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Design and Implementation of a Wireless-Controlled Home Lighting System

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Abstract: *In modern society, as the country's economy continues to develop, intelligent devices have become the foundation for human survival and social activities, becoming indispensable in people's daily production and life. Among these, intelligent devices for daily home life hold a significant position. The application of smart home technology profoundly impacts our family life and lifestyle. The ultimate goal of a smart home is to provide people with a comfortable, convenient, and safe living environment, while also promoting a more environmentally friendly way of life.A key component of intelligent living is the wireless control of home lighting systems. This thesis explores the combination of microcontrollers, WiFi communication modules, and other hardware, such as mobile phones, to develop a program using C and Java languages. The basic principles of an intelligent home lighting system are explained, demonstrating how a mobile phone can remotely control the home lighting system. Finally, the current state and future prospects of smart homes are considered, based on personal experiences.*

Keywords: *Wireless control, Microcontroller, Smart Home*

1. Introduction

1.1 Background of the study

In recent years, China's rapid development in science and technology has significantly advanced the country's communication technology. Closely related to this progress is the daily life of families, where smart devices are becoming increasingly common. People are gradually adapting to the convenience of these smart devices. For example, this year, Xiaomi released a new generation of Xiao Ai, which allows users to remotely control various household appliances with just a word. The convenience is self-evident.China is a populous country. According to data released by the National Bureau of Statistics on January 18, 2013, China's total population reached 1.35 billion by the end of 2012. With a large family base and the continual pursuit of life efficiency, the development of smart home living has accelerated. Unlike ordinary homes, smart homes use IoT technology to connect various common household devices such as entertainment systems (TVs, speakers), lighting systems, door locks, curtains, air conditioning, and more. These devices can be controlled remotely and through timing controls, providing a comprehensive information interaction platform that saves significant manpower and resources.The concept of a smart home was first proposed in the United States as early as the last century, but there was no specific physical manifestation. The first complete smart home was introduced in 1984 by United Technologies Corporation in the USA, marking the beginning of the global development of smart homes.

1.2 Domestic and international research status

The smart home industry in our country is still relatively new but is developing rapidly and vigorously. With people's enthusiasm for pursuing a convenient lifestyle, the market prospects for smart homes are enormous. Consequently, various domestic home appliance manufacturers are heavily investing in the research and development of smart home technologies. Not only international giants like Apple, but also numerous local brands such as Xiaomi, Gree, and OPPO, are rising swiftly. Their businesses are not limited to the domestic market; they are also expanding overseas, aiming to become leaders in the global smart home industry.

After decades of development, numerous smart home solutions have emerged worldwide. Countries around the globe are eagerly joining the smart home battlefield. China entered the smart home industry relatively late, which means the United States and several European countries currently hold leading

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positions in the international smart home market.

Based on domestic and international research, the study and development of smart home control systems have become focal points for both academia and industry. In China, scholars have conducted extensive and in-depth research in this field. Weizhuang Liu and colleagues[1] explored the application of Wi-Fi technology in smart home control, emphasizing the importance of wireless network technology for achieving remote and automated control. Zhihao Tao and colleagues[2], as well as Xin Xie and colleagues[3], analyzed the architecture and implementation methods of smart home control systems from different perspectives, proposing the concept of multi-mode control to further enrich the interaction modes of smart homes. Xuewei Lin and colleagues[4], along with Yanli Wang[5] and colleagues, focused on the design and implementation of smart home control systems based on the STM32 microcontroller, demonstrating how to build an efficient smart home central controller through detailed hardware selection and software programming guidance. Yixuan Li and colleagues[6] concentrated on implementing smart home lighting control systems using the ESP8266 chip, providing key points of hardware design and specific examples of software programming.Shuting Wang and colleagues[7] conducted a comprehensive design analysis of smart home control systems, covering the entire process from requirements analysis to system design, and discussing potential issues and solutions in practical applications. Xuxia Huang and colleagues[8] proposed a smart home control system design scheme based on WeChat Mini Programs, utilizing a popular social platform to achieve convenient control of home devices and enhance user experience. Chao Wu and colleagues[9] studied the construction of an IoT-based smart home control system using the STM32, focusing particularly on how IoT technology can be integrated with smart home systems to improve system intelligence and connectivity. Hongbin He[10] provided a detailed analysis of smart home control system design based on the Android platform, emphasizing the importance of mobile devices in smart homes and offering users the possibility of controlling their home environment anytime, anywhere. Hancai Hu[11] offered foundational knowledge on microcontroller principles and interface technology, laying a solid foundation for understanding the core technologies of smart home systems.

