A Novel Pixel-level Local Dimming Backlight System for HDR Display Based on mini-LED†

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Abstract
Recently, people present higher standard of the luminance and contrast for display system, especially for large UHD display which increasingly demands for HDR 1000 compatible. Compared with the side-emitting LED backlight, direct lit-type backlight can provides higher luminance, but global backlight control cannot satisfy high requirement for the contrast and the power loss. In order to improve the performance the backlight system, the local dimming backlight control with Mini-LED become one of the best choices for us. In this paper, we present a pixel-level local dimming backlight system, which is applied for the 75 inch UHD display system.

Author Keywords
HDR Display, mini-LED, pixel-level, local dimming, lower power consumption

1. Introduction
Nowadays, with the continuous developments of the LCD display technology and people's requirement for the large size monitor, the shipments for the monitor larger than 65 inch increase year by year, which is shown in fig.1 IHS report. In this paper, we propose a UHD 75 inch monitor with the direct lit-type backlight to provide better brightness uniformity.

The conventional direct lit-type backlight display system is hard to satisfy the HDR requirement for the contrast due to its limitation of the quantity for the local dimming segment. On the other hand, the conventional backlight module is always thick, usually between 10 and 15 millimeter. Sometimes, the thickness can reach larger than 20 millimeter with less LED to save the cost.

Considering the above limitation, local dimming backlight system with Mini-LED is proposed as a good HDR solution for UHD display. The backlight module thickness can reduce about 90 percent with the Mini-LED method. Moreover, this technology can improve the contrast and also reduce much power consumption when the picture has much black area. Currently, the local dimming segments is less than 5000. In such circumstance, the UHD display will appear Halo effect inevitably.

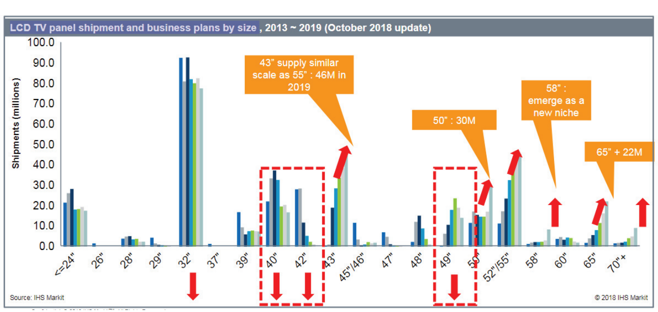


Figure 1. LCD panel shipment from HIS report

This paper proposes a novel pixel-level local dimming backlight system with more than 20,000 segment, one of which includes only 40x40 pixel. This paper designs the hardware through combining the LED and backlight driver circuit in one PCB board with the FR4 material to reduce more backlight thickness effectively. Furthermore, this paper adopts dynamic scanning method to control the backlight, which can reduce the amount of the driver IC about 75 percent. In this paper, our pixel-level local dimming backlight system can realize high brightness, high contrast, less power consumption to satisfy the HDR display standard with the low Halo effect.

2. Mini-LED Backlight System
The mini-led dynamic backlight mentioned in this paper is mainly used in 75-inch UHD display system. Table 1 shows the corresponding pixel points, control area and number of driving IC under different segments and control modes. In this paper, the entire backlight system is divided into 20,736 segments, and the backlight is controlled by dynamic scanning mode.

2.1 Optical Control System
In this paper, we use blue Mini-LED to emitted the blue light, which is irradiated onto the QD film to excite red and green light. The specific backlight module stack is shown in the fig.2 below. Compared with ordinary phosphor-excited illuminating methods, QD film emits a narrower wavelength range of light, which can effectively ensure the color gamut of the display system, as is shown in fig.3.

In this paper, we use the 20,736 segments to control the backlight, which determines that we need at least 20,736 LED lights. If using one LED light per segment, 20,736 LED lights are used for the backlight system, the requirement for OD distance is about 3 mm. The OD distance can be effectively reduced by increasing the number of LED lights. However, if we use 41,472 LED lights for the backlight system with two lights per segment, it will influence the homogeneity of the backlight system. In this paper, the backlight system with four lights per segment is selected, which can not only ensure the homogeneity of backlight display but also reduce the distance of OD to less than 1.5 millimeter.

