Design of Smart Street Lamp Control System Based on NB-IOT Technology

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Abstract: This project aims to develop an intelligent street lamp system that integrates intelligent lighting, environmental monitoring, remote communication and emergency alarm functions. Its core design closely focuses on three major themes: energy conservation and emission reduction, intelligent management and public security. After testing, the system successfully realizes precise remote control of street lamps, real-time fault diagnosis and automatic alarm. The intelligent street lamp also has a one-click alarm function. This function, by integrating the SMS sending module, can quickly send alarm messages to the preset police number in emergency situations, greatly shortening the response time and providing a strong guarantee for urban public security. It is also equipped with a human-computer interaction function. The voice recognition technology can quickly respond and process users' instructions, and quickly provide the required services or information. To further enhance environmental comfort, the street lamp is built with an atomizing sheet device, which can automatically start according to preset conditions or environmental humidity and release fine water mist into the surrounding air to increase air humidity in a timely manner and improve the urban climate. The results show that the intelligent street lamp control system based on NB-IOT technology has good application prospects and promotion value in the field of smart city lighting, providing strong support for the intelligent development of urban lighting.

Keywords: Energy-Saving and Efficient; Intelligent and Safe; Real-Time Alarm; Human-Computer Interaction; Speech Recognition Technology; Remote Communication

1. Introduction

According to statistics, the global smart street lamp industry market size was approximately 7.51 billion US dollars in 2020, and it is expected to exceed 14 billion US dollars by 2024. Both domestically and internationally, the development is basically synchronized, with multiple breakthroughs. All regions are innovating, but there are not many large-scale application cases of smart street lamps, and it is still in the stage of innovative exploration, mainly focusing on energy conservation and environmental protection and smart city services [1]. The smart street lamp system has an advantage in the market due to its technological innovation and diversified functions. With the integration of Internet of Things, big data, cloud computing and other technologies, the smart street lamp system not only has the traditional lighting function, but also can realize remote monitoring, automatic brightness adjustment, fault warning, one-key alarm and other functions, greatly improving the lighting efficiency and reducing energy consumption. Through intelligent control and management, smart street lamps can significantly reduce energy consumption and carbon emissions, making contributions to urban environmental protection. As a new low-power wide-area network technology, NB-IOT has significant advantages such as wide coverage, large connection capacity, low power consumption and moderate transmission rate, which can effectively solve the pain points of traditional communication technologies in the application of street lamp control systems.A smart street lamp system based on NB-IOT technology has been designed to address the above problems. This system provides a more reliable, efficient and intelligent

solution for public safety services in smart cities, improving the overall level of urban public safety services.

2. Design Scheme

The research technology route of intelligent street lamp system is a systematic and comprehensive process. It adopts multi-system architecture design, which usually includes data acquisition system, data transmission system, data processing system and data display system. Data acquisition system: 2.4G human radar sensor, MQ-135 air quality sensor, DHT11 humidity sensor, photoresistor sensor, STM32G431RBT6 controller and other devices are deployed to monitor the status of street lights and environmental illumination in real time. Data transmission system: The data of the sensing layer is transmitted to the platform layer through the Lora communication module. Data processing system: storage, analysis and processing of street lamp data through Lora communication module to achieve intelligent regulation and data upload. Data display system: provides user interface and application programs to achieve street lamp monitoring, operation and maintenance management, data analysis and other functions.

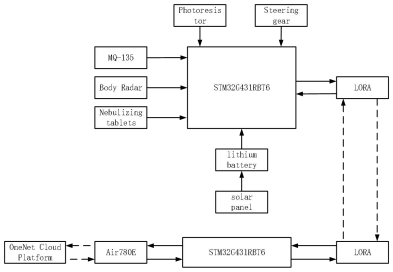

Figure 1. Overall Design Scheme

3. Hardware Design

3.1 Overall Introduction of Hardware Design

3.1.1 Core control unit

STM32G431RBT6 microcontroller: As the core control unit of the intelligent street lamp system, the STM32G431RBT6 microcontroller integrates a high-performance ARM Cortex-M4 kernel, with a wealth of peripheral interfaces and powerful computing power. It is responsible for processing input signals from human radar sensors, MQ135 air quality sensors, etc., implementing the control strategy for the brightness of the road light, and managing the low power mode of the system. At the same time, it is also responsible for communication with LORA wireless communication module and Air780E 4G module to achieve remote data transmission and monitoring.

