Design of Intelligent Agricultural Greenhouse Environment Monitoring System

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Abstract: Aiming at the problem of greenhouse environmental information collection in agricultural production, this paper designs a greenhouse monitoring system based on STM32 microcontroller. The system uses STM32F103 series MCU as the main control unit, which is used to receive the detection results of the sensor. The host computer software displays and processes the monitoring data. The temperature and humidity sensors monitor air temperature and humidity. The capacitive soil moisture detection sensor monitors soil moisture. The carbon dioxide sensor monitors the concentration of carbon dioxide. The photosensitive sensor monitors light intensity. This design has low hardware cost and high data acquisition accuracy, which can be applied to the actual greenhouse agricultural production and has wide practicability.

Keywords: STM32F103 Microcontroller, Temperature and Humidity Sensor, Photosensitive Sensor, PC Software

1 Introduction

China has a large population, but the current situation of our country's agricultural development is that population development does not match agriculture. With the continuous improvement of economic level and population, people's requirements for food quality and quantity continue to increase. In this case, the traditional "relying on It is difficult to meet the ever-increasing requirements of the model of eating from the sky, and agricultural greenhouses have also emerged.

With the expansion of our country's agricultural production scale and the improvement of the economic level, the people's demand for daily life is constantly changing from "eat enough" to "eat well", which puts forward higher requirements for the production and supply of crops. Traditional The traditional agricultural production methods are difficult to meet the increasing demand, and the greenhouse came into being. In traditional greenhouse agricultural production, the method of manually measuring environmental parameters and controlling and adjusting equipment is often adopted. This method has high time and labor costs, and the control accuracy is greatly affected by subjective factors.

In order to maintain the best growth environment for the crops in the greenhouse, the design process needs to be understood according to the growth environment requirements of different crops, including the light, temperature, water and other factors of crop growth. Table 1 lists the growth requirements of some common crops.

The same crop has different environmental requirements at different growth stages. In daily agricultural production, keeping crops growing in the most suitable environment can greatly increase yield and avoid the occurrence of diseases.

Table 1 Common Crop Growth Environment Requirements

	Watermelon	Cucumber	Tomato
Illumination	Strong Light	Medium Light	Medium Light
Air Humidity	50%~60%	65%~75%	45%~65%
Soil Moisture	75%~85%	80%~85%	85%~90%
Temperature	25℃~30℃	25℃~29℃	20℃~30℃

2 Overall System Design

The overall scheme of the system design is shown in Fig.1.

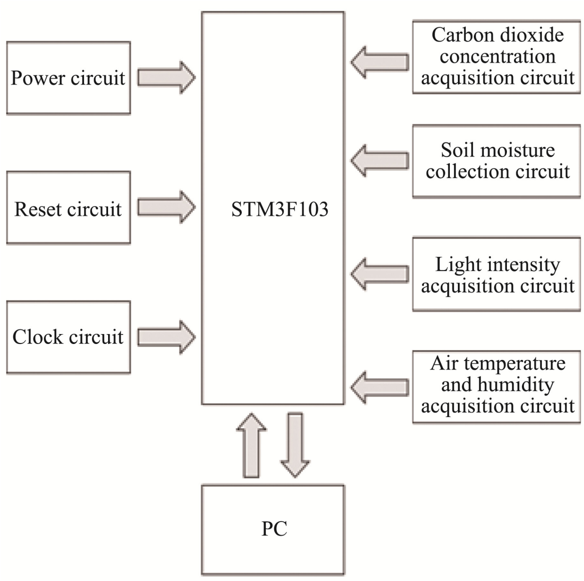

Fig.1 Overall System Block Diagram

The smart agricultural greenhouse environment monitoring system collects environmental parameters through sensors, replacing the original method of manually measuring environmental parameters. After collecting data, it is transmitted to a single-chip microcomputer. The single-chip microcomputer compares the current data with the set threshold to determine whether to adjust and control. After processing the data, the single-chip computer communicates with the upper computer through the serial port to transmit data, and the monitoring and control software of the upper computer can display relevant parameters in different forms in real time. The convenience of reading data is guaranteed, and the control of environmental variables is more accurate and timely.

