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Study and Design of a Novel Intelligent LED Lighting Controller

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Abstract: Based on the dimming characteristics of the LED lighting, a novel intelligent LED lighting controller was designed. The controller can intelligently perceive the number of people lighting places and ambient parameters, uses dual-loop intelligent fuzzy PI control algorithm to real-time adjust the brightness and color of LED light source, and achieve the best lighting effects. The controller design and implementation were described, and developed a prototype intelligent LED lighting controller. Prototype tested experimental results show that the effect of the intelligent control can be achieved, and the designed controller has good promotion prospects.

Keywords LED lighting; Intelligent controller; Fuzzy and PI;

INTRODUCTION

LED (light emitting diode) lighting has the advantage of high efficiency, good controllability, etc. As an alternative new generation lighting system to traditional incandescent, fluorescent and other lighting, with LED technology development and promotion, LED lighting has been widely used in general lighting[1-4].

Due to LED lighting dimming toner has good characteristics, can develop different control drive system, to meet different lighting need[5-12].

This paper designed a novel intelligent LED lighting controller, which can intelligently perceive the number of people lighting places and ambient parameters, real-time adjust and change the brightness and color of LED light source, to achieve the best lighting effects. Finally, a prototype intelligent LED lighting controller was developed and experimental verified.

CONTROLLER COMPOSITION AND DESIGN PRINCIPLE

Composition

The controller composition shown in Fig.1, The controller consists of MCU minimum system, the detection module, the man-machine interface module, communication network circuit, LED drive circuit and power supply modules and other components, Wherein the detection module including human infrared sensor module, light intensity and color detection modules.

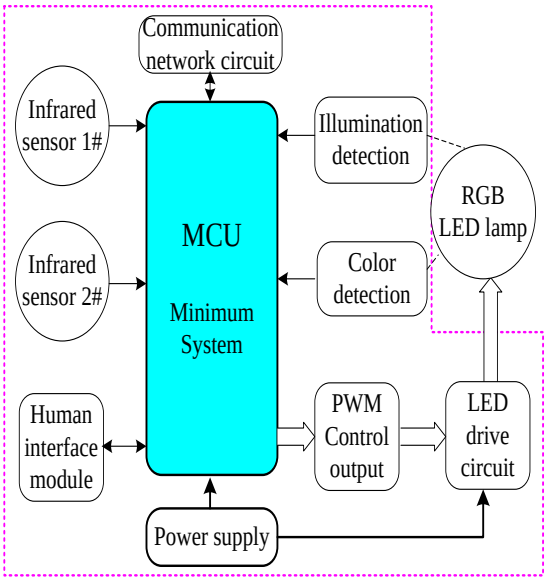

Figure 1. The structure of intelligent LED lighting controllers

Design Principle

When the controller operates, MCU acquire the infrared sensor module signal data, once detecting the signal input, controller starts working and according to the different number of people, combined with the acquisition of light and color data, after MCU intelligent fuzzy control algorithm control, the controller output three PWM control signals, adjust and change the LED driver circuit output current value, thus changing the brightness and color of LED lighting to achieve the best lighting effects.

