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Design of Intelligent Control System for Vegetable Greenhouses Based on Microcontroller

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ABSTRACT: *This design mainly user the temperature and humidity sensor, the pcf8591 conversion module, esp8266 and smoke sensor module to complete a vegetable greenhouse intelligent control system design based on single-chip microcomputer.*
In this paper, first of all, according to the requirements of vegetable greenhouses to map the system flow chart, Then according to the flow chart of the specific function design, implementation of the final can adjust the detection system. The system design is mainly composed of display module, temperature and humidity module, smoke alarm module, pcf8591 module and serial communication. Through this design can achieve detecting temperature and humidity, light intensity, smoke alarm, real-time display various data and automatically regulate the function of the external environment. By actual testing and regulation, according to the results of, This system has real-time monitoring can coordinate the environmental temperature, through the PC data display and control, as well as the advantages of can to alarm in emergency.
Key words: *Vegetable greenhouse; Single chip microcomputer; Smoke sensor; Dht11; Pcf8591 module*

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Ⅰ. INTRODUCTION

With the progress of society and the rapid development of technology, people's demands for material life have become increasingly high, and technology has gradually penetrated into various fields. Agriculture is the foundation of human survival and development, and technological regulation is essential to increase vegetable yield and reduce labor costs. The appearance of greenhouse has improved the yield of vegetables to a certain extent, but the yield of vegetable greenhouses is greatly reduced due to the inability to timely control the internal environment of the greenhouse to make it the most suitable environment for vegetable growth. In order to increase vegetable production and reduce labor costs, real-time monitoring of various environmental parameters inside the greenhouse can be used to keep the interior of the greenhouse in the most suitable environment for vegetable growth. Specially designed for real-time monitoring and simple adjustment of temperature, humidity, and light intensity, this design is also equipped with smoke sensors to facilitate alarm in case of fire or other major crisis situations, allowing people to be informed in a timely manner and take corresponding measures to minimize unexpected losses to a certain extent.

In order to achieve the high yield development of vegetable greenhouses, it is necessary to select some sensors to measure the changes in important indicators, and make intelligent adjustments in case of abnormal data, as well as emergency handling in the face of some unexpected situations. There are various factors that affect vegetable yield. This paper mainly studies the measurement, regulation, and alarm processing of temperature, humidity, light intensity, and smoke However, there are still some problems with the intelligent control system for vegetable greenhouses in China, such as low content of greenhouse control technology, lack of theoretical basis, outdated environmental regulation technology, and lack of excellent control software. So this article uses sensors to detect the environmental parameters required for data, the microcontroller receives the parameters, transmits the data to the PC and displays it. This system has advantages such as simple operation, good stability, and the ability to control on the computer.

At present, considering the lower cost of microcontrollers compared to other controllers, as well as some advantages of microcontrollers themselves, and the difficulty of accurately regulating air temperature, humidity, and light intensity in traditional vegetable greenhouses. For the treatment of environmental regulation issues in vegetable greenhouses, sensors are used to detect environmental parameters, and microcontrollers are used to process environmental parameters. Intelligent regulation of various parts is achieved by controlling exhaust fans, irrigation valves, and shading nets. This intelligent system based on microcontroller technology can effectively improve the production efficiency of plants in vegetable greenhouses, providing a more superior growth environment for vegetables.

Ⅱ. OVERALL SYSTEM DESIGN

System Overall Structure Analysis

The design of the intelligent control system for vegetable greenhouses is mainly divided into three parts: sensor application, microcontroller data transmission and reception, and computer control. The total data interaction design diagram is shown in Fig 1.

After collecting temperature data for vegetable greenhouses, the microcontroller needs to control the temperature within a small range of variation. If the temperature is too high, turn on the exhaust fan to reduce its temperature, and turn off the exhaust fan if it falls within the set range; If the temperature is too low, temporarily turn off the exhaust fan and perform heating treatment. The humidity also needs to be within a threshold. If the real-time humidity is greater than the set threshold, turn on the exhaust fan to reduce its humidity; If the real-time humidity is less than the set threshold, start the irrigation system to increase its humidity. The lighting intensity also needs to be within a fixed range. When the real-time lighting exceeds the maximum value of the set threshold, the shading net will be turned on to reduce the lighting; If the real-time lighting is less than the set minimum value, this design adopts fully opening the shading net to improve the lighting intensity.

