Ultra High Contrast 8K Dual-Cell Display Based on IGZO Technology

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ABSTRACT

By combining our 8K technology with the newly developed Dual-Cell technology, we have developed a display that achieves high resolution and high contrast ratio of over 1,000,000 : 1. In addition, a 3-layer driving technology that combines this 8K Dual-Cell with a local dimming backlight has realized ultra-high contrast ratio of over 2,000,000: 1.

1 Introduction

In recent years, with the establishment of the 8K standard and the start of 8K broadcasting, the infrastructure for 8K such as SoC is being prepared. As a result, the need for 8K is increasing not only for large TVs but also, for medium-sized in the fields of broadcasting, medical care, security, and so on. In response to those needs, we have been developing medium-sized 8K displays based on IGZO technology [1].

Moreover, in the fields of broadcasting and medical applications, not only high resolution but also high contrast is required. OLED is an example of display technology that can achieve high contrast. OLED is self-luminous display that can control emission on pixel-by-pixel basis, so it can achieve high contrast without Halo. Halo is a phenomenon which occurs in the low gray level area where LCD cannot completely block the backlight leak, causing black floating. However, OLED has reliability problems such as lifetime and image sticking, and it is difficult to achieve high brightness due to these problems. There is a method of using local dimming LED backlight as a technology to realize high contrast for LCD, but it causes the issue of Halo. Although it is possible to decrease Halo by making the zoning size of backlight local dimming smaller, there is a limit for the zoning size. For LCD, it is difficult to control the light at the pixel level like OLED.

Therefore, we have developed an 8K display that uses dual-cell technology to achieve the same contrast performance as OLED while taking advantage of the high brightness and high reliability of LCDs. The next chapter describes the newly developed elemental technologies for dual cells.

2 High Transmittance Rear Cell

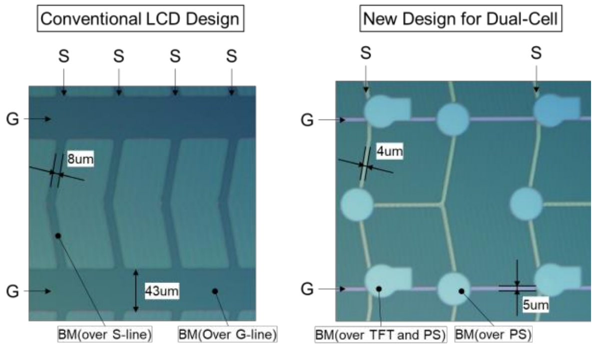
2.1 Transmittance Issue of Dual-Cell

The basic configuration of the Dual-Cell is a three-layer structure consisting of a front cell for display, a rear cell for light control, and a backlight. Dual-Cell can obtain high contrast compared to conventional LCD by stacking these two cells, a front cell and a rear cell. On the other hand, the decrease in transmittance due to overlapping two cells is one of the major issues of Dual-Cell. If the transmittance is low, it is necessary to increase the backlight brightness, which leads to problems of power consumption and heat. In addition, this time we adopted 8K for the front cell aiming at both high definition and high contrast, so the transmittance of the rear cell became an important factor. In the rear cell of Dual-Cell, it is common to remove the RGB color material of CF to make a monochrome LCD in order to maximize the transmittance. The following segment will explain the other transmission improvement measures we have taken.

2.2 Maximize Aperture ratio

In order to improve the transmittance of the rear cell, the aperture ratio was maximized by newly optimizing the design for Dual-Cell. The size of the rear cell is 31.5 inches with 4K resolution. Figure 1 shows a comparison between the conventional LCD design and the new design for Dual-Cell. Figure 1 (a) shows a 1-pixel photo of the conventional LCD design, and Figure 1 (b) shows a 1-pixel photo of the new design for Dual-Cell.

First, we adopted BM-less design for increasing the aperture ratio. As shown in Figure 1 (a), in the conventional LCD design, BM is placed on the source line to partition each RGB color material. In addition, BM is placed on the gate line so as to cover the TFT and PS. The rear cell of Dual-Cell is monochrome, and there is no need to partition RGB. Therefore, as shown in Figure 1 (b), BM can be removed other than those on TFT and PS. The metal wiring that appears on the table due to the deletion of BM was also thinned. As a result, it has become possible to make the source line: 8 → 4um (▼ 4um) and the gate line: 43um → 5um (▼ 38um) thinner than the conventional LCD.



(a) (b)

Figure 1. Comparison between (a) the conventional LCD design and (b) the new design for Dual-Cell.

Second, we minimized the TFT size with IGZO. Since the rear cell of Dual-Cell is monochrome, it is not necessary to divide it into three RGB sub-pixels as for the conventional LCD. Therefore, it is possible to have one source line and one TFT per pixel. However, in that case, the pixel charging area per TFT is about three times bigger than that of the conventional LCD. Normally, as the pixel charging area increases, the TFT size also needs to be increased. But we have made it possible to charge such big pixels without increasing the TFT size by using IGZO-TFT technology. By these BM-less design and minimization of TFT size with IGZO, the aperture ratio has been improved to 1.3 times better than that of the conventional LCD. In addition, by combining with the optimization of the liquid crystal material, the rear cell transmittance could be improved to 1.4 times higher than that of the conventional LCD.

