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Design and Implementation of Orchard LED Supplement Light Control System based on Wireless Network

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ABSTRACT:

In this paper, we design and implement an orchard light supplement system based on wireless network technology, including STC15F2K60S2 microcontroller, photosensitive module, LCD1602 screen and RGB tone modulator. The light intensity is obtained using the internal AD of the microcontroller and displayed on the LCD1602 screen. The serial port of the ESP8266Wi-Fi module is connected the host computer and microcontroller through Wi-Fi, so the light intensity data could be sent real-time from the microcontroller to the upper computer. The required light intensity parameters can be set through the key of the MCU or the ratio of RGB light, light intensity and the start and end times of supplementary light through the App of the mobile phone to adjust the lighting quality of LED to meet the needs of fruit trees. This design adopts modular structure, accurate control, high reliability and can be used to improve fruit yield and quality.

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I. INTRODUCTION

The development of almost every living organism including fruit trees is regulated by light[1,2]. Light (solar radiation) is the source of energy for plants that controls a high number of developmental aspects of growth[3,4]. Under natural conditions, the plants affect the morphology and growth of plants, flowering, weight, appearance and quality of fruit through the changes of light intensity, light quality and photoperiod[5]. Insufficient light intensity results in the inhibition of photosynthesis, which affects the yield and quality of fruit. Along with the fast development of advanced science and technology, light supplement technology makes agricultural planting get rid of the limitation of natural conditions and promotes the development of agricultural automation and intellective level.

As a semiconductor light emitting device, LED (light emitting diode) have become a fascinating field in recent years for its excellent features such as high luminescent efficiency, low energy consumption and quick response[6-8]. In addition, it is convenient to adjust and combine the spectrum so that the absorption peak of plant photosynthesis and LED light source spectrum can be completely consistent[9]. In recent years, there are numerous researches on the LED plant light supplement system[10-12]. Chiang et al. demonstrated that the adequate light could effectively promote plant photosynthesis and speed up plant growth and development under temperature conditions suitable[13]. Through experiments, Olvera-Gonzalez et al. proved that the different LED light duration and different wavelength LED light sources can effectively improve crop yield[14].

In the cultivation process of peach trees, a light supplement system is designed to improve the fruit yield and quality. The monitor can measure light intensity using the internal AD of the microcontroller and displayed on the LCD1602 screen in real-time. Connect the serial port of the ESP8266Wi-Fi module to the host computer and microcontroller through Wi-Fi, and send the light intensity data from the microcontroller to the upper computer, and set the required light intensity parameters through the key of the MCU or the ratio of RGB light, light intensity and the start and end times of supplementary light through the App of the mobile phone and reach the requirements of fruit trees supplementary light.

II. DESIGN OF THE SYSTEM SCHEME

1 Demand analysis

We designed a convenient, simple and accurate monitor system for environmental light intensity parameters in accordance with the requirements. The system could provide real-time monitoring of orchard light intensity and display the light intensity data in the phone APP, PC or LCD, and the light intensity, RGB light ratio and supplement light time be set freely as required.

2 Whole schemes

According to the design requirements, the structure of system whole scheme is divided into five modules, as shown in Fig. 1. The data module is the basis of all the work, so it is the most important one. We chose the photosensitive sensor to measure and obtain the light intensity parameters. The data processing and control module is the core of the whole scheme. The single chip microcomputer STC15F2K60S2 is selected, and mainly responsible for processing the data from the photosensitive sensor and the command from the mobile terminal. We select the ESP8266 Wi-Fi module as the communication unit, and the key feature is in charge of sending data to the mobile terminal and transmitting the commands to the single chip microcontroller. The functions of the display module include monitor and display the data processed, and the real-time clock information on the LCD screen. The execution module consists of RGB tone modulator and LED light, and mainly used to drive LED light source array to emit light of different intensity and light quality ratio for orchard supplement light.

