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Research and design of switching power supply of intensity adjustable powerful LED

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Abstract: Due to the disadvantages of the current linear regulated power supply for LED which has high power consumption and large volume, a PWM (pulse width modulation) switch power supply based on LM2575 DC/DC step-down chip has been designed with the characteristics of luminous efficiency of above 80%, small volume, steady performance, low cost. It is used to drive powerful LED by constant current which can be adjusted by regulating external potentiometer, and the light intensity of LED is also changeable.

Key words: LED; pulse width modulation; switch power supply; constant current driving

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光强可调大功率 LED 开关电源的设计与研究

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摘 要:针对当今 LED 线性稳压源功耗高、体积大的不足,利用 LM2575 DC/DC 降压芯片设计了一种恒流驱动大功率 LED 的 PWM 开关电源。其发光效率在 80%以上,且体积小、性能稳定、成本低,通过调节外部电位器可以改变驱动电流进而改变 LED 的发光强度。

关键词:发光二极管;脉冲宽度调制;开关电源;恒流驱动

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1　Introduction

As a solid light source, light emitting diode (LED) is becoming the focus of attention for many present scholars and businessmen because of its particular advantages, such as energy conservation, environmental protection, firm structure, long life, short start-up time, small volume, low operating voltage and so forth[1]. The United States, Japan, the European Union, China Taiwan and other countries and regions have developed the corresponding semiconductor lighting program[2]. In China, LED lighting products and engineering has also been included in the key projects through the National Program for Medium-to long-term scientific and technological development and 'Eleventh Five-year' 863 Plan.

The many advantages of LED lay the foundation for the extensive use, however, the light efficiency, cost, the elimination of heating, especially the design of driving power need to be further resolved, if the LED wants to be widely used. At the present time, there are three main methods to drive the LED[3]: current-limiting type driving, using resistor; constant voltage type driving and constant current type driving. Current-limiting type drive because of its low efficiency and the constant voltage drive because of its larger damage are increasingly replaced by the constant current drive. Although there are some chips currently used to produce the constant current drive, the PWM frequencies of these drive powers are too high to be expensive, moreover, the complex designs of their peripheral circuit lead to large volume[4-6]. This article designs a switching power supply of intensity adjustable powerful LED based on LM2575 DC/DC step-down chip that overcomes the shortcomings of the above driving circuits. And it can be applied to the electric motor car to improve its power efficiency.

2　The design of switching power supply

2.1　Schematic diagram

This research based on LM2575 DC/DC step-down chip designs a driving power which can convert the 24～36 V input voltage into output constant current. It can drive multiple serial powerful light emitting diodes, and by adjusting the external potentiometer R_x, it also can vary the output current in the rating of 20%—100% to achieve the purpose of adjustable light intensity. Its schematic diagram is shown in Fig. 1.

