

# A Novel 480Hz OLED Display with DFR Gate Driver for Premium Monitors

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## Abstract

*This paper presents a novel 480Hz OLED display with DFR gate driver for premium monitors. New key technologies are applied to the developed 480Hz OLED display, including the DFR driving method, DFR gate driver in a panel, WOLED with micro lens array, pixel aperture ratio improvement, and cinematic sound OLEDs. The MPRT value of the OLED panels was reduced to 1.7 ms under gaming mode using the DFR driving method. Those technologies enable the high image quality and motion blur-free characteristic of the OLED display panel. Finally, we have successfully launched the world's first 480Hz 27-inch and 31.5-inch DFR OLED monitors.*

## Author Keywords

480Hz OLED display, DFR driving method, DFR gate driver in the panel, WOLED with micro lens array, pixel aperture ratio improvement, cinematic sound OLED, MPRT. 31.5-inch DFR OLED monitors.

## 1. Introduction

Recently, organic light-emitting diode displays (OLEDs) have been positioned as major displays due to their excellent image quality and high dynamic range, replacing liquid crystal displays (LCDs) in the high-end monitor market [1,2]. OLEDs provide several major technology enhancements for display, such as a high contrast ratio, wide viewing angle, high brightness, and fast response time [3].

There has been some progress in major technologies for OLED displays. In the case of the TFT backplane, Oxide TFTs have been used as OLED display backplanes, its structure has been developed into a coplanar type with small and low parasitic capacitance to increase the pixel aperture ratio [4]. From a performance point of view, there were improvements in TFT and reliability characteristics [5]. Material improvement and structure development have been made for OLED to increase efficiency and color gamut. Also, several light extraction methods such as micro-lens arrays, photonic crystals, scattering films, and wrinkled devices have been reported to increase the device efficiency [6].

In designing higher refresh rates and higher-resolution OLED display panels, the driving method becomes more difficult, and the aperture area decreases unavoidably. A narrow panel bezel is increasingly required in the high-end display market, and technology to reduce the area of the integrated gate driver is required to realize a narrow bezel while lowering manufacturing costs and achieving a design form factor [7].

In monitor displays, the gray-to-gray (GtG) response time of OLEDs can be much faster than that of LCDs. However, the refresh rate of OLEDs is generally lower than that of LCDs. The refresh rate is the number of times per second that a monitor represents a new image.

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 for a person to recognize the motion blur. [8]. Increasing the refresh rate reduces perceived motion blur, and further helps the monitor represent clear moving objects. As the eyes follow the moving object on the screen, the moving object is perceived as blurred. The main factors affecting motion blur are GtG response time and refresh rate [9]. The 240Hz refresh rate is sufficient for watching TVs. On the other hand, a high refresh rate exceeding 240Hz is required for gaming monitors.

In this paper, we introduce novel 480Hz OLED display technologies using dynamic frequency and resolution (DFR) driving method, integrated gate driver for DFR driving and narrow bezel, WOLED with micro lens array, pixel aperture ratio improvement, and film type cinematic sound OLEDs.

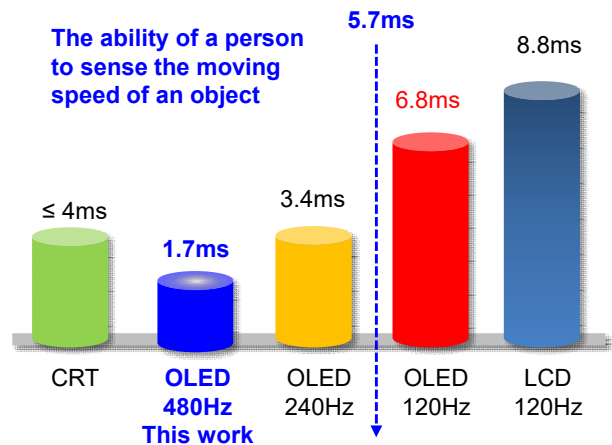


Fig. 1. Comparison of the MPRT characteristics classified by display type and driving conditions.

