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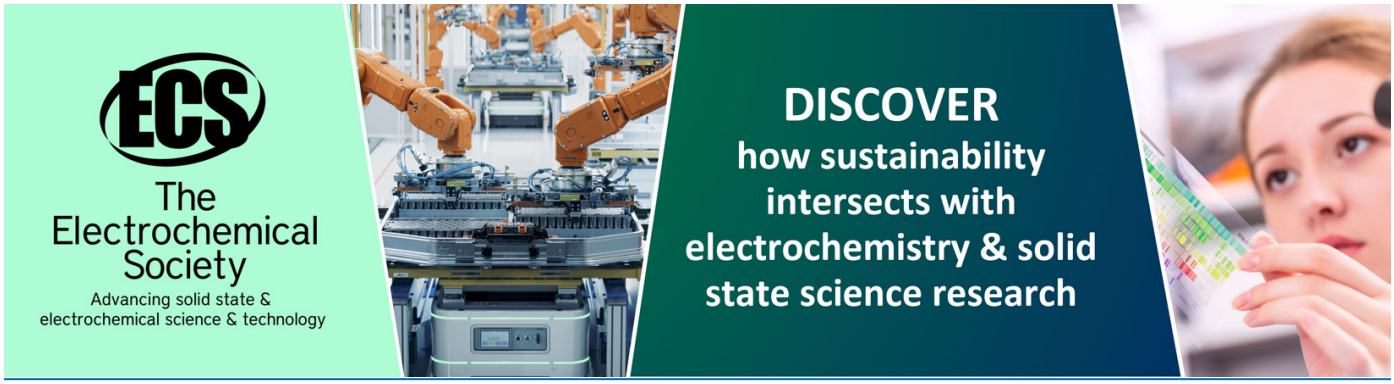

Design of intelligent temperature and humidity monitoring system based on STM32

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Abstract: In the closed warehouse environment, this paper designed an intelligent temperature and humidity monitoring system based on the modular design method to solve the problem that the product is easy to damage. Based on the interaction between the STM32 Main control chip and the upper computer, the warehouse temperature, humidity dual control, and other functions can be realized. Experimental results show that the design can timely control the temperature and humidity in the warehouse. Moreover, the system has the function of data broadcasting. Consequently, product quality can be guaranteed to a great extent.

1. Introduction

Nowadays, with the continuous improvement of people's requirements for the quality of various commodities, many businesses have begun to focus on storing products in warehouses. To store the products in the warehouse well, it is necessary to create favorable conditions for them. If such factors as high temperature or high humidity are unfavorable to the storage of products, it is necessary to find ways to adjust such adverse conditions. Therefore, an intelligent temperature and humidity monitoring system must be established to accurately grasp product quality dynamics, improve product quality, and reduce costs [1]. At the same time, we are currently in a harsh environment where outbreaks occur, so we must implement epidemic prevention and control into our daily work.

As people attach importance to product quality and the epidemic continues, it will be more challenging to control the quality of warehousing products and prevent the epidemic at work, increasing the burden on staff. Therefore, this intelligent temperature and humidity monitoring system is designed to reduce the pressure on staff and enable them to work safely and conveniently.

This project is of great practical significance. The current limiting measures of the warehouse gate can enhance the safety of the staff to a certain extent. In addition, the dual control function of the voice recognition module in the warehouse and the upper computer in the console outside the warehouse can effectively help staff to monitor the temperature and humidity in the warehouse in real-time and control the temperature in time, to reduce the risk of product damage.

This project can collect the temperature and humidity in real-time and display and broadcast the data to make the data transparent. Moreover, staff can control the fans, lights, and voice broadcast module through the voice recognition module connected to the STM32 Main control chip in the warehouse or the upper computer in the console outside the warehouse. They not only timely control the temperature and humidity and prevent damage to the product but also ensure that the staff can

generally work at night. In addition, a pair of infrared photoelectric modules are installed near the warehouse door to count the number of personnel in the warehouse in real-time, which plays a role in limiting current flow and implementing epidemic prevention and control.

