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A novel automatic lighting control system combined normal lighting and emergency lighting[1]

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Abstract. The normal lighting and emergency lighting are divided into two separate systems in practice. In order to reduce the waste of resources and system complexity, this paper proposed an automatic lighting control system based on MCU (Micro Control Unit). This system can intelligent adjust the brightness of LED in different condition by using PWM (Pulse Width Modulation). It also should steadily work in fire by design two separate power supplies (mains supply and battery). It integrates all nodes into a unified management by server based on communication module, which improves the intelligence of the system.

Key words. Normal lighting, emergency lighting, automatic lighting control, PWM..

1. Introduction

Over the last several decades, intelligent-building has widely been paid attention which provide users an efficient, convenient, comfortable and humanized architectural environment [1]–[3]. Normal lighting and emergency lighting are two important parts to evaluate the intelligent level of building. There are many laws and regu-

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lations, industry standards have issued. In China, Code for Fire Protection Design of Building(GB50016-2014) has expressly stated that staircase and atria need set fire emergency lighting when building is higher than 27 m [4]. Without doubt, normal lighting is also needed to meet the living of people. By new Europe standard (EN50172), large intelligent-building ought to set the automatic emergency lighting test system to check the battery and lamp conditions [5]. Besides, all data collected from this system need uploaded to servers by communication system, which will store and analysis these data to monitoring the operation of building in real-time.

There are still some differences between normal lighting and emergency lighting, even all of them are necessary parts of building. First of all, normal lighting used in normal circumstance, should controlled by manual, audible or infrared signal. In the case of fire condition, emergency lighting need activated rapidly. It only obeys the FAS (Fire Alarm System). Then, they require different power sources. Emergency lighting supplied from battery, while normal lighting can powered just by mains supply. And last, the illumination intensity of emergency lighting is only asked not less than 5 lux. This paper proposed a novel automatic lighting control system to integrate emergency lighting with normal lighting. The system contains 10 parts, they implement rectification, energy storage, power supply switch, LED, LED drive, voltage acquisition, infrared induction, CAN (Controller Area Network), single-machine control and network control, respectively.

2. The proposed automatic lighting control system

In this section, the details of the proposed automatic lighting control system are described. According to the function of this system, a simple architecture is shown in Figure 1 and the procedure of the system is summarized as follows:

1. System Initialization
2. while if MCU received fire signal from server
3. then open LED as emergency lighting
4. else if someone enter infrared detection area && environment luminance is low
5. then open LED as normal lighting
6. end if
7. end if
8. if battery is low
9. then charging battery
10. end if
11. MCU upload system data to server

12. end while

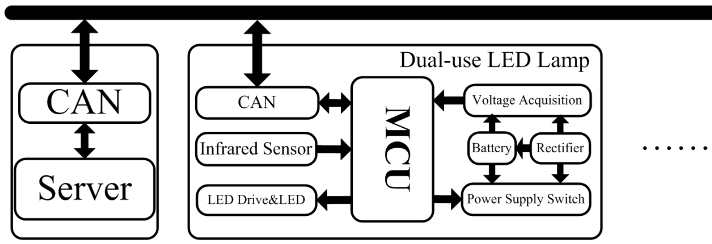

Fig. 1. The architecture of system

2.1. MCU

The performance of MCU is the decisive factor for arbitrary automatic control system. Just as the system need work in extreme circumstance (eg. fire, power-off), MCU must possess the characteristics of low energy consumption and stable performance. STC15W401AS has width operating temperature rage, from $-40\,^{\circ}\mathrm{C}$ to $85\,^{\circ}\mathrm{C}$. In energy consumption, it only consumed $4\,\mathrm{mA} - -6\,\mathrm{mA}$, corresponding to $20\,\mathrm{mW} - -30\,\mathrm{mW}$. In normal operation, MCU collects signal from infrared sensor in real time. It will activate normal lighting (LED) when infrared sensor detect people enter the surveyed area in dark environment. Due to the system need obtained energy from mains supply or battery in different condition, MCU also controls energy supply switch to alternate the energy source. Certainly, MCU collect voltage information uninterruptedly and decide whether charge energy from mains supply to battery. MCU also communicate with server through CAN module.

