Developing Controller Apparatus to Extend Lifetime of LED Sensor Luminaire

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Abstract

The lime time of LED sensor luminaire decreases due to many factors, being the heat is one of them. We develop a controller to expand the lifetime of LED sensor luminaire. By controlling the current through the LED, the temperature of PN junction of LED maintains the proper level to prevent the overheating of LED, then the lifetime can be expanded. This study measures the illumination of Maximum life span refers to a measure of the maximum amount of time one or more members of a population has been observed to survive between birth and death. This study shows the method to measure the illumination of LED, controls the amount of current flows in order to maintain the level of illumination of LED output, extend the lifetime of LED, and guarantees the minimum illumination of LEDs.

Keywords: *lifetime, luminaire, electron-hole pair (EHP), recombination, light-emitting diode (LED), dopant, LED oscillator*

1. Introduction

Lifetime refers to the length of time of how long a product is expected to operate as intended, given a specific set of environmental and mechanical requirements. A luminaire's "lifetime" or "end of life" is known to be when it no longer emits light. For conventional lighting technologies, the "rated life" of a light emitting diode (LED) sensor luminaire, for example, is usually considered to be the time when half of the LED sensor luminaire have failed [1]. LED is essentially a PN junction diode made from a direct band gap semiconductor in which the electron-hole pair (EHP) recombination results in the emission of photon. The emitted photon energy is approximately equal to the band gap energy. Emission of photons by recombination of electrons and holes in direct band gap materials. The photoluminescense is due to excess electrons and holes required for the radiative recombination generated by photon absorption and the electroluminescense is due to excess electrons and holes required for the radiative recombination as result of an electrical current. LEDs, as solid state light sources, are characterized by long lifetimes when operated under certain conditions. However, like any other device they gradually lose their performance over time. The true reliability and lifetime of light-emitting diode (LED) lighting systems is generally not known. Even worse, lumen maintenance values of LED devices are widely used as a proxy for the lifetime of an LED lighting system, which is misleading since lumen maintenance is but one component of a luminaire's reliability. In fact, quite often the lifetime of a well-designed and manufactured luminaire is not determined by LED lumen depreciation [2]. The LED is a semiconductor light source. LEDs are used as indicator LED sensor luminaire s in many devices and are increasingly used for other lighting. Appearing as practical electronic components in 1962 early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness [3, 4].

In contrast to the conventional lightening system such as incandescent LED sensor luminaire and fluorescent light, LED the efficiency of transforming electric energy to light energy is 90 % at most, so that energy can be conserved. In general, when the illumination of LED at a specific time reaches at about 50 % of the initial illumination, the lie time is considered as expired. As time elapses, the brightness of LED decreases with the same amount of input current.

2. System Configurations

2.1. Schematic Diagrams of Light Emitting Diodes (LED)

Figure 1 shows a two-dimensional schematic diagrams of light emitting diodes (LED).

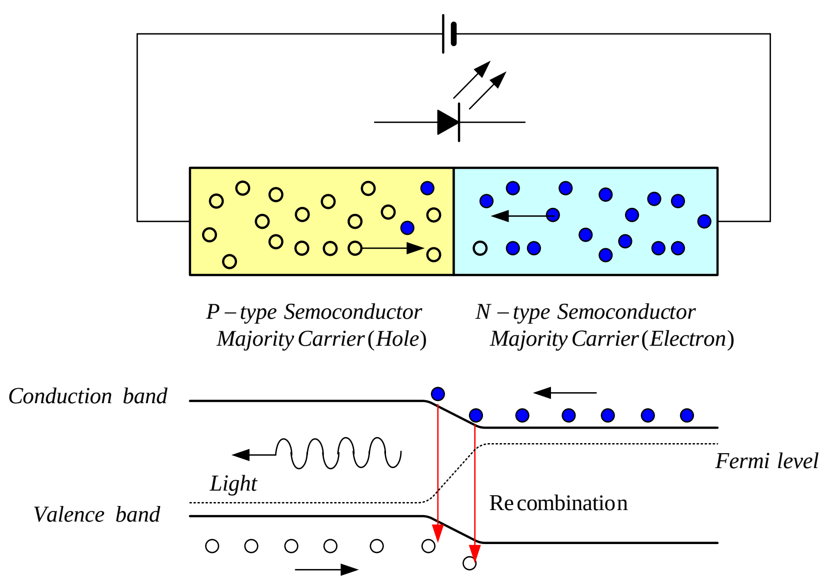

Figure 1. Schematic diagrams of Light Emitting Diodes (LED)