2. The general design scheme of the system

The system collects the temperature and humidity in the warehouse from the STM32 Main control chip and transmits the measured data to the display screen to display the measured real-time data [2]. The LD3320 voice recognition module is connected to STM32 in the warehouse, and the upper computer is in the console. They can control the fans, LED lights, and SYN6288 voice broadcast module. The upper computer and the STM32 Main control chip communicate remotely through the LORA modules to achieve dual control inside and outside the warehouse, as shown in Figure 1.

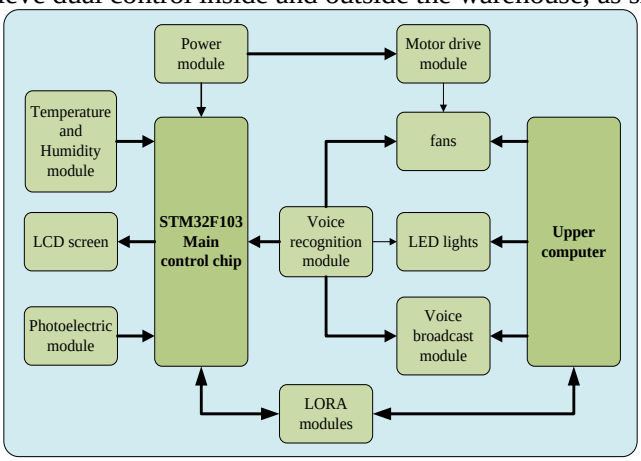

Figure 1. Overall System Structure.

3. Hardware design of the system

3.1. Overall hardware design scheme

The system uses the STM32F103C8T6 chip as the main control chip, collects the temperature and humidity in the warehouse from the main control chip, and displays the data on the OLED LCD screen. The LD3320 voice recognition module and the upper computer can control the fans, LED lights, and SYN6288 voice broadcast module at the same time. The upper computer and the STM32 control chip communicate remotely through the LORA modules to achieve dual control inside and outside the warehouse.

The system connects the DHT11 temperature and humidity module on the STM32 Main control chip to collect the temperature and humidity in the warehouse and then displays the collected data on the OLED LCD screen with a voice broadcast function. When the temperature and humidity in the warehouse reach a specific value, two methods can be used to control the fan switch. When the staff is in the warehouse, they can switch the fans through the LD3320 voice recognition module; If the staff is in the console, the two configured LORA communication modules can directly operate the upper computer to achieve the effect of remote control of the fans in the warehouse. The above two methods are to ensure the quality of the products. At the same time, there are LED lights in the warehouse, which can facilitate the staff's everyday work at night. The voice recognition module or upper computer also controls the control method. In addition, a pair of E18-D80NK photoelectric modules are installed near the warehouse door to judge the direction of personnel entering and leaving in combination with the data processing of the STM32 Main control chip and accurately count. Managers can master the flow of personnel in real-time [3]. Figure 2 and Figure 3 are the Hardware system diagram of the STM32 Main control chip and the upper computer hardware system diagram, respectively.

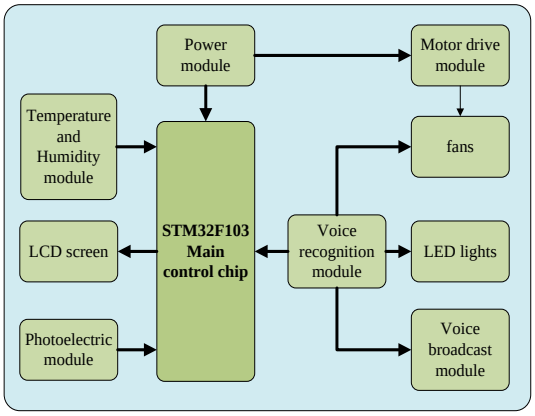

Figure 2. Hardware System of Main Control Chip.