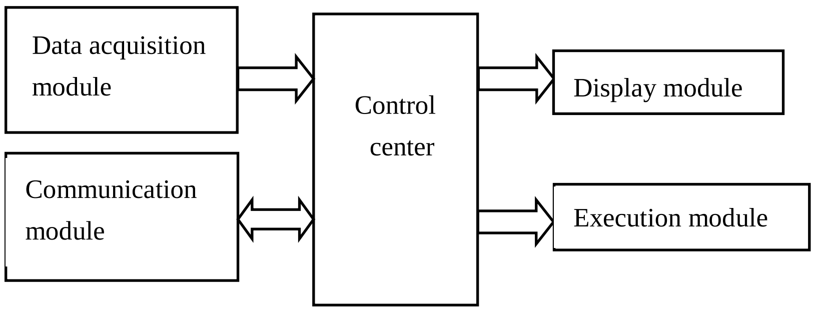

Fig. 1 Structure of system whole scheme

III. RESULTS AND DISCUSSION

1 DESIGN OF SYSTEM HARDWARE

1.1 Photosensitive sensor unit

The photosensitive monitoring circuit is composed of three 10K resistors, two capacitors, two LED indicators, a thermistor and an LM393 voltage comparator. It contains two output ports, AO for analog signal whereas DO for digital. The photosensitive module is so sensitive to the perception of light that it could generally be used to detect the intensity of light in the surrounding environment and trigger the microcontroller or relay module for the next operation. Fig. 2 shows the circuit diagram of the photosensitive unit.

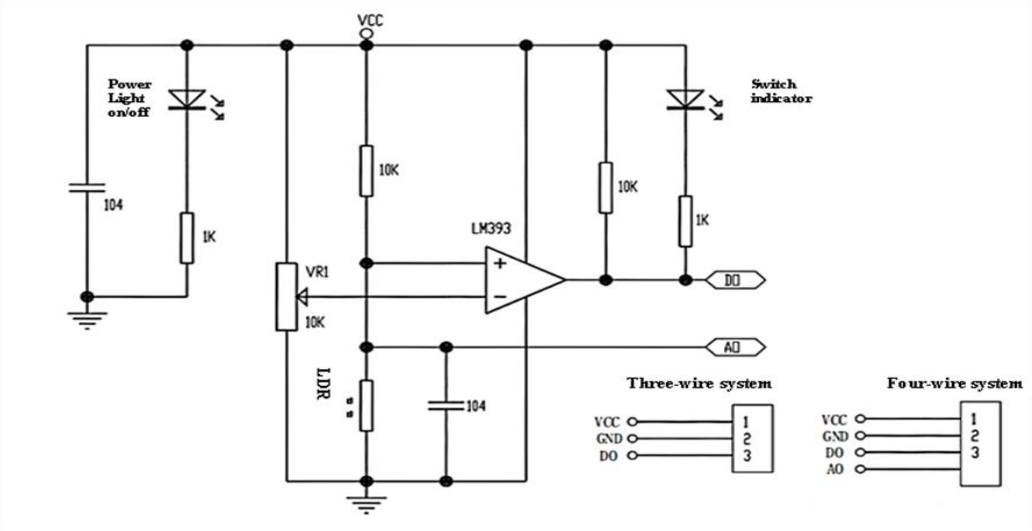

Fig. 2 Circuit diagram of the photosensitive sensor module

The physical photosensitive sensor has the following specifications:(1) The photosensitive unit uses LM393 comparator for output, with a strong driving capacity, more than 15mA; (2) Operating voltage: 3.3V-5V; (3) Output form: DO digital output (0 and 1) and AO analog output (voltage) respectively; (4) Regulate the potentiometer, the then adjustable light brightness. The physical photosensitive sensor is shown Fig. **3.**

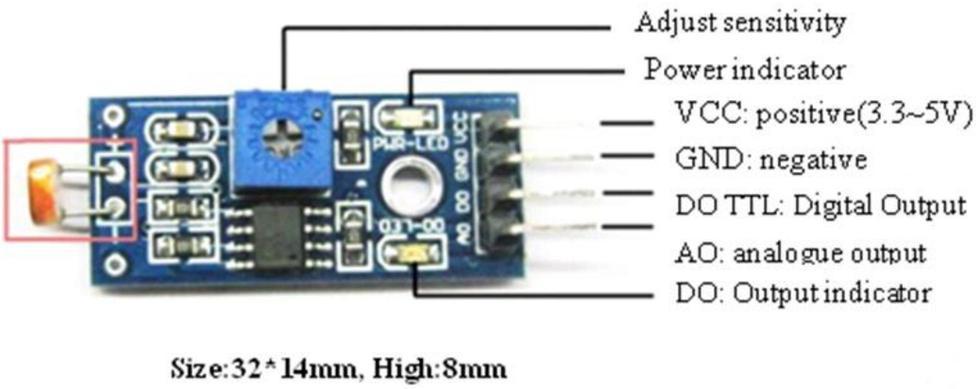

Fig. 3 The physical photosensitive sensor

The analog output AO can be connected to the AD module. Through AD conversion, the ADC sampling values from the MCU in turn are directly stored in the internal register, then read the data from the register after sampling. Fig. 4 shows the flow chart of the photosensitive sensor working.