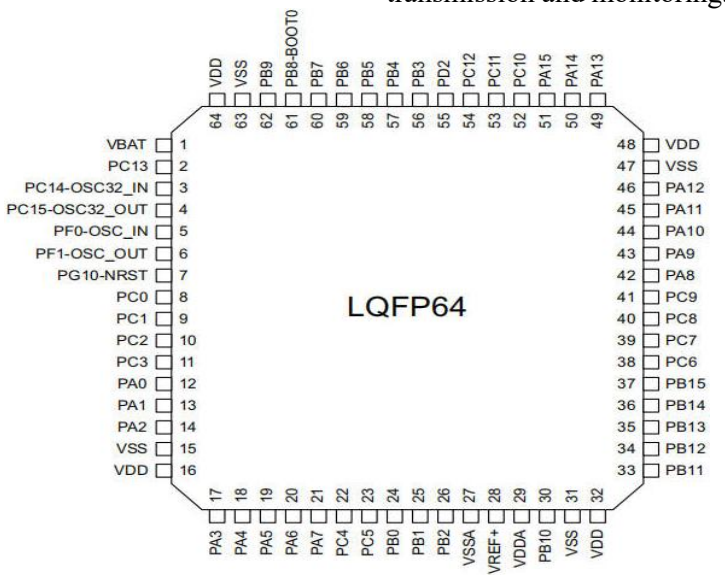

Figure 2. Pin Diagram of the Main Control Chip

3.1.2 sensor module

(1) Human radar sensor: The use of advanced radar detection technology, can accurately sense the movement of pedestrians or vehicles. When a person or vehicle is detected approaching, a signal is sent to the STM32G431RBT6, triggering the brightness adjustment of the street lamp. When no one passes, the system automatically enters low-power mode to save energy.

(2)MQ-135 Air Quality sensor: Used for real-time monitoring of air quality, such as carbon dioxide, nitrogen oxides, etc. The MQ-135 sensor sends the detected data to the

STM32G431RBT6, based on which the system assesses the air quality.

(3)Temperature and humidity sensor DHT11: can accurately measure the temperature and humidity of the surrounding environment, and transmit the data to the STM32G431RBT6 microcontroller. Through the analysis of intelligent algorithms, the intelligent street lamp system can automatically adjust its working mode according to the temperature and humidity of the environment and trigger the ultrasonic atomization module for moderate adjustment. And in the weather conditions of high temperature and high humidity, the smart street lamp system will adjust the lighting strategy according to the change in humidity to optimize the road visibility and improve driving safety. In addition, temperature and humidity data can also be integrated with the city's meteorological monitoring system to provide more comprehensive environmental information support for city management.

(4)Photosensor: combined with the steering engine, to achieve the intelligent light tracking function of the solar panel. The light sensor can sense the intensity and direction of the surrounding light, convert the collected light signal into an electrical signal and transmit it to the control system. According to the data provided by the photosensor, the control system calculates the best light Angle through precise algorithm, and drives the high-precision steering gear to adjust the corresponding Angle. As an actuator, the high-precision and fast response characteristics of the steering gear enable the solar panel to quickly and accurately track the position of the sun, ensuring that the solar panel is always facing the sun and maximizes the absorption of solar energy. This intelligent light-following design not only improves the utilization efficiency of solar energy, but also prolongs the autonomous power supply time of the intelligent street lamp system, further enhancing the self-sufficiency of the system [4].

3.1.3Communication Module

(1)LORA wireless communication module: It is responsible for long-distance, low-power wireless communication between the data acquisition system and the data processing system [5]. The LORA module can transmit the status information and environmental data of the street light system to the data processing system in real time for staff to monitor and analyze.