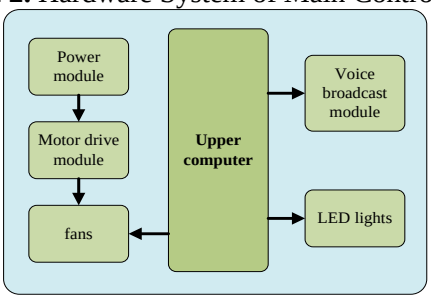

Figure 3. Upper Computer Hardware System.

3.1.1. Functions of each module. DHT11 temperature and humidity module: collect the temperature and humidity in the warehouse in real-time to ensure the timeliness of data; SYN6288 voice broadcast module: broadcast the temperature and humidity data in the warehouse to ensure that the staff can understand the situation in time; OLED LCD screen: display the current temperature and humidity data for the convenience of the staff; LD3320 voice recognition module: the staff in the warehouse can directly control the temperature and humidity of the current environment through voice; LORA communication modules: the upper computer and the STM32 Main control chip are respectively connected to the LORA modules for communication, which can facilitate the staff in the console to control the temperature and humidity in the warehouse through the upper computer; Fans: cooling and dehumidifying; LED lights: to enable the workers to work generally at night; E18-D80NK photoelectric module: it is placed at one side of the warehouse door, and the number of personnel in the warehouse is strictly counted.

3.2. STM32 Main control chip hardware circuit

3.2.1. Circuit Introduction of STM32 Main Control Chip. As shown in Figure 4, the STM32F103C8T6 chip is selected in the hardware design of the system, which is a 32-bit microcontroller chip. Its internal storage space has reached 64KB, and the working voltage is about 2V to 3.6V. It has the advantages of broader application scenarios, more complete functions, and robust scalability [4]. Its working voltage range of 2.0V to 3.6V is compatible with mainstream battery technologies such as lithium and nickel metal hydride batteries. Executing code from flash memory at 72 MHz consumes only 27 mA. There are four low-power consumption modes, which can reduce the current consumption to two microamps. Fast startup from low power consumption mode also saves power; The starting circuit wakes up the microcontroller from the stop mode using the 8MHz signal generated inside STM32, which lasts less than 6 microseconds. It is a microcontroller chip with high-cost performance. Based on this design scheme, the chip is finally used as the main control chip of this design.

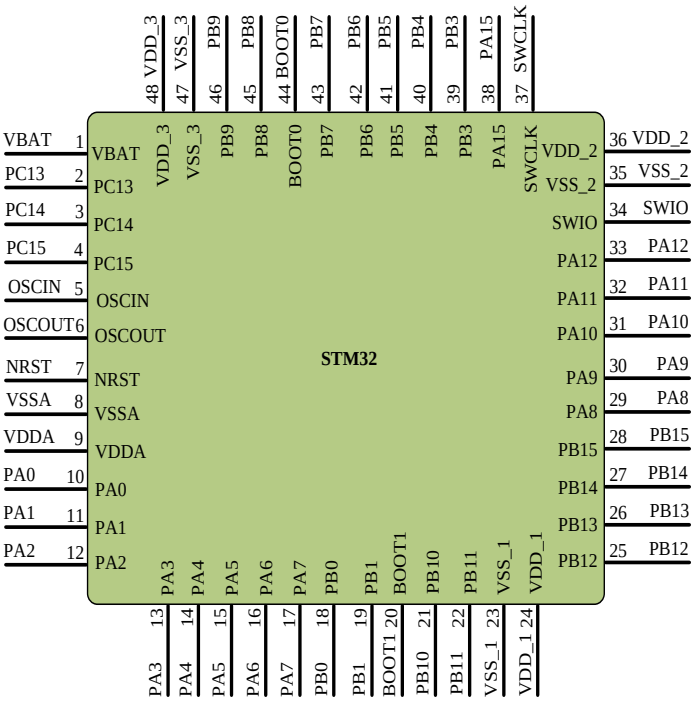

Figure 4. STM32F103C8T6 Circuit.