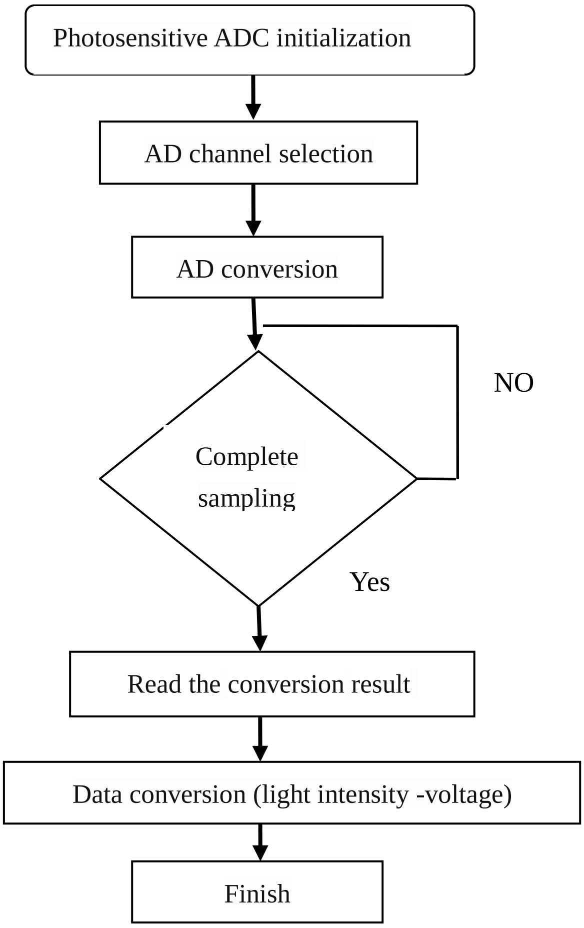

Fig. 4 The flow chart of the photosensitive sensor work

1.2 Control center

We chose the STC15F2K60S2 microcontroller, produced by the macro crystal technology, as the Control center MCU. It is a new generation of 8051 microcontroller with velocity, high reliability, low power consumption and strong anti-interference. It is the internal integration of crystal circuit and reset circuit, do not need external connection, save space, rich interface to facilitate communication with the host computer. The inside integrates the crystal circuit and reset circuit, and rich interface conveniently communicates with the host computer.

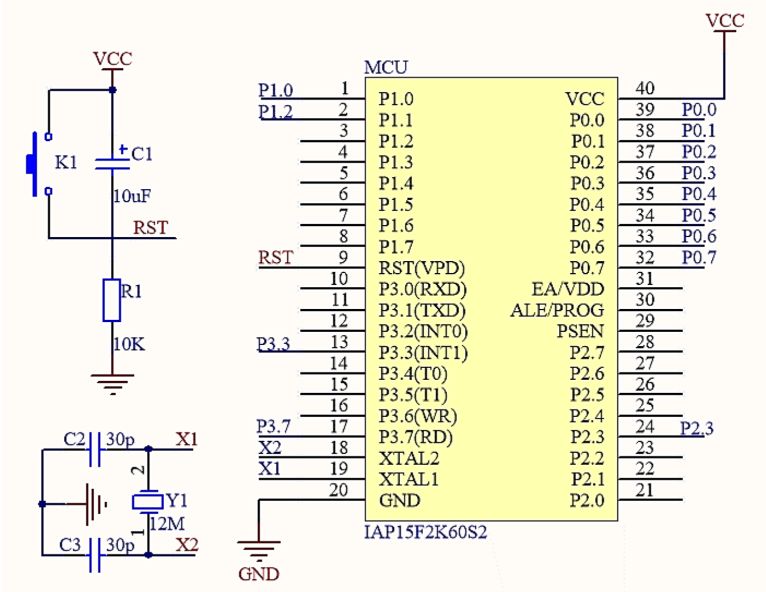

Fig. 5 The minimum system in single-chip microcomputer

The key features of STC15F2K60S2 is shown below: (1) RAM date memory storage with large capacity: 2048 bytes; (2) High reliability reset circuit: There are 8 levels of reset threshold voltage optional using ISP programming, so it is more convenient to use and more concise to wire; (3) Low power consumption design: It contains three working modes, namely low speed mode, idle mode and power off mode, respective. Additional, it integrates the high precision R/C clock, ± 1% temperature drift (-40°C ~ + 85°C) and 5% temperature drift at room temperature, so that the chip completely saves the expensive crystal clock; (4)Operating frequency: 5~35MHz; (5) High Capacity of EEPROM: It could support the erasure and write times ≥100000;(6)Advanced instruction set: It is compatible with the ordinary 8051 instruction set.

1.3 Communication Unit

The ESP8266 with the Wi-Fi module was developed to connect the user's device to the Internet or LAN for data exchange.

