Design and Implementation of LED Constant Current Drive Circuit Based on Microcontrollers

Dengrong Zhou
School of Intelligent Manufacturing, PanZhiHua University, Panzhihua 617000, China
e-mail: 494982494@qq.com

Abstract. In the paper, the LED light operating feature is analyzed, and the design, simulation and test on peak current control of Buck circuit are carried out to improve the reliability for LED drive circuit. Meanwhile, the PWM waveform of DC-DC switch tube and current waveform of LED Light are simulated and analyzed. Through these ways, it is found that the LED light current waveform is constant with small ripple under this modulation.

1. Introduction
In the human history of lighting, LED light has become the most ideal light after incandescent light and fluorescent light for its small size, low power consumption, and high luminous rate. For a LED light, its working voltage is 2 ~ 3.6 V, working current is 0.02 ~ 0.03 A, and electrical energy consumption is 0.1 W at most, with the features of high brightness, low heating, long service life (LED has a service life of 100000 hours), nearly 100% optical power conversion (the same lighting can save over 80% energy than traditional light) and others. In recent years, the LED drive circuit technology has been a research hotspot. LED drive circuit mainly consists of DC-DC conversion, PWM waveform generation and constant current control. And in this paper, the topological structure of LED light drive circuit is analyzed and the peak current control idea is put forward. Each component is conducted design and simulation. It is best verified by building experimental circuit for test. The experimental results demonstrate that this method can provide stable and reliable constant current drive for LED light, which has certain theoretical and engineering application significance.

2. Generation of PWM Waveform
The generation of PWM waveform is comprised of square wave generation, triangular wave formation and PWM wave formation, etc.

Operational amplifier is adopted to produce positive feedback and generate square wave signal, then square wave signal forms triangular wave signal through integral circuit, and modulate triangular wave to generate PWM (SPWM) wave by modulating signal.

Figure 1. Square and triangular wave forming circuits
As shown in the figure 1, there are two operational amplifiers in TL082. One (U4), an integrator, is used to transform the square wave into a triangular wave by integral. The other (U1), working as a comparator, performs zero-cross comparison to triangular wave and generate square wave to output. R3 and R2 provide hysteresis thresholds. Z1 and Z2 are Zener Diodes used to limit the square wave amplitude. The working process shows as follows. Square wave positive voltage from U1 enters inverse-phase end of the integrator through R1, then U4 outputs negative voltage to charge C1 under negative feedback, and the negative half-cycle of triangular wave is produced. When the negative half-cycle voltage of triangular wave is lower than 0V after superimposed hysteresis voltage, U1 output turns to square wave negative voltage. This voltage enters the inverse-phase end of the integrator through R1, then U4 outputs positive voltage to charge C1 under negative feedback, and the triangular wave starts to turn and rise. When the positive half-cycle voltage of triangular wave is higher than 0V after superimposed by hysteresis voltage, U1 output turns to square wave positive voltage. After repeating the process, the square and triangular waves are produced.

As shown in the figure 2, PWM wave generation circuit is made up by TL082. While the triangular wave enters the reverse-phase end of TL082, reference voltage enters the positive-phase end of TL082 by R9 and R6 to provide comparison threshold voltage. When reference voltage superimposed hysteresis voltage is higher than the triangular wave voltage, TL082 outputs the positive voltage. Conversely, when hysteresis voltage superimposed hysteresis voltage is lower than the triangular wave voltage, TL082 outputs the negative voltage.

In one cycle of PWM wave, the ratio between positive voltage time and whole period time is called duty ratio. When reference voltage is 0V, positive voltage and negative voltage of PWM have the same value, with 50% duty ratio. When reference voltage as positive voltage is more than 0V, positive voltage time of PWM is more than negative voltage time, with over 50% duty ratio. When reference voltage as negative voltage is less than 0V, positive voltage time of PWM is less than negative voltage time, with below 50% duty ratio. When reference voltage is changed, duty ratio can be adjusted and PWM wave can be output. The simulation results, shown as figure 3, can be found that the PWM edge occurs at the intersection of reference voltage and the triangular wave. The PWM circuit composed of TL082, having a steep edge, is nearly a perfect square wave.
The duty ratio of PWM will change with control voltage. For example, if reference voltage is altered with a substitute of sine wave, PWM duty ratio will vary with sine wave amplitude and generate SPWM wave.

As shown in the figure 4, it can be seen that the sine wave, working as a reference voltage, forms SPWM wave, which can be restored by RC low-pass filtering. And the duty ratio of SPWM wave varies with sine wave amplitude.

Figure 4. SPWM wave generation simulation

3. DC/DC Conversion Circuit
There are three common forms in DC/DC conversion circuit, including Buck, Boost and Buck-Boost. The three circuits are used for various load types and different design requirements. Due to the low working voltage of LED light, Buck switching circuit is adopted to drive, as shown in figure 5.

Figure 5. Buck DC/DC conversion circuit

Switch tube S works under PWM control. When the switch tube S is switched on, the DC power voltage Vin is directly output through the switch tube, with voltage Vo=Vin. Meanwhile, diode D cuts off under reverse voltage, id=0. The power current flows into inductive load through the switch tube, and the inductance current iL rises. When the switch S is switched off, the inductive current iL passes through diode D circulation and attenuates to zero. During the process, diode D conducts, and output voltage Vo of the convertor approximates to 0. With continuous inductance current, average output voltage is Vo=Ton/T*Vin and DC/DC transformation is realized.

