DESIGN AND IMPLEMENTATION OF LED PLANT LIGHT COMPENSATION SYSTEM

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1. Introduction

Previous studies have suggested that the impact of environmental factors on the quality of crop growth is significant in the cultivation of plants. Using the LED as a light source of plant growth is most common and effective way of indoor hydroponic cultivation. As the maximum spectral sensitivity range of plants is 400~700 nm, when using artificial light to supplement the amount of light, the spectral distribution of the light source should be close to this range. The wavelength between 400~500nm of the plant irradiation is very important for the plant differentiation and regulation of stomata. The red light of wavelength at 660nm can strengthen the capacity of the plant sprouting. The light of wavelength of 500-550 nm affects the formation of the plant carotenoids while strengthening the metabolism of carbohydrates and nitrates. Appropriate UV (300~400nm) light can effectively increase the anthocyanin content (lettuce category). This study proposed a self-contained multi-band LED plant light compensation system, and applied it to a semi-open-type greenhouse. It is operated by graphic control method, and aims to solve the problem of difficulty in adjustment and inconvenient manpower management of the varied compensatory light sources of the modern greenhouse plant production systems. The proposed system can sense the intensity of the lights deficiency in the surroundings to provide different compensatory light output to optimize the plant irradiation intensity.

2. Design Concept

This light compensation system mainly consists of a proportional-gain (PD) micro control unit (MCU), expert knowledge bank, LED optical modules and photometric data conversion unit interface (as shown in Figure 1). MCU is used to determine the amount of red, light green, blue and UV lights. The expert knowedge database includes the plant growth pattern data and the relevant data of corresponding red light green light, blue light and UV light amounts. Interface converter circuit converts spectral radiation intensity into photon flux density (PFD) to comply with the light intensity and standards required for crop cultivation. Through light compensation circuit chip system, it can effectively adjust the proportions of light quality and quantity at different wavelengths according to the irradiation intensity to optimize the crop growth.

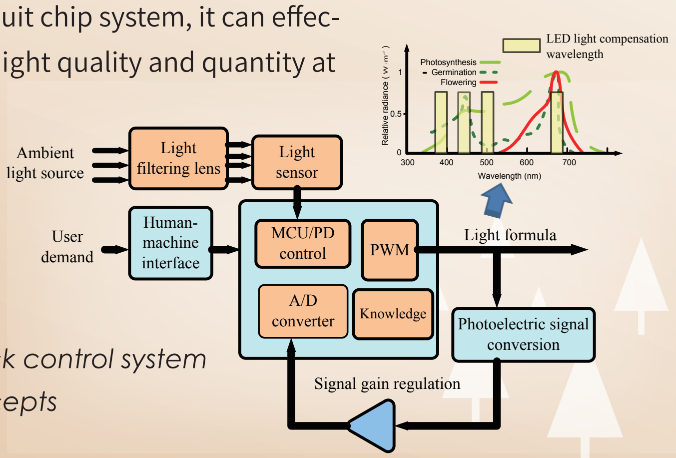


Figure 1 *PD feedback control system design concepts*

3. Technical Development

1) Hardware design principles

The proposed system uses a digital type pulse width modulation (PWM) for light power modulation. The main core digital processor uses a PD controller of 8-bit and 20 clock MHZ. Through data transmission of USB communication port, it allows the user to set the target values of human-machine interface program. The wide-band (30 nm ~ 1100 nm) photodiode in combination with filter strip allows lights of specific wavelengths to pass. The change in light is converted into signals of change in voltage by the diode module. The analog voltage passes the high precision 18-bit analog-digital chip (ADC) to enter the microprocessor as the feedback signal. When there is a gap between the set signal and the feedback signal, the control system (PD) immediately changes the duty cycle of the field effect transistor, adjusts light source power, and finally regulates the feedback signal to the same level of the specific target signals to realize the control effect. The overall control circuit output is as shown in Figure 2 (a).

2) Software Design

(1) RS-232/USB communication protocol interface development

Personal computer (PC) RS-232 communication protocol is responsible for the transmissionand echo of the data between computer and control interface. The microprocessor software is written by using C language. The design development interface can start multiple human-machineoperational windows to set different communication ports and adjust different light sources.

