New Driving Method of High Brightness LED Backlight Using Active Current Source

S. Hwang, J. LEE, S. Lim, and M. H. Oh
Information Display Research Center, Dankook University,
29 Anseo-dong, Cheonan, Chungnam 330-714, Korea
Phone : 82-41-550-3593, E-mail : sacheonsa@dankook.ac.kr

Keywords : backlight, LED driving, Active current source

Abstract

The brightness of LED changes according to the current flowing through LEDs. The current mirror was used to drive LEDs effectively. The reference current of the current mirror was usually controlled by the resistor but the size of this resistor is very large and this resistor consumes too much power for high power LED backlight driving. The reference current of the current mirror LED driver was controlled by using flyback converter at small size with low power consumption in this paper. The concept of active current source was presented.

1. Introduction

The cold cathode fluorescent lamp (CCFL) has been used as the light source with reliability for more than thirty years. Recently, the external electrode fluorescent lamps (EEFL) and light emitting diode (LED) emerged as the counter part of CCFLs. The multi-lamp EEFL backlight needs only one inverter and replaces CCFLs. The flat fluorescent lamp (FFL) was introduced as another light source for LCD backlight but the production cost is not low enough to replace CCFL or EEFL backlights. But CCFL, EEFL, and FFL use Hg and the request for Hg-free light source is imminent. Therefore, LEDs now receive a lot of attention as the next generation light source for LCD backlight.

The LED generates light as the voltage is applied to the input. Currently, big outdoor signage displays for advertisement and traffic lights are using LEDs. Now it is time to discuss about using LEDs as a light source for LCD backlight. But the LCD backlight using LEDs are now much more expensive than that of CCFL or EEFL so that it is necessary to find the ways of reducing LED backlight cost.

Sony started to use LED backlight for its LCD TV names as QUALIA. Samsung Electromechanics started volume production of LED backlight since the second half of 2006.

LCD TV can have much wider color gamut than that of the CRT if LED backlight is used. LED backlight does not use Hg so that it is RoHS free. The life time of LED can be extended up to 100,000 hours if the LEDs are operated in optimum condition.[1]

But LEDs have lots of problems to be solved. Low optical conversion efficiency, high heat dissipation, and high production cost need to be resolved in order for LED to be used as a major light source of LCD backlight.

The luminance of LED depends on the current flowing through LED. Small change of current generates big difference in brightness. Therefore, the method of current control will be important for operating LED backlight with reliability. The voltage increases and the current decreases when driving LEDs connected in series. Current mirrors are now used to drive the LEDs connected in series and parallel but reference current generation needs high power resistor with big size. In this paper, a new driving method using current mirror with flyback converter was suggested to drive LED backlight with parallel arrays of LEDs connected in series.

2. Current Mirrors

The constant current sources are used in biasing MOS IC amplifiers. Fig. 1 shows the basic current source circuit, current mirror. The drain of transistor Q1 of the current source is connected to the gate so that the transistor is in saturation mode as in eq. (1).

$$I_{D1} = \frac{1}{2} K_n (\frac{W}{L})_1 (V_{GS} - V_t)^2 \qquad (1)$$

The drain current of Q1 is supplied by V_{DD} through R. The drain current of Q1, I_{D1}, is described as in eq. (2).

$$I_{D1} = I_{REF} = \frac{V_{DD} - V_{GS}}{R} \qquad (2)$$

I_{D1} in eq. (2) is the reference current, I_{REF}, which flows through resistor R.

The drain current I_o of Q2 has the same V_{GS} and is assumed to be in saturation mode so that it can be described as in eq. (3).

$$I_o = I_{D2} = \frac{1}{2} K_n (\frac{W}{L})_2 (V_{GS} - V_t)^2 \qquad (3)$$

Therefore, the relationship between I_o and I_{REF} is described in eq. (4).

$$\frac{I_o}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1} \qquad (4)$$

It is easily understood that $I_o = I_{REF}$ if Q2 is the same transistor as Q1.[2][3]

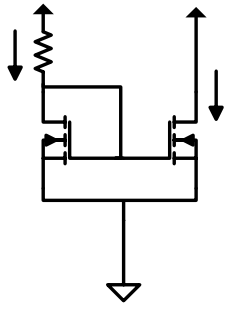

Fig. 1 Basic current mirror circuit

The reference current in current mirror is decided by selecting resistor R in the circuit. This current mirror is used as a current source for small signal operation in ICs. It is difficult to decide the reference current in the current mirror circuit if there are many loads requiring high voltage and large current. It is necessary to design current sources for driving high voltage at large current if the loads are composed of many LEDs connected in series.