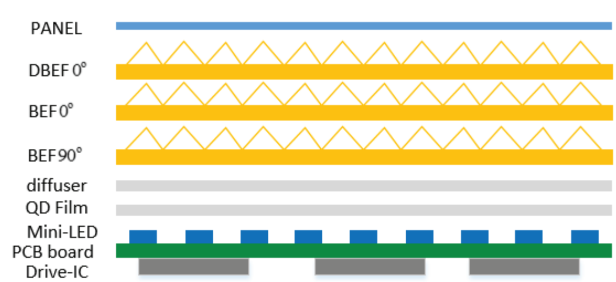
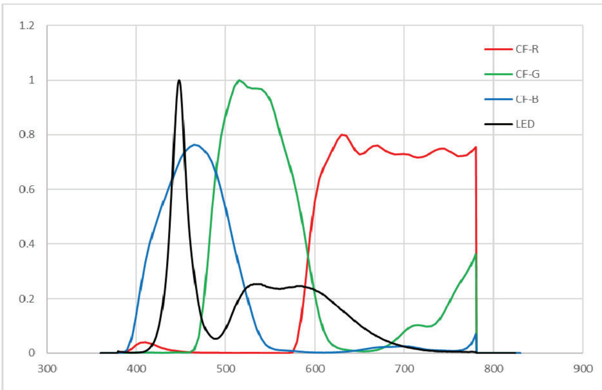


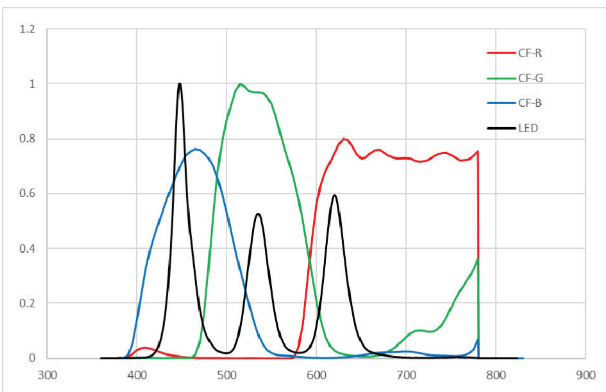
Figure 2. Mini-LED Backlight Module stack

Table1. Specification of different segements for local dimming backlight

Number of segement	Segement（HXV）	One Segement		Number of Driver IC	
		pixels	Area (mmxmm)	static	scan
2304	64x36	120x120	20.6x20.6	48	12
5184	96x54	96x54	17.2x17.2	108	27
14400	160x90	48x48	10.3x10.3	216	54
20736	**192x108**	**40x40**	**8.5x8.5**	**432**	**108**



(a) phosphor-excited methods



(b) QD film excited methods

Figure 3. Wavelength Range of Different Excited Methods

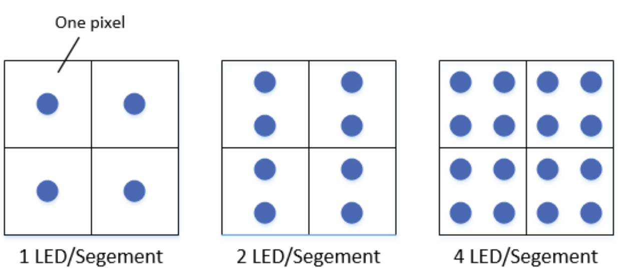


Figure 4. LED Distribution of Different Quantity

2.2 Backlight Drive system

The following fig.5 shows the system block diagram of the dynamic backlight system under 20,736 segments, which mainly includes power module, FPGA control module, screen display module and backlight module. The backlight driver is controlled by the FPGA based on the SPI communication protocol and the data selection signal. The mini-LED is controlled by a dynamic scanning control method, and only 1/4 of the LEDs of the backlight unit are illuminated during unit time. The dynamic scanning control method mainly controls the backlight driving units through the decoder and the data selection signal. Compared with the static backlight driving method, this driving method can reduce the number of the backlight driving IC to 1/4 of the original, which will effectively reduce the difficulty of PCB layout of the backlight driving circuit and reduce the cost of the whole system.

