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A Simple Short Detection and Current Regulation Circuit for LED Driving Circuit

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Abstract

Background/Objectives: LED short and current imbalance problems generate the over currents in the LED strings and they damage the LED back light system. To solve these problems, this paper proposes a new simple short detection and current regulation circuit for LED driving circuit**. Methods/Statistical analysis:** The proposed circuit is composed of a bipolar junction transistor (BJT), anop-amp, three resistors, a capacitor, and two diodes. It can reduce the current imbalance among the LED string by using the negative feedback technique, and protect a LED driving circuit and LEDs from a LED short problem by controlling the BJT operation**. Findings:** To verify the analysis and effectiveness of the proposed circuit, it was tested on three LED strings by using the PSIM simulator. In simulation, it reduced the current deviation among LED strings from 33 % to~ 0 %, and protected the LED driving circuit and LEDs from a LED short problem. **Application/ Improvements:** The proposed circuit has the simpler structure and fewer components than the existing LED short circuits.

Keywords: BLU (Back Light Unit), Current Mirror, Current Regulation, LED (Light Emitting Diode), Short Detection

1. Introduction

Light emitting diode (LED) strings, which are made from LEDs in series connected in series, are widely used as the light source for the LED backlight unit of a LED TV[1–10]. As shown in Figure 1, they are driven by LED driving circuit consists of a step up converter, regulation circuits (CRs), and short detection circuits (SDs)[2–12]. A step-up converter makes the high dc voltage from a low dc voltage produced by power factor correction (PFC) and multi-output dc/dc converter[2-6]. In general, a dc/dc boost converter is used as a step-up converter for a LED driving circuit. Also, its output voltage, which is a driving voltage (V_{LED}) of LED strings, is decided by the number of LEDs connected in series and specifications of LED. Current regulation circuits reduce current imbalance among LED strings so that LED backlight has the same light intensity at all locations of the backlight[2–15]. Short detection circuits protect a LED driving circuit and LEDs when LED short problem occurs[6,8,10].Current regulation and short detection circuits have a problem of reducing a power efficiency of LED driving circuit, but they must be needed to operate stably LED driving system.

Current imbalance among LED stings and LED short problems, which make an unstable operation of LED backlight system, are summarized as follows.

1.1 Current Imbalance Problem

It is made by impedance deviation among LEDs occurs due to differences of manufacturing tolerance, operating temperature, and other operating conditions. It prevents a LED backlight from having the same light intensity at all locations of the backlight.

1.2 LED Short Problem

It is made by LEDs which are damaged by the high voltage and current spikes, and high operating temperature. It makes to decrease the impedance of LED strings has short LEDs. As a result, over currents are generated in

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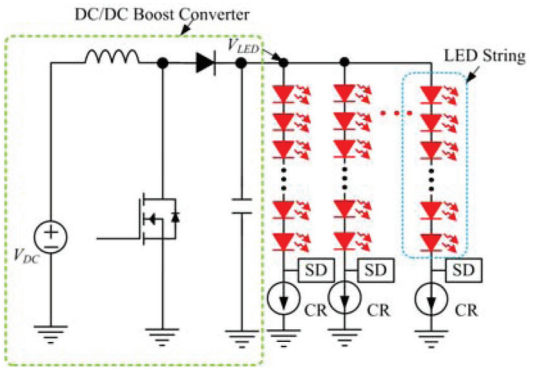

Figure 1. The structure of the LED backlight system.

a LED driving circuit and LED string, and it damages the LED backlight system.

To solve the above mentioned current imbalance and LED short problems, this paper proposed a new simple short detection and current regulation circuit for LED driving circuit detection circuit. The structure, components, and operational principle of the proposed circuit are described in Section II. The results are given in Section III, and a conclusion is given in Section IV

2. The Proposed Circuit

2.1 Structure and Components

As shown in Figure 2, the proposed circuit consists of a current regulation circuit (CR) and a short detection circuit (SR). The components of the proposed circuit are a BJT, an OP-amp, three resistors (R_e, R_{c1}, and R_{c2}), a capacitor (C_c), and two diodes (D_e and D_c). It is connected with each LED string, and the number of the proposed circuit is the same as that of LED strings. A current regulation circuit (CR), which consists of a BJT, an OP-amp, a resistor (R_e), and a diode (D_e), can reduce the current deviation among LED strings and control the value of the current of each LED string. A short detection circuit which consists a BJT, an OP-amp, two resistors (R_{c1} and R_{c2}), and a diode (D_c), and a capacitor (C_c) can protect a LED driving circuit and LED strings when LED short occurs.