The ESP8266 chip with 16-bit compact mode, supports 80MHz and 160MHz, integrating the Wi-Fi MAC/BB/RF/PA/LNA and antenna mounted on the board. Meanwhile, it also supports RTOS, the standard IEEE802.11b /g/ N protocol, rich Socket AT instructions, UART/GPIO data communication interface, complete TCP/IP protocol stack, Smart Link intelligent networking function [5], and can be upgraded remotely. ESP8266 is a high performance wireless SOC with the lowest cost and the greatest utility. The chip ESP8266 is shown Fig. 6.

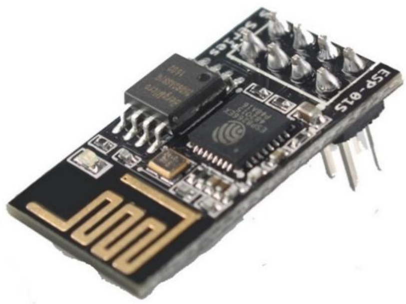

Fig. 6 The chip ESP8266

The RXD pins and TXD pins are connected to the corresponding serial ports on the ESP8266chip. Fig. 7 shows the ESP8266 module wiring diagram and table 1 shows the ESP8266 pins and function.

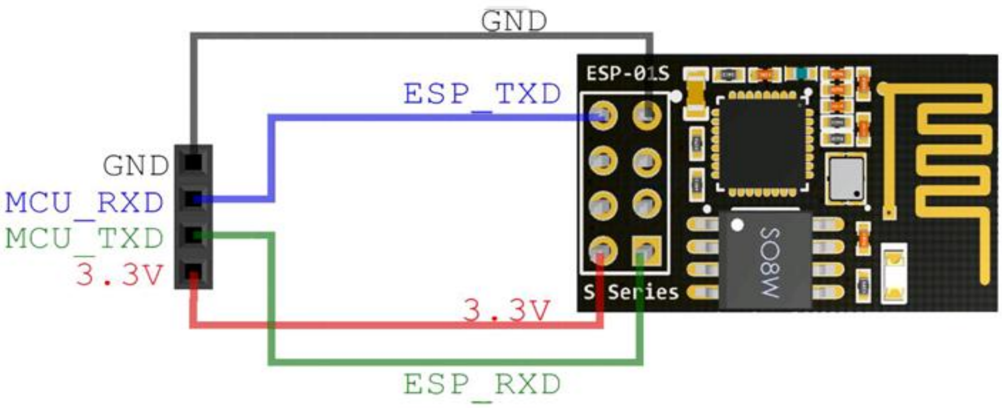

Fig. 7 The ESP8266 module wiring diagram

Table 1 The ESP8266 pins and function

pins	function
3.3	3.3 volt power supply
RX	RART_RXD, asynchronous serial receive port
RST	Reset Circuit
IO0	Connected to FLASH button, boot fails if pulled LOW
EN	Enable Pin, work at high level
IO2	HIGH at boot connected to on-board LED, boot fails if pulled LOW
UTXD	YART_TXT, asynchronous serial send port
GND	ground wire

In our study, we choose the AP mode, which is equivalent to opening a LAN hotspot, so that the external devices such as mobile phones and computers can connect to this Wi-Fi for data exchange and control.

1.4 LCD display module

The display module adopts the LCD1602, which has been widespread use for a long period of time. It consists of a character mode CD display, drive and control main circuit, extended driver circuit, a small amount of resistance, capacitance elements and structural parts assembled on the PCB board. The pins and functions of LCD1602 are described in table 2.

Table 2 The pins and functions of LCD1602

Pin	Function
VSS	power ground
VDD	positive pole
VL	LCD contrast adjustment
RS	register select pin, data register at high level; instruction register at low level
R/W	Read/write signal, read at high level; write at low level
E	Enable Pin, LCD run commands when the high level becomes low
D0~D7	8 bytes bidirectional transmission data line
BLA	Back light positive
BLK	Back light negative

1.5 LED light-compensating module

The LED light-compensating module consists of the RGB dimmers and LED lights. The operating principle of the RGB dimmer is the accurate PWM controller generated by on-board STM8S microcontroller controls RGB three-color LED lights through three on-board MOS tube driver circuits. The circuit diagram and image of the RGB dimmers are shown Fig. 8 and Fig. 9, respectively.