3.2.2. DHT11 temperature and humidity module. The circuit of the temperature and humidity module is shown in Figure 5. This module has a built-in capacitive humidity sensing element, an NTC temperature measuring element, and a high-performance 8-bit MCU, which has exceptionally high reliability and excellent long-term stability [5]. It mainly collects temperature and humidity data in the warehouse and uses a 5V power supply.

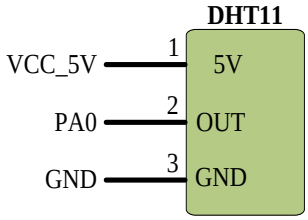

Figure 5. DHT11 Temperature and Humidity Module Circuit.

3.2.3. OLED LCD screen module. The circuit of the OLED LCD screen module is shown in Figure 6. The display has the advantages of low power consumption, small space occupation, and thin volume [6]. Its response speed is breakneck, the available luminous materials are vibrant [7], and the brightness it can achieve is much higher than LCD. The module is mainly responsible for displaying the temperature and humidity data collected in the warehouse and uses a 3.3V power supply.

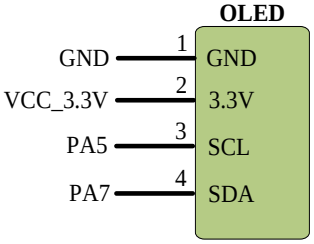

Figure 6. OLED LCD Module Circuit.

3.2.4. LD3320 voice recognition module. The circuit of the voice recognition module is shown in Figure 7. This module is mainly used to facilitate the staff in the warehouse to control the fans, lights, and voice broadcast module through voice and use a 3.3V power supply.

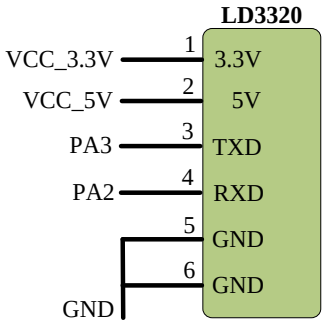

Figure 7. Circuit of LD3320 Voice Recognition Module.

3.2.5. SYN6288 voice broadcast module. The circuit of the voice broadcast module is shown in Figure 8. The module has strong anti-interference ability, a high cost-performance ratio, and easy expansion [8]. It is mainly responsible for voice broadcasts of temperature and humidity so that the staff in the warehouse can timely understand the current situation in the warehouse. SPK+ and SPK - are speaker interfaces and use a 5V power supply.

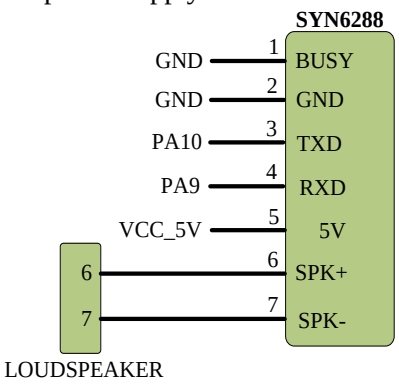

Figure 8. Circuit of SYN6288 Voice Broadcast Module.

3.2.6. LORA communication module. The circuit of the communication module between the STM32 Main control chip and the upper computer is shown in Figure 9. An essential component in the LORA communication device is the LORA communication module AS32-TTL-1W, and the transmission mode corresponding to LORA is a kind of wide transmission [9]. This module is mainly responsible for realizing the functions of remote control of fans, lights, and voice broadcast modules so that the staff in the console can timely control the environment in the warehouse. It has operational and configuration modes and uses a 5V power supply.