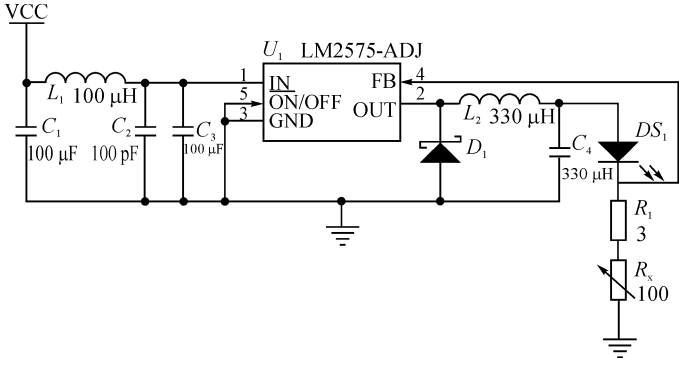

Fig. 1　The schematic diagram of switching power supply

The circuit mainly consists of two parts. The first part which is made up of U_1, L_2, C_4, D_1, DS_1 as well as R_x and R_1 is a step-down, steady flow and the light intensity adjustable circuit. As the reference voltage of LM-2575T-ADJ equal 1.23 V, if the value of R_x remains unchanged, the current through R_x and R_1 is also unchanged, namely, the current through the powerful LED is constant, playing a role in constant current. If R_x is changed, the current through R_x will be changed because the V_{FB} should be 1.23 V. The luminous flux of the powerful LED is determined by the current through it, and that change the value of R_x can adjust the luminous flux of LED that achieves the purpose of adjustable light intensity. The second part which is made up of the capacitors C_1, C_2, C_3 and inductor L_1 constitutes the filter circuit. The selection of the value of R_1: the rated current equal 300 mA and V_{FB} equal 1.23 V, so the sum of R_x and R_1 is 4 Ω. But actually R_x is difficult to adjust to zero, so R_1 is taken 3 Ω. When the R_x is 22 Ω, the current through LED is 50 mA. When the value of R_x changes from 1 to 22 Ω, the current

of LED also changes from 50 mA to 300 mA.

2.2 Hardware production

It is greatly important to consider the PCB layout in the switching power supply, because the fast switch current as well as wiring inductance, parasitic capacitance, and spurious inductance will generate transient voltage. And the transient voltage will yield electromagnetic interference. So the input capacitors, such as C_1 and C_2 and C_3, output capacitor like C_4, diode D_1 and the inductors L_1, L_2 should be as much as possible close to the LM2575T-ADJ chip. Moreover, use the short pins to weld to shorten the current circuit and the circuit common port is preferably at the same point. In order to minimize the sensitive circuit, the output pin 2 of the chip should be welded as small as possible and the reactive circuit of feedback pin 4 should be as short as possible. Last but not least, we must pay attention to the order of each pin.

3 Test and analysis

Because whether the driving LED current is constant has greatly influence on the LED life, the constant level of the switching power supply is an important index. Of course, the efficiency of the switching power supply is also an important index. As this switching power supply will be used in the electric motor car, it is an index that whether the intensity of LED is adjustable and the scope of regulation of the luminous intensity. This study analyzes the steady flow performance, intensity adjustable performance and the power efficiency of the switching power supply by using HP860LED intensity distribution tester, HP860LED 300 mm integrating sphere, HY3003F-3 DC power supplies and VC9805A$^+$ DMM.

3.1 Steady flow analysis of single LED

The relationships between input voltage V_i and output current I_o, reference voltage V_{FB}, relative flux of LED Φ_r as well as the voltage across LED V_{LED} are shown in Fig. 2 and Fig. 3.

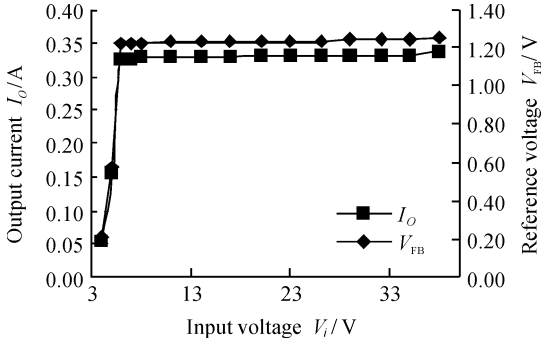

Fig. 2 The relationship between input voltage and output current, reference voltage

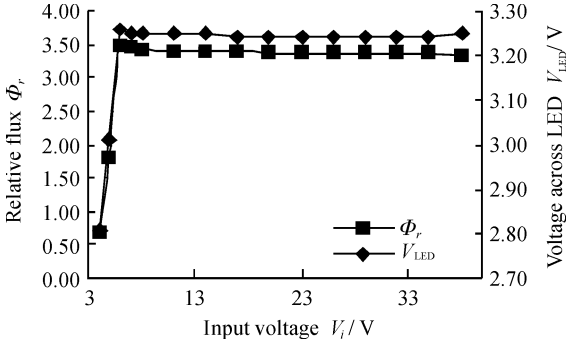

Fig. 3 The relationship between input voltage and relative flux, voltage across LED

From Fig. 2 and Fig. 3 when the input voltage changes from 11 V to 38 V, the output current of the circuit does not change. The constant flow effect is very good when the input voltage is above 11 V. When it is used in the 36 V electric motor car and the voltage of the electric motor car's storage battery falls from 36 V to 11 V, LED brightness can still keep constant. Not only does it guarantee the LED life, but also increases the users' safety.