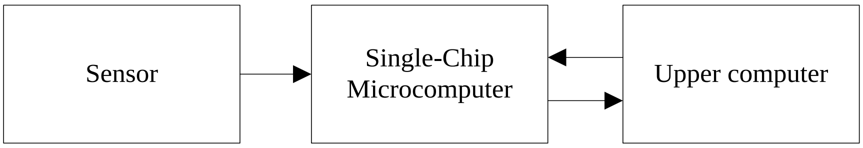

Fig. 1 Overall data interaction design diagram

System Monitoring Functional Analysis

The core of system control is to collect external environmental data through sensors, and then send the collected external environmental data to the microcontroller for further processing. The microcontroller will send the received data information to the computer according to different instructions, and the computer will further process and display the data.

1) Upper computer transceiver function: The upper computer can receive instructions sent by the microcontroller, and can also control the microcontroller by sending instructions. The upper computer has the same function as the buttons in the system. The upper computer can receive real-time values of temperature, humidity, and light intensity, as well as the maximum and minimum upper limits of temperature, humidity, and light intensity. After receiving the instructions sent by the microcontroller, the upper computer can visually see it on the computer end. The upper computer can send instructions to the microcontroller for data adjustment, including the maximum upper limit and minimum lower limit values of air temperature, air humidity, and light intensity. Real time viewing of parameter values and adjustment of parameter ranges can be achieved through the computer.
2) Single chip transceiver function: The microcontroller can receive data sent by the sensor, and after data conversion, the received data is displayed on the display screen, allowing for a visual display of the parameter values detected by the sensor. If the collected data is not within the range set by oneself, then turn on the corresponding LED indicator light, exhaust fan rotation, etc. And use various devices to adjust the air temperature, air humidity, and light intensity inside the vegetable greenhouse to reach the set data measurement range [7]. The microcontroller and upper computer transmit data to each other through RXD and TXD. The serial port structure of the microcontroller is shown in Fig. 2
3) Sensor sending function: This system uses temperature and humidity modules, A/D conversion modules, and smoke modules to detect the required external environment. The temperature and humidity module transmits the received signals to the microcontroller, while the PCF8591 module directly converts the detected light intensity data into digital quantities and sends them to the microcontroller. The smoke sensor adopts a wiring method connected to the DO port for smoke data monitoring and direct critical alarm. The sensor provides the detected environmental parameters to the microcontroller, performs a specific program flow, and displays the environmental data on the LCD1602 display screen.

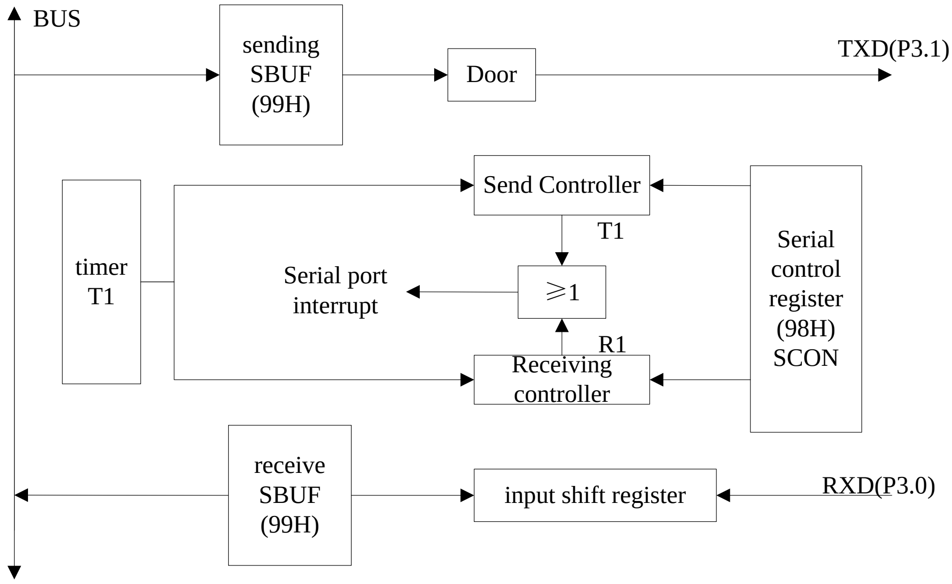

Fig. 2 Single chip microcomputer serial port structure

Ⅲ. Module functional analysis design

Functional Requirements and Practicality Analysis

From the perspective of user usage, this system should mainly address situations where temperature, humidity, and light intensity exceed the set range, and handle corresponding situations. It is also important to consider encountering smoke, such as a fire that can minimize losses as much as possible. The microcontroller used in this design is the IAP15F2K61S2 microcontroller, which has the advantages of low power consumption and high performance. The microcontroller can provide flexible and effective environmental testing effects for the intelligent control system of vegetable greenhouses [8].

