

An LED Drive Circuit of LCD BLU with Protection Circuits

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Abstract: In this paper, two kinds of the protection circuits are proposed, simulated and experimented to verify their performances. One is an over current protection circuit, and the other is a no load protection circuit which reduces power consumption. These protection circuits which use a method of going down V_{CC} of the controller IC of an LED drive circuit can reduce power consumption and prevent to damage the elements. Also, following the experimental results, the transistors of the output voltage are able to get voltage stress less than previous LED drive circuit.

1. Introduction

Because of advancing electron and communication technology, almost electron and communication machinery is progressed in more small and light size. Upcoming a multimedia period, not only information is simple such as voice and text etc, but also information that can see us such as an image and so on is highlighted. Recently almost electron and communication machinery has display that can see information to our eyes.

Lately, LCDs are the mostly used display among flat panel displays. Although LCDs can be manufactured as a smaller size than the conventional CRTs, they need an additional light source, because they cannot light by themselves. With this light source, one can observe an image on an LCD screen and a performance of the light source directly affects a quality of the image. A conventional light source for LCDs has been the CCFL. LEDs are, however, expected as a next generation light source due to their advantages, and some researches are reported about an LCD backlight unit using LEDs [1], [2].

Single LED is very small, and its luminance is related to the amount of driving current. To obtain sufficient luminance for an illuminator, a number of LEDs must be connected together and a constant current must be supplied to each of the LEDs for equivalent luminance. The total voltage and total current of a serial connection varies, depending on the occurrence of short circuit LED breakdowns. Consequently, the LED drive circuit must have constant-output-current control [3].

An LED drive circuit and its protection circuit are proposed, which consists of a boost DC-DC converter with constant-output-current control and dimming control.

In section 2, circuit description and operation for the LED drive are described. In section 3, and section 4 provides the simulation and experimental results.

2. Circuit Description and Operation

2.1 An LED Drive Circuit of LCD BLUs

Figure 1 shows the block diagram of an LED drive circuit which consists of the five parts: a boost DC-DC converter, constant-output-current control, a LED array, Dimming control for LED, and the proposed two kinds of the protection circuits. One is a over current protection circuit, and the other is a no load protection circuit which reduces power consumption.

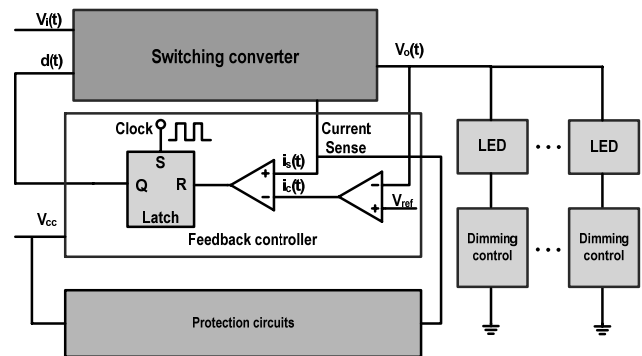


Figure 1. Block diagram of LED drive circuit.

2.2 No load protection

2.2 During turn off period of BJT Q4

From the figure 2, it can be seen that the current of an inductor and a resistor does not flow, when the BJT Q_4 turns off. In order to turn on the BJT Q_1 , the parameters of the circuit shown in the figure 2 should be changed. Choosing the resistor R_2 and the capacitor C_2 make that the BJT Q_1 turns on. Then, the BJT Q_1 does not turn on if the current flows through the load. On the contrary, the BJT Q_1 turns on if the current does not flow through the load. When the current does not flow through the resistor R_s , a voltage of V_{C3} is discharged and the BJT Q_3 turns off as shown in the figure 3. When the BJT Q_3 turns off, the voltage of the capacitor C_2 is elevated by a resistor R_2 and the capacitor C_2 . When V_{C2} is higher than 1.4V, the BJT Q_1 turns on and the operation of the control IC is stopped. Because a power source V_{CC} of the IC is decreased below UVLO. In the figure 2, PULSE 1 of the BJT Q_2 should be chosen to lower than a frequency of the BJT Q_1 and then V_{C2} is periodically discharged. Therefore, if the power source V_{CC} of the IC is turned off at no load condition, the power consumption of IC will be decreased.