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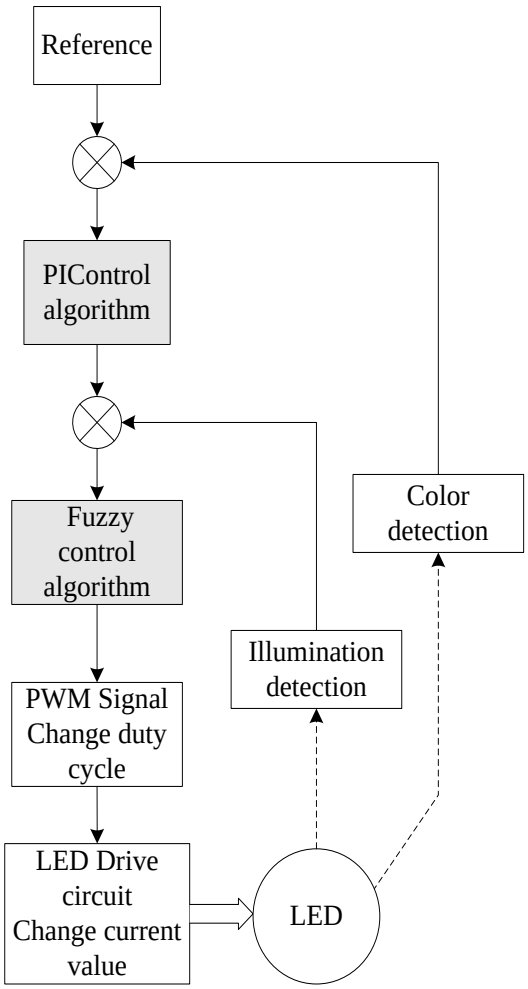

Figure 2. The dual-loops control diagram of intelligent LED lighting

The designed intelligent LED control principle diagram shown in Fig.2, according to people perceive different of LED lighting color and illumination, the outer loop color control uses classic PI control algorithm to realize the error of adjusting color LED lighting control.

The number of different preset values detected by the human infrared sensor module is given by the look-up table, and as compared with the measured values of the color detection, preset values based on the different detect number of human infrared sensor module, given by look-up table, and as a comparison with the measured color value, the error value as input of color PI controller, the corresponding output different duty cycle value tri-color RGB LED driving control signals, send the illumination intelligent fuzzy controller, then compared with the illumination detection value, resulting error and error change rate fed into the light intensity adjustment control intelligent fuzzy controller, the output of fuzzy controller is at the same time changing RGB three PWM duty cycle changing values. The new three-way final output PWM control signal,control and adjust the LED drive circuit output current value, to achieve LED light dimming and color control.

CONTROL ALGORITHM

Color PI controller design

For the outer loop color control, digital PI controller[13-15], control algorithm expression as shown in formula (1):

$$d_{ct}(t) = K_p e_{ct}(t) + K_i \int_0^t e_{ct}(t)dt \quad (1)$$

Wherein K_p is a proportionality factor, K_i is the integral time constant, $e_{ct}(t)$ is the error signal of color, $d_{ct}(t)$ is the controller output signal. Formula (1) is discretized, the MCU can realize digital PI control algorithm by the program and implemented by software programming.

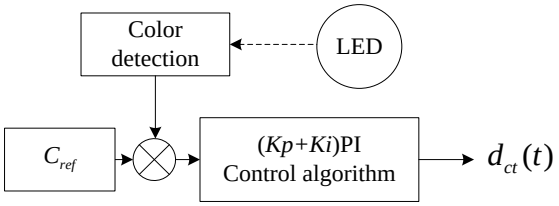

Figure 3. Color PI controller structure

Illumination fuzzy controller design

Illumination inner loop control using intelligent fuzzy controller to achieve dimming control. Fuzzy control is a computer-based digital control of fuzzy set theory, fuzzy linguistic variables and fuzzy logic[16]. Its biggest feature is the expression expert control experience knowledge into the control rules language, use rules to control the target system[17]. The fuzzy control is introduced to the intelligent LED lighting illumination control, to improve the accuracy and effectiveness of the light adjustment control.The control design uses a dual-input single-output fuzzy controller to achieve fuzzy illumination adjustable control, the structure of designed fuzzy controller and shown in Fig.4.

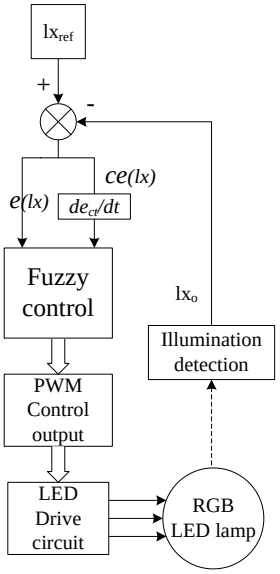

Figure 4. Illumination fuzzy controller structure

The input of illumination fuzzy controller are illumination error e (lx) and the error rate change ce (lx), the output is duty cycle change value of PWM control signal d (lx).