The Buck-type LED drive circuit designed is shown in figure 6.

Figure 6. The Buck-type LED drive circuit

Set up the experimental circuit and test the waveform. By observing the steady-state waveform, we can know that the circuit works usually, performs DC/DC transformation and outputs stably under the action of PWM wave.
4. LED Constant Current Drive Based on Microcontrollers

![LED Constant Current Drive Based on MCU](image)

Figure 7. LED Constant Current Drive Based on MCU

As shown in the figure 7, the LED constant current drive circuit based on MCU mainly comprises PWM waveform generation, drive circuit, control circuit, sampling circuit and other parts. It adopts control principle, control flow and related test point waveform in voltage and current double-loop control mode. And PWM pulse is usually obtained by sampling load voltage and current and controlling outer voltage loop and the inner current loop. For the constant current control with LED load, it can be used the peak or average current control of inductive current. By these ways, it will be more stable and reliable for convertor output current by the sampling and control. With constant pressure control alone, the current will change when anyone LED light in series or parallel is broken. In addition, the current control can also enhance the transient response, and play the role of current limiting with overcurrent protection. Comparing output voltage of LED light load and the reference voltage can get the error voltage Ve. Then, combing sampling signal Is of inductance current, the output signal Ve of error amplifier and the clock signal CP is to generate PWM pulse signal. And the constant current of LED load can be controlled in real time after driving to control on-off of the switch tube. The peak current directly controls inductance current peak. Because of the double-loop control by adjusting PWM pulse width. Owing to the double-loop control, the peak current type control has fast transient response to changes of input voltage and output load current.

![Simulation of LED Drive Circuit](image)

Figure 8. Simulation of LED Drive Circuit

Simulation of the LED drive circuit is shown in Figure 8. In drive circuit simulation, the parameters are taken as input voltage Vg=12V, load current I=350mA, period T=40us, inductance L=15uH, and filter capacitor C=470uF. The simulation waveform of inductance current iL and output current i are shown in the figure. It can be found that after 2ms, the current enters a steady state and reaches about 350mA, providing constant current for LED light. The results ensure the LED light luminous efficiency and service life as well as its stability and reliability. For the peak current type control LED drive device, parameters in design are the same as that in simulation circuit. By testing the voltage and current of the LED lamp, the experimental results are consistent with the simulation results., with 350mA output current.

5. Conclusion

The paper analyzes the main circuit of Buck LED light. To ensure the luminous efficiency and service life of LED light as well as its stability and reliability, peak current or average current is adopted to control the load. The drive circuit of Buck LED light based on microcontroller control is analyzed in details. The design, simulation and test on each unit are carried out, through which the feasibility of the
proposed constant current control of LED light is proved. The idea also applies to Boost circuit and Cuky circuit. In the paper, it adopts peak current control method and analyzes the feasibility of the proposed method on simulation and theory. However, there are errors between the peak current and the average current which is difficult to correct, as well as poor noise immunity, labile sub-harmonic oscillation, and required slope compensation. For these problems, works will be deeply analyzed and studied in the future.

**Acknowledgments**

Fund Project: Scientific Research Projects Supported by Science & Technology Department of Sichuan Province (No. 2015JY0250), Science and Technology Department of the Panzhihua Institute(No. 2014PY2-10), Solar Energy Integration Technology Popularization and Application Key Laboratory of Sichuan Province(No. 2014TYNZ-01).

**References**

[1] Zhou Zhimin, Zhou Jihai, Ji Aihua, Design and Application of LED Drive Circuit [M]. Posts and Telecom Press, 2006: 29-30, 17-20, 73.

[2] Zhou Zhimin, Zhou Jihai, Ji Aihua, LED Lighting Technology and Application Circuit [M], Electronic Industry Press, 2009: 12.

[3] Yang Qingde, Kangya, Ji Aihua, LED and Its Engineering Application [M]. Posts and Telecom Press, 2007: 7.

[4] Dongsheng Ma, W-H Ki, Fast-Transient PCCM Switching Converter with Freewheel Switching Control. IEEE Transactions on Circuits and Systems, Part II, Vol. 54, No. 9, 2007: 825-829.

[5] Prathyusha Narra and Donald S. Zinger. An Effective LED Dimming Approach. Industry Applications Conference, 2004(3): 1671 -1676.

[6] F. C. Lee and R. A. Carter. Investigations of stability and dynamic performances of switching regulators employing current-injected control[J]. in Proc. IEEE PESC’82 Conf., 1982, pp. 3-16.

[7] Lloyd Dixon. Average Current Mode Control of Switching Power Supply[Z]. Unitrode Product & Applications Handbook, 1995-96.

[8] SHEN Xia, LI Hong-wei, XU Jin. Design of LED Driver Power Supply Based on Flyback Converter without Photocoupler[J]. Electrical Measurement & Instrumentation, 2012,49(7).

[9] ZHOU Guo-hua. Study on the Digital Current Mode Control of Switching-Mode Power Supply[D]. Xian: Southwest jiaotong university master's degree thesis, 2008.

[10] YANG Jing. Study on LED Driver Methods Applying Multiple-Output Switching Converter [D]. Xian: Southwest jiaotong university master's degree thesis, 2011.