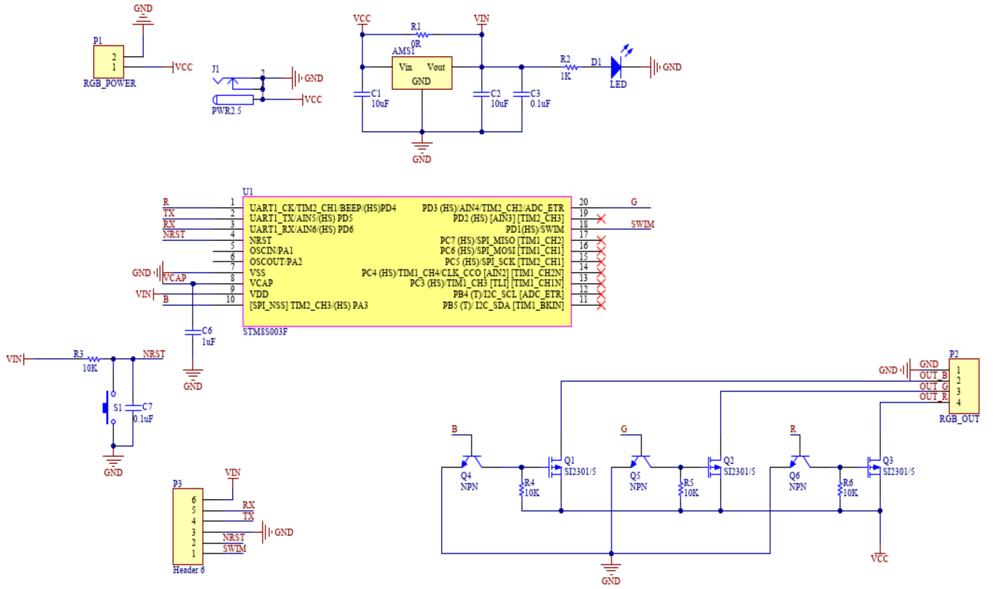

Fig. 8 The circuit diagram of the RGB dimmers

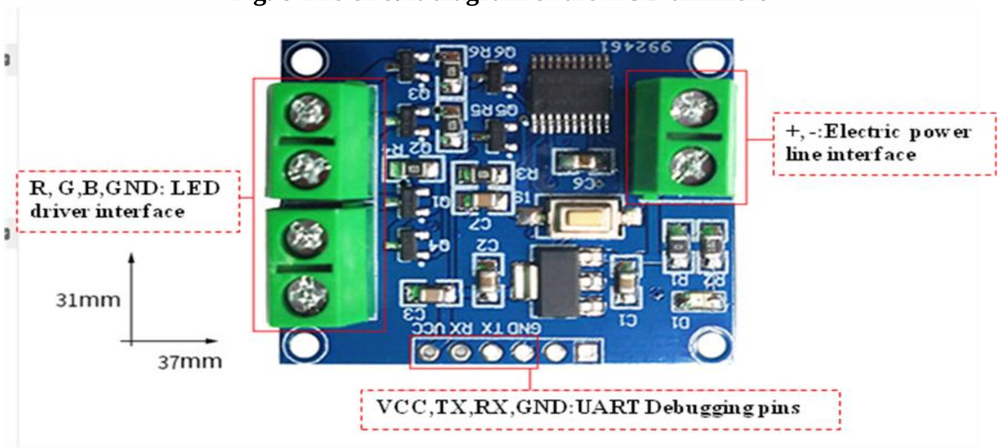

Fig. 9. The image of the RGB dimmers

The dimming principles：Different spectral ranges have different physiological effects on plants, for example, blue light stimulates plant growth, and red promotes flowering and fruiting and ripening. We adjust the ratio of red, green and blue light to meet the needs of plant production. The required light intensity parameters and duration were set by the key on the single chip microcomputer and the APP of the mobile phone.

Dimming refers to adjusting the light flux of an LED lamp through changing the driving current. We choose a constant current which adjust the duty cycle of current break as a result of the advantage of the basically fixed transient light flux, convenient to simulate calculation and accurate control.

LED has an obvious feature: the LED light flux is zero when the current is zero, and the light flux increases with the current (Fig.10).

