

# A Supplementary Lighting System for Plant Growth with Lighting-Emitting Diode Based on DT TS&IC

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**Abstract.** In order to achieve quantitative supplementary lighting at different stages of plant growth, design a lighting system with LED that can provide different light quality. The system monitor illumination of light quality with specific wavelength in real-time,ambient temperature, the amount of light that plant really need, and control the brightness of red, blue LED lights by pulse width modulation (PWM) signal. The system can be used for different plants at different growth stages under different environments with different demand in light quantity and quality , with accurate, intelligent, low-power features. The system prevents plants from suffering light deficiency or excess, improve energy efficiency.

## 1 Introduction

Plant growth and blossom are inseparable from light regulation and participation.With the improvement of luminous efficiency of LED,good monochromaticity, small size, long life, low energy consumption, using direct current, and low heat and the feature of flexible,LED in the area of plant cultivation will gradually replace traditional lamps[1].In agricultural fields,fluorescent lamps or high pressure sodium lamps and other artificial lights were commonly used.Compared with these artificial lights, the light quality of LED is adjustable, the heat that LED produced is less, the quality of cultivation[2] is enhanced. For agricultural production with environmental system in closed spaces, such as greenhouses, plant factory, LED is a kind of suitable artificial light sources [3]. But R/B ratio of light intensity in most existing research and development plan for plant lighting and products is constant,which is not match with the selective plant absorption spectrum.And continuous irradiation ways are often used ,which cannot adjust light density, photoperiod and irradiation way in a quantitative modulation way, without considering the difference of light quality and light quantity that plants need at different stage ,resulting in supplementary lighting insufficient or excessive[4].The problem of high energy consumption and the waste of light are still not solved[5].

Research has shown that the light involved in photosynthesis is primarily red and blue light .The wavelength coverage of them are respectively 400-500nm and 600-700nm[6].The coverage of wavelength 640-660nm red light and 430-450nm blue light are the most important for plant growth[7].Red and blue light have different influence on growth and development of plant.Different blue light is beneficial to the growth of

plant leaves, red light is beneficial to plant stem elongation[8]. Strong Blu-ray made the shape of plants lower, strong red light made plants stems too long and caused the phenomenon of yellowing[9]. Therefore, the appropriate red and blue luminous flux ratio of R/B is necessary to cultivate plants that own sound form [10].

In order to improve light utilization, and reduce energy consumption, we analysis light quality and quantity that plants really need, propose a precise method to adjust light quality and quantity,design a LED supplementary lighting system which is based on DT (detection technology), and TS(temperature sensing technology)[17,19] and IC(intelligent control technology)[12-16], all of which are modern electronic information technology[18].The system used STC12C5A60S2 single chip as core processor, PT4115 for LED drive module[20].According to the measurement result of temperature and light intensity,use PWM (pulse width modulation) signal adjusting LED light on plant aiming at meeting the needs of plants in different stages.

## 2 Supplementary lighting pattern

Light not only as a source of energy control the photosynthesis of plants, but also as a signal source affect plant growth and development in all its aspects. Blu-ray affect cryptochrome in plants, thereby regulating the phototropism of plants; Red light affects phytochrome of plant ,thereby regulating leaf differentiation of plant , so the photomorphogenesis of plants can be adjusted by changing R/B, thus breeding plants with specific form requirements. Red light of 610-720nm can reduce the content of gibberellins in plant, thus reducing section between plant height and length; R/B ratio has become an

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important assessment parameters on controlling plant growth. In the nature, as the season and weather change, the light intensity is different. Light intensity in winter and spring is weaker than that in summer and early autumn. And it is weaker in sunny days than that in rainy days. The demands of different plants on light intensity are different. The coverage of light intensity that Shade plants needs is 500~2500lx. The coverage of light intensity that neutral plants need is 2500~30000lx. The coverage of light intensity that positive plants needs is greater than 30000lx.

Considering that different photosynthetic pigment has different peaks of absorption spectrum, absorption peak of photosynthetic pigment of red light is at 625~640nm, the absorption peak of blue light is at 420~470nm, so the peak wavelength of 660nm LED as a red light, the peak wavelength of 450nm LED as a blue light [6]. In order to monitor light environment of plant growth in real-time, the spectrum of 400~500nm and 600~700nm were respectively detected by light sensor; Join the temperature detection module in this system at the same time; according to the real-time temperature, it is determined whether to supplement light. This method can improve the utilization rate of light source and prevent plants suffering harm that caused by supplementary lighting under the condition of excessive temperature stress.

Different spectral range has different effect on plant growth process. The ratio of light and the light quantity that plant growth need are different at different growth stage. Fixed light quality and light intensity of the supplementary lighting pattern is difficult to meet the demand of plant growth at different growth stage. And the light compensation point and light saturation point are different. If light intensity was lower than light compensation point, or more than the light saturation point, it will cause supplementary lighting insufficient or excessive, and cause invalid energy consumption and photoinhibition[7]. In this paper, a method that light quality is adjustable and the quantity of supplementary lighting is on-demand is presented. Users can set different value of light quality and light density according to light saturation point and light compensation point at different stages of plant growth. According to the differentials between current value and the value set before, light quantity and light quality that supplementary lighting needed in next cycle is obtained by periodic monitoring, then complete the feedback adjustment and realize the work mode that output of light intensity is on demand.