Design of Intelligent Control Module for Vegetable Greenhouse Based on Microcontroller

After understanding user needs from multiple aspects, the main functions of the intelligent control system in this design can be determined through analysis. After learning about its main functions, the design of various parts required for system design can be determined. The design of the main functions implemented in this system includes:

1) Temperature and humidity collection design: Detects the temperature and humidity in the air, outputs a digital quantity, and sends the output data to the microcontroller. The temperature and humidity module is shown in Fig 3.

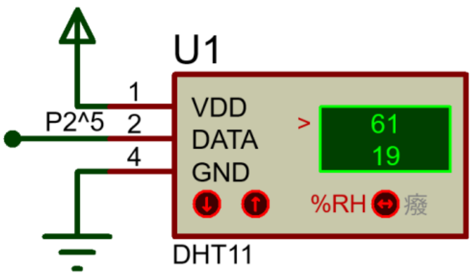

Fig. 3 Temperature and humidity module

2) Smoke alarm design: When smoke is detected in the surrounding air, the DO port will output a low level, causing the buzzer to sound and give an intelligent alarm. The buzzer alarm system is shown in Fig 4.

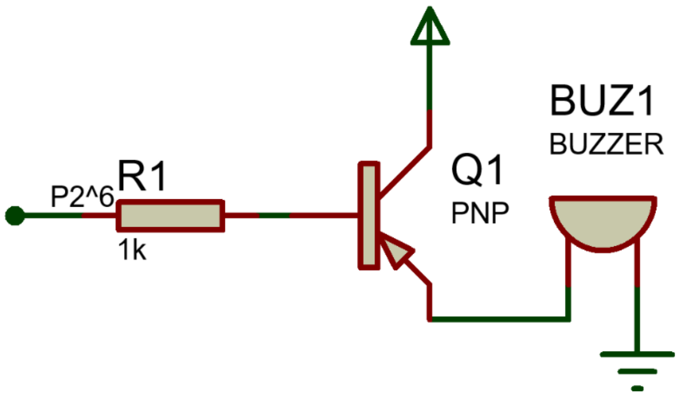

Fig. 4 Buzzer alarm system

3) Lighting intensity collection design: The PCF8591 module is used to collect lighting intensity. The collected analog quantity can be directly converted into digital quantity through PCF8591, and then sent to the microcontroller through IIC bus. The internal schematic diagram of the A/D conversion module is shown in Fig 5.

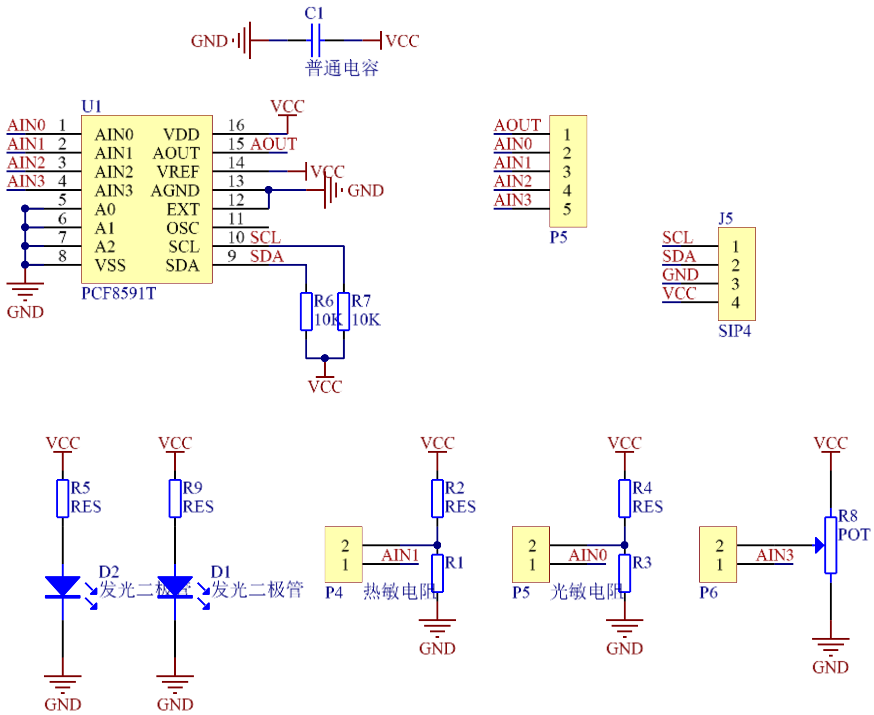

Fig. 5 Schematic diagram of A/D conversion module

4) Intelligent control design: achieving direct detection and control on the PC end, making it more convenient to regulate and detect data.