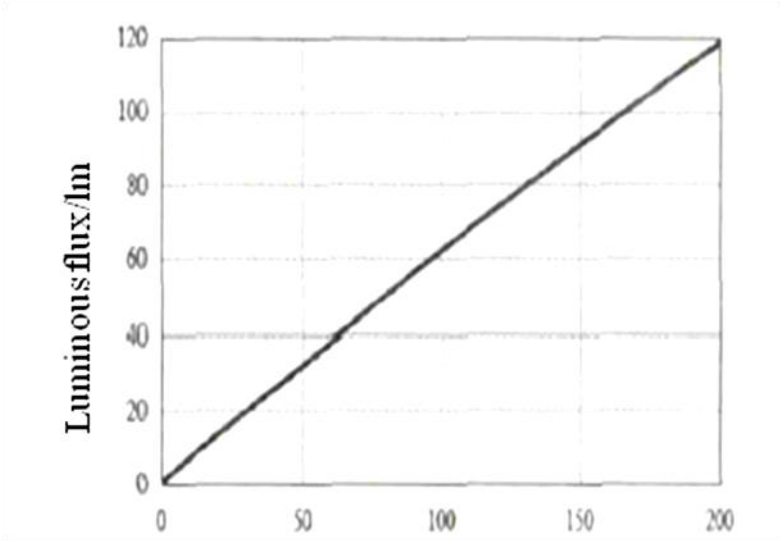

Fig. 10 The curve of light flux along with current

H(t) represents the duty cycle function, which is a periodic function and the specific formula is shown:

$$H(t)=\begin{cases}1, kT<t\le(k+\eta)T\\0, others.\end{cases} \quad (1)$$

k =0, 1, 2, … means the duty cycle. That is, the ratio of the conduction time to the whole cycle ∈ [0,1]. The schematic diagram of H(t) is shown Fig.11.

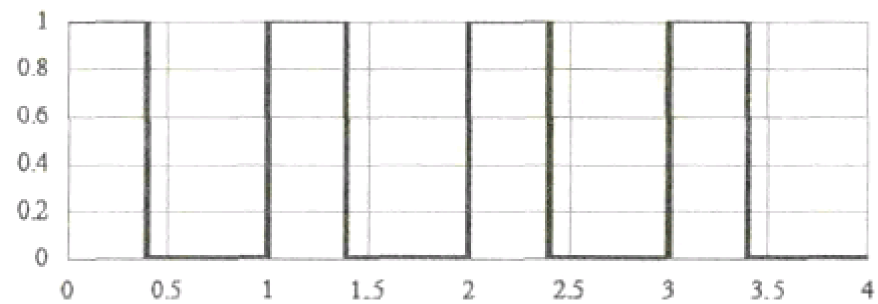

Fig. 11 The curve of duty cycle function

2 DESIGN OF SYSTEM SOFTWARE
2.1 Design of system overall program

First, the device is energized and initialized, then the clock starts to time, and the MCU driver makes the sensor start to collect and send data back to the MCU. Then the data is displayed in LCD screen and transmitted to the PC through the WIFI. After reaching the set time, the dimming module is ready to run for adjusting the light and shade and choosing the red or blue. The commands from the upper computer operated by the user are transmitted to the microcontroller through the Wi-Fi module, and the microcontroller receives the commands and execute corresponding operations. The flow chart of system main program is shown in Fig. 12.

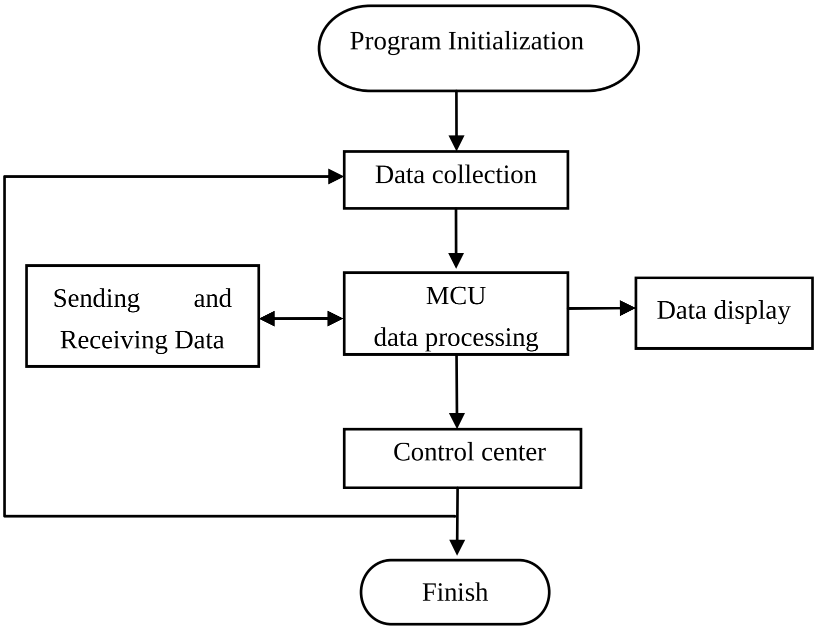

Fig. 12 The flow chart of system main program

2.2 ESP8266AT instruction sets

We adopted the AT instructions as shown below: (1) AT+RST\r\n：Restart；(2) AT+CWMODE=2\r\n：Start AP mode； (3) AT+CWSAP=\"FIRST\",\"11223344\",1,3\r\n:ConFig.urate the parameters（The commands are valid only when AP mode is enabled）, and the access point name: FIRST, and the password:11223344, channel number:1.3; (4) AT+CIPMUX=1\r\n： Start multi-connection mode; (5) AT+CIPSERVER=1,9000\r\n：Setting up the server; (6) AT+CIPSTO=0\r\n：Set the server timeout period.