A new current mirror with different method of setting the reference current is suggested. The flyback topology in DC/DC converters can be used as the method of deciding reference current in the current mirror.

The basic operation principle of flyback converter is that current will flow through the primary winding of transformer if Q is turned on and the voltage will be generated. The voltage with opposite polarity will be induced at the transformer output so that the diode DF will be turned off. Therefore, the inductive energy will be stored in the primary side of the transformer. The current will flow through Df due to the voltage induced at the output of transformer if the transistor Q is turned off.

The maximum average of the input current of the flyback converter is described as in eq. (5).[4]

$$I_{i\max} = \frac{P_o}{\eta V_{i\min}} \qquad (5)$$

The input current of the flyback converter will be the reference current of the current mirrors. It is possible to control the reference current by using sense resistor and feedback to PWM circuit. The change of reference current is possible by controlling the gate signal of switching FET.[5][6] The secondary output voltage can be reused as the input of the current mirror so that energy saving will be achieved at the same time.

3. Proposed LED BLU's Composition

The new circuit for LED backlight control is suggested as in Fig. 2 using flyback converter. The flyback converter was used instead of the resistor in the reference current circuit. The sense resistor connected to the source of the switching FET Switch was chosen to control the reference current. The input current is limited by controlling FET gate signal by feedback of the current sensed by the sense resistor to the input of PWM control. The secondary output of flyback converter is applied to the input of current mirror.

Fig. 3 shows the current mirror using converter.

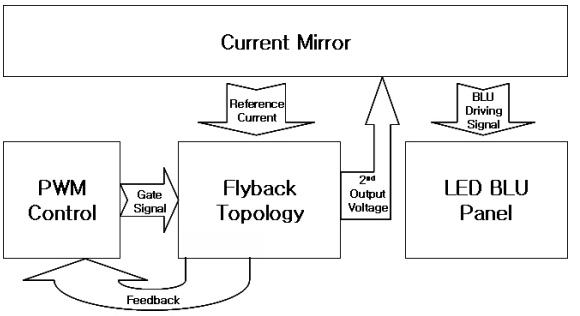

Fig. 2 Block diagram of LED backlight control using flyback topology

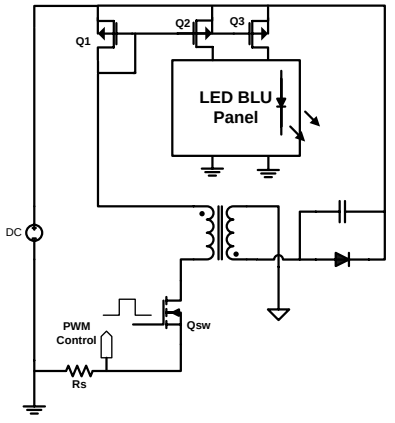

Fig. 3 Current mirror using flyback converter

4. Experimental

The LED backlight driving circuit and module as shown in Fig. 4 was assembled and tested as suggested. The LED backlight module as shown in Fig. 5 was assembled using 1.2W white LEDs. The 20 LEDs were connected in series as a unit and 5 units were arrayed in parallel. Therefore, the input voltage and the current of the assembled LED module will be 70V (3.5V x 20) and 1.75A (0.35A x 5). The switching frequency was set at 41.67kHz.