The input fuzzy linguistic variable values of eeror variable E and eeror change variables CE selected {negative big (NB), negative medium (NM), negative small (NS), zero (Z), positive small (PS), middle (PM), positive big(PB)}, the output linguistic variables selected D {negative big (NB), negative small (NS), zero (Z), positive small (PS), positive big (PB)}.According to the requirements of LED lighting dimming control and control experience, adoption fuzzy control rules as shown in Tab.1.

Table 1. Illumination fuzzy control rule

D		*E*						
		NB	NM	NS	Z	PS	PM	PB
CE	NB	NB	NB	NB	NB	NS	NS	Z
	NM	NB	NB	NB	NS	NS	Z	PS
	NS	NB	NB	NS	NS	Z	PS	PB
	Z	NB	NS	Z	Z	PS	PS	PB
	PS	NS	NS	Z	PS	PS	PB	PB
	PM	NS	Z	PS	PS	PB	PB	PB
	PB	NS	Z	PS	PB	PB	PB	PB

INTELLIGENT LED CONTROLLER DESIGN AND IMPLEMENTATION

Hardware Design

The intelligent LED controller hardware including MCU control module, sensor module, human-machine interface module, communication module, LED drive circuit module, communication modules and other components. System hardware structure shown in Fig.5

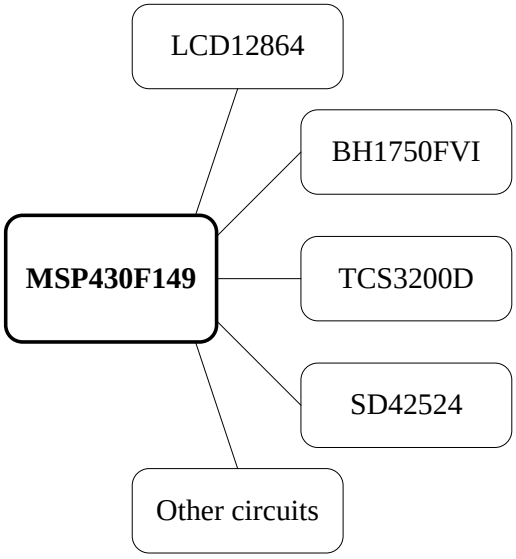

Figure 5. Hardware circuit diagram

MCU control module as the core of intelligent LED controller,the MCU selection TI's MSP430F149 main control chip, the chip has advantages of low power consumption, stable operation system,high-performance analog technology and many on-chip peripheral modules, etc[18].The MCU minimum system circuit schematics shown in Fig.6.