3 SYSTEM TESTS

3.1 The implementation and test of the hardware

Hardware test mainly includes sensor data acquisition, transmission and steering gear rotation angle test. The proteus simulation diagram is shown in Fig. 13.

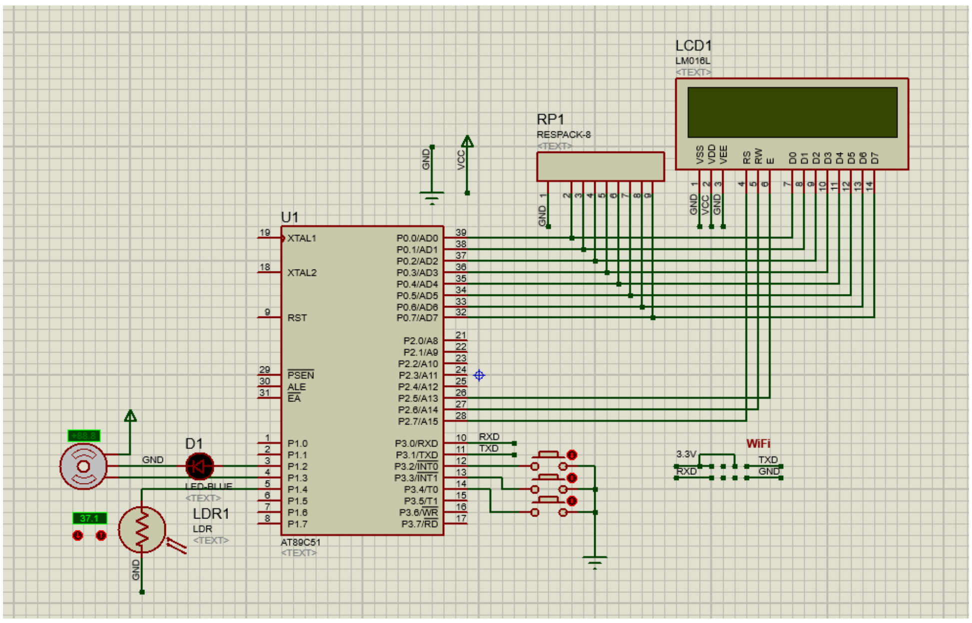

Fig. 13 The proteus simulation diagram

The purpose of sensor collection function test is to judge whether the collected data within the measurement range and the accuracy met the design requirements. After several laboratory tests, the sensor module works normally. The test results are shown in Table 3.

Table 3 The test results of the photosensitive sensors collecting data

Testing environment	Range	Result	Achieve the desired effect
The direct flashing light from phone	0~100	97	Yes
Black box	0~100	3	Yes
10:00am, indoor	0~100	63	Yes
10:00am, outdoor	0~100	80	Yes

The purpose of communication function test is to determine whether the communication line, Wi-Fi transmission and AT command response is normal. After the test, the communication line works normally, as shown in Table 4.

Table 4 The test results of communication function

Test equipment	Order type	Response	Return	Result
ESP8266	AT	OK	OK	Normal

The purpose of RGB dimmers test is to detect whether the brightness of Red, Green and Blue lamp meets the working requirements of the system. After several laboratory tests, the RGB dimmers works normally. The test results are shown in Table 5.

Table 5 The test results of RGB dimmers

Test equipment	Order type	Bright	Result
RGB dimmers	1F 01 63 85	Red 99%	Normal
	1F 02 01 22	Green 1%	Normal
	1F 03 32 54	Blue 50%	Normal

3.2 The implementation and test of the software

Software test mainly includes supplement brightness and RGB three color light ratio, light on and off time test. The Keil programming is shown in Fig. 14.