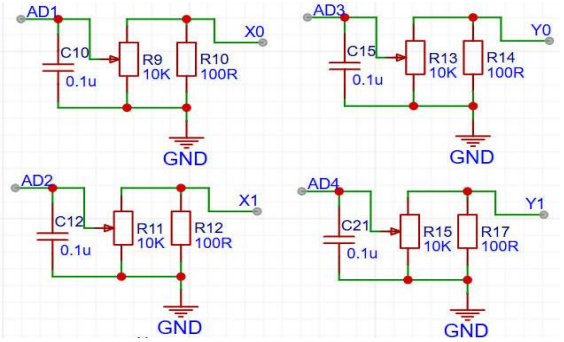

Figure 3. ADC Sampling Circuit

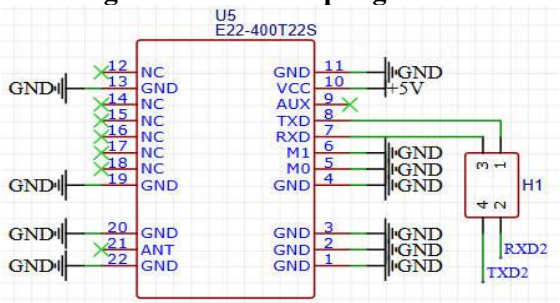

Figure 4. LORA Communication Module

(2)Air780E 4G module: As the core of remote communication, Air780E 4G module supports high-speed and stable mobile network communication. It is responsible for uploading the data of the smart street lamp system to the OneNet cloud platform through the 4G network to achieve cloud storage, processing and visual display of data. At the same time, it can also receive instructions or data from the cloud platform to achieve remote control of the smart street lamp system.

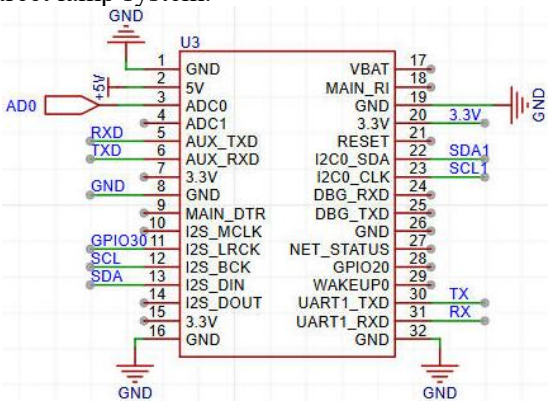

Figure 5. 4G Communication Module

3.1.4.human-computer interaction

The 3.2-inch capacitive touch screen can quickly respond to and process the user's instructions to quickly provide the required service or information. The intelligent street lamp system can intelligently adjust the lighting brightness, play emergency broadcasting, provide road condition information, etc., according to the needs of users, and achieve more intelligent

services.

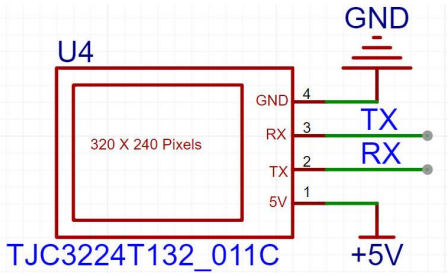

Figure 6. Serial Screen

3.1.5.power module

In order to enhance the self-sufficiency of the system, the smart street light system is also equipped with a solar charging module. The module uses efficient solar panels and automatic light tracking system [6] to convert solar energy into electricity, and stores the electricity into large-capacity batteries through the booster module to provide stable and reliable power support for the street lamp system. In the case of sufficient sunlight, the solar energy charging modules ensure continued operation of intelligent street lamp system. When the outside world need an extra charge for intelligent street lamp system, intelligent street lamp system is equipped with a set of booster module and the voltage regulator chip. This module can boost the external input electrical energy, and output stable voltage and current through the voltage regulator chip, providing safe and reliable power guarantee for various components of the smart street lamp system. This design not only improves the flexibility and scalability of the system, but also ensures stable operation under different power conditions.