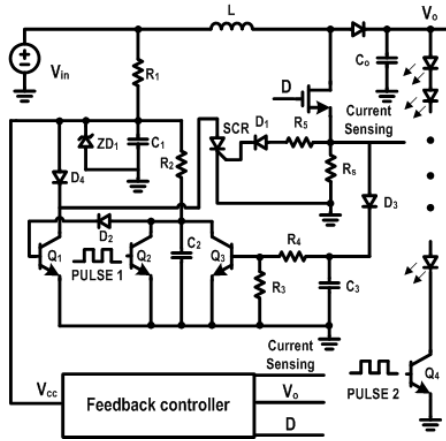


Figure 2. Protection circuits of LED drive circuit.

2.2.2 During turn on period of BJT Q4

When the BJT Q_4 and Q_2 turn on at the same time, V_{C2} is discharged as shown in the figure 3. When V_{C2} is discharged, the BJT Q_1 is turned off. When V_{CC} is higher than UVLO of the IC, the IC operates as shown in the figure 3. When the control IC operates, the current will flow through the inductor and the resistor. The BJT Q_3 is turned on and the converter is operated as shown in the figure 3.

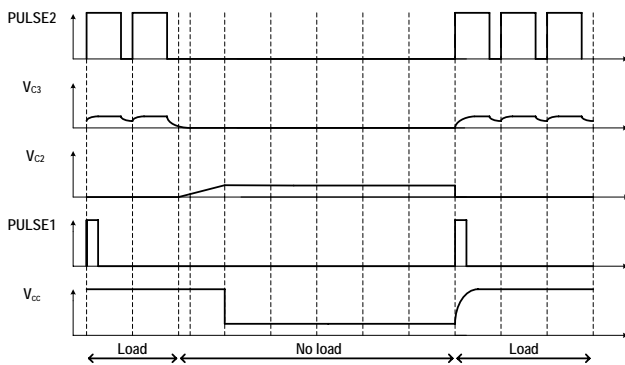


Figure 3. Operation waveforms at load and no load.

2.3 Over Current Protection

When the over current flows, the current of the inductor L is increased as shown in the figure 4. R_S is a sensing resistor of the current to flow through the inductor L . In the case of flowing over current in LED drive circuit, R_S detects a current. When a voltage of the resistor R_S is large enough to turn on the SCR, the IC operation does not operate as V_{CC} is decreased lower than UVLO as shown in figure 4. The IC does not operate to prevent damage of elements until the input voltage of the converter is turned off. If the IC of the converter does not operate due to flowing over current, an input voltage of the converter should be turned off. Thus SCR is turned off.

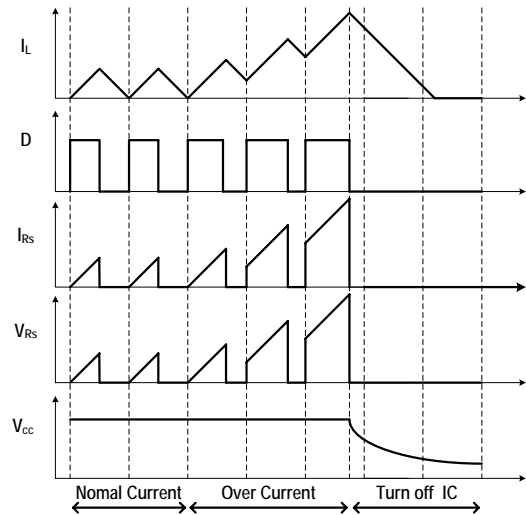


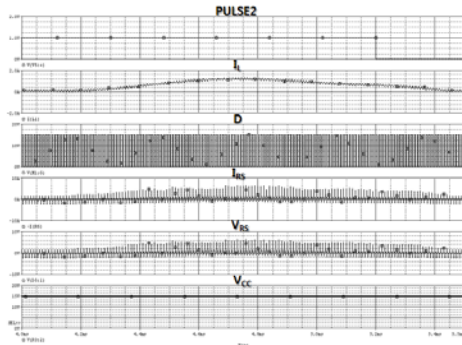
Figure 4. Operation waveforms of over current protection circuit.