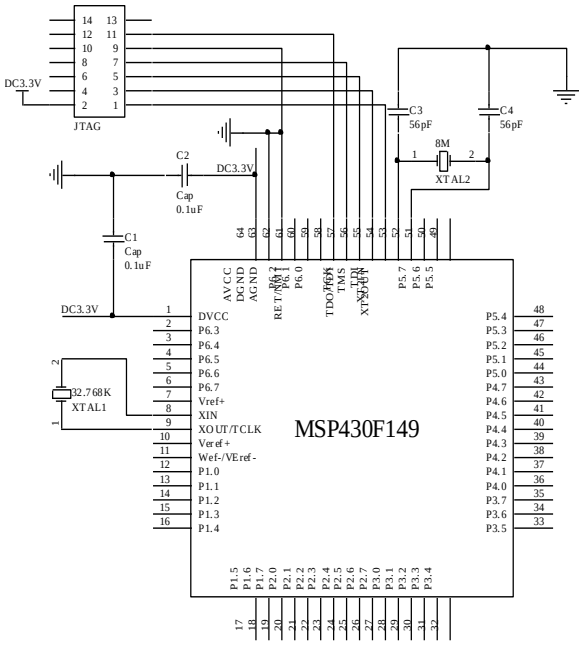

Figure 6.MCU minimum system circuit schematics

The people number and folw sensor detection module selects pyroelectric infrared sensor module[10].Light intensity sensor selects 16-bit digital ambient light intensity sensing BH1750FVI, the sensor chip can detect 1lx-65535lx range of light intensity, and communicates with the MCU via IIC bus. The color detection sensor select TCS3200D, through its red, green and blue tristimulus values of the sensor to obtain highly accurate color measurement[19]. Communication module uses RS485 bus circuit, achieve the controller networking and remote operation control. Human interface module includes a key input and display output, which display part select LCD12864 liquid display that can display real-time status of the people number, light intensity, color values and other parameters of the controller information. LED drive circuit used Buck, PWM control, power switch built-in LED driver chips SD42524 composition, using three independent RGB drive power circuit, three PWM control signal microcontroller output constant current regulator, in order to achieve LED lighting smart dimming and color control.

Software design

The design and development of intelligent control software use modular programming ideas, mainly including: the main program, sensor data acquisition routines, digital PI and fuzzy control subroutine, PWM control subroutine, the man-machine interface

processing routines, communication subroutine modules. When the controller working, after initialization subroutine call to the man-machine interface, to determine whether the controller is turned on，then call the appropriate sensor detection subroutine, human traffic, light intensity and other parameters of information acquisition and processing, intelligent control subroutine call, complete intelligent LED lighting dimmer control palette, the design of the main program flow chart shown in Fig.7.

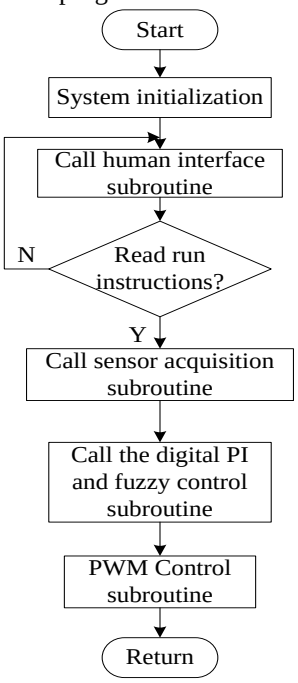

Figure 6. Controller main program flow chart

RESULTS AND DISCUSSION

Development of intelligent LED controller prototype was tested using three experimental LED light source lamp beads RGB1W. By changing the control signal duty cycle of the controller in real-time realization LED light source dimming and color control,the different lighting colors in Fig.8.

Figure 8. Experimental different lighting colors

The recording PWM control signal waveforms shown in Fig.9.

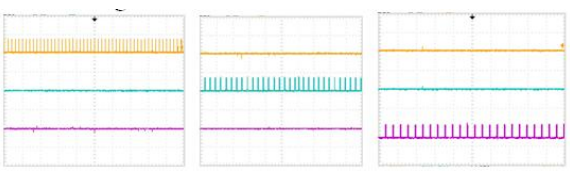

Figure 9. PWM control waveforms

Experiments under the people flow in different environmental conditions under different illumination were carried out, the controller can achieve high-precision control dimming and color control.

CONCLUSION

A novel intelligent LED lighting controller was introduced and designed in this pape.The designed controller based on different lighting applications, used color and illumination dual loop control strategy, the color outer control used digital PI control algorithm, the inner illumination used fuzzy intelligent control algorithm.

The development and implementation of controller hardware design and software were described. Finally, the prototype was tested experimental results show that the effect of the intelligent control can be achieved, which has good promotion prospects.

