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A High-Image-Quality OLED Display with Motion Blur Reduction for Ultra-High Resolution and Premium TVs

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Abstract

We have developed a high image quality OLED Display with motion blur reduction technology. Our latest work includes driving method which reduces motion blur using an adaptive black data insertion, brightness compensation technology, the simple structure pixel with low capacitance coupling for horizontal noise, and the multi-function integrated gate driver. The MPRT value of the OLED display panel with a fast response time was significantly affected by the frame frequency and the compensation driving method. The decrease in the MPRT value originated from the turning of the emitting pixels off in advance resulting from providing black data. The integrated gate drivers were designed to achieve the normal display, the black data insertion, and the compensation mode. The MPRT value of the 65-inch UHD OLED panels was decreased to 3.4ms by using an integrated gate driver circuit. The motion blur of large-size OLED display panels was significantly reduced due to a decrease in the MPRT value.

Author Keywords

High Image Quality, MPRT, OLED, TV

1. Introduction

Recently, display technologies have been rapidly developing due to the advancement of the materials and the electronic technologies. Among the several displays, organic light-emitting devices (OLEDs) have positioned as next-generation display panels, replacing liquid crystal displays (LCDs) in the high-end TV market. The self-emission characteristics of the OLEDs can realize perfect black without light leakage and high brightness. Simultaneously, achieve a wider viewing angle and uniform luminance by using precise compensation [1-4]. Despite this overwhelming performance, the high price of the OLEDs that slow down the transition to the OLEDs, which was previously developed the integrated gate driver in the direction of the cost reduction [5]. On the other hand, it is one thing to emphasize the advantages of the OLEDs more clearly by improving the picture quality of the OLEDs [6]. In the case of the response time, many improvements have been performed in the LCDs [7], and it is necessary that OLEDs have to be differentiated from the LCDs [8-10]. The oxide TFTs have been used as OLED display backplanes, which are different from a-Si TFTs commonly used for LCDs. Because the oxide TFTs have the mobility of 8 to 10 times higher than a-Si TFTs, the integrated circuits in OLEDs tend to be smaller. On the other hand, being depletion-mode transistors, they often have a negative initial threshold voltage (Vth), which results in leakage current and even in malfunction if not well designed.

Figure 1 shows the MPRT characteristics classified by display type and driving conditions. Traditional cathode ray tube (CRT) displays do not have the sample-hold characteristic. Due to the sample-hold characteristic of LCDs and OLEDs, fast moving scenes displayed on those display panels are often seen blurred. This phenomenon is known as the motion blur. It is necessary to have less than 5.7 ms that a person can recognize the motion blur. The motion picture quality enhancement technology is considered to apply to the integrated gate driver and developing black data insertion technology into the gate driver. LCD technologies such as the black data or frame insertion, the backlight local dimming, and the high frequency driving has been applied to improve the motion picture response time (MPRT) characteristics.

This paper presents a new technological solution for the fast MPRT OLED panel with a novel integrated gate driver to improve the image quality and price competitiveness of the OLED display panels. The motion blur issue has been improved by using the design approach of the MPRT enhancement driving method with an integrated gate driver circuit.

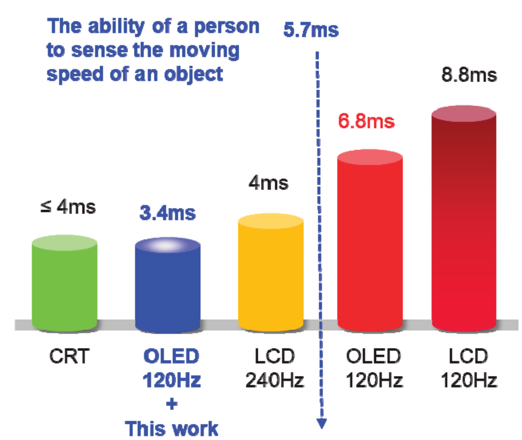


Figure 1. Comparison of the MPRT characteristics classified by the display type and the driving condition.

2. OLED Display with Motion Blur Reduction

2.1. Proposed OLED Display Panel and Circuit

The proposed OLED display panel and driving circuit for the ultra-high-resolution OLED TVs are shown in Figure 2. The proposed pixel circuit, which consists of three TFTs, one capacitor, a current source for the OLEDs, scanners, sensors, and a sensing line, compensates for variations in the threshold voltage and the mobility of the carriers in the TFTs. The T_{DR} is used as a current source, the T_{SC} acts as a switch for inputting the image data, and the T_{SE} electrically connects the T_{DR} to the external circuit during sensing operations. The sensing line contains one pixel consisting of red, white, green, and blue sub-pixels. The initial high luminance uniformity of the OLEDs can be maintained by continuously compensating for variations in the luminance with respect to its initial values; this is possible because the proposed circuit can sense the mobility of the carriers and the threshold voltage in real time. This method also corrects the threshold voltage shift and the mobility shift by using real-time sensing and compensation to continuously maintain initial high luminance uniformity.