3. Simulation Results

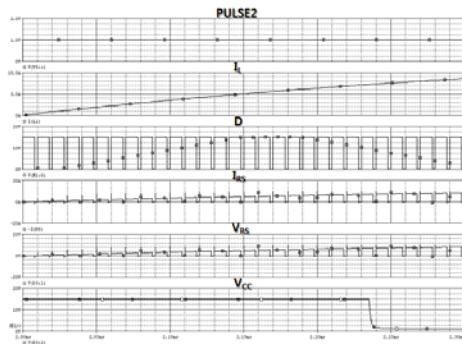
This paper performed the simulation waveforms of the protection circuits. In the figure 5, the waveforms of operation were simulated at no load and load, respectively. The input voltage V_{IN} was 24V, the inductor L was 500uH, the duty ratio D was 40%, the output current was 500mA, and the output voltage V_O was 40V. From the figure 5, when the PULSE 2 was low, a power source V_{CC} was decreased under UVLO. The figure 6(a) shows the waveforms of the operation, when the duty ratio was 40%. One can see the normal operation waveform, when PULSE 2 was turned on. In the figure 6(b), the duty ratio was 80%. When PULSE 2 was turned on, the current of the inductor and the sensing resistor were increased. As the current of the sensing resistor was increased, the voltage of the sensing resistor also was increased, and then SCR was turned on. V_{CC} of the IC was decreased under UVLO due to turned on SCR. However, the simulation was performed open loop circuit. Although V_{CC} was decreased under UVLO, the converter still continues to operate. If close circuit is experimented, the converter will not operate as shown in the figure 4.



Figure 5. Simulation waveforms at load and no load.



(a) Duty ratio is 40%



(b) Duty ratio is 80%

Figure 6. Simulation waveforms of over current protection circuit.

4. Experimental Results

To obtain experimental results better than previous protection circuit, an LED drive circuit and its protection circuit were modified. New protection circuit in figure 7 have only a no load protection circuit because of having UC3843 a current limit control.

To describe the operations of the protection circuit, red, green and blue LED converter were made as shown in figure 8. Each of their inductance in figure 8 was 405 μ H, 1.26mH and 1.35mH. All of their output capacitor C_o were 20 μ F. The input voltage was 24V. Each of their output voltage was 28.75V, 73.01V and 42.5V. UC3843 was used for a PWM control IC, switching frequency of the three converters was 100kHz and dimming control switching frequency was 600Hz. Each of their maximum output current was 657mA, 273mA and 489mA.

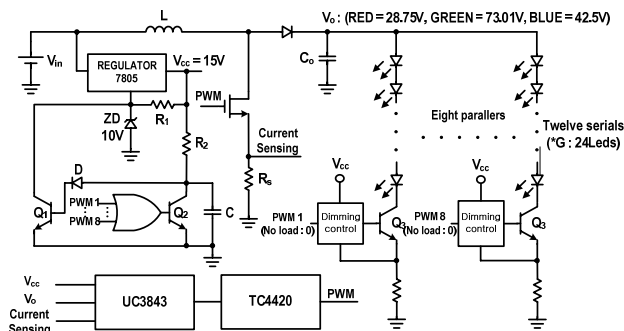


Figure 7. An LED drive converter including a new protection circuit.