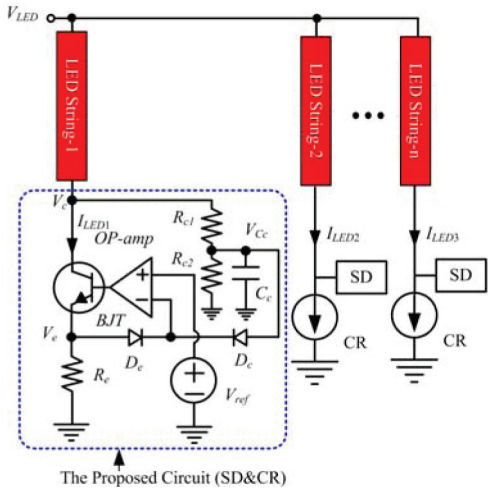

Figure 2. The schematic diagram of the proposed circuit.

2.2 Operational Analysis

2.2.1 Current Regulation Operation

When all LEDs normally operate, the voltage(V_{Cc})of the capacitor (C_c)is less than the emitter voltage (V_e)of NPN bipolar junction transistor (BJT). As a result, the diode D_c is open but a diode D_e is short. In this operation mode, the current of the LED string is controlled by the negative feedback operation of OP-amp, diode (D_e), and a resistor (R_e). The current (I_{LED}) of a LED string is determined by the negative feedback operation and given as

$$V_{ref} = V_e - V_f \tag{1}$$

$$I_{LED} = \frac{V_e}{R_e} = \frac{V_{ref} + V_f}{R_e} \tag{2}$$

Where, the V_f is the forward voltage of diodes (D_e and D_c) and the V_{ref} is the voltage of the positive input of the OP-amp.

2.2.2 Short Detection Operation

When one or more LEDs in a LED string become short, the value of the capacitor voltage(V_{Cc})increases with an increase of the collector voltage (V_c) of BJT. Finally, it is greater than the emitter voltage (V_e)of BJT. As a result, a diode D_c is short but a diode D_e is open. In this case, the voltage (V_{ne}) of the negative input of OP-amp is given as

$$V_{ne} = V_{Cc} - V_f \tag{3}$$

And BJT opens because

$$V_{ne} > V_{ref} \tag{4}$$

$$V_{BE} < 0.7V \tag{5}$$

where the V_{BE} is a base-emitter voltage of BJT.

Therefore, the current of the LED string with a LED short problem becomes zero, and LED driving circuit and LEDs are protected from LED short problem.

3. Results

To verify the analysis and effectiveness of the proposed circuit, it tested on three LED strings by using PSIM simulator. The PSIM simulation model of the proposed circuit consisted of three LED strings, three proposed circuits, and an event circuit for LED short occurrence as shown in Figure 3. In simulation model, the driving voltage (V_{LED}) for a LED string was 27V and each LED string consists of five LEDs connected in series. The values of components are given in Table 1. For the simulation, two LED strings (I_{LED1} and I_{LED3}) operate in the normal state and a LED string (I_{LED2}) operates with a low impedance state or a short LED state.

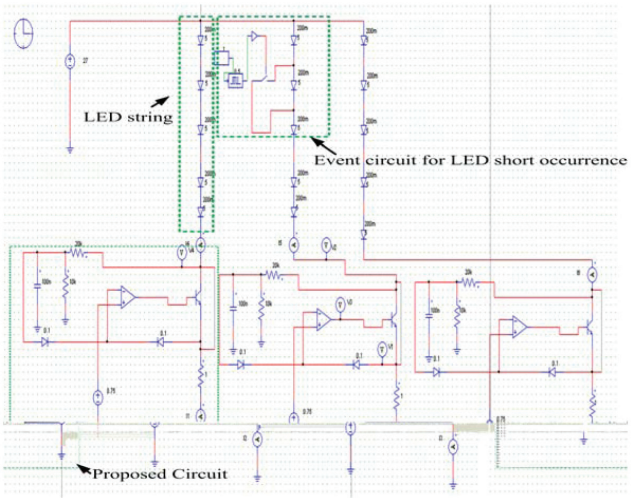

Figure 3. The simulation model of the proposed circuit.