5) Button control design: mainly realizes on-site control function, which can directly adjust the parameter quantity through buttons on the site.

After analyzing and introducing the design of each part, the required data transmission flowchart can be drawn, as shown in Fig 6.

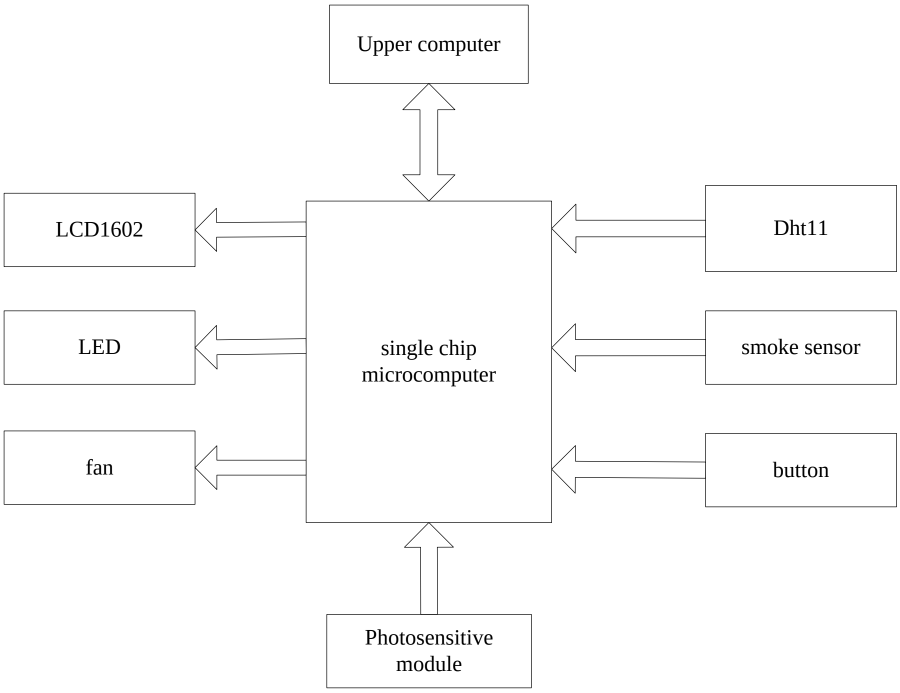

Fig. 6 Data transmission flowchart

Ⅳ. PROGRAMMING

This design is based on the drawn program flowchart to write the program. According to the flowchart, the program design mainly includes the following types: main program, display page, button control, temperature and humidity collection, light intensity collection, and upper computer subroutine design. After powering on the device, the microcontroller initializes devices such as interrupts, serial ports, and LCD1602 displays. The required parameters detected by different types of sensors, processed by the program, are finally displayed on this display screen through a series of microcontroller programming. Users can directly observe the real-time parameter values detected from this display screen. The microcontroller detects various data such as temperature, humidity, and light intensity through program operation, thereby controlling the working status of the shading net and exhaust fan. If on-site control of the sunshade work is required, the sunshade can be adjusted by controlling terminals such as buttons or computer devices [12-18]. The microcontroller detects environmental parameters and regularly sends the detected parameters to the upper computer.

The system diagram of the system design is shown in Fig 7.