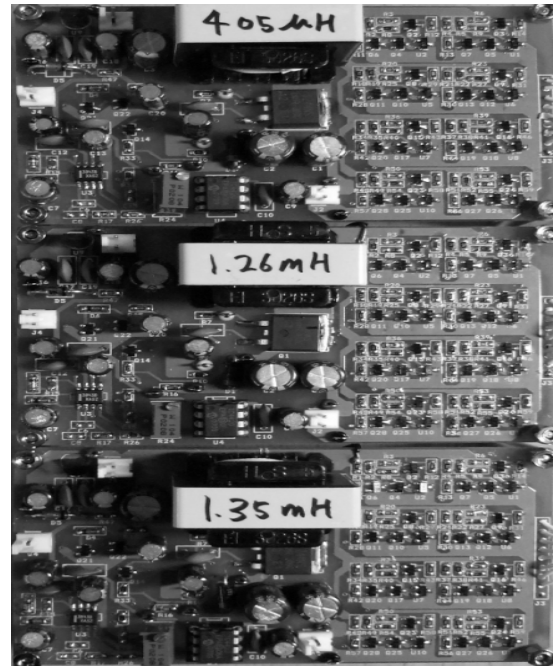


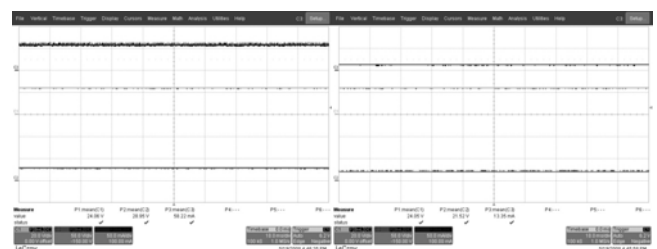
Figure 8. Experimental circuits.

Figure 9 shows measured input current, input voltage and output voltage at no load. Input current of the red LED converter which does not use protection circuit was 58.22mA, the green LED converter which does not use protection circuit was 72.15mA and the blue LED converter which does not use protection circuit was 62.45mA. Output voltage of the red LED converter which does not use protection circuit was 28.95V, the green LED converter which does not use protection circuit was 103.19V and the blue LED converter which does not use protection circuit was 43.40V.

On the other hands input current of the red LED converter which uses protection circuit was 13.35mA, the green LED converter which uses protection circuit was 13.86mA and the blue LED converter which uses protection circuit was 14.03mA. Output voltage of the red LED converter which uses protection circuit was 21.52V, the green LED converter which uses protection circuit was 21.60V and the blue LED converter which uses protection circuit was 21.67V.

Each of power consumption of the converters reduces 1.08W, 1.4W and 1.16W. And each of V_o of the converters reduces 7.43V, 81.59V and 21.73V.

As results of the figure 9, we know that protection circuit is able to save the energy and reduce voltage stress of the transistor of the dimming control for LEDs.