Additionally, the research by Cai[12] and Huang and Pai[13], although not directly targeted at the smart home field, provided valuable information on energy management and power system integration. This knowledge is significant for the energy efficiency and grid compatibility of smart home systems.

1.3 Research significance

China has the world's largest population and is the world's second-largest economy. With economic development, the smart home industry is undoubtedly a future development trend for our country. However, there are currently no clear regulations regarding smart home standards in China. Thus, the core aspect of smart homes—wireless control—remains crucial.

Smart homes can make residents' lives more convenient and efficient while reducing unnecessary energy consumption in daily activities. In a world that prioritizes environmental protection, this aligns perfectly with the green lifestyle that humanity seeks.

Therefore, this paper is of great significance in the design and implementation of a home lighting system based on wireless control.

1.4 Main structure of the paper

This thesis consists of five parts:

Introduction: This part provides a strategic context for the project, detailing the history, background, and recent trends in its development.

Feasibility and Design: This section analyzes the feasibility of the project, outlining the general design and framework, and identifying the realistic conditions required for its realization.

Hardware Description: This part introduces and describes all the hardware involved in the project, detailing the circuit structure and the reasons for selecting each component.

Software Design: This section focuses on the writing and design of the software, explaining the main program for each module of the system.

Summary and Future Outlook: The final part summarizes the overall design and completion of the project, and provides insights into the future prospects of this experiment.

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The thesis concludes with a list of references.

2. System Programming

2.1 System solution

The microcontroller is the core of the entire system, responsible for controlling the lighting of the small lights. The system connects to a cell phone through a WiFi module. Once connected, the cell phone displays the relevant information. The microcontroller system continuously monitors the WiFi data in real time, parses this data, and then uses Pulse Width Modulation (PWM) to control the brightness of the LEDs.

The system block diagram is shown in Figure 1 below.

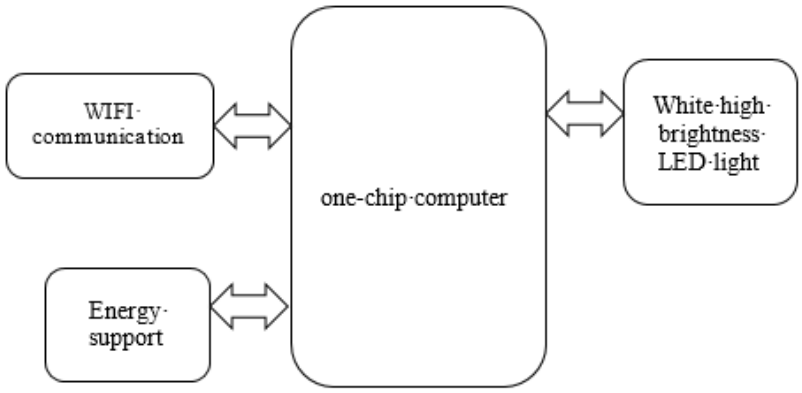

Figure 1: System block diagram

2.2 System function

Wireless control via WiFi allows cell phones to remotely control home lighting.

2.3 System feasibility analysis

(1) Technical feasibility

The STM32 microcontroller is the core of this control system. The system is developed using Java, resulting in an APK installation package that can be installed on a mobile phone. Through a WiFi connection, the phone communicates with the physical device and its various modules. Since WiFi only needs to meet the distance requirements to connect to the host computer, and the environmental conditions within this distance are not stringent, this project is technically feasible.