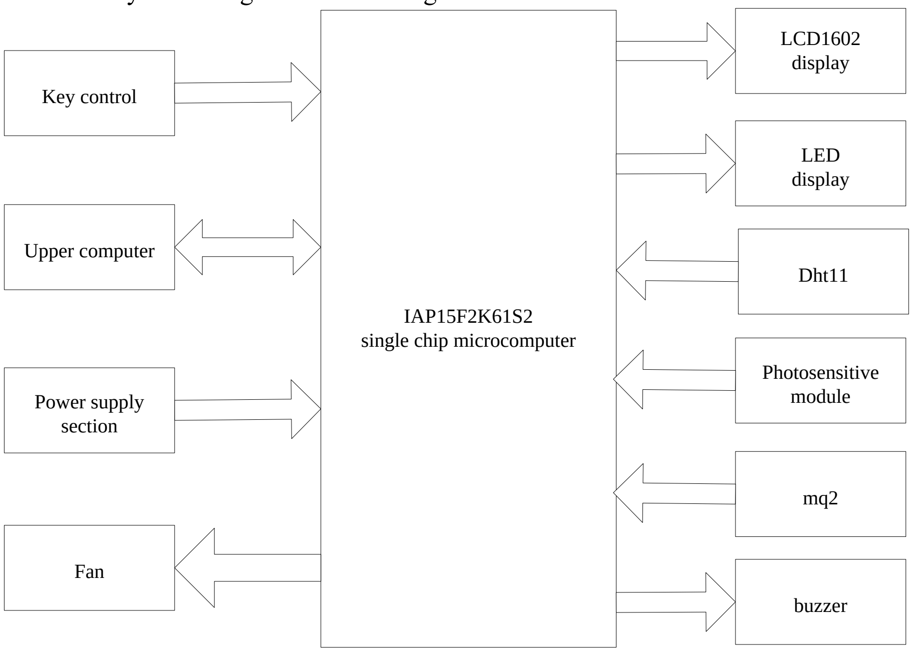

Fig. 7 System Block Diagram

Main Program Design

The main program is the most important part of the program. In the main program, it is initially necessary to initialize the sensors, interrupts, and serial ports used in the system. A while (1) {} loop is usually established in the main function, so that the microcontroller can suppress the loop operation after being powered on. Call functions as required in the loop to achieve the desired requirements.

The main function of this system is mainly to call various functions. For example, temperature and humidity function, IIC, display function, upper computer data sending and receiving program, smoke sensor function, and button control function.

Application of UART Function Programming

UART is a universal asynchronous transceiver, which is a common serial, asynchronous, and full duplex communication protocol in daily life, and is widely used.

The baud rate used in this system design is 9600bps. First, execute the UART initialization program, and then enter the UART interrupt service program. In this program, set the number of flag bits. In this design, the number of flag bits is two, and finally, send serial port data and string design.

Apply UART to the main function, which sends serial port timed data. Place the data receiving function in the interrupt function, and after the microcontroller receives the data, perform an interrupt and immediately execute the transmitted instructions.

A/D Conversion Program Design

The A/D conversion module is a digital to analog conversion module with PCF8591 as the core chip. This module provides four interfaces for inputting analog signals and one analog signal output port. Users can transmit external signals to the input end of the module, and collect, process, and convert them through the module. At the same time, the module is also equipped with a serial IIC bus interface, allowing users to easily communicate and exchange data with other devices. This module has multiple interfaces and functions, enabling complex signal processing and control applications [19]. It can be connected to multiple external devices and control the bus for simultaneous measurement. This design uses the PCF8591 module to measure the light intensity level, with SDA as the serial data line and SCL as the serial clock line. Only one data is measured, so this design directly uses the built-in device of the module for data measurement conversion. The program design first indicates the bus start and stop conditions, followed by the response part, and finally controls the sending and receiving of data through the IIC bus, ultimately obtaining the data to be measured and outputting it.

Upper Computer Program Design

The upper computer program uses instructions to control the sending and receiving of data, enabling it to be displayed or adjusted. The program instruction receiving aa displays real-time data of light intensity, receiving ba displays real-time data of humidity, and receiving ca displays real-time data of temperature. Receiving ap displays real-time data of the upper limit of light intensity, while receiving aq displays real-time data of the lower limit of light intensity. Receiving bp displays real-time data of the upper limit of humidity, while receiving bq displays real-time data of the lower limit of humidity. Receiving cp displays real-time data of the upper temperature limit, while receiving cq displays real-time data of the lower temperature limit. Combining instructions to control microcontroller data transmission.

The upper computer sends instructions ab, ac, ad, ae to the microcontroller, and the upper and lower limits of the light intensity are increased or decreased by 1. Send commands bb, bc, bd, be to the microcontroller, with the upper and lower humidity limits increased or decreased by 1. Send commands cb, cc, cd, and ce to the microcontroller, with the upper and lower temperature limits plus or minus 1. Combining instruction control with microcontroller upper and lower limit adjustment.

V. FUNCTIONAL TESTING

The hardware part of this system uses Altium Designer to draw PCB diagrams, uses online board making, purchases the required components online, and self welds them. The physical image is shown in Figure 5-1. To ensure that the measurement data is not affected by external factors such as device damage, it is necessary to conduct a single device test on the welded board first to ensure that the measured devices are all correct before powering on. Before testing, it is necessary to burn the written program into the microcontroller. The software used for this burn is the STC-ISP serial port debugging assistant. After the program download is completed, functional testing of various parts can be carried out, including data transmission and display of various sensors, measurement of button control, and measurement of data transmission and reception between the upper computer and the microcontroller.