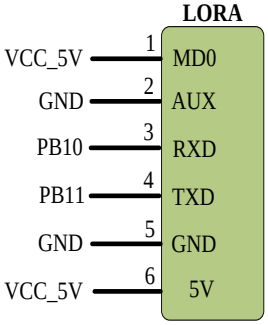

Figure 9. LORA Communication Module Circuit.

4. Software design of the system

4.1. Overview of system software design

The software design of this system is composed of Keil and eclipse development environment. The DHT11 temperature and humidity module are connected to the STM32 Main control chip to collect the temperature and humidity in the warehouse. Then the collected data is displayed on the OLED LCD screen with a voice broadcast function. When the temperature and humidity in the warehouse reach a specific value, two methods can be used to control the fan switch. When the staff is in the warehouse, they can switch the fans through the LD3320 voice recognition module; If the staff is in the console, the two configured LORA communication modules can directly operate the upper computer to achieve the effect of remote control of the fans in the warehouse. The above two methods are to ensure the quality of the products. At the same time, 5W power LED lights are connected in the warehouse, facilitating the staff's regular work at night. The voice recognition module or upper computer also controls the control method. In addition, a pair of E18-D80NK photoelectric modules are installed beside the warehouse door to count the number of personnel in the warehouse strictly.

4.2. Software design of STM32 Main control chip

The hardware part is coded through the Keil5 development environment and then burned to the STM32 Main control chip through the USB to TTL module.

The design of the voice recognition module is shown in Figure 10. The LD3320 voice recognition module is internally equipped with an STC11L56XE 51 chip. During voice recognition judgment, it is realized through the design mode of two-level passwords. The LD3320 performs processing and judgment. At the same time, it uses first-level and second-level passwords to improve recognition efficiency and accuracy and significantly reduce the error rate of voice recognition [10]. Finally, the 51 chip sends the corresponding secondary instructions to the designated serial port. The receiving end compiles the interrupt function of the designated serial port through Keil5 compiler software, judges the data received by the serial port, and executes the corresponding operation if it recognizes the secondary instructions sent by the 51 chip to realize the dual chip communication function between the 32 chip and the 51 chip.

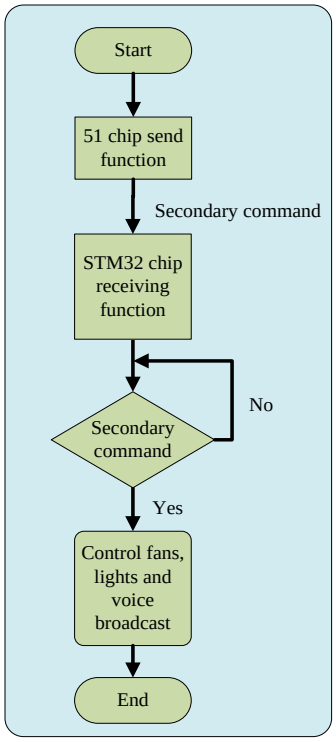

Figure 10. Flow Chart of 51 and 32 Chip Communication.

4.3. Upper computer software design

As shown in Figure 11, the upper computer software of this system is written in Java because it is easy to use Java language for making interfaces.

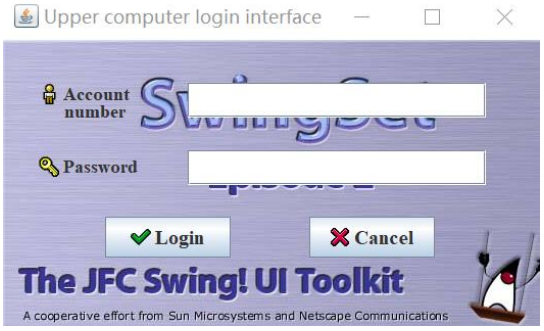

Figure 11. Upper computer login interface.

As shown in Figure 12, when the staff clicks the login button, the written Java statement code will judge whether the staff has entered an account and password. An error prompt box will pop up if the account or password is entered incorrectly.