Table 1. Specifications of components for simulation

Components	Value
LED	V_{led} = 5 V, R_{led} = 200 mΩ
BJT	β=1000
OP-amp	G=100000, R_o=80Ω
R_{c1}	20 kΩ
R_{c2}	10 kΩ
R_e	1 Ω
C_c	100 nF
V_{ref}	0.75 V
D_e, D_c	V_f= 0.1 V

Figure 4 shows the values of the LED currents at each LED string when the impedance deviation among LED string occurs. For the simulation, the forward voltage and resistance of the LEDs in LED string-2 was modeled as 5 V and 100 mΩ, respectively. And the values of other components were modeled as the specification given in Table 1. When there was not the proposed circuit except the resistor R_e in the simulation model, the values of the LED currents of the LED string-1 and 3 were 1 A but that of LED string-2 was 1.33 A, because the impedance of LED string-2 was less than those of LED string-1 and 2. In this case, the max current deviation among the LED strings was 33 %. When there was the proposed circuit in the simulation model, the LED currents of all LED strings had the same values of ~0.85 A. In this case with the proposed, the current deviation among the LED strings was almost eliminated by the current regulation circuit.

Figure 5 shows the current waveforms of LED strings without and with the proposed circuit when LED short occurs. For the simulation, the values of all components were modeled as the specification given in Table 1 but a LED in the LED string-2 became short. In the case without the proposed circuit except the resistor R_e, the currents of LED string-1 and 3 were 1 A but the current of LED string-2 with a short LED is 4A (Figure 5(a). In the case with the proposed circuit, the current of LED string-1 and 3 were 0.85A and the current of LED string-2 with a short LED was 0A (Figure5(b). From the simulation results

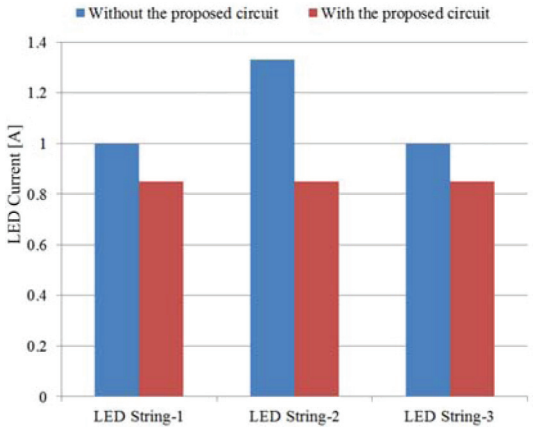

Figure 4. The value of the LED current at each LED string when the impedance deviation among LED strings occurs.

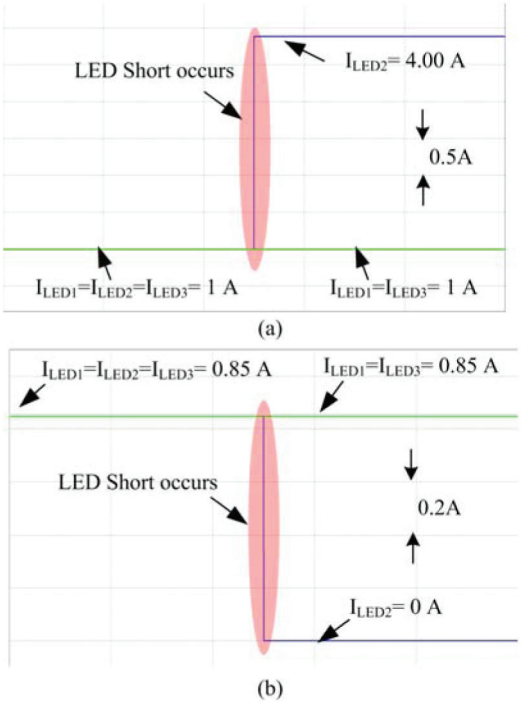

Figure 5. The current waveforms of LED strings (a) without (b) with the proposed circuit when LED short occurs.

shown in Figure 5(b), the current of LED string with LED short becomes 0A due to the short detection circuit. As a result, a LED driving circuit and LED strings are protected from the LED short problem.

4. Conclusion

A new simple short detection and current regulation circuit for LED driving circuit is proposed. The proposed circuit is composed of a bipolar junction transistor (BJT), anop-amp, three resistors, capacitor, and two diodes; it can reduce the current imbalance among the LED strings and protect a LED driving circuit and LEDs from a LED short problem. In the simulation, the proposed circuit was tested on three LED strings. The simulation results shows that it is useful for reducing the current imbalance among LED strings and protecting the LED driving circuit from a LED short problem.

5. Acknowledgement

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6. References

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