3.2 The analysis of single LED intensity adjustable

The relationships between different resistance of R_x and output current I_o, reference voltage V_{FB}, relative flux of LED Φ_r as well as the voltage across LED V_{LED} are shown in Fig. 4 and Fig. 5.

From Fig. 4 and Fig. 5 when the external regulation resistance changes from 1 Ω to 18 Ω, the output current changes from 300 mA to 50 mA and the LED relative flux changes from 3.5 to 1. It achieves the intensity adjustable purpose.

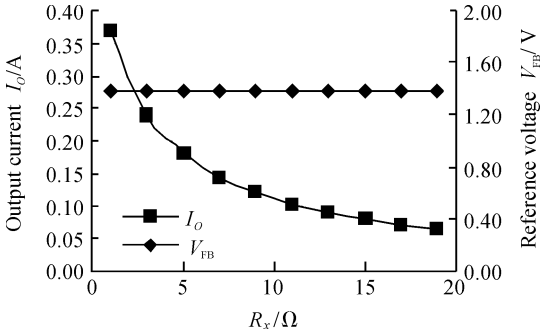

Fig. 4　The relationship between R_x and output current, reference voltage

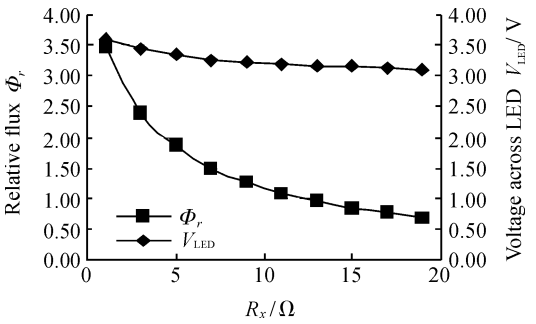

Fig. 5　The relationship between R_x and relative flux, voltage across LED

3.3　The relationship between the number of LED and the power efficiency

When different numbers of LED connect in series, the relationship between the number of LED and the switching power supply efficiency is shown in Fig. 6.

From Fig. 6 when driving single LED, because of the relatively large consumption of the resistor that the LM2575T feedback sample, the power efficiency is low. With the increment of the LED quantity, the circuit conversion efficiency is also greatly improved.

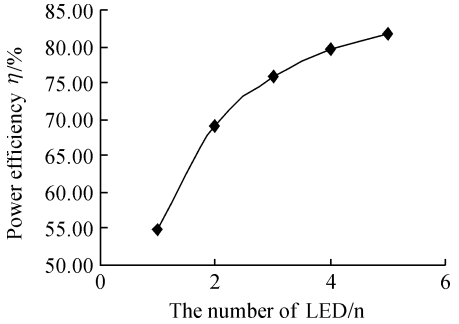

Fig. 6　The relationship between the number of LED and power efficiency

4　Conclusions

The switching power supply which designed in this study possesses simple structure, steady performance and small volume. By the test data and analytical curves it can be seen that when the input voltage of the switching power supply changes from 11 V to 38 V, its output current and the LED relative flux remain constant. Single LED luminous efficiency is between 50% and 60%. And from the data and curve of the relationship between number of LED and luminous efficiency can be seen that with the increment of the LED quantity, the luminous efficiency is continuously increased. It can reach above 80% when the number of LED is more than five. Also from the intensity adjustable curve it can be learned that the alteration of the value of the regulation resistance can achieve the intensity adjustable purpose. The actual measurements prove that the power supply has a high performance cost ratio and promotional value. As can be seen from the test parameter, the switching power supply meets the requirements of the electric motor car and can be applied to the electric motor car. So it has utility value.

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