Figure 12. Error Prompt Box.

As shown in Figure 13, staff will enter the upper computer communication selection interface after successful login. Serial communication is used between the upper computer of the system and the STM32 Main control chip.

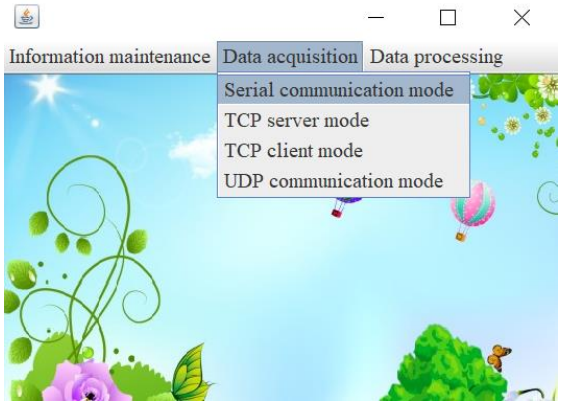

Figure 13. Upper Computer Communication Selection Interface.

As shown in Figure 14, staff can enter the upper computer's serial port communication function interface after selecting the serial port communication mode. The software automatically recognizes all available serial ports and provides staff with various baud rates. The primary function is to send the command to switch lights, switch fans, and voice broadcast to the STM32 Main control chip through the selected serial port and then realize the function of remote control of lights, fans, and voice broadcast through the LORA communication modules. It can display the temperature and humidity data transmitted by the central control chip in real time.

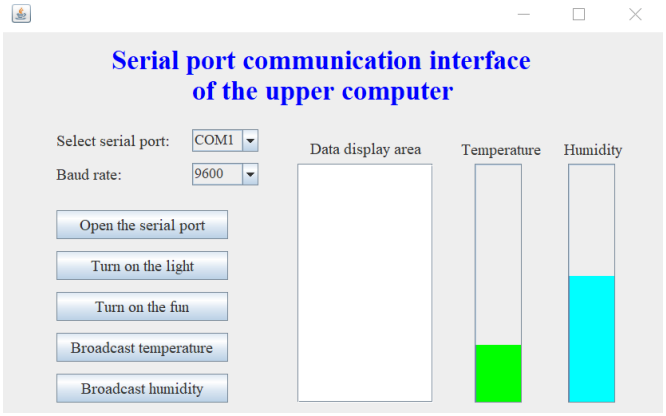

Figure 14. Serial Port Communication Function Interface of the Upper Computer.

5. System commissioning and result display

5.1. Overview of system commissioning

- Upper computer program test: the command for switching lights, fans, and voice broadcast is sent to the designated serial port, and whether the corresponding instructions can be received through the serial port debugging assistant is tested.
- LORA communication module test: two LORA modules are connected to the same upper computer through the serial port and then receive and send data through the serial port debugging assistant for the simulation test.
- LD3320 voice recognition module test: the STM32 Main control chip is used to burn the test code to test whether the voice module can receive instructions. The instructions will be displayed on the serial port debugging assistant interface if it can receive instructions.

5.2. System commissioning results

5.2.1. Temperature and humidity module commissioning. As shown in Figure 15, the collected temperature and humidity data are sent to the serial debugging assistant through the serial port and display the data.

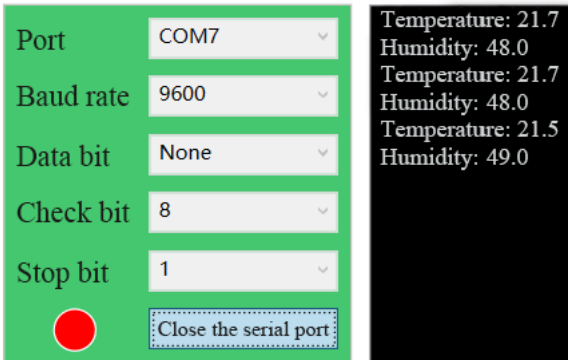

Figure 15. Temperature and Humidity Module Test.