### 3 Prototype design of the system

As is shown in Figure 1, the modular design of this system consists of power module, detection module, control module, lighting module and user interface module. The power supply module uses the battery power supply mode. The red light detection module and the blue light detection module use 3V power supply; Temperature detection, buzzer, indicator light, display module use 5V power supply; Control module uses

micro-controller as the core. According to the data collected by the system, set the threshold. The calculation of the duty cycle of the corresponding PWM control signal is realized and two PWM control signals output; detection module detects red, Blue light intensity and real time temperature, and the detection signal is filtered, amplified and transmitted into the MCU, thus realize the detection of relevant environmental information; In order to achieve accurate quantitative light ,the supplementary light module uses PWM current control function with two constant current drive circuit, respectively control the red, blue LED lighting lamp array ; Display module use the LCD screen to show the test results ; Keyboard is used to achieve the required threshold modification and other functions. Completing threshold modification and setting can effectively improve the convenience and expansibility of this system.

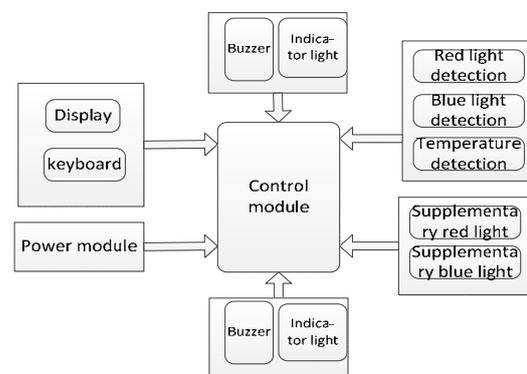


Figure 1. System principle block diagram.

## 4 Hardware design

### 4.1 Control module

The core CPU is STC12C5A60S2, it integrates the MAX810 dedicated reset circuit. And the CPU equips with two PWM outputs, four 16-bits timers, eight 10-bits-precision A/D conversion, and flash storage space of 56k and RAM of 1280 byte. They realize acquiring data, adjusting threshold and controlling intelligently. Provide foundation and guarantee for the functions of system. The circuit is shown in Figure 2. P0 is connected to the eight data ports of LCD; P1 is connected with sampling signal; the signal of double solid state reactance is exported by P1.0. the warning is produced by P1; P1.5 is accessed temperature the signal detection, P1.6, P1.7 are connected to the signals of red and blue light detection. So as to collecting data detected by sensor. P2 is connected to 4\*4 Matrix Keyboard. P3.0, P3.1 are responsible for reading and writing data between the micro-controller and port, so as to realize programming the program. P3.2-P3.7 are connected to the terminal of controlling to LCD. P4.2 and P4.3 are the ports to export signal. Adjust brightness of light precisely through controlling the brightness of the light by the PWM signal of different duty cycle.

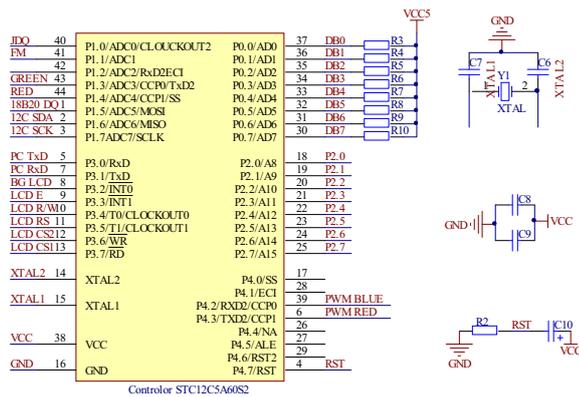


Figure 2. Principle diagram of the control module.

### 4.2 Light detection module

The module of illumination detection measured light intensity and temperature by relate sensors. And it fed back data to the micro-controller for processing; the schematic is shown by figure 3. The module of detecting temperature was composed by 18B20 and the standard adjustable circuit. It is acquired by the data-line accessing to P1.5. The detection of light included light intensity detection about red and blue. Light is filtered through different filters. The wavelength range is 400-500nm or 600-700nm. Then it detected the processed red or blue ray by light sensor of ISL29010. The detected signal was sent to SCM. The light sensor was connected to P1.6, P1.7 of SCM, so as to completing the light detection of two-band.

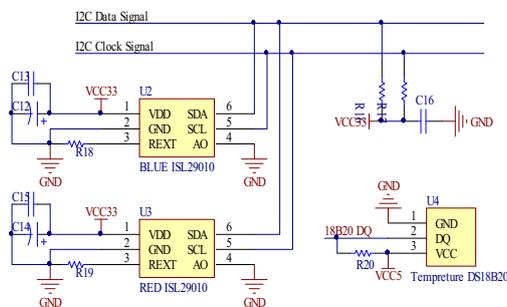


Figure 3. Light detection module.