(2) Affordability

This system only utilizes the basic principles of smart home technology. Its purpose is to demonstrate the fundamental processes of a smart home. The system involves fewer components, uses inexpensive materials, incurs low costs, and has simple connections between modules. Therefore, from an economic perspective, there are no significant issues.

(3) Application feasibility

With China's large population base and rapid economic development, the smart home is destined to become a major trend in the future. The design and implementation of a home lighting system based on wireless control will contribute to the future development of smart homes in our country, helping more people understand the basic principles of smart home technology.

3. Hardware design

The system is roughly composed of five hardware components. The STM32F103C8T6

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microcontroller serves as the main hardware. White high-brightness LEDs simulate the lights of the smart home. The WiFi module is responsible for communication, sending and receiving control commands. The ESP8266 handles energy conversion, and there is also a power supply. Each of these hardware components is soldered using tin and wires. In a later stage, a computer program is used to burn assembly language into the hardware to ensure the stable operation of the entire system.

3.1 One-chip computer

STMicroelectronics produces the renowned STM32 series processors, which are 32-bit microcontrollers based on the ARM Cortex-M architecture and feature emulation and tracing technology. The primary reason for choosing the STM32 series processors is their ability to support a wide range of complex functions. Additionally, they offer various circuit interfaces that facilitate the development of diverse experimental systems, peripheral expansion circuits, and design projects. After completing an MCU course, the control chip will be easier to learn. STM32 processors are widely used in medical devices and provide substantial value for learning and experimental research.

The main advantages of STM32:

(1) Has the most advanced processor core.

(2) Powerful processor performance.

(3) Smaller power consumption with guaranteed performance.

(4) Convenient and portable appearance.

(5) With a large user base, it is the most suitable platform choice.

(6) Convenient development, suitable for novices to get started quickly.

The interface circuit diagram of the STM32F103C8T6 microcontroller core board is shown in Figure 2 below.

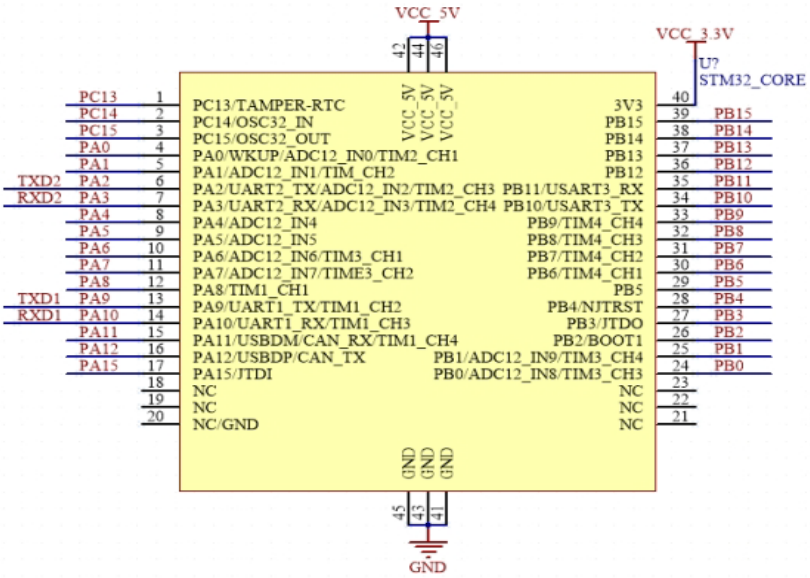

Figure 2: Microcontroller Schematic

The physical diagram of the STM32 microcontroller is shown in Figure 3.