## 2. Novel OLED Display Technology

### 2.1 Panel Structure

The proposed OLED display panel for premium monitors is based on a combination of advanced coplanar oxide TFT, and OLED with micro lens array (MLA). As a bottom emission type, the OLED display panel is composed of one layer of glass and solid phase encapsulation (SPE). Figure 1 shows a cross-sectional view of the proposed OLED display panel for premium monitors. The advanced coplanar oxide TFT has been developed for high-resolution and high-speed OLED display panels. Unlike

conventional coplanar structures, gate and source/drain (S/D) layers are formed at once to fabricate the advanced coplanar oxide TFTs. Additionally, the OLED display panel includes WOLED with MLA to increase maximum brightness, transparent metal technology to increase the aperture ratio for pixels, and an integrated gate driver for DFR operation and panel bezel reduction.

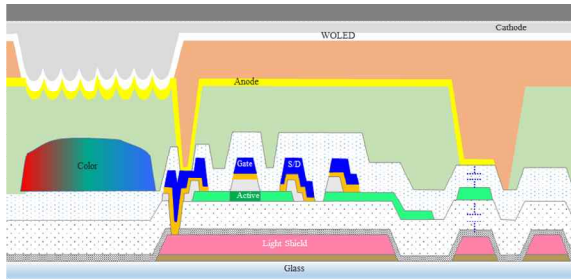


Figure 2. Cross-sectional view of the novel OLED display panel for premium monitors

2.2. DFR Driving Methods

The concept of the proposed dynamic frequency and resolution (DFR) driving methods for dual mode display is shown in Figure 3. This technology allows users to freely switch between the 480Hz high refresh rate mode and the 4K high-resolution mode according to their choice. The 480Hz ultra-high refresh rate mode provides a smooth screen without any interruption in genres that require fast speed, such as racing games, and the 4K high-resolution mode allows you to enjoy rich, natural colors and brightness clearly and three-dimensionally as if you were seeing it with your own eyes.

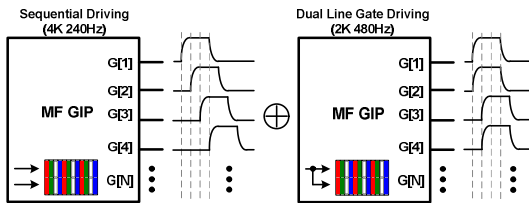


Figure 3. DFR driving concept and integrated multi-function gate driver waveforms

In high refresh rate mode, users can enjoy games where speed and screen changes are particularly important, such as first-person shooter (FPS) or racing genres. Switching to high-resolution mode offers an exceptionally immersive experience watching movies with rich visual effects or high-definition 4K content. By comparison, conventional panels have a fixed resolution even when the refresh rate is changed, limiting their versatility for multiple applications.

2.3. Multi-Function Gate Driver in Panels

A proposed integrated gate driver for the DFR driving method is shown in Figure 4. It consists of a circuit block for high-resolution driving, a circuit block for high-speed driving, a DFR selector, and control signals. By selecting control signals, the sequential output is generated in high-resolution mode, and dual line gate (DLG) outputs are generated simultaneously in high-speed driving mode.

To reduce the integrated gate driver, a gate driver block consists of a control circuit, a shifter register circuit, and a buffer, and has a structure in which multiple buffers are connected to one shifter register circuit. The panel bezel width is determined by the size of the gate driver circuit arranged on the left and right sides of the panel.

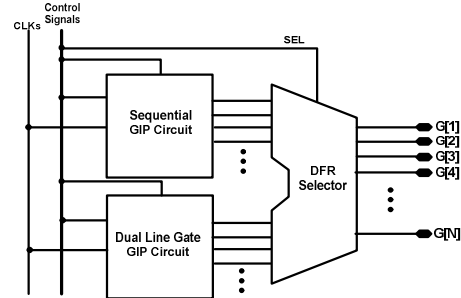


Figure 4. The proposed multi-function gate driver for DFR driving methods

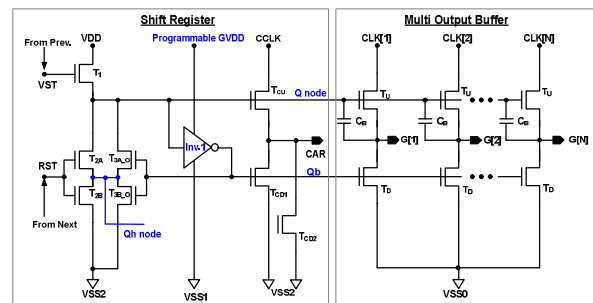


Figure 5. Simplified the schematic of the multi-function gate driver circuit for DFR driving methods.