The system can realize the collection and real- time display of crop growth environment parameters, automatic control, and information security management on the software side, which greatly reduces labor costs, realizes environmental data monitoring and control, and improves crop growth efficiency. .

The intelligent agricultural greenhouse environment monitoring system mainly includes the lower computer monitoring system and the upper computer monitoring software. The monitoring system uses STM32F103C8T6 single-chip microcomputer as the main control chip. The specific hardware part includes: STM32 single-chip microcomputer minimum system, carbon dioxide sensor module, soil humidity sensor module, light intensity sensor module, air temperature and humidity monitoring and adjustment module, and the software is computer-side monitoring software. Soil humidity sensor, light intensity sensor, carbon dioxide concentration sensor and air temperature and humidity sensor DHT11 transmit the collected data to the STM32F103C8T6 single-chip microcomputer, and use the integrated analog- to-digital conversion module inside the single-chip microcomputer to convert the analog quantity into a digital quantity, and the single-chip microcomputer converts the digital quantity through the serial port The communication method is transmitted with the computer, and the monitoring software on the computer side displays the values of various environmental parameters in real time. The computer-side monitoring software can display the relevant environmental parameters in a line chart, which is convenient for observing the change trend

2.1 Sensor Technology

A sensor is a detection device that can use physical effects to collect actual environmental data, and convert analogy quantities into digital signals that can be received and processed by computers through relevant rules.

Classified by working principle, sensors can be divided into resistive sensors, capacitive sensors, inductive sensors, Hall sensors, photoelectric sensors.

The metal oxide semiconductor gas sensor obtains the value of the gas concentration through the change of the electric current after the measured gas touches the gas sensor, the conductivity of the semiconductor changes. The gas sensor is divided into P type and N type. After contacting O_2, Cl_2, CO_2 and other gases, the resistance of P type decreases, and the resistance increases after contacting combustible gases. The electrical conductivity of the N-type gas sensor increases after exposure to CH_4, CO and other gases.

The sensing element of the capacitive sensor is a capacitor, which can convert the change of the measured physical quantity into the change of the capacitance value, and convert it into the change of current and voltage through the measurement circuit to collect the value and convert it into the relevant physical quantity value according to certain rules. It can be applied in displacement, angle, medium characteristics, etc. According to variable parameters, it can be divided into three categories, including: variable medium type, variable area type, and variable pole distance type.

Photosensitive sensors are manufactured based on the principle of photoelectric effect. According to the different characteristics of the photoelectric effect, it can be divided into: external photoelectric effect, internal photoelectric effect, and photovoltaic effect. Common photosensitive elements such as photo resistors and photodiodes used in daily use the internal photoelectric effect. The internal photoelectric effect refers to the change of the conductivity of an object with the change of light intensity. Many metal sulphides, selenides, etc., such as: CdS and CAS, the resistance will decrease when the light becomes stronger.

2.2 Transfer Protocol

IIC is a protocol developed by Philips that is suitable for communication between the main control system and peripheral devices. It is a serial communication bus. In the II C protocol, there are two signal lines, the clock line SCL and the data line SDA, both of which are bidirectional. Data transfer is controlled by the host. The master issues a start clock signal or a stop clock signal on the SCL line. When the clock line remains high and the data line changes from high to low, it is start; when the clock line remains high and the data line changes from low to high, it is stopped.

The IIC protocol is built in the STM32 microcontroller, and related pins can be used, but because of logical defects, the same processing method is often used for chips that do not have protocol pins such as STC51, and the high and low levels of the pins are passed according to the rules of the protocol. The output is paired with an analog IIC-related level combination.The transmission rate can reach 100Kbit/s in standard mode, 400Kbit/s in fast mode, and 3.4Mbit/s in high-speed mode. The rate is related to the clock frequency.

The SPI protocol is a serial interface technology designed by Motorola, which consists of four lines, including the master input line (Master Input Slave Output), the master output line (Master Output Slave Input), the clock line (Serial Clock), chip select line (Chip Select). Under the control of the clock line, two 8-bit bidirectional shift registers exchange data. In the embedded system, it is mainly used in the communication between the host computer and EEPROM, Flash, ADC, etc.