2.3 Excellent light-resistance characteristics of IGZO TFT

Even if the transmittance of the rear cell is improved as described above, a high-brightness backlight is required to achieve a high brightness of over 1000 nits with Dual-Cell. In general, TFT elements are designed so that they are not directly exposed to the light of the backlight, but there are concerns for indirect or stray light from the high-brightness backlight to influence badly for TFT characteristics. We have developed the excellent light-resistant IGZO-TFT technology [2]. By using this IGZO technology, we have realized a highly reliable rear cell with high aperture ratio.

3 Additional pixel design for rear cell

Dual-Cell has a specific problem, that is lack of display at the screen edges in oblique viewing due to the effect of parallax between the two panels. Therefore, as a countermeasure, additional pixels were placed on the left, right, top, and bottom of the rear cell display area(3,840 x 2,160), which is overlapping area with front cell display area.

A schematic of our additional pixel design for the rear cell is shown in Figure 2. The figure shows an enlarged view of a corner of the panel on the source signal input side. As a countermeasure to the lack of display at the screen edges, there is a method of placing additional pixels on the screen edges of the rear cell as shown in this figure. However, when additional pixels are placed, the increase in input signals causes problems for peripheral circuits as well as input signal specifications. For example, S-Dr, G-Dr and TCON for ordinary LCDs (Single-Cell) cannot be used and must be newly developed. Also, the input signal specifications must be changed. To solve those problems, we have developed a rear cell that can avoid the lack of display at the screen edges by using the peripheral circuits for ordinary LCDs without changing the input signals.

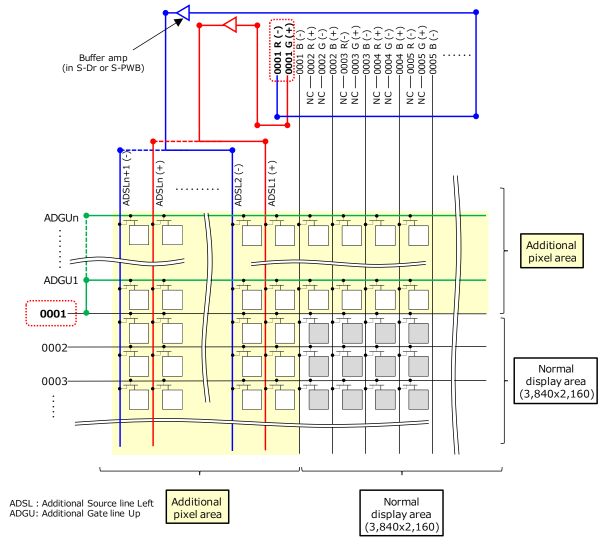


Figure 2. Additional pixel design of Rear cell

First, let's discuss the additional pixels in the left and right source directions. Since the rear cell is monochrome, the source input to the normal display area only needs to be one of the RGB input signals.In our case, we used the Blue signal for the normal display area. Therefore, we used the remaining two input signals (0001R / 0001G) in the outermost rows, and connected them to the additional source wirings. Multiple additional source wirings are bundled together and connected to 0001R and 0001G in accordance with the polarity cycle of the column inversion drive. Since the rear cell is a monochrome input (R=G=B), the additional source wirings are usually driven in conjunction with the outermost row (0001B) of the normal pixel area. In other words, there is no need to input a new separate signal for the additional source wirings.

In the case of multiple additional source wirings, the input signal and additional source wirings are connected via a buffer amplifier in the S-Dr or S-PWB in order to avoid signal level drop.

Next, we will explain the additional pixels in the upper and lower gate directions. Multiple additional gate wirings are bundled together and connected to the gate input signals (0001 / 2160) of the outermost rows. As the additional source wirings, the additional gate wirings are usually driven in conjunction with the outermost rows (0001 / 2160) of the normal pixel area.

In order to drive multiple additional source and gate wirings in a bundle, high charging capacity is required. Since IGZO can be formed in low temperature process, it is easy to use low resistance wiring as gate metal. In addition, IGZO-TFTs have a high pixel charging capacity. With these advantages of IGZO, charging is possible even when multiple additional wirings are bundled.

With the above design, we were able to realize the placement of the additional pixels without changing the peripheral circuits for ordinary LCD(Single-Cell) and input signal specifications (3840 x 2160).