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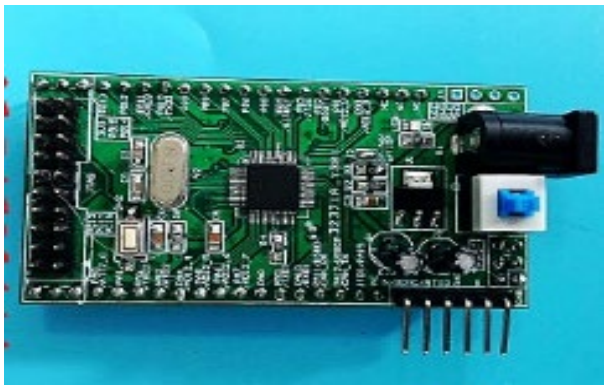

Figure 3: STM32 microcontroller

3.2 WIFI communication module

Today, there are many kinds of WiFi modules available on the market. The most common type is found in cell phones and computers, which often come with built-in WiFi modules. Some computers can also connect via USB interfaces. The advantage of these modules is their portability and independent operation, but they require a strong CPU core processor for support.

The second type of WiFi module is used in homes and public places, typically in wireless routers. These modules have the advantage of wide coverage but also have significant disadvantages, such as higher power consumption.

The third type of WiFi module is the embedded microcontroller module. This module is widely used in various welding designs, making it suitable for projects like ours. After detailed investigation and comparison, we selected the ESP8266 WiFi module for this project. The ESP8266 is a UART-WiFi transmission module known for its ultra-low power consumption and compact package size, giving it a significant advantage and high competitiveness in the industry. It is designed for mobile devices and IoT applications, and is compatible with both 3.3V and 5V power supplies. Additionally, it supports connection to cell phones, facilitating real-time control of the light status through an app.

In summary, the ESP8266 WiFi module is the right choice for this project.

The ESP8266 schematic is shown in Figure 4.

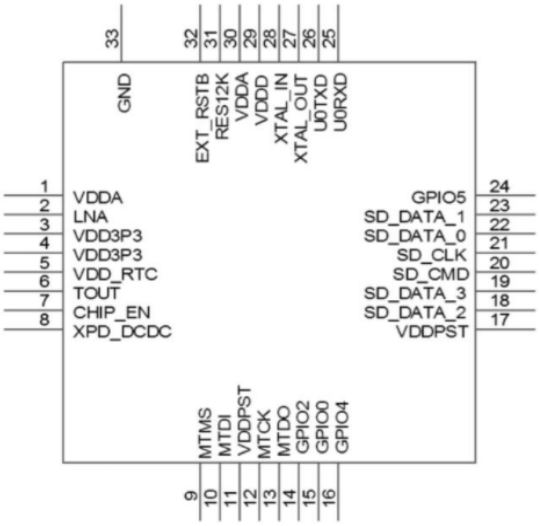

Figure 4: ESP8266 Schematic

One of the biggest advantages of the ESP8266 is its three antenna interface options. This allows the project to directly choose between an onboard PCB antenna and an IPEX interface antenna without needing additional matching circuitry, which greatly reduces work intensity. Since this project does not involve an external antenna, this thesis will not elaborate on the third interface of the ESP8266. The ESP8266 circuit diagram is shown in Figure 5.

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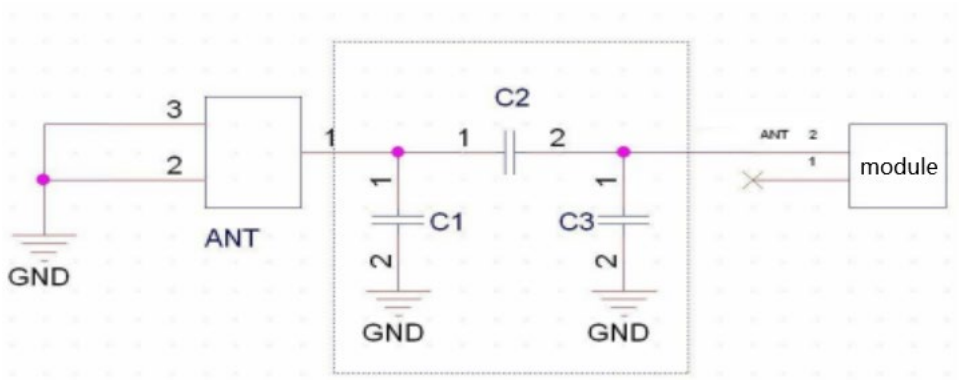