SPI can communicate in full-duplex mode, provide a clock whose frequency can be changed by programming, can send an end interrupt flag in the data, and has functions such as write conflict and bus competition protection. During use, adjust the polarity (Clock POLarity) and phase (Clock PHAse) to choose four working modes. Under different working modes, the high and low levels of SCLK are different when idle, and the sampling time is also different. The most used are SPI0 and SPI3.

Onewireproposed by the Dallas SEMICONDUCTOR company in the United States, this technology uses a single signal line, which is both a clock line and a signal line, and data transmission is bidirectional. This structural feature makes it simple in wiring, saves I/O ports, and is convenient for bus The advantages of expansion and maintenance.

When the transmission protocol is in use, it is initialized first, and the process is composed of a reset pulse sent by the master and a response pulse from the slave. Following the initialization is the ROM command. When there are multiple devices on the bus, the ROM sent by the host determines which device to exchange data with. The ROM command is followed by a function command to determine whether the master sends data to the slave or reads data at this time.

3 Hardware Circuit Design

3.1 MCU Minimum System

The STM32F103C8T6 microcontroller used in this design is a 32-bit microcontroller based on the ARM Cortex-M core STM32 series. The core size is 32 bits, the program memory capacity is 512KB, and the power supply is 2V-3.6V. –40°C-85°C. It has low power, low voltage, and combines excellent performance with real-time functions. It integrates a high-performance RISC core with a running frequency of up to 72MHZ, embedded memory, and enhanced input/output with enhanced range. It features 12-bit ADC, timer, PWM timer, standard and advanced communication interfaces.

The minimum system of a single-chip microcomputer is a system that can work with a single-chip microcomputer composed of the fewest components. The minimum system consists of three parts: power supply, clock circuit and reset circuit.

The power supply circuit is shown in Fig.2: the power supply used by the sensor module is 5V~7.6V, and the traditional power supply module cannot directly supply power, so a step-down DC/DC converter TD7590 is used to build a power supply circuit to provide +5V power for the sensor.

The formula for TD7590 output voltage is:

$$V_{out} = (1 + R_2 / R_1) * 1.222V$$

STM32F103 series MCU working power supply is 3.3V, using AMS117-3.3 regulator to step down the +5V power supply to +3.3V for use.

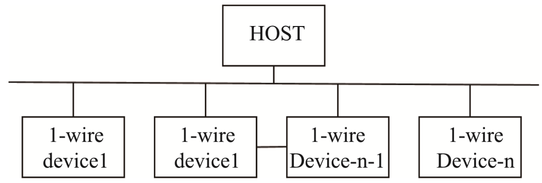

Fig.2 One Wire Connection

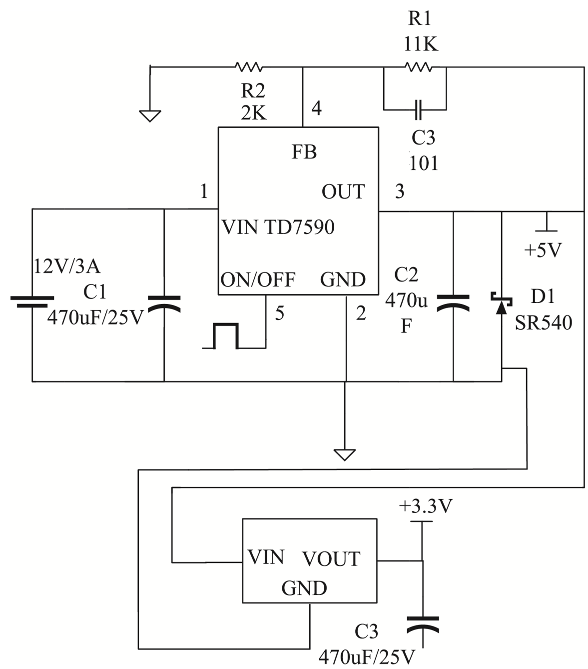

Fig.3 Power Management Circuit

The clock circuit uses a 32.768kHZ crystal oscillator to provide a reference clock signal for the microcontroller system. All the work inside the microcontroller is based on this clock signal. The two ends of the crystal oscillator are connected to the crystal pins of the microcontroller, and two 10pf capacitors are added to help the crystal oscillator starts to oscillate and maintains the stability of the oscillating signal.