2.2. LED module

Contrast ordinary light source, LED has the advantages of small size, high luminance, low heat, long life with low consumption. As the execution unit of the system, LED give out high-light in normal lighting and dim-light in emergency lighting. There are two methods to adjust luminous intensity of LED: PWM or only open a few lamp beads. Compare to the former, the latter can't electrodeless dimming and it may cause unequal working hours to each lamp beads. Hence, this paper adjusts the luminous intensity by PWM. We use NCP5006 as the LED driver which not only can drive several LED at the same time, but also provide OVP (Over Voltage Protection) and OTP (Over Temperature Protection).

2.3. Energy module

Battery can used in system directly since it worked under 5 V DC, otherwise, mains supply need dropping and rectification. And we select LT1510 as battery charging chip. The normal lighting powered by mains supply, however, emergency lighting have to powered by battery since mains supply require cut off in fire. The battery needs provide enough power to make sure the system work for 90 min stability. Just as the highest energy dissipation chip is LED, it also becomes the focus of us. The battery classical energy capacity can calculated through

$$F = \frac{P * t_{\text{work}}}{(A_1 - A_2)}\,, \tag{1}$$

where F is battery classical energy capacity, P is power of LED, t_{work} is working time, A_1 is battery discharge efficiency and A_2 is battery self-discharge rate. All the power of LED and working time must meet the minimum requirements. The battery discharge efficiency, which contained in denominator, represents the total energy can released by battery before it cut-off discharge. The vast majority of efficiency is distributed from 85 % to 95 %. In previous work, the Boltzmann function fits self-discharge rate perfectly [6]. The self-discharge seriously with time increased. They meet the following relationship

$$A_2 = \frac{\alpha}{1 + \exp\left(\frac{t_{\text{shelve}} - t_0}{dt}\right)} + \beta\,, \tag{2}$$

where t_{shelve} is shelve time. α, β, t_0, dt are constants. It is well known that, battery self-discharge rate is connected with shelve time and temperature [7]. Under the same temperature, the self-discharge rate will improve as time goes on. At different temperature, the self-discharge rate curve based on time has shown in Fig. 2.

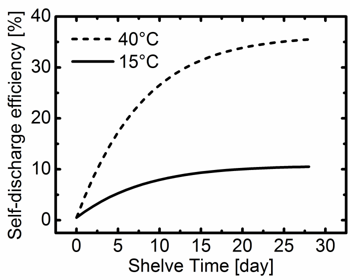

Fig. 2. Battery self-discharge efficiency

According to Fig. 2, the main self-discharge occurs in first 20 days, no matter under 15 °C or 40 ∘ C. In last 10 days, the curves tend to be steady. Combine the power of LED is 1 W and work time of system in fire is 90 min, we can get that the lowest battery energy capacity is 400 mAh by set $A_2 = 10\,\%$ and $A_1 = 85\,\%$ in Eq. (1). This has a guiding significance to select battery type.

2.4. Communication module

This system requires real-time communication between MCU and server. Consequently, the server can monitor the system state, meanwhile, it can send instruction to MCU in fire conveniently. We use CAN in this system since it is high reliability, good performance of real-time and strong flexibility [8], [9]. A total of 110 network nodes can linked to CAN, it is enough to a fire unit.

More essential, server can send a global force instruction to turn on LED disposability through CAN since all data are transmitted over two lines. This extremely high response speed has great significance when the fire broke out.

2.5. Server

The main functions of server were enumerated as follows: firstly, it need detect environment status and change the system from normal mode to fire mode when fire broke out. If the fire scope is small, the server can only open the relevant area LED to reduce energy consumption. Secondly, server can stores data which uploaded from MCU, including LED condition, battery capacity and so on. The server can determine the state of the system through data monitoring and analysis. When the system appearance abnormal situation, the server also can alert controller accurately and timely. Thirdly, the server should open LED as normal lighting in dark when mains supply interruption, all the power of system supplied by battery. Fourthly, system prefer powered by mains supply over battery if mains supply remains stable in fire. This can save battery energy and improve system robustness.

3. Conclusion

In this paper, we have proposed a novel automatic lighting control system based on MCU, LED and other modules. Compare to previous work, this system integrates normal lighting and emergency lighting without complex design or extra invest. Since the system powered by mains supply, system will adjust PMW to set LED attain full brightness. On the contrary, the energy resource of system in fire is battery. In order to select a reasonable battery model, the limit of battery energy capacity is discussed based on several elements: the power of LED, system working time, battery self-discharge rate and discharge efficiency. Profit from the server, system can work in multiple modes and should connected to other intelligent systems. This automatic lighting control system has a wide application prospect.

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