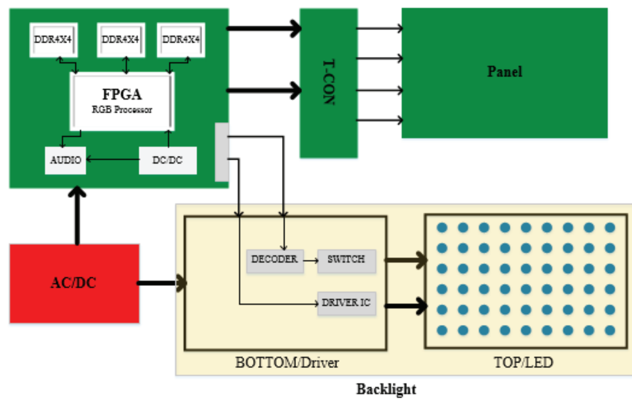


Figure 5. Backlight System Blocks

3 Backlight Signal Control Method

Since the quantity of the Mini-LED segment is very large, this will lead to the large requirement of driver IC for the backlight system. This paper chooses to compose the LED and the driver in one board, which means the area of the backlight circuit cannot be larger than the LED board. Assuming that the quantity of the backlight driver chip is large, this will increase the difficulty of the PCB layout design and the thermal design with more cost. There is no doubt that reducing the quantity of the chip without changing the local dimming backlight segments will be our best choice.

As is shown in fig.6, dynamic scanning method is applied in this paper to control the backlight. Signal A and B are the digital signal to control the switch 1~4 to determine which group is powered on. The whole backlight system is divided into four groups and only one group LED backlight is powered on at the same time, as is shown in Fig.7.

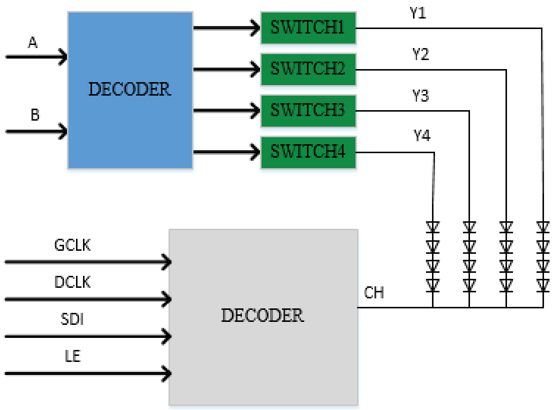


Figure 6. Signal Control Blocks

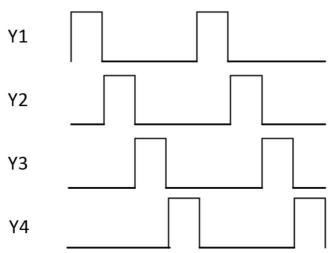


Figure 7. Timing Control Sequence for Backlight System

Equation (1) is the image conversion formula from the RGB parameters to YUV parameters.

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.2126 & 0.7152 & 0.0722 \\ -0.1146 & -0.3854 & 0.5000 \\ 0.5000 & -0.4542 & -0.0458 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

As is known, the parameter Y can show the brightness of the image information. After obtaining the RGB image information, we will choose the Y parameter, then will get the image only with the brightness information as is shown in Fig.8.

Assuming that we have determined the segment of the local dimming backlight, such as the segment is MxN. If our image pixel information is AxB, then a signal segment of the backlight must be M/A or N/B. To ensure the homogeneity of the backlight brightness, M/A must be equal with N/B.