Figure 5: ESP8266 Circuit Diagram

The physical diagram of ESP8266 is shown in Figure 6

Figure 6: ESP8266 physical diagram

3.3 Power Conversion Module

Once the overall design has been determined, the next step is to address the energy supply for the entire system. Just like a car, even if all the hardware is complete, it cannot run without fuel. As previously detailed, the ESP8266 WiFi module is compatible with both 3.3V and 5V power supplies. To ensure the communication module operates normally, the project must convert the voltage from a standard 220V power outlet or a rechargeable power bank to 3.3V or 5V. The AMS1117 voltage regulator is ideal for this purpose. The AMS1117-3.3 is a positive low-dropout voltage regulator, widely used in power chargers, laptop power management, and microcontroller power supplies.

The circuit diagram of the AMS1117 is shown in Figure 7

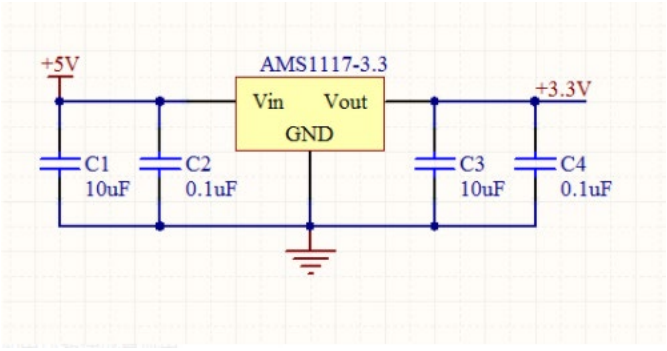

Figure 7: Circuit diagram of AMS1117

The physical diagram of AMS1117 is shown in Figure 8.

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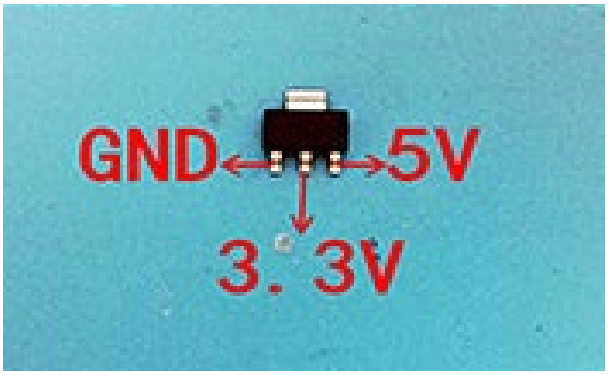

Figure 8: AMS1117 Physical drawing

3.4 Lighting circuit design

Nowadays, LED white lights are commonly used in home lighting due to their high brightness and low power consumption. The small lights used in this design are nearly a hundred times brighter than ordinary small lights, while consuming much less power. Considering these advantages, a single high-brightness LED light was chosen for this project. Figure 9 below shows the circuit schematic diagram of the high-brightness LED light.

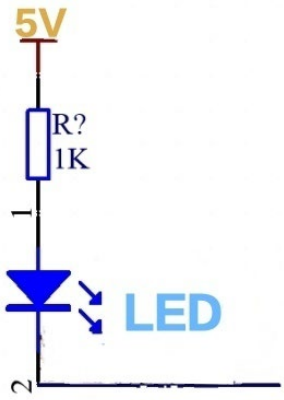

Figure 9: High-brightness LED light circuit schematic diagram

4. Software design

To enable the functions of the above modules, the preparation of the software program is essential. If the hardware is like a car, then the program is its central nervous system. Without software control, the hardware cannot operate normally. Therefore, software development is a top priority in the overall design. Through continuous optimization and improvement of the program, the expected results of this project can be achieved.