The reset circuit is shown in Fig 4. There are generally three types of MCU reset: power-on reset, manual reset, and program automatic reset. This design adopts the manual reset method, when the NRST pin of the microcontroller generates a low level, the microcontroller will be reset. Working principle of manual reset: When the button is released, an external

10k pull-up resistor is connected to the NRST pin, and the NRST pin remains at a high level. low, the micro-controller generates a system reset.

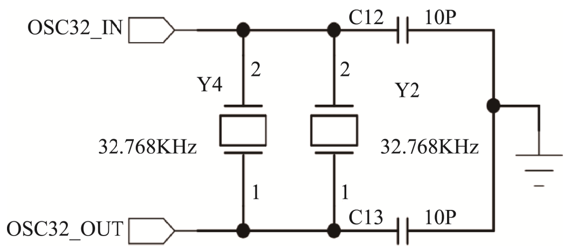

Fig.4 Clock Circuit

The minimum system PCB board designed based on the STM32F103C8T6 microcontroller is shown in Fig.5:

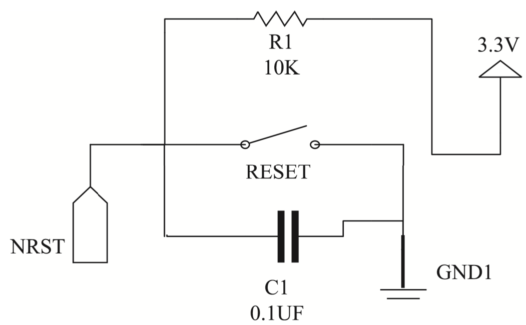

Fig.5 Reset Circuit

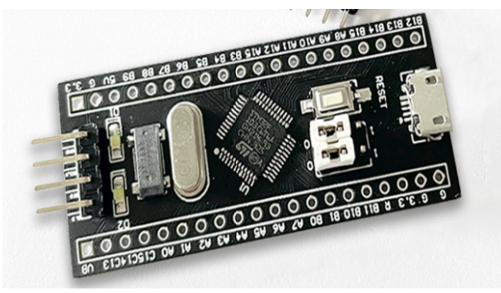

Fig.6 The Minimum System PCB

3.2 Sensor Detection Module

The carbon dioxide sensor SGP30 is a metal oxide gas sensor with multiple sensing elements on a single chip, integrating 4 gas sensing elements with a fully calibrated air quality output signal. The SGP30 sensor module takes up less space, making it easy to use in some compact designs. Power supply voltage 3.3V or 5V; power consumption 40mA. Measurement data is read through the IIC protocol.

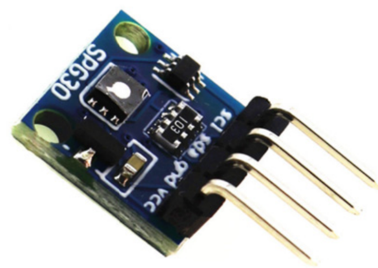

Fig.7 Physical Map of Carbon Dioxide Sensor

Soil moisture sensor YL69 is a variable dielectric constant capacitive sensor. The surface of the sensor probe is treated with anti-corrosion, the area is enlarged, and nickel-plated treatment is adopted to improve the conductivity, reduce the loss in use, and increase the use time. The YL69 sensor can measure the soil moisture in a wide range, and the working voltage is 3.3V-5.5V. Through the peripheral circuit of the sensor, the change of the capacitance value is converted into the change of the voltage, and the voltage value is read by STM32 and converted into a digital quantity through the internal integrated AD converter.

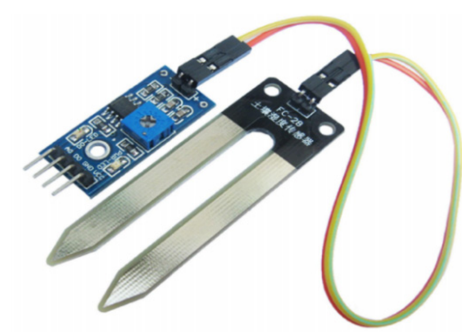

Fig.8 Physical Map of Soil Moisture Sensor

The DHT11 digital temperature and humidity sensor is a composite sensor. Its sensor part includes a humidity sensitive resistor and a thermistor, and applies digital module acquisition technology. The digital quantities of temperature and humidity can be read separately through the relevant rules of One Wire. AD conversion. The DHT11 sensor has high measurement accuracy, humidity ±5%RH, temperature ±2°C, and working voltage 3.3V-5.5V.