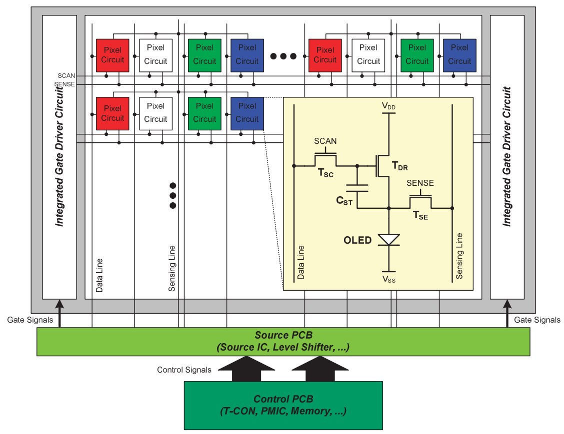


Figure 2. The proposed panel and driving circuit for the ultra-high-resolution OLEDs.

2.2. MPRT Enhancement Driving Method

Figure 3 shows the concept of the proposed panel driving method with the adaptive black data insertion (ABI) to reduce the motion blur in fast moving images. First, video data is written first, a black data is used after holding duty, and the video data, which has been used before, is erased with the black data.

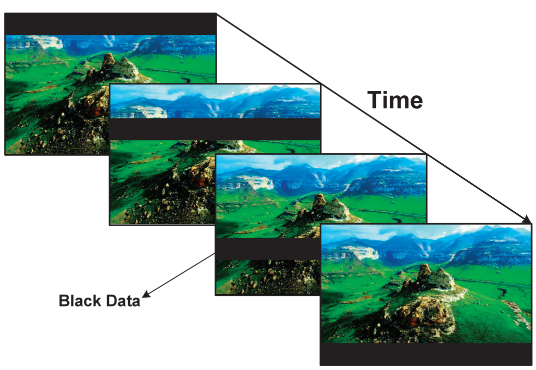


Figure 3. The concept of the adaptive black data insertion (ABI) to reduce the motion blur in fast moving images.

Then, another video data come out of the next frame again, and this process is repeated. When the gap between video data and black data is longer, holding duty becomes longer, resulting in a decrease in the MPRT improvement effect, the MPRT improvement effect increases with decreasing holding duty. Figure 4 shows a driving waveform, which explains sending the black data. When N lines are simultaneously applied to black data, the frame frequency becomes less than 240 Hz. OLED display is required to sense and compensate the threshold voltage of the pixel TFT for sustaining uniform luminance. The setting of the sensing timing makes it difficult to implement the ABI technology. Therefore, it becomes more complicated for sensing timings to avoid overlapping timings for video data and black data. The sensing pixels of the line typically operate in a porch time between the frame and the frame right after scanning the last line of the display. Even though the video data have been written on the last line, the black data are still being written in the middle of the screen.

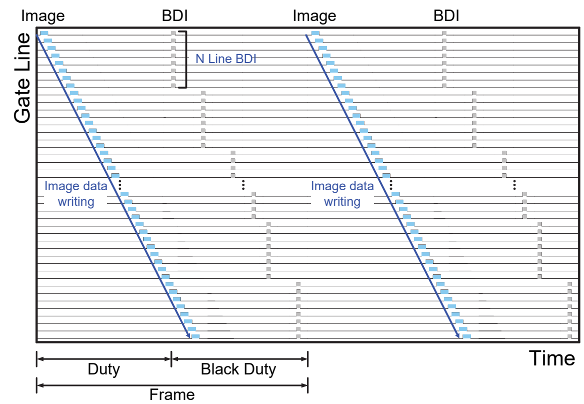


Figure 4. The driving waveform of the adaptive black data insertion to reduce the motion blur in fast moving images.

Therefore, the sensing timing should be established to no crash with another gate signal such as video scanning clock signal and black data clock signal. Because the sensing timing should be performed within serious limitations, the sensing method in the pixel is different from the conventional one to achieving sufficient sensing performance. The black data insertion with a duty of 50 % is equivalent to a holding time of 240 Hz, which is expected to contain a similar effect in the improvement of the motion blur.

In order to apply black data without increasing the frame frequency, N lines were selected at the same time and black data were applied at the same time.