Figure 5 shows the multi-line channel gate circuit of the gate driver in panels. We proposed a circuit structure that has small design area to reduce the bezel of OLED display panels. By using multiple output buffers in one shift register block, we were able to significantly reduce the complex circuit configuration of the shift register. However, the  $T_u$  TFTs that use the same gate node each have capacitive coupling effects on the Q node when turning on, resulting in different gate voltages and output characteristics for each output TFT. To overcome this problem, we applied individual RC delay time control technology for CLK outside the panel to compensate for the difference in falling time and ensure high image quality.

Figure 6 shows the timing diagram of the proposed gate driver, which is divided into the display data writing period and the compensation period. The display data writing period can be explained in four steps. First, a start pulse (VST) comes to the shift register and the input TFT ( $T_1$ ) charges the gate node of the buffer TFT. The rising transition of the clock that enters the drain node of pull-up TFT increases the Q node by bootstrapping and a gate pulse ( $G[n]$ ) is generated at the same time ( $T_2$ ). As the clock signal changes to the low level,  $G[n]$  is discharged by pull-up buffer TFT, and the Q node returns and keeps the previous level of  $T_1$  until the reset pulse (RST) comes ( $T_3$ ). Finally, the Q node is completely discharged by a high level of reset pulse ( $T_4$ ), and the Qb node is charged by low level Q node signal.  $G[n]$  is rising to VSS0 voltage level. This under-driving method is a key technology for reducing the falling time of the gate driver in

panels. The proposed method of real time compensation is necessary to make an additional gate pulse during blank time. The operation of the compensation gate pulse period (T5-T8) is 100 times longer than display data writing period driving (T1-T4), and one stage gate pulses are generated per frame, whereas another frame has only one gate pulse of real time compensation at another sequence.

Figure 7 shows the optical microscope image of the fabricated gate driver applied to 31.5-inch OLED display panels. It consists of the control signals, control logic circuit, shifter register, and output buffer stages, and has a structure in which multiple output buffers are connected to one shifter register circuit. The size of the proposed gate driver is 40 % smaller than that of our previous gate driver. Therefore, we reduced the size of the panel bezel by 34 %.

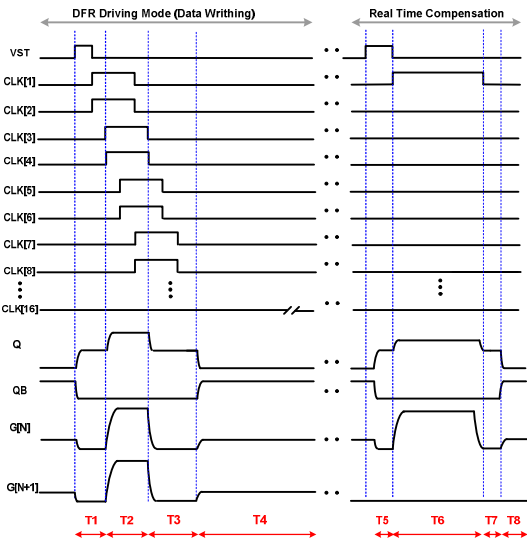


Figure 6. Driving waveform of the proposed integrated gate driver

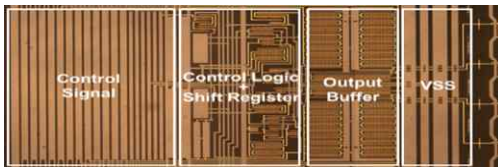


Figure 7. Optical microscope image of the fabricated gate driver applied to 31.5-inch OLED display panels

### 2.3. High Aperture Pixel Structure

The aperture ratio is increased by using transparent metal as the circuit connection line within the pixel and reducing the hole size using a phase shift mask. Figure 8 shows the high aperture ratio OLED pixel structure. Using those technologies, the pixel aperture ratio of the 31.5-inch OLED panel could be increased from approximately 15% to 26%. WOLED with MLA is used to improve the brightness of the OLED display panel.