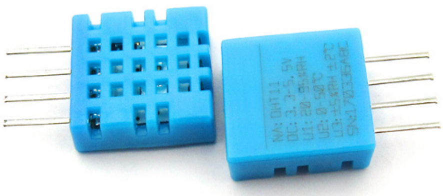

Fig.9 Physical Map of Air Temperature and Humidity Sensor

The photosensitive sensor uses a photoresistor to convert the light signal into an electrical signal. With the peripheral circuit, the resistance value can be obtained in real time, and the current light intensity can be calculated according to the change curve. The obtained electrical signal is converted into a digital quantity through an AD converter, which is convenient for the next communication transmission.

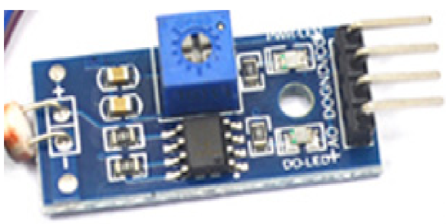

Fig.10 Physical Map of Photosensitive Sensor

3.3 Communication Module

The USB to TTL chip adopts CH430g, full-speed USB2.0 interface, supports communication baud rate 50bps-2Mbps, and is used for the connection between the UART serial port of the MCU and the USB of the computer to realize the conversion between the USB level and the UART serial port TTL level.

In the application of the environmental monitoring system for smart agricultural greenhouses, there are often many sensors and complex wiring. In order to use too many data lines, it will also bring errors to data collection. A PCB that integrates various hardware modules is designed.

Fig.11 Communication Module Physical Map

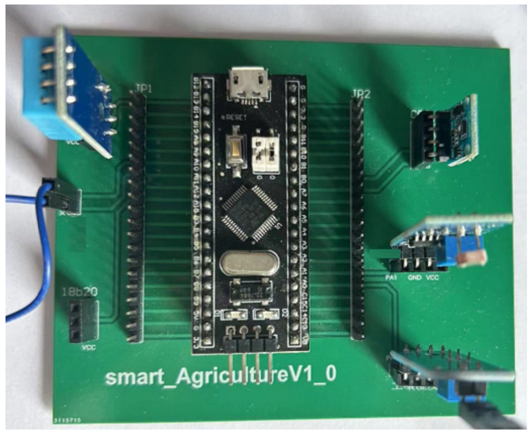

Fig.12 Hardware Module Physical

4 Software Design

Use the SPL standard peripheral library of STMicroelectronics to develop STM32, and use the default clock configuration of the standard library, and the main frequency of the system clock is 72MHz.

The basic program of the system includes: delay program, timing program, NVIC interrupt grouping, USART communication program, simulation IIC program, One Wire program, interrupt grouping is used to set interrupt preemption priority and response priority levels. In addition to the basic program, it also includes the driver program and function program

Software program design: enter the main program to initialize the MCU and sensor module first, and enter the acquisition stage after completion. After the single-chip microcomputer obtains the collected information, it performs data processing. If it is an analog quantity, it performs analog-to-digital conversion. The serial port is sent to the host computer.

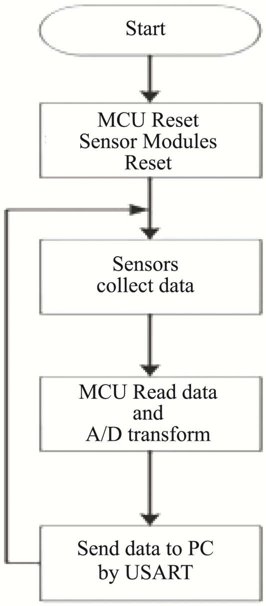

Fig.13 Greenhouse Monitoring System Software Flowchart

5 PC Software Design

In daily agricultural production, it is often necessary to collect environmental parameters of different planting locations. If it is necessary to go to each collection device to obtain the current parameter value, the efficiency will be low. Therefore, the design of the host computer monitoring software can facilitate real-time monitoring of different Collect device information.