2.3 Multi-Function Integrated Gate Driver in Panel

The proposed integrated gate driver is implemented on the oxide TFT substrate and performs functions such as image display, compensation operation and black data insertion function. Figure 5 shows the schematic diagram of the gate driver circuit. A block for Q-node charging to sense and compensate the OLED pixel in the previous version of the gate driver, which is installed in addition to the Q-node charging [11]. However, an additional Q-node reset function is installed in this work. In this part, the sensing is completed in the previous circuit, and the whole frame is automatically reset in the next frame. However, because the reset function is omitted due to the black data insertion function in this circuit, a block for resetting of the Q-node is necessary.

Figure 6 shows the timing diagram of the proposed integrated gate driver, which is divided into the display data writing period and the black data insertion period. The display data writing period can be explained with four steps. First, a start pulse (VST) comes to shift register and the input TFT (T1) charges the gate node of the buffer TFT. The rising transition of the clock that enters the drain node of pull-up TFT increases Q node by bootstrapping and a gate pulse (G[n]) is generated at the same time (T2). As the clock signal changes to low level, G[n] is discharged by pull-down TFT and Q node returns and keeps the previous level of T1 until the reset pulse (RST) comes (T3). Finally, Q node is completely discharged by a high level of reset pulse (T4). The proposed method of MPRT enhancement is necessary to make additional gate pulse for insertion of black data. The operation of the black data insertion period (T5-T8) is almost similar to display data writing period driving (T1-T4) except that N stage gate pulses are generated simultaneously (T6), whereas another has only one gate pulse at a time. In other words, black data is inserted while these lines are turned on together.

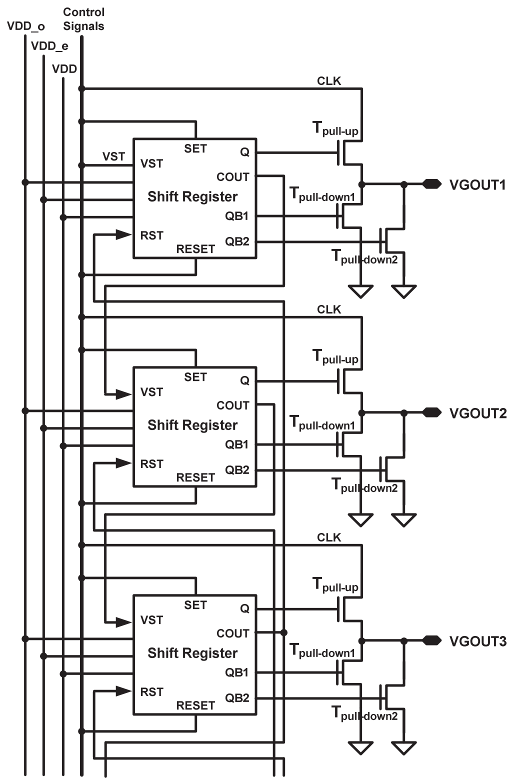


Figure 5. Simplified schematic of the proposed integrated gate driver for multi-function operation.

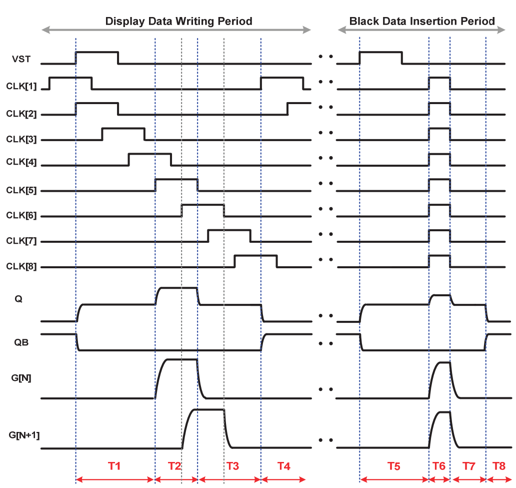


Figure 6. Driving waveform of the proposed integrated gate driver.

3. Results and Discussion

Figure 8 shows a 65-inch UHD OLED panel fabricated to verify enhancement of the motion blur in large-size OLED panels by using integrated gate driver circuits with a moving picture response time reduction method.

Figure 9 shows the measurement results of the integrated gate driver. The falling time of the circuit is approximately 1.2 µs, which is fast enough to drive UHD OLED displays with enhanced MPRT at 120 Hz frame frequency. Because the gate on-time of the UHD OLED displays is 3.0 µs, its falling time should be 1/2 to charge and discharge within this time. The gate driver has the dual pull down configuration that slows down the degradation rate of the positive voltage bias thermal stress (PBTS) and the response to the initial negative threshold voltage (Vth) of the oxide device. The reliability characteristics of the whole circuit are determined by the Vth shift amount of TFTs on the QB-nodes, such as the pull-down TFT, which have the dominant turn-on duty. Therefore, the dual pull down technology comprising two sets of pull down TFTs is applied to delay the degradation speed and increase the lifetime.