Figure 9 shows the proposed MLA based OLED structure deposited on the patterned over-coating layer to efficiently extract light from OLED in the front direction. In the proposed device, the planarized overcoat layer is first patterned by photolithography to form the MLA structure with a hexagonal array of microlenses with maximum fill factor. Then, the white organic emitting layers

are deposited on it. The pitch and height of the MLA structure are controlled within a few microns. A white organic light-emitting layer is then deposited on top of it. The pitch and height of the MLA structure are controlled within a few microns. It also includes two electrodes to achieve the microcavity effect. The MLA-based OLED structure can improve the efficiency and viewing angle characteristics by suppressing the light loss compared to the conventional OLED structure and increasing the outcoupling efficiency. The luminance efficiency measurement result shows that the efficiency was improved by about 20 %.

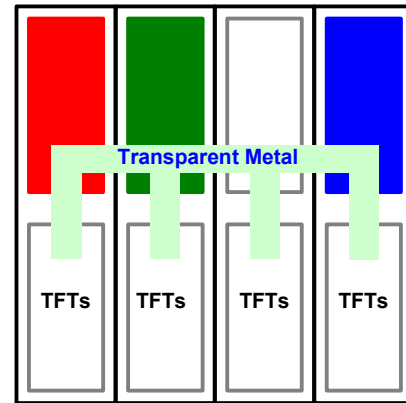


Figure 8. High aperture ratio pixel structure of the OLED display panel

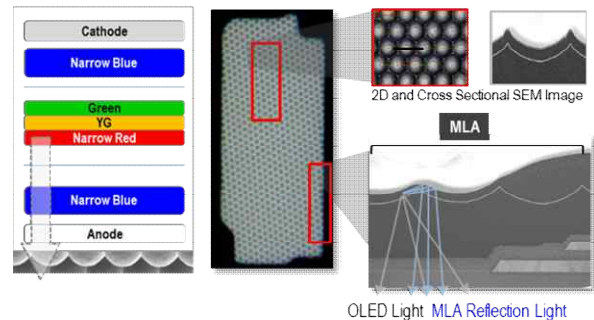


Figure 9. MLA based OLED structure and cross section SEM Image of MLA based OLED

### 3. Results and Discussion

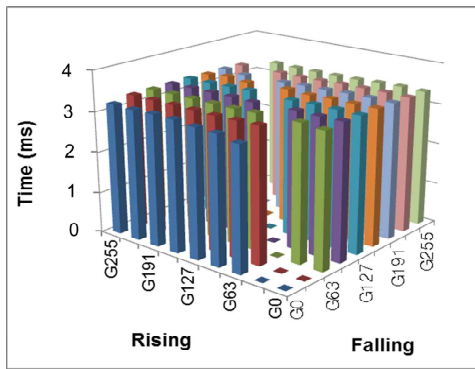
Figure 10 is a photograph of the developed 480Hz 31.5-inch UHD OLED display with dynamic frequency and resolution driving gate driver for premium monitors. New key technologies are applied to the developed 480Hz OLED display, including the integrated gate driver for DFR driving methods, WOLED with micro lens array, pixel aperture ratio improvement, and film-type cinematic sound OLEDs.

Figure 11 shows the MPRT characteristics of the 31.5-inch UHD OLED displays. In high refresh rate DFR on mode, the MPRT value of the OLED panels was decreased to 1.7ms by using an integrated gate driver circuit. The MPRT characteristics of the OLED displays were successfully enhanced. Therefore, users can enjoy games where speed and screen changes are particularly important. Switching to high-resolution mode offers an exceptionally immersive experience watching movies with rich visual effects or high-definition 4K content. Table 1 shows the characteristics of the fabricated OLED displays. The maximum