The mobile phone app software needs to achieve the following functions:

1) It can connect with the hardware normally.

2) It has a switch to control the light of the small lamp.

3) It has a button to control the brightness of the small lamp.

4.1 Programming language

In microcontroller designs, two languages are commonly used: assembly language and C. Assembly language is a low-level language, making it less readable and not portable. In contrast, C is a high-level language that can also directly control hardware. This makes it very beginner-friendly and suitable for easy modification and maintenance.

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Given these considerations, C was chosen as the language for this project. The programs are written according to the pin functions of each module. The main program controls the entire system, ensuring that all functions are implemented.

4.2 Main program

The main program acts as a bridge between the modules. The STM32F103C8T6 microcontroller has been selected for this project to control the modules. Other components include the ESP8266 WiFi module, which generates the WiFi signal that the mobile phone connects to. The mobile phone app contains buttons to control the different states of the small light. Through various operations, the ESP8266 WiFi module receives command information sent by the mobile phone. This information is then immediately relayed to the microcontroller, which makes the corresponding changes, thereby altering the state of the small light. The main program flowchart is shown in Figure 10 below.

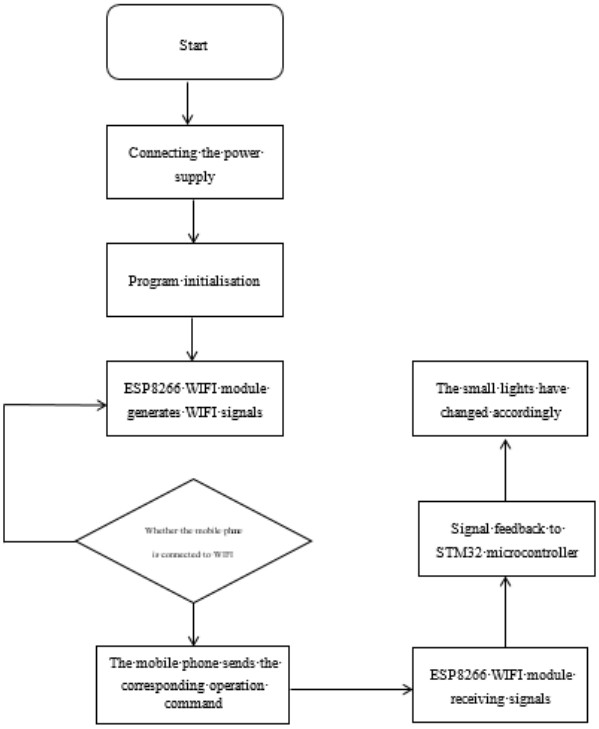

Figure 10: Main Program Flow Chart

5. Conclusion

Nowadays, people are increasingly pursuing a higher quality of life, which is essentially about enhancing their sense of well-being. More and more intelligent devices are being introduced, and smart establishments such as inns and home experience museums are emerging rapidly. The convenience of smart homes is highly favored by consumers, indicating a very promising future development trend for the smart home industry.

This design is based on the fundamental principles of smart home technology, simulating the basic processes of a smart home according to the living environment. The STM32F103C8T6 microcontroller serves as the most important hardware in this project, acting as the "brain" of the entire intelligent system. The ESP8266 WiFi module is used as a communication module, addressing the limitations of conventional smart home systems with fixed switches. By developing a program and using a mobile phone app for control, users can achieve their desired functions with just a few taps on their phone, embodying the essence of "smart" technology.

Back in 2016, Premier Li Keqiang proposed the development of smart homes at the National People's Congress. By 2021, smart homes have evolved from simple security devices to a wide range of products such as smart speakers, smart hangers, and smart toilets. I've experienced Xiaomi's smart inn, where lighting, security, and monitoring are controlled through speakers, greatly improving convenience and

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comfort. With the improvement of living standards and the arrival of the 5G era, smart homes will become a significant trend in future development. More and more intelligent concepts will gradually be realized.

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