The schematic diagram of this design is shown in Fig 8.

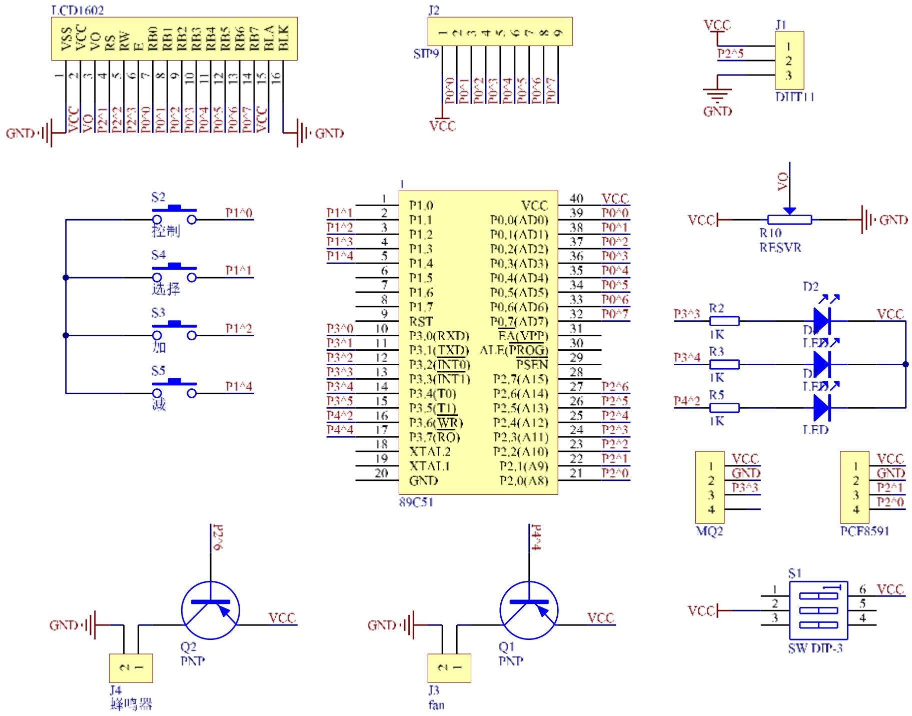

Fig. 8 System schematic diagram

The PCB of this design is shown in Fig 9 and Fig 10.

