density performance line Arm®-based 32-bit MCU with 64 or 128 KB Flash, USB, CAN, 7 timers, 2 ADCs, 9 com. interfaces.* 2023.

[11] Team Mouser Electronics. Stmicroelectronics stm32f103c8t6. `https://eu.mouser.com/ProductDetail/STMicroelectronics/STM32F103C8T6?qs=bhCVus9SdFtq6kqxsU5%2FDA%3D%3D`.

[12] Team Digikey. Stmicroelectronics stm32f103c8t6. `https://www.digikey.com/en/products/detail/stmicroelectronics/stm32f103c8t6/1646338`.

[13] Team AdaFruit. Dht11 basic temperature-humidity sensor + extras. https://www.adafruit.com/product/386.

[14] Zhengzhou Winsen Electronic. *MQ-4 Semiconductor Sensor for Flammable Gas*. Zhengzhou Winsen Electronics Technology Co., LTD, 2014.

[15] Berisso Kevin. Rfid basics. https://www.rfidjournal.com/rfid-basics.

[16] Ryan V. Light-dependent resistor (ldr). https://sensorwiki.org/sensors/light-dependent_resistor.

[17] H. Newton. *Newton's telecom dictionar*. Flatiron Publishing, 2007.

[18] Guangzhou HC Information Technology. *Products datasheets*. 2007.

[19] MIT. Mit app inventor. https://appinventor.mit.edu/.

IoTInternet of Things RFIDRadio-Frequency Identification PWMPulse Width Modulation HVACHeating, Ventilation, and Air Conditioning HSEHigh-Speed External I2CInter-Integrated Circuit SPISerial Peripheral Interface GPIOGeneral Purpose Input/Output RHRelative Humidity