The deterioration of the LED is determined by the temperature and current of operation, it is due to the temperature of PN junction of LED, where a PN junction is a boundary or interface between two types of semiconductor material, p-type and n-type, inside a single crystal of semiconductor. It is created by doping, for example by ion implantation, diffusion of dopants, or by epitaxy (growing a layer of crystal doped with one type of dopant on top of a layer of crystal doped with another type of dopant). If two separate pieces of material were used, this would introduce a grain boundary between the semiconductors that severely inhibits its utility by scattering the electrons and holes. p–n junctions are elementary "building blocks" of most semiconductor electronic devices such as diodes, transistors, solar cells, LEDs, and integrated circuits; they are the active sites where the electronic action of the device takes place. For example, a common type of transistor, the bipolar junction transistor, consists of two p–n junctions in series, in the form N–P–N or P–N–P [5, 6]. The majority carriers, holes in P-type semiconductor and electrons in N-type semiconductor recombine for the proper operation of LEDs. Majority Carriers that are injected to the opposite side of the diode under forward bias become minority carriers and recombine. In a direct band gap material, this recombination can result in the creation of photons. In a real device, special areas are used to trap electrons and holes to increase the rate at which they recombine. These areas are called quantum wells [7].

2.2 Overall Configuration of the System

When the operating temperature of PN junction in the LED is high, the lifetime becomes shorter, and when the operating temperature of PN junction in the LED is low, the lifetime becomes longer. In order to implement LED system with a longer lifetime, a radiator was used to send heat from the system to the surrounding space. However, due to the area, volume, and the weight of radiator, larger than the LED system, and it was not easy to implement the LED system in the integrated packages. The goal of this paper is to present a design of controller to extend the lifetime of LED system by maintaining the proper temperature of PN junction of LED [8]. The temperature of enclosure is measured to control the current through the system using the temperature resistance from junction to the enclosure. Figure 2 shows the control system designed to expand the lifetime of LED illumination composed of several subsystems.

1. The LED oscillator, comprised of two or more LEDs, is operating to receive the voltage input signal.
2. Voltage source used to supply voltage to ignite the LED oscillator. It regulates and normalize an alternating voltage signal of 110 or 220 V to ignite the LED oscillator.
3. Current meter measures the current applied to the LED oscillator. As the current through the LED increases, the temperature of PN junction in the LED easily increases, then the lifetime of LED decreases. Therefore the current is a crucial indicator to predict the lifetime of LEDs.
4. Temperature indicator to measure the temperature of LED oscillator and enclosure of LED illumination system.
5. Measurer of light speed to detect the speed of light from the LED oscillator.
6. The controller measures the temperature of junction of LED included in the LED illuminant, and controls the current to keep the level of illumination to a constant level based on the ignition instant and measured output of measurer of light speed. Based on the ignition time and light speedometer, the light from the LED emitter maintains to a certain level of initial illumination. In other words,

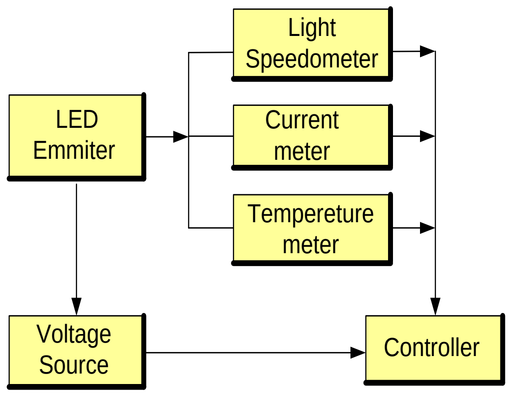

Figure 2. Overall configuration of the controller system to extend the lifetime of LED sensor luminaire

3. Configuration of Thermal Resistors in the Temperature Meter

In Figure 3, the detailed configuration of digital signal oscillator is shown. It is composed of the current source, three resistors, and two capacitors. If the thermal resistance of temperature indicator is 50℃ the temperature of PN junction, dissipating a power of 1 watt, is 75℃. If the temperature of surrounding space is 85℃,the temperature of PN junction, dissipating a power of 1watt, is 135℃. For the temperature of 135℃ in the junction, the lifetime of LED sensor luminaire is expected to be about 30,000 hours.