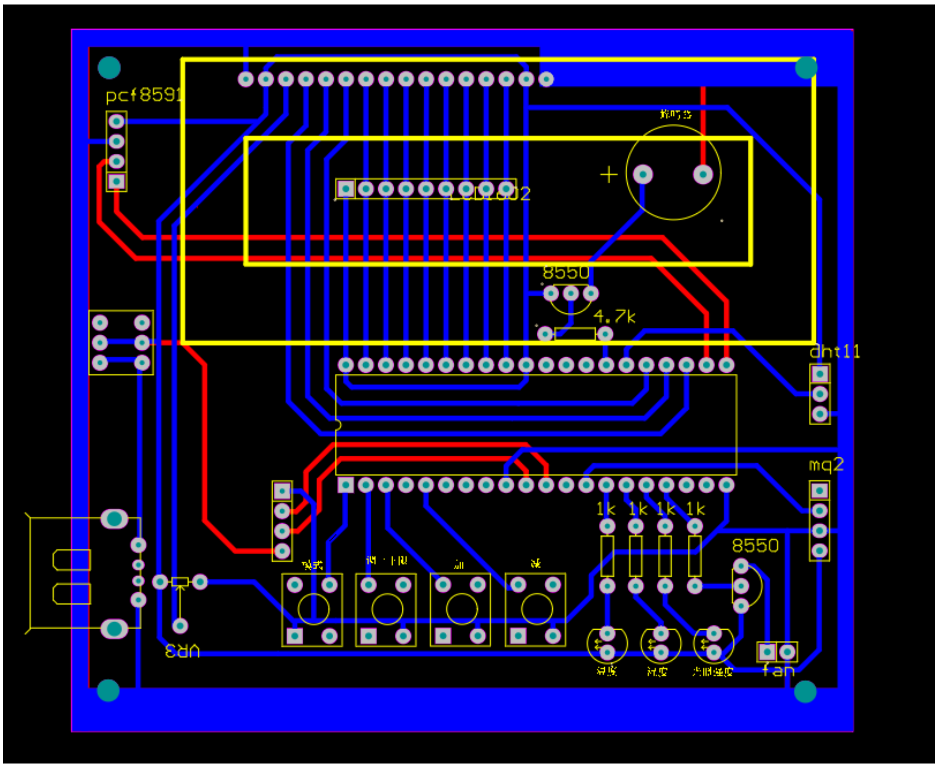

Fig. 9 PCB bottom design diagram

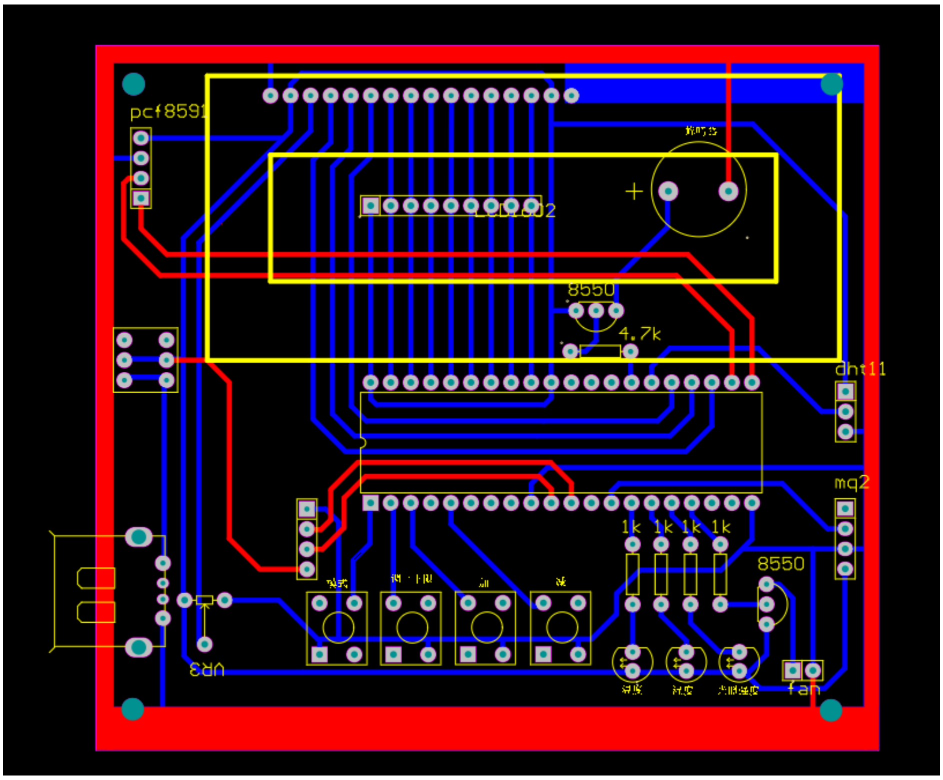

Fig. 10 PCB top design diagram

The software page design of the upper computer is shown in Fig 9.