(2) Software graphic control interface design and development

Software graphic control interface is written with Visual Basic (VB) programming language. The human-machine interface window has functions including communication link, light source power parameters, plant growth light source parameter setting, light condition monitoring, and data logging (as shown in Figure 2(b)). Date recording is necessary for the collection of information about plant growth parameter experiments, light source irradiation condition, and system power consumption. Therefore, the system records the set target values, feedback values, power consumption information of the light compensation system every 10 min to facilitate users to perform statistics and energy conservation assessment.

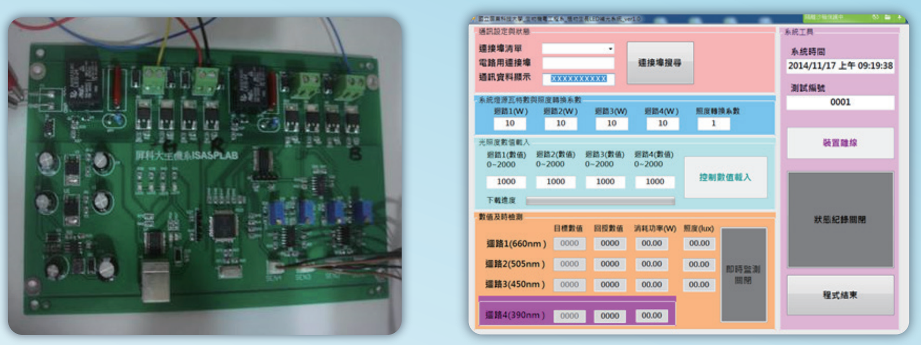
(3) Peripheral circuit program link

LED load driving circuit is displayed by 0~255 levels of light of each circuit. The input voltage terminal can be DC 24V or 15V. The power consumption of each circuit is 6 amps (can be customized). The light source can be other planar light sources. The system uses PC terminal device (Microsoft operating system). The chip software is written with C language, and the human-machine interface program is written with C and VB languages. It is connected with the microprocessor development circuit board by USB. The control parameters of the microprocessor can be changed by communication commands to modulate the wavelengths through the independent channel pulse bandwidth. Through the change in the proportion of gate opening and closing of MOSFET, LED luminance can be adjusted. The modulation principle is as follows.

$$W = W_{max} \cdot t_{on} / (t_{on} + t_{off}) \qquad (1)$$

where, W is the value of pulse width modulation, Wmax is the pulse width modulation value, ton and toff are the on and off time. Based on the above, the MCU, as the core hardware, coupled with a high-power field-effect transistors and digital pulse width modulation (PWM), can control the brightness of LED lights, thereby achieving the purpose of precise regulation.

Figure 2 *Software and hardware system implementation;*



(a) control circuit board implementation *(b) human-machine interface design*

4. Technological Competitiveness

The product competitiveness derived from the findings of this study is as follows:

1) four-wavelength light compensation plant growth lamps suitable for all kinds of plant growth;
2) automatic light compensation systems and human-machine interface software, favorable for cultivation and management and data analysis human-machine interface;
3) automatic recording of plant light intensity parameters to reduce the labor burden and get rid of the fear of insufficient supply of light;
4) the use of digital technology dimming technology, non-ordinary resistive dimming tech nology that can save energy.

5. R&D Result

The system is as shown in Figure 3, and the product specifications are as follows:

1) 4 groups of visible light wavelength sensors (wavelength ranging from 380 nm to 820 nm);
2) 4 groups of window-sized filtering pieces (filtered wavelength is subject to the user demand);
3) photoelectric signal converting module: analog / digital converter 4-channel 12 bit;
4) Light compensation system: 255-level modulation / 4-channel / 21-watt (single-circuit); Input voltage: red light LED: DC 15V; light green light / blue / UV LED: DC 24V;
5) Status monitoring and human-machine interface software: Through RS232 communication port, data exchange of light compensation setting value / current value of the state is realized; light intensity value display, set value downloading, recording and other basic functions.

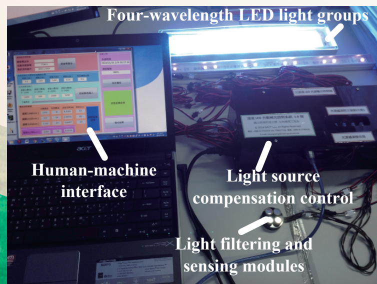


Figure 3 *Test of plant growth light source compensation system*

Acknowledges

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Reference

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