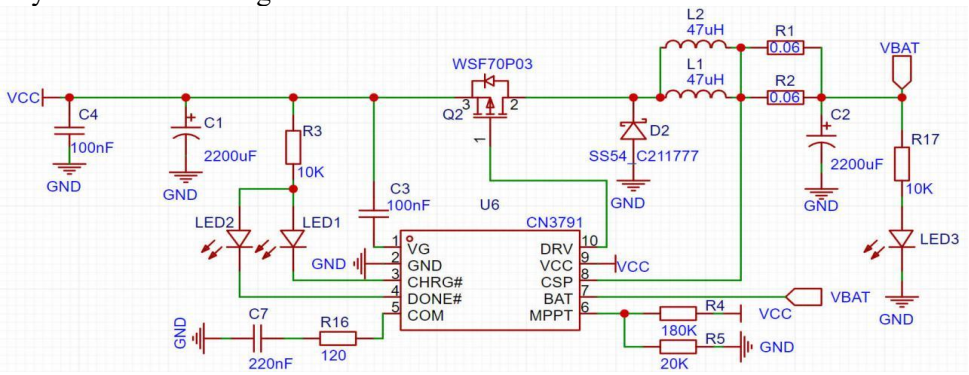

Figure 7. Solar Charging Circuits

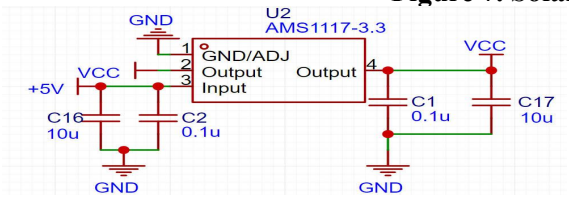

Figure 8. 3.3V Power Supply Circuit

3.1.6 One-click alarm function

The smart street lamp system integrates a one-button alarm function, and when encountering an emergency, the user can trigger the alarm signal by pressing the alarm button set on the street lamp pole. The alarm signal will be sent to the police or designated rescue agencies in the form of SMS via the Air780E 4G module to achieve rapid response and rescue.

3.1.7 Data processing and display

Data monitoring and visualization interface: The data processing system realizes real-time monitoring of intelligent street lamp system status, environmental humidity, air quality and other information by receiving data transmitted by LORA wireless communication module and Air780E 4G module [7]. At the same time, the data display system is also equipped with a visual interface to visually display various data indicators in the form of charts, maps, etc., which is convenient for staff to carry out data analysis and decision-making.

3.1.8 Printers and Other Hardware

Integrated chassis, crossarm, light pole, etc. : these hardware constitute the physical support structure of the smart street lamp system. The integrated chassis is used to install core components such as STM32G431RBT6 microcontrollers, batteries, sensors, and communication modules. The crossarm and light pole are responsible for fixing accessories such as LED lamps and cameras (if equipped) in the designated position to ensure the normal operation of the street light system.

3.2 Introduction to Mechanical Design

3.2.1 illumination module

LED as the lighting source of the smart street lamp system, its brightness can be intelligently adjusted according to the signal of the human radar sensor to achieve on-demand lighting. At

the same time, combined with the light sensor and the steering gear, to achieve the solar panel light chasing effect, with high efficiency, energy saving, environmental protection and other advantages.

3.2.2 Supporting structure and accessories

(1) Integrated chassis: used to install core components such as STM32G431RBT6 microcontrollers, sensors, and communication modules to protect them from external environment.

(2) the arm and the light pole: as a physical support structure of street lamps, the LED lamps and lanterns, all kinds of sensor attachment fixed at the specified position, to ensure the stability and security of intelligent street lamp system.

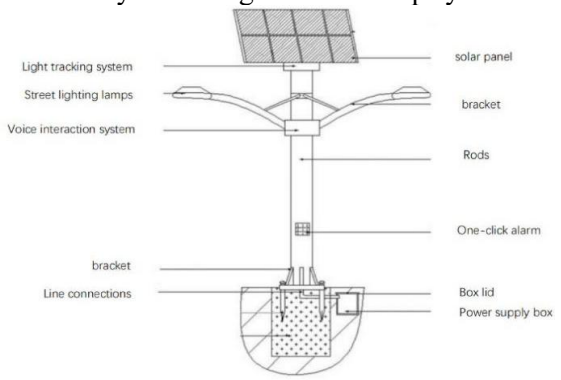

Figure 9. Diagram of the Finished Model

4. Software Design

Smart street lamp system software adopts multi-system architecture design [10], mainly including data acquisition system, data transmission system, data processing system and data display system, and communication and data interaction between the systems through standardized interfaces to ensure the flexibility, scalability and stability of the system. The STM32CubeMX is used for initial configuration of hardware ports to ensure that all components can be correctly connected and initialized. Then, Keil5 is used for programming to realize complex functional logic and data processing, and the data is uploaded to the OneNet cloud platform through the 4G module.

5. Conclusion

Participating in the research and development and production of the smart street lamp project is a challenging and rewarding experience. During the project, we deeply realized the importance of technological innovation in promoting the development of the industry and the key role of teamwork in the success of the project. At the same time, we also realize that there is still a long way to go on the road of smart city construction, and we need to continue to learn and explore new technologies and new methods to cope with future challenges and opportunities. In the future work, we will continue to uphold the spirit of innovation, collaboration and excellence to contribute more wisdom and strength to the construction of smart cities.

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