4 3 Layer Driving

4.1 Contrast evaluation of Dual-Cell

As mentioned above, Dual-Cell enables high contrast by stacking two cells, a front cell for display and a rear cell for light control. In order to confirm the contrast improvement effect of this Dual-Cell technology, we developed an 8K Dual-Cell prototype and evaluated the contrast. Figure 3 shows the system configuration of the 8K Dual-Cell prototype. In order to express overwhelming reality, we used a 31.5-inch 8K LCD as front cell. We used a 31.5-inch 4K monochrome LCD as the rear cell. There is no RGB in the rear cell for suppressing the reduction in transmittance due to stacking two cells. It is possible to control the light from backlight at pixel level by means of 4K rear cell. In addition, we used a local dimming backlight. It is a 2048-divided high-brightness direct-type LED backlight so that it could achieve a high-brightness of over 1000 nits as a Dual-Cell. Each of these three layers can be controlled using an FPGA board.

Using the prototype shown in Figure 3, we compared and evaluated the contrast of three types of driving method: (1) Single-Cell with local dimming, (2) Dual-Cell driving, and (3) 3-layer driving. The Single-Cell with local dimming driving of (1) is not a Dual-Cell but a normal LCD (Single-Cell) with local dimming driving. In the evaluation, the rear cell was always displayed in full white, so that it was in a pseudo Single-Cell, and the backlight was in a local dimming driving. Dual-Cell driving of (2) is a Dual-Cell where LED is fully lit without local dimming backlight. The 3-layer driving of (3) is a combination of Dual-Cell and local dimming backlight. By evaluating these three types of driving methods, we verified the contrast improvement effect of the newly developed Dual-Cell compared to the Single-Cell with local dimming, and further contrast improvement by 3-layer driving is possible.

4.2 Contrast evaluation method

A measuring instrument having the measurement performance shown in Table 1 was used to measure the contrast. In each driving methods, the brightness of measurement locations A and B shown in the evaluation image of Figure 4 was measured, and the contrast within a screen was calculated from the results.

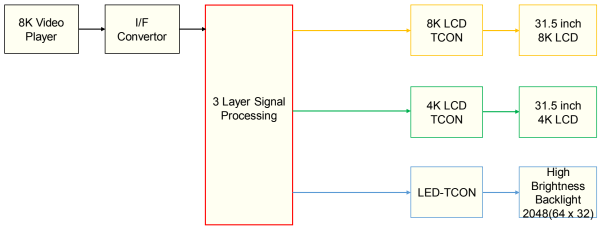


Figure 3. System structure of 8K Dual-Cell Prototype

Table 1. Luminance measurement performance of measuring instruments

Item	Specifications
Measuring equipment	SR-LEDW
Maximum brightness[nit]	5,000,000
Minimum brightness[nit]	0.0005
Brightness accuracy	within ±2%

Figure 4. Image for Contrast evaluation

4.3 Evaluation results

Table 2 shows the measurement results of the contrast for each driving methods. The numbers in parentheses indicate that the measured luminance has reached the minimum guaranteed brightness of the measurement device, and that the contrast is calculated using the minimum guaranteed brightness value. In Dual-Cell drive of (2), the contrast of over 1,000,000: 1 was obtained, and it was confirmed that the contrast was improved by approximately 4 times that of the Single-Cell with local dimming of (1). With 3-layer driving of (3), the black brightness at point B was below 0.0005 nit, which is the guaranteed minimum brightness of the measuring instrument. Therefore, the contrast value is also the value calculated with the guaranteed minimum brightness of the measuring instrument, but the result exceeds 2,000,000: 1.

Table 2. Contrast measurement results

Drive method	Brightness [nit] A	Brightness [nit] B	Contrast ratio
(1)Single-Cell with local dimming	1,072	0.00355	301,632 : 1
(2)Dual-Cell driving(w/o local dimming)	1,110	0.00086	1,292,652 : 1
(3)3-layer driving (Dual-Cell with Local dimming)	1,092	(0.0005)	(2,184,000 : 1)

5 Prototype Specification

Table 3 shows the specifications of the 8K Dual-Cell prototype. The Dual-Cell, which combines a 31.5-inch 8K front cell and a 31.5-inch 4K (monochrome) rear cell, achieves a brightness of 1,000 nits and a contrast of over 1,000,000: 1 without local dimming, and over 2,000,000: 1 with local dimming.

Table 3. Specification of 8K Dual-Cell Prototype

Item		Specifications
Size		31.5 inch
Resolution	Front Cell	7680 X 4320 X RGB
	Rear Cell	3840 X 2160
Brightness		1000nits
Contrast	w/o Local dimming	＞1,000,000 : 1
	w/ Local dimming	＞2,000,000 : 1

6 Conclusion

We have developed an 8K display with a high contrast of more than 1,000,000:1 by using our 8K technology and the newly developed Dual-Cell technology. In addition, we have confirmed that a high contrast of over 2,000,000: 1 can be achieved by 3-layer driving with local dimming backlight. In this development, Dual-Cell technology was applied to a 31.5-inch 8K display for the broadcasting industry, which requires high quality, but Dual-Cell high-contrast technology can be applied to various other fields including medical and automotive applications. We will continue to develop this technology in accordance with the size, resolution, brightness, and contrast required by users.

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