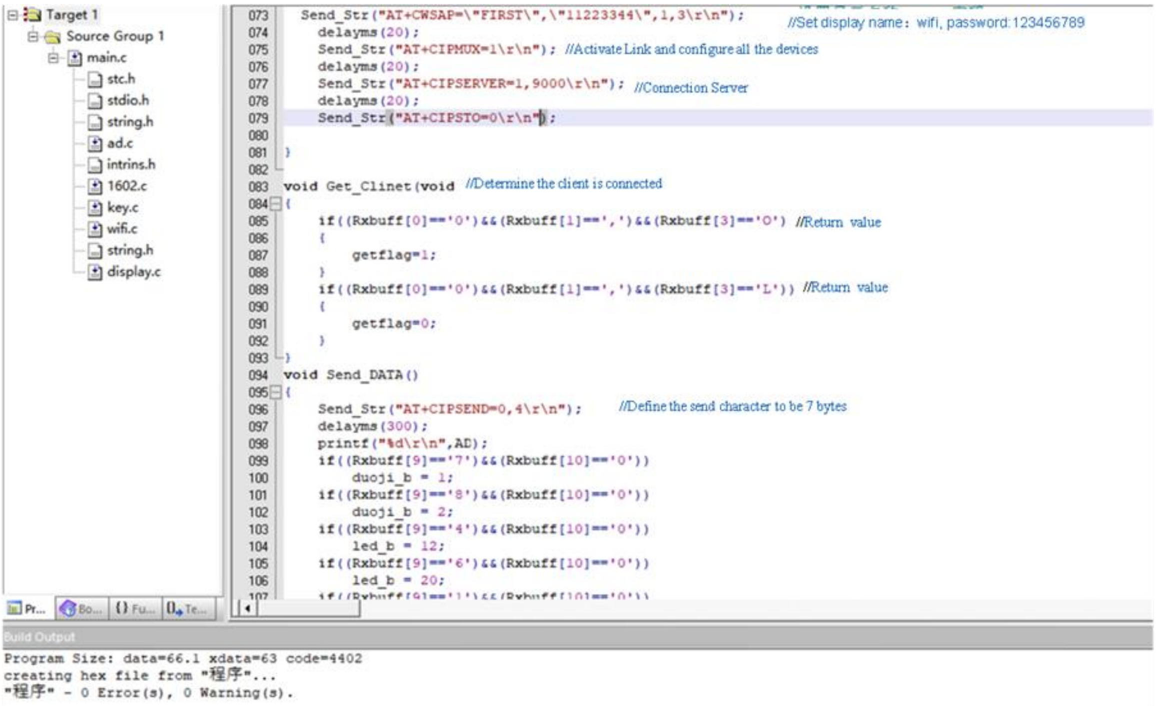

Fig. 14 The Keil programming test

In order to facilitate simple settings when the device is offline, two keys are set to adjust the brightness of the supplement light. The key function test is shown in Table 6.

Table 6 The test results of the key function test

Key	Function	Result
1	Increase	Normal
2	Decrease	Normal

The control function of mobile terminal is the core for user operation. In order to make it convenient to use, it needs to verify whether Luminous intensity, RGB ratio and Supplement light turn-on/off time can work normally. The test situation is shown in Table 7.

Table 7 The test results for control function of the of mobile terminal

Settings button	Function	Result
Luminous intensity	Adjust the supplement light intensity	Normal
RGB ratio	Adjust the RGB ratio	Normal
Supplement light turn-on time	Supplement light turn-on time	Normal
Supplement light turn-off time	Supplement light turn-off time	Normal

5.3 The program interface in the Mobile phone

Given the openness of Android system, we choose the mobile phone with Android systems to equip with the upper computer program. The program interface in the Mobile phone is shown in Fig. 15.

Fig. 15 The program interface in the Mobile phone

The program interface consists of three parts: title, control and display data area. The data collected from the photosensitive sensor module is sent to the top computer through the Wi-Fi module after processing. Similarly, the set data from the mobile phone is also sent to the MCU through the Wi-Fi module.

The detailed process is shown as follows: Enter the Wi-Fi password，connect to the system and open the upper computer after connecting the power supply. The light intensity can be displayed on the screen in real time，the larger value means the greater light intensity. Click the supplement light intensity sets and enter the required light intensity. Then click the RGB light ratio sets, and enter the required light ratio of each component, and set the supplement light turn-on/off time. If you forget to set the supplement light turn-off off time, the maximum time is 16 hours by default. Click the reset button and the time setting will take effect, and all click operations will return a TOAST reminder on the screen. The modified data can also be visually displayed on the display screen of LCD1602.

IV. CONCLUSION

In this study, we designed a orchard LED supplement light system based on wireless network with the sensor data collection and transmission, single-chip microcomputer and PC control, WIFI technologies. The system not only realized the real-time monitoring of orchard light intensity, but also enabled to display the light intensity data in real time through the phone APP, PC or LCD. Thus, it is convenient and simple to adjust the light intensity and the ratio of red and blue light according to the requirements. Our design could adjust the light parameters by intelligent control equipment, provide the most suitable light environment for fruit trees, and ensure the requirements of intelligent planting. The experiment showed that our system was stable, practical and advanced, and could effectively solve the problem of insufficient illumination of fruit trees. Our study proposes a new solution for automated agricultural Internet of things.

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