5.2.2. OLED LCD debugging. As shown in Figure 16, when the STM32 Main control chip is powered on, the LCD screen will display the temperature and humidity of the current environment after initialization.

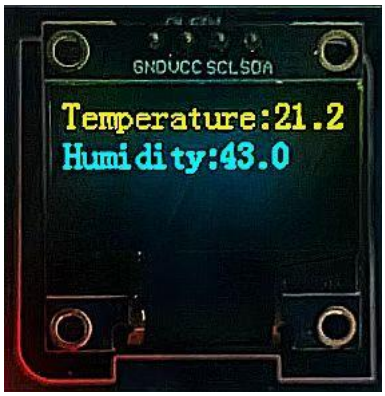

Figure 16. LCD Screen Test.

5.2.3. Voice recognition module debugging. As shown in Figure 17, staff can arbitrarily say a written instruction and test whether the instruction is displayed through the serial port debugging assistant.

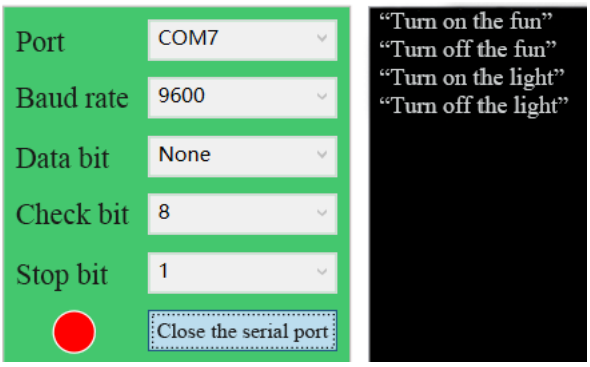

Figure 17. Voice Recognition Module Test.

5.2.4. Photoelectric module debugging. As shown in Figure 18, if the photoelectric module senses that someone is passing by, the current number of people will be displayed on the serial port debugging assistant.

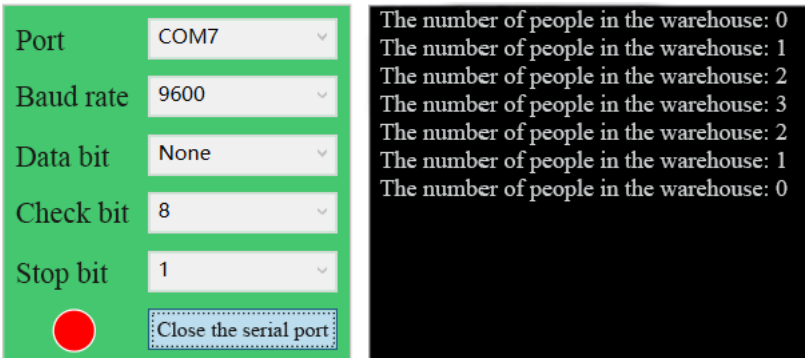

Figure 18. Photoelectric Module Test.

5.2.5. LORA communication module debugging. As shown in Figure 19, after the two LORA communication modules are configured, they can send and receive data from each other through the serial port debugging assistant, indicating that the communication is successful.

Figure 19. LORA modules Communication Test.

6. Conclusions

Around the product quality problems caused by warehouse environmental factors, this paper designs an intelligent temperature and humidity monitoring system based on STM32, which has achieved initial success in circuit board production, module control, and upper computer communication. It verified that the system operates stably and can achieve the corresponding functions of each module through the voice recognition module and upper computer control. The system can be used in various indoor environments that need to monitor temperature and humidity. However, due to the influence and limitation of many factors, the system still has many aspects that can be improved and optimized, such as humidity control, circuit board electrostatic protection, and other issues. In the future, the system design can continue to be improved to improve the adaptability and operational flexibility of the system to different environments in the warehouse.

Acknowledgments

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