### 4.3 Driver circuit module

LED array using step-down constant current drive mode in driver circuit module, constant color output of LED can be obtained. The module selected PT4115 constant current drive chip, driver circuit is shown in figure 4. PT4115 is a step-down constant current source with continuous inductance current conduction mode. It has a wide range of input voltage 6 V dc to 30 V , output current is adjustable, up to 1.2 A, it can drive series of small power LED. PT4115 built-in power switch, the use of high-end current sampling set the average current of LED, and DIM pin can accept the signal of analog dimming, and a wide range of PWM dimming. The largest average current of LED is determined by RS which is

connected with both ends of VIN and CSN resistance. Joining variable duty cycle of PWM signal by the DIM pin can adjust output current to achieve dimming. Output current can be calculated by formula  $I_{OUT} = 0.1 * D/RS$ , type D is in the PWM duty cycle.

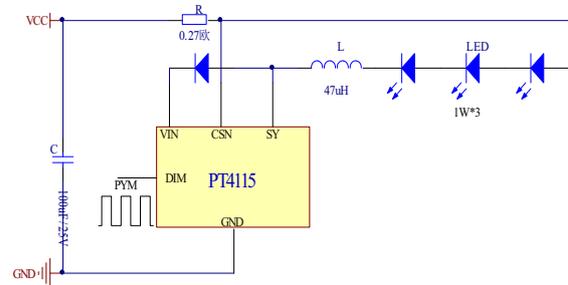


Figure 4. Principle of drive module.

### 4.4 Alarm light and keyboard module

Design detection alarm indicator module in this system. By computing amplitude changes of two adjacent light intensity in the system, and compared PWM output changes, the system automatically judge whether LED headlamp unit work properly or not. If the result of judgment is abnormal, the MCU P1.1 port will output warning signal, control buzzer and warning lights, achieve early warning function. User interaction module mainly include LCD screen and keyboard implementation system. Use 4 \* 4 matrix keyboard system to set parameters.

### 4.5 System software

System is initialized at first, users can set temperature range at different growth stage according to photosynthesis effective temperature range. Choose value between the light compensation point and light saturation point as red blue light target parameters. Collect cycle temperature to determine whether meet the requirements of the temperature of the photosynthesis, otherwise turn off the supplementary light module when it is beyond the range; If the temperature is appropriate, then the red light blue light sensors detect the current light quality, according that the filter can get specific red and blue light intensity of illumination, and then judge whether the illuminance values is within the set threshold; If the value of detected light is greater than the target value set before, turn off supplement lighting module; Instead, calculate the red and blue light by formula, the amount of supplementary equals default values minus the actual values, then according to the red and blue light quality that need to supplementary, respectively adjust PWM duty ratio signal, then realize accurate supplementary light . After a period, detect red blue light quality again, if two test results do not conform to the requirements, and then start the buzzer alarm.

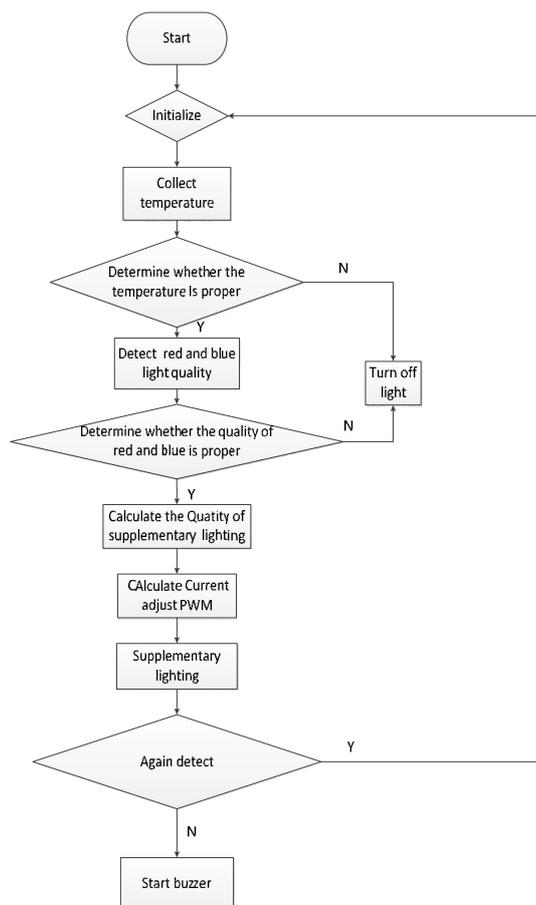


Figure 5. System software diagram.

## 5 Conclusions

Through analyzing the mechanism of supplementary lighting for plant growth during different periods, setting temperature and light intensity, light quality that plant required, developed a supplementary lighting system based on single-chip STC12C5A60S2. This system monitor real-time temperature, light intensity and other factors, and through PWM dimming, control LED, thereby control the current, realize precise supplementary lighting on demand, avoid supplementary lighting insufficient or excessive. The system can be used to cultivate plants in plant factory and greenhouse with the advantage of goal-oriented and high-efficiency supplementary lighting. The experimental results show that the system is stable. It can meet the demand for supplementary lighting for different plants at different stages with replicability.

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