Red LED converter

(a) No protection circuit

(b) Protection circuit

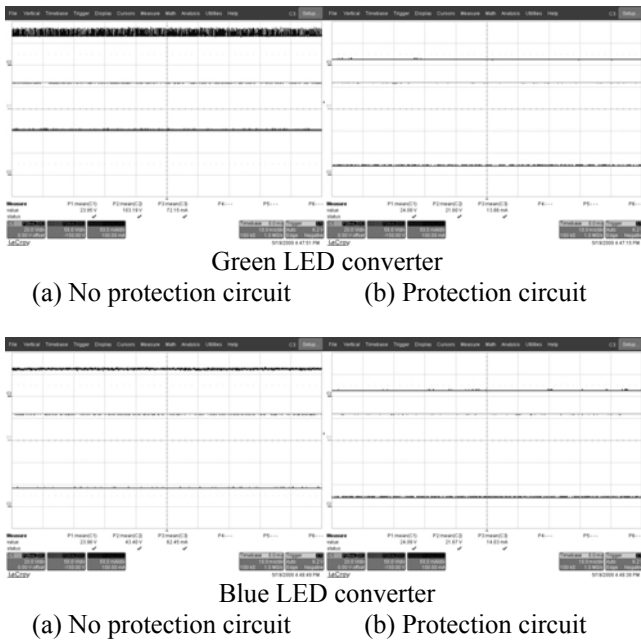


Figure 9. Measured input current, input voltage and output voltage

Figure 10 shows the reason that output voltage V_O of the LED drive including protection circuit is lower than no protection circuit. The no load protection circuit can be not to operate UC3843, and TC4420. So, PWM is not generated and V_O reduces up to about 21.6V due to input voltage of 24V.

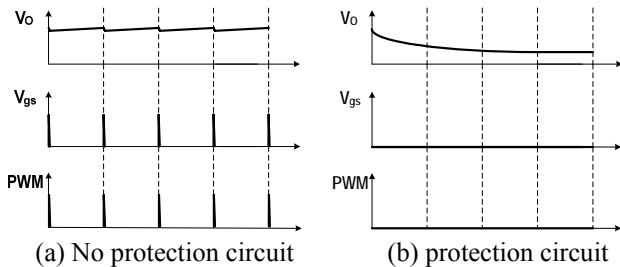


Figure 10. Comparison of V_O at no load.

Figure 11 shows measured efficiencies of the three converters according to the variation of LED dimming duty cycle. The maximum efficiency of the red LED drive circuit was 88.30%, the green LED drive circuit was 86.87% and the blue LED drive circuit was 88.73%.

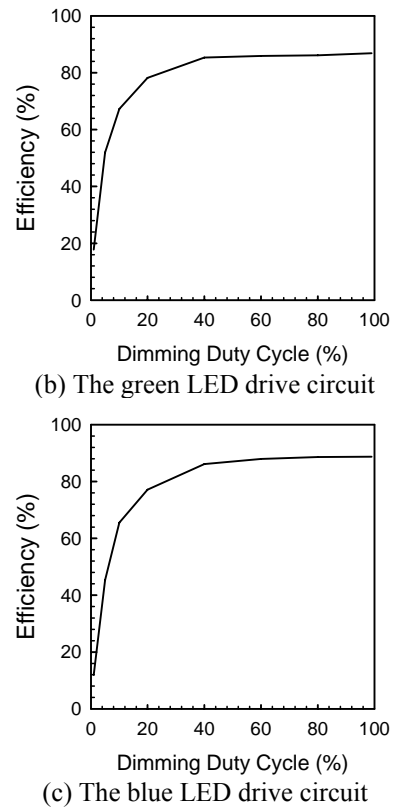
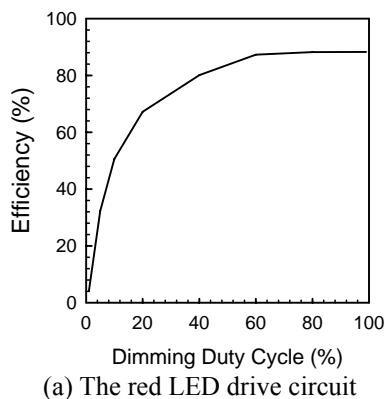


Figure 11. Measured efficiency versus duty cycle variation.

4. Conclusion

An LED drive circuit that consists of a boost DC-DC converter with constant-output-current control, dimming control and its protection circuit is proposed. Protection circuits are over current protection circuit and no load protection circuit which reduces power consumption. The former protection circuit was proposed and simulated. The latter protection circuit is proposed, simulated and experimented. Specially the latter protection circuit can reduce power consumption at no load better than no protection circuit. In addition, protection circuit is able to reduce voltage stress of the transistor of the dimming control for LEDs. Most of all, V_O of the green LED drive circuit was dropped at no load remarkably. Therefore, we will expect to make LED drive circuit of more efficiency and safety, if we use a drive circuit of LCD BLU including protection circuits.

References

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