Figure 8. Photograph of the fabricated 65-inch UHD OLED display panel.

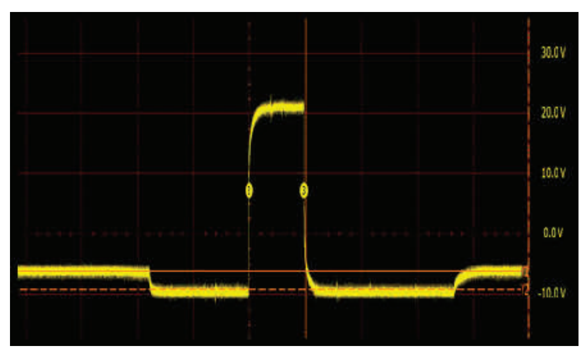
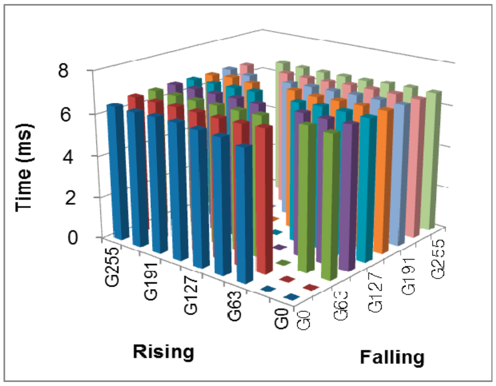
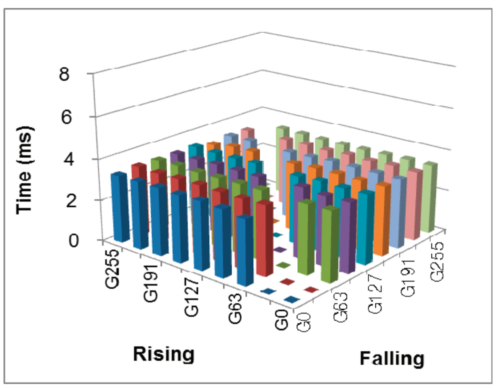


Figure 9. Measurement results of the integrated gate driver.

Figure 10 shows the MPRT characteristics of the 65-inch UHD OLED displays. The panel is normally functioning with scanning operation and sensing operation, and the motion blur on the screen decreases when the adaptive black data insertion function is turned on. The MPRT value of the 65-inch UHD OLED panels was decreased to 3.4ms by using an integrated gate driver circuit. Therefore, the MPRT characteristics of the OLED displays were successfully enhanced, which can implement a better picture quality on the advantages of the previous version of the integrated gate driver, such as cost reduction, narrow bezel, and flexible display, which might significantly contribute to the popularization of the OLED displays. Table 1 shows the device performances of the 65-inch high MPRT OLED display fabricated utilizing the proposed integrated gate driver. The fabricated 65-inch UHD panel achieves 6.5 mm bezel, normal screen, and compensation drive works properly. When the ABI function is turned on, it is confirmed that the motion blur is surely reduced. The differentiated image quality of the OLED displays, such as black expressiveness, color rewrite and fast pixel response, can be clearly enhanced in comparison containing the panel with the integrated gate driver of the previous version.



(a)



(b)

Figure 10. MPRT characteristics of (a) the conventional OLED display, (b) the fabricated 65-inch UHD OLED display with motion blur reduction.

4. Conclusion

The high image quality OLED displays fabricated utilizing the integrated gate driver circuits by using the MPRT reduction method for the large size TVs were achieved. The motion blur of the large-size OLED display panels was significantly reduced by using the integrated gate driver circuit with the MPRT reduction method. The decrease in the MPRT originated from the turning of the emitting pixels off in advance resulting from providing black data. The integrated gate drivers were designed to achieve the normal display, the black data insertion, and the compensation mode. With these results, the MPRT value of the 65-inch UHD OLED panels was decreased to 3.4 ms by using an integrated gate driver circuit for high-image quality OLED TVs.

Table 1. Specifications of the fabricated 65-inch OLED display with motion blur reduction.

Item		Content	Unit
Panel size		65	Inch
Resolution		3840×2160	-
Frame rate		120	Hz
Brightness		150/500	cd/m^2
MPRT	ABI On	< 3.5	ms
	ABI Off	< 6.8	ms
GTG		<0.001	Ms
TFT Backplane		IGZO	-
Panel Structure		1G-1D	-

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