High Power-Efficient LED Backlight Driving System Independent of Forward Voltage Variation of LED for Large-Sized LCD using Channel Reordering Method

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Abstract
A new light emitting diode (LED) backlight driving system which controls the multi-channel LED backlight for large-sized liquid crystal display (LCD) is proposed. To maintain high power efficiency of LED backlight module in spite of forward voltage variation of LEDs in a channel ($\Delta V_{f,ch}$), the proposed system adopts channel reordering method. The proposed system is simulated by using 0.35$\mu$m Bipolar CMOS DMOS (BCD) process technology. Simulation results show that power efficiency is 90.66% in spite of 2.2$V$ difference in $\Delta V_{f,ch}$ between worst case channel and best case channel on 30% pulse width modulation (PWM) duty ratio.

1. Introduction

Light emitting diodes (LEDs) have been used as an alternative to the cold cathode fluorescent lamp (CCFL) for backlight units (BLUs) of liquid crystal displays (LCDs) due to their various advantages such as dimming capability, wide color gamut, superior lifetime, thin structure, and low power consumption [1].

Recently, various researches on LED backlight driving circuits have focused on high power efficiency, high uniformity of LED current, and fast transient response of the LED current [1-4]. The double loop control method and the phase-shifted pulse width modulation (PWM) dimming method were used to improve power efficiency and transient response of the LED current [2]. In the LED backlight driving system using the double loop control method, the output voltage of boost converter ($V_{out}$) is fixed to the voltage driving LED channel which has largest LED forward voltage drop in each channel. However, the $V_{out}$ is excessive for driving the other channels. Therefore, the excessive $V_{out}$ makes power efficiency of the system lower.

In this paper, a LED backlight driving system for large-sized LCD using channel reordering method is proposed to achieve the high power efficiency, the high uniformity of LED current, and the fast transient response of LED current. The results of simulation targeting a 24-channel LED BLU in large-sized LCD verify the improvement of performance of the proposed system.

2. Circuit design

The proposed system is shown in Fig. 1. A discrete power MOSFET, a boost converter control IC, and a LED current control IC are used. The LED current control IC consists of LED channel characteristic analyzer, channel reorder block, lowest voltage selector, phase shift control block, and dimming control block. The LED channel characteristic analyzer senses
V_ch in the LED channels and transmits these voltages to channel reorder block. The channel reordering block ranks the each LED channel according to magnitude of each channel voltage. The lowest voltage selector detects the lowest voltage (V_lowest) among the V_ch of each LED channel. The phase shift and dimming control block generates phase-shifted PWM signal (V_dim) for each LED channel, and determines the order and the duty ratio of the V_dim based on the rank from channel reordering block and brightness of image data from I2C interface.

The channel reordering block is shown in Fig. 2. To reorder the order of each LED channel, a 6-bit SAR-ADC, DATA registers, a comparison and ranking block, and RANK registers are used. The comparison and ranking block rank the digital data converted from V_ch in the SAR-ADC.

Fig. 3 shows the timing diagram of the V_dim and the V_out at the 3 channels operation. In analysis period, V_lowest is selected to V_ch of the worst case LED channel which has biggest LED forward voltage drop. The order of V_dim is determined sequentially by a prescribed order. The V_out is constant while characteristics of LEDs in LED channel are analyzed. In operation period, the V_dim is reordered by a newly generated rank. When the V_lowest is determined by the order of V_dim and each V_ch, the V_out is determined by optimized voltage which is required to drive each LED channel. To preserve dimming data in next dimming period, pre-pumping operation is performed. In pre-pumping operation, the V_lowest is determined by channel voltage of first channel in newly generated order.

3. Results and discussion

To verify the proposed system, the proposed system is simulated by using 0.35µm BCD process technology. The boost converter and the LED current control IC are designed to drive the 24 channel LED strings. The input voltage of boost converter (V_in) is 24V, the target V_out is 60V, the inductor is 17µH, and output filtering capacitor is 33µF.

Fig. 4 shows simulation results of the V_out according to a sum of forward voltage variation of LEDs in a channel (∆V_LED) on 30% PWM duty ratio. In the simulation results, the tracking operation of the V_out and the pre-pumping operation are presented. The simulated results show that power efficiency with the proposed method is 90.66% when the ∆V_LED is 2.2V. The improvement of power efficiency by using the proposed method is 0.86% when and ∆V_LED is 2.2V, respectively. Fig. 5 shows improvement of power efficiency according to the ∆V_LED.

4. Conclusion

A new LED backlight driving system for large-sized LCD is proposed by using channel reorder method. In the proposed method, characteristics of LED channels are analyzed and the order of LED channel is reordered. Because the V_out is determined by optimized voltage required to drive each LED channel, the proposed system maintains high power efficiency in spite of ∆V_LED.

Fig. 4. Simulation results of the boost converter output voltage at the 24 channel operation when ∆V_LED is 2.2V.

Fig. 5. Simulation results of power efficiency according to the ∆V_LED.

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References