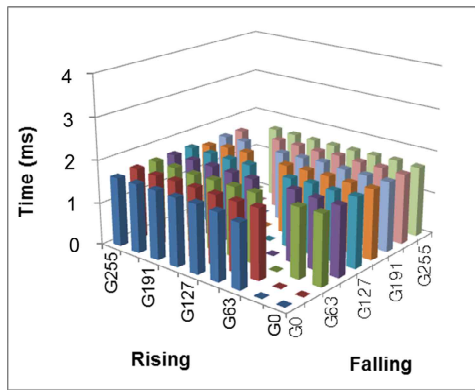
brightness of the panel is 1300 nit, and in the high-speed 480 Hz gaming mode, the GtoG response speed was 0.02 ms and the MPRT was 1.7 ms. When implementing fast-moving images, we were able to confirm that motion blur-free images were displayed.



Figure 10. Photograph of the developed 31.5-inch DFR OLED displays



(a)



(b)

Figure 11. MPRT characteristics of the fabricated 31.5-inch OLED display, (a) high resolution mode (DFR off), (b) high refresh rate mode (DFR on).

4. Conclusion

We developed the world's first OLED display with a switchable refresh rate and resolution for premium monitors. New key technologies are applied to the developed 480Hz OLED display, including the DFR driving method, DFR gate driver in a panel, WOLED with micro lens array, pixel aperture ratio improvement, and cinematic sound OLEDs. The MPRT value of the OLED panels was

reduced to 1.7 ms under gaming mode by using the DFR driving method. This OLED panel allows users to freely choose between a high refresh rate and a high-resolution mode depending on the content. It has been applied for the first time with 31.5-inch Gaming OLED monitors

Table 1. Characteristics of the developed OLED displays for premium monitors

Item	Content		Unit
Panel size	31.5		Inch
DFR	OFF	ON	-
Resolution	3840×2160	3840×1080	-
Frame Rate	240	480	Hz
OLED	WOLED+MLA		-
Brightness	1300/450/275		cd/m <sup>2</sup>
Color Gamut (DCI)	99		%
Gray to Gray	0.03	0.02	ms
MPRT	3.4	1.7	ms
Bezel (L/R)	4.7		mm

5. References

- [1] H. J. Shin, S. H. Choi, Y. H. Kim, et al., "A Novel Ultra Large Size OLED Display for Premium TVs," SID Digest, vol. 54, no 1, pp. 329-332, June 2023.
- [2] H. J. Shin, S. H. Choi, and D. M. Kim et al., "A Novel 88-inch 8K OLED Display for Premium Large Size TVs," SID Digest, vol. 52, no 1, pp. 611-614, May 2021.
- [3] C. W. Han, J. S. Park, M. J. Lim, et al., "Advanced Technologies for Large-sized OLED TV," SID Digest, vol. 45, no 11, pp. 770-773, June 2014.
- [4] C. H. Oh, H. J. Shin, W. J. Name, et al., "Technological Progress and Commercialization of OLED TV," SID Digest, vol. 44, no. 1, pp. 239-242, June 2013.
- [5] H. J. Shin, S. Takasugi, K. M. Park, et al., "Novel OLED Display Technologies for Large-Size UHD OLED TVs," SID Digest, vol. 46, no. 1, pp. 53-56, June 2015.
- [6] H. J. Shin, S. Takasugi, K. M. Park, et al., "Technological Progress of Panel Design and Compensation Methods for Large-Size UHD OLED TVs," SID Digest, vol. 45, no. 1, pp. 720-723, June 2014.
- [7] H. J. Shin, M. K. Chang, Y. H. Kim, et al., "An Improved Gate Driver Using Oxide TFTs for Large OLED Displays," SID Digest, vol. 55, no. 1, pp. 501-504, May 2024.
- [8] H. J. Shin, S. H. Choi, S. J. Kim, et al., "A High Image Quality OLED Display with Motion Blur Reduction for Ultra-High Resolution and Premium TVs," SID Digest, vol. 51, no 1, pp. 1131-1134, August 2020.
- [9] C. M. Yang, K. H. Lim, T. Y. Park, "Simulation of Perceived Motion Blur on 480Hz OLED Monitor," SID Digest, pp. 1519-1522, May 2024.