Use C# language to develop computer-side monitoring program. C# is an object-oriented programming language derived from C and C++ released by Microsoft. The basic structure of the software is: login verification, human-computer interaction, communication parameter setting, and USART interface.

In the daily operation of the system, in order to ensure that the system is used by operators and avoid other personnel from operating it, it is very necessary to add login verification before use. The form development of the login interface includes the user name and the corresponding password, and the next interface can only be entered after the two are verified to match. This ensures the safe operation of the system and information security.

Fig.14 Login Shell

The main interface can monitor the running status and detection data of the device, and enter different interfaces such as monitoring and setting through the menu bar. Considering the actual situation of agricultural production, the design is simple to operate and the data display is clear.

Fig.15 Computer Software Main Interface

Select the main interface to enter different function pages. The monitoring interface is shown in Fig.16, and the values of relevant parameters can be read in real time.

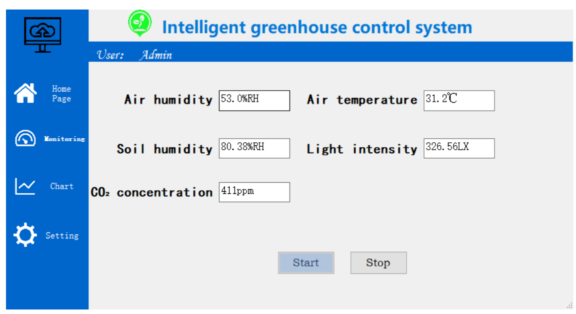

Fig.16 Computer Software Monitoring Interface Running

In the process of agricultural production, it is very necessary to obtain information such as temperature in real time, but the value is constantly changing. It is impossible to understand the changing trend of relevant parameters only by observing real-time data. In order to reflect the change process of related variables more intuitively, a chart interface is set up in the host computer software. In this interface, the change of environmental variables such as air temperature can be displayed in the form of a line graph, and the change process of the value can be intuitively understood.

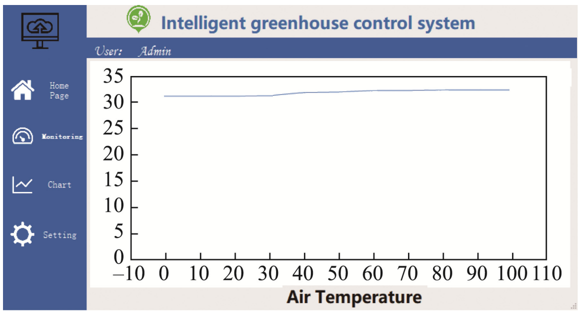

Fig.17 Computer Software Chart Interface Running

6 Conclusion

This paper summarizes the environmental requirements of crops. The key environmental factors in greenhouse agriculture include: carbon dioxide concentration, light intensity, air temperature and humidity, soil temperature and humidity, etc. According to these environmental quantities, the hardware monitoring system of the lower computer is planned. Select the appropriate sensor based on the data to be collected.

When selecting hardware, in line with the principle of improving the acquisition rate and accuracy and reducing costs, the sensor module is chosen, which greatly improves the reliability of the system and facilitates the maintenance and replacement of a single sensor after failure. Module failure affects other normal work. The hardware system is planned and realized, the schematic diagram of the lower computer hardware and the peripheral circuit of the sensor module using STM32 as the central control chip is drawn, the real object is made and the program is debugged.

In order to improve the convenience of data reading, the computer-side monitoring and control software was developed based on Visual Studio using C#, and the version of the software was upgraded according to the hardware upgrade and function improvement of the lower computer, and finally realized real-time data reading and data change trend display function, and increased the login verification steps to improve the information security of the system. The computer-side software is easy to use and simple in function.

The function of this system is easy to expand, the system reliability is high, and the computer-side monitoring software is easy to operate and intuitive to display. Moreover, the market demand is large, the product cost is lower than other similar products, and it can produce obvious economic benefits, which is convenient for popularization and use.

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