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REFERENCES

Fu Shaobo, ChenXi, ZhangTao, Sun Yingke. The fuzzy controller in the application of the temperature control of centre air-conditioning system[J]. Microcomputer Information,2005,21(4):36-37

GAO Yingming,ZOU Nianyu,BI Jianfeng,GUO Xu,CAO Guanying. Energy efficient characters of LED daylight lighting system[J]. Journal of Dalian Polytechnic University,2013,32(5):367-370

GHANG Jing.YANG Yingping.GHANG Jinmin,CHEN Mengwei. Color reproduction and classification with TCS3200D[J]. Engineering Journal of Wuhan University,2013,46(2):258-260

GONG Rui-rui,GE Hong-juan. The Conception of a Constant-current Drive Circuit of the Dimmable High-power LED Illumination[J]. Power Electronics, 2011, 45(6): 97-99

JIA Zhengsong. Design of Intelligent-illuminating Control System Based on Single Chip Computer[J]. Modern Electronics Technique,2009(17):105-107

LEI H，NADARAJAH N． An accelerated test method for predicting the useful life of an LED driver[J]. IEEE Transaction on Power Electronics,2011,26(8) :2249-2257

LI Xuan,JIN Shang-zhong, WANG Le,WANG Yan-hua,LIANG Pei,GEN Song-yuan, LI Xiao-yan. Effect of different color temperature LED sources on road illumination under mesopic vision[J]. Journal of Optoeleclronics .Laser,2011,22(7):997-999

LI Yuqin, CHEN Changying, WANG Yuan, LIU Pingyu, WEI Qifeng. Design of Auto Control of Color Temperature for White-LED Lighting System[J].

LIU Pingyu, CHEN Changying,ZHANG Hao,LI Yuqin, CAI Rong. Adjustable Color Temperature LED Illumination System Based on RWB Model[J].

Lv Haiiun. The Current Situation and Future Prospect of China's LED Industry Development[J]. China Illuminating Engineering Journal, 2013,23 (4):6-10

MA Teng,LI Yuan,LI Bao—ying,LU Ying. Design for intelligent control system of LED street lamp[J]. Journal of Dalian Polytechnic University,2012,31(2):75-78

TANG Zhi-de, WANG Guan-tao, YANG Hong, et al. The power supply based on BUCK with active ripple compensation for LED[J]. Journal of Chongqing University,2012, 35(12): 40-45

Tian Lidong, Zhou Jijun, Qin Huibin. Design of PWM dimming LED driver [J]. Journal of Mechanical & Electrical Engineering, 2012, 29(4): 465-468

WANG Ji-yong,WANG Jian-ping. A Dimming Method for LED Based on Two Channels' PWM[J]. Opto-Electronic Engineering,2012,39(7):132-136

XIONG Zhen-xing,HUANG Shi-sheng,LI Peng,TANG Chao-yang. PI-based Digital Control of Inverter Power System for Fuel Cell Power Plant[J]. Power Electronics,2009,43(11):33-34

Xu Daisheng,Chen Xiao,Zhu Xiang,Zheng Lihua. A Dimming Lighting Source Based on Cold and Warm White LEDs[J].ACTA OPTICA SINICA,2014,34(1): 0123004

YANG Jian-feng,WANG Shuai,XIE Yan-kai. Research on Expert PI Control of Active Filter DC Voltage[J]. Power Electronics, 2014,48(9):71-73

ZHANG Yangfei,YUAN Yue,HAO Sipeng,ZHU Jianzhong,CHEN Buyun,LU Hairong. Parameter identification of digital PI controller and experiment validation[J].Electric Power Automation Equipment, 2010,30(11):40-42

Zhou Xiaoming, Shao Zhidong and Xu Jiabin. The impacts of different wave range LED on non-visual effects[J]. JOURNAL OF SHENZHEN UNIVERSITY SCIENCE AND ENGINEERING,2014,31(4):410-414

Zhang Hao, Xu Haisong. Comparative study of correlated color temperature algorithm for lighting sources [J]. Optical Instruments, 2006, 28(1): 54-58