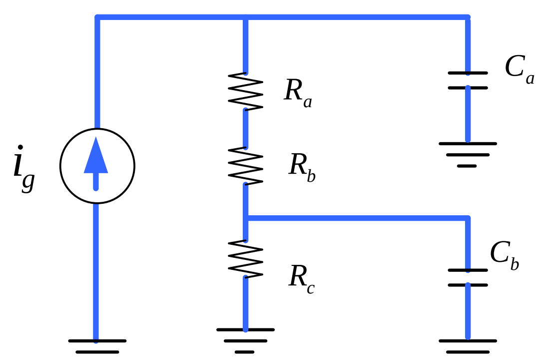

Figure 3. Detailed configuration of thermal resistors in the temperature meter

If we decrease the dissipating power from 1 watt to 0.6 watts by decreasing current through the LED emitters, the temperature at the PN junction is equal to 85+(50*0.6)=105 degrees in centigrade. The temperature tells the expected values of lifetime to be 50,000 hours. In other words, if the amount of current through the LED emitter is reduced by 40% and the temperature of PN junction is decreased, then the expected lifetime can be extended by 20,000 hours. Figure 4 shows a lifetime of LED sensor luminaire from the datasheet of technology white paper of Philips. It shows the changes in junction temperature affect the useful lifetime of an LED. All electric light sources experience a decrease in the amount of light they emit over time, a process known as lumen depreciation. Incandescent filaments evaporate over time and the tungsten particles collect on the bulb wall. The primary cause of LED lumen depreciation is heat generated at the LED junction. To provide an appropriate measure of useful life of an LED, a level of acceptable lumen depreciation must be chosen. These were the highest output Luxeon emitters produced, with single-emitter flux of up to 200 lumens at 1500mA. They produced more light than the Rebel line which replaces them. The new Altilon line produces more output per device, but barely exceeds the K2 in lumens per die. The K2 was the first Luxeon product to allow the use of FR-4 PCB material instead of metal core, but only at reduced current or under exceptionally favorable thermal conditions.

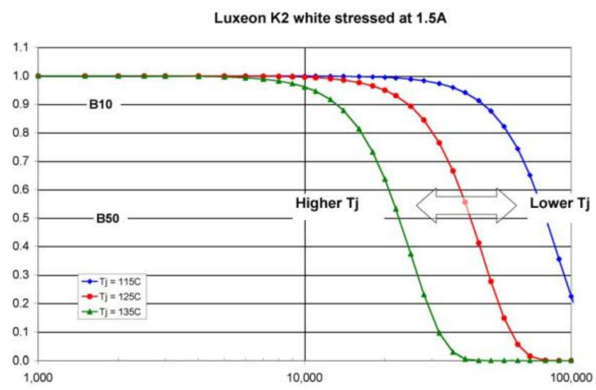

Figure 3. Lifetime of LED sensor luminaire from Philips

The current amount can be increased or decreased depending on the pre-set tolerance based on the characteristics of LED circuit. Another possible control of current is to design a circuit where the current is inversely proportional to the temperature. In other words, the ignition time and light speed is known, the illumination of light during operation is known. With this, in our study, the LED emitter is controlled to keep a proper level of illumination. If the current through the LED emitter is decreased the light density from the emitter is also decreased. When the light illumination falls below the pre-set level of LED sensor illumination, it is decided that the lifetime of LED is expired. Our research keeps the constant level of current flow in order to keep the minimum level of illumination and the temperature of LED junction within the tolerance of deterioration in illumination. By doing so, the lifetime of LED sensor luminaires can be extended as stated above. As a real example, it is reasonable to keep the speed of light larger than about 50 % of initial speed of light for the LED self ballated lamp of which the safety standard is specified as the KS-IEC/PAS 62612 edition 1.

4. Conclusions

We have proposed a controller to extend the lifetime of LED sensor luminaire. The current through the LED is controlled so that the temperature in the PN junction of LED kept constant level. By controlling the current, the illumination of LED is detected, the level of illumination of output light from the LED is maintained to a constant level, the lifetime is extended.

Remark: This work is the modified version of presentation at the conference of ISA 2013(April 26-28, Cebu, Philippines).

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