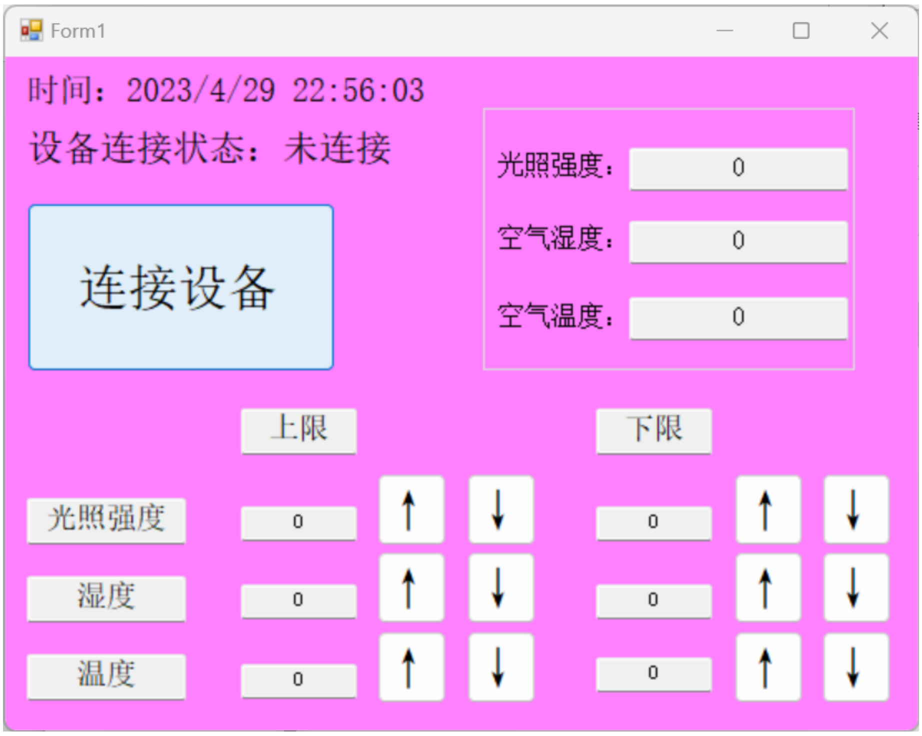

Fig. 9 Software page design diagram

Hardware Testing

In hardware testing, the first step is to measure and send sensor data. The environmental parameters detected by the temperature and humidity sensors and the PCF8591 module can be easily seen on the LCD1602 display screen. When the smoke sensor detects combustible gas, the LED light of the module itself will light up, and the system will sound a buzzer when detecting the presence of combustible gas, simulating the alarm system.

After confirming that there are no issues with the sensors, start measuring the buttons, which is also a measurement of the display function. Press button 1 to switch between three modes. Press button 2 to select which parameter's upper and lower limits to adjust. Press button 3 and press button 4 to adjust the upper and lower limit parameters, respectively. Press button 2 to adjust the upper and lower limit values displayed on the display page. During the debugging process, always observe whether the data displayed on LCD1602 has changed, ensuring that the parameter lower limit cannot be greater than the parameter upper limit, etc.

Communication Debugging Between Upper Computer and Lower Computer

The STC-ISP serial port debugging assistant is used for serial communication, where users can send instructions to the microcontroller and view the response information and data returned by the microcontroller. This can verify whether the communication between the microcontroller and the serial port is correct and stable. Connect two USB to TTL, and send instructions to the upper computer page in the serial assistant. After receiving the instructions, the upper computer will synchronize the data. Click the button in the upper computer to send specific instructions to the lower computer, and observe whether the instructions are successfully sent.

After both the microcontroller and the upper computer receive and receive instructions correctly, connect the upper computer to the microcontroller and observe whether the data received by the upper computer is consistent with the data displayed on LCD1602. After adjusting the buttons, whether it still remains consistent. If it remains consistent, it indicates that the data sent by the microcontroller and received by the upper computer are normal. Then perform the debugging of the upper computer control function. Press the six buttons on the page at once, observe the display results of the microcontroller and the upper computer, and check whether they follow the button press adjustment. If there is no error, it proves that the direct command transmission between the upper computer and the microcontroller is normal and can communicate normally.

Ⅵ. CONCLUSION 结论

This article mainly studies the design of an intelligent control system for vegetable greenhouses based on a microcontroller. With the rapid development of technology, intelligent control systems for vegetable greenhouses have become a trend. Therefore, this design closely follows the trend of the times and designs an intelligent control system for vegetable greenhouses, which is very important for the intelligent development of vegetable greenhouses. After determining the design of the intelligent control system for vegetable greenhouses, the functions of each part were sorted out based on the flowchart drawn, and corresponding functions were designed and completed, followed by corresponding testing work. The intelligent control system for vegetable greenhouses ultimately achieved the following functions:

1) Temperature and humidity measurement and control function: can measure temperature and humidity parameters, and automatically adjust existing parameters based on the upper and lower limits of temperature and humidity;
2) Light intensity detection and regulation function: It can perform light measurement and automatically adjust the light according to the set light threshold;
3) Smoke measurement alarm function: When a certain amount of combustible gas is detected, the system can take emergency alarm measures;
4) Computer control function: It can directly adjust the threshold on the computer.

At present, this design has achieved functions such as temperature, humidity, and light intensity detection and control, smoke alarm, and computer-based intelligent control. The intelligent system has the characteristics of intelligent control, strong operability, and comprehensive functionality. However, due to the short preparation time, the structure of this knowledge is not rigorous enough, and there are still some shortcomings in this design. Firstly, due to time constraints, this design did not monitor the concentration of carbon dioxide. Secondly, there is a certain degree of delay in the transmission and reception of instructions between the upper computer and the microcontroller. If there is an opportunity, I will work with interested classmates to improve the functionality in the future.

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