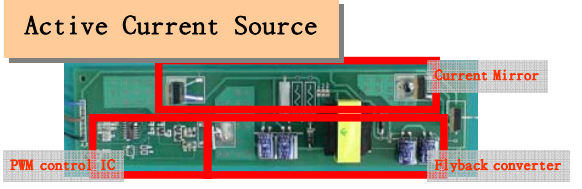

Fig. 4 LED module assembled for test

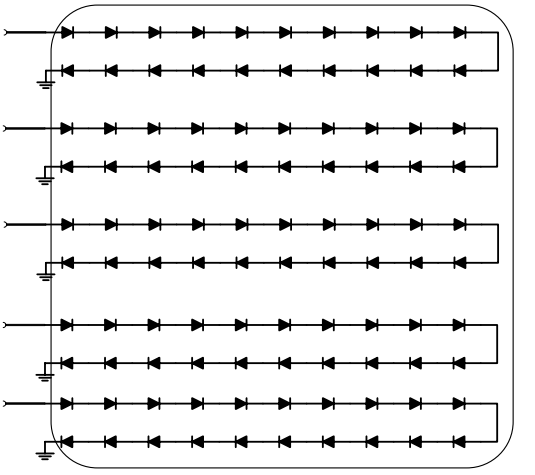

Fig. 5 LED module

Fig. 6 shows the waveforms of the reference current from active current source and LED driving current. There is about 5mA difference in LED driving currents of LED1 unit and LED2 unit. The difference between reference current and LED current is greater than 100mA before filtering but the difference will be very small after filtering.

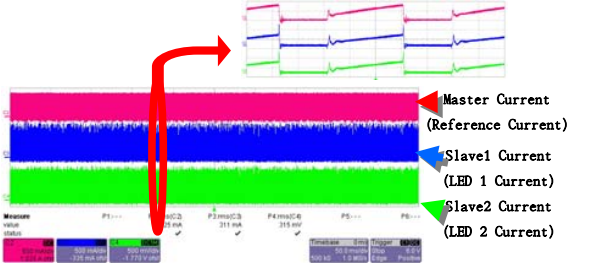

Fig. 6 Reference current and LED Current before filitering

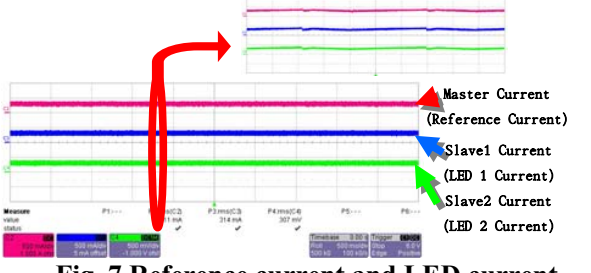

Fig. 7 Reference current and LED current after filtering

The reference current and LED1 current, and LED2 current are almost the same without any big difference. The small difference is due to the difference in LED and MOSFE characteristics. Fig. 8 shows the LED backlight composed of several LED modules.

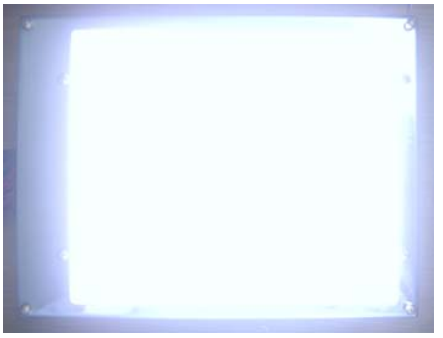

Fig. 8 LED backlight in operation

5. Conclusion

A new current mirror circuit using flyback converter was suggested to drive LED backlight. An LED backlight was assembled by using several LED module composed of parallel array of 5 units of LED strings. A string of LEDs was composed of 20 LEDs. The input voltage and current of an LED string was 70V and 350mA.

The big size and high power resistor should be used if the driving current for LED strings are high. The reference current resistor was replaced by flyback converter to control the voltage and current for LED module with small size and at a low power consumption.

The reference current of the current mirror and the LED current of the current sources found to be the same during the operation. It was shown that the current mirror with flyback converter would be very useful in driving high power LED backlights.

6. REFERENCES

[1] Sungkyoo Lim, “LCD Backlight,” Dankook University Press, pp.79.(2005)
[2] Sedra, and Smith “Microelectronic Circuits” Fourth Edition, Oxford University Press Korea Ltd, pp.585-585.(2003)
[3] Mark N. Horenstein, “Microelectronic Circuits And Devices” Second Edition, Cheong Moon Gak, pp.464-475.(1998)
[4] Hee Jun Kim, “Basic Design of Switching Power Supply,” Sung-An Press, pp.69-79.(2004)
[5] Hee Jun Kim, “Switching Mode Power Supply,” Sung-An Press, pp.34.(2005)
[6] Electronics Technology Research, “Power Supply Circuit Design Master,” Keemoon Press, pp.232-241.(2003)