AMOLED IR-drop Automatic Compensation Based on Real ELVDD

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Abstract

This paper introduces a scheme to compensate IR drop in real time based on the real ELVDD in display. The real ELVDD of each row of pixels at the time of charge and discharge is obtained by designing detection circuits on both sides of the display, and the pixel voltage V_{data} is adjusted by the detection voltage. In this way, the display problem caused by local and global IR drop can be solved in a direct and effective way.

Author Keywords

OLED; Detection Circuit; IR drop Compensation; Brightness uniformity

1. Introduction

Since the introduction of organic electroluminescent diodes [1], Organic Light Emitting Diode (OLED) displays have become increasingly popular. As the size of OLED products become larger and larger, and the brightness of the white screen becomes higher and higher, the IR drop problem of ELVDD traces becomes more prominent. This is due to the presence of peripheral trace impedance, bonding impedance, and trace impedance within the display, resulting in different ELVDD voltage drops from the Power IC terminal to different pixel rows in the AA（active area）. IR drop can be divided into two categories: local IR drop and global IR drop [2].

In Fig. 1, R_IN represents the internal trace impedance of the displays. Due to the large current in the display, ELVDD decreases line by line in the AA. This makes the current flowing through the OLED device in different rows (determined by ELVDD and V_{data}) different, which ultimately leads to poor brightness uniformity of the display. R_OUT represents the peripheral trace impedance and bonding impedance of the display. When the display shows any specific gray level, the on pixel ratio (OPR) changes, and the global IR drop will change accordingly, which result in a significant difference in brightness. The smaller of OPR is , the higher brightness of the display is.