Since one segment has many pixels, not only one, so we must decide the brightness value of one pixel. The easiest method is to choose the maximum brightness or the average one, but these two method will generate some problems. For example, if we choose the maximum brightness of the image, the maximum brightness can be reserved but the brightness change largely between two local dimming segments. Otherwise, if we choose the average brightness, the change between two segments is smooth, but we cannot obtain the largest luminance of the whole backlight system. Therefore, we compromise between the two method using the weighted algorithm to control the backlight system.

First of all, when receiving the image, we will use the Equation (1) to obtain the brightness information of each pixel and calculate the average brightness. Then we compare each pixel luminance with the average value and calculate pixel proportion of the distribution. According to the calculation result, each segment of the display brightness will be weighted calculated and then we can get the local dimming brightness.

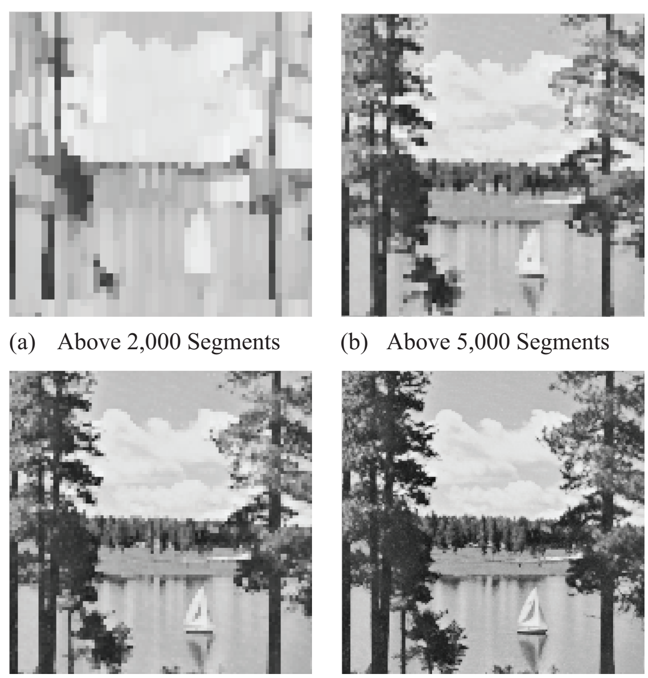
(a) Original image (b) brightness paramater image

Figure 7. Timing Control Sequence for Backlight System

4 Simulation and Result

In this paper, we simulate the local dimming backlight system of different segments such as above 2,000 segments, above 5,000 segments, above 10,000 and above 20,000 segments using the control method above as is shown in Fig.8.

From the simulation result, we can see the 2,000 segments cannot show the outline of the image clearly, let alone the local dimming effect. The segments above 5,000 and 10,000 can provide some image information, but the brightness has large difference with the image in Fig.7 (b). The brightness of the segments above 20,000 is similar to the image converted only with the brightness parameter, also with the clearly image outline.



(a) Above 2,000 Segments (b) Above 5,000 Segments

(c) Above 10,000 Segments (d) Above 20,000 Segments

Figure 8. Local Dimming Backlight Control of Different Segments

5 Conclusion

This paper proposed a novel pixel-level local dimming control system for HDR display concluding its Mini-LED backlight system and the control method. This pixel-local dimming control can easily realize the HDR 1000 standard with high luminance, high homogeneity and high contrast. Compared with other local dimming system less than 10,000 segments, the one in this paper can reduce the Halo effect deeply. Since the image usually has some dark field, the backlight system's power consumption can be largely reduced when used.

The LED light and its driver IC are composed in one PCB board using FR-4 material. In order to reduce the PCB layout area of the driver and the cost of the backlight system, this paper takes the dynamic method to control the system, which can reduce 75 percent driver IC and the cost compared with the static control method. The backlight control algorithm presented in this paper can effectively balance the maximum brightness and the image outline.

As the simulation result, it is of great significance for us to develop the local dimming backlight system, especially more than 20,000 segments. This must be the trend of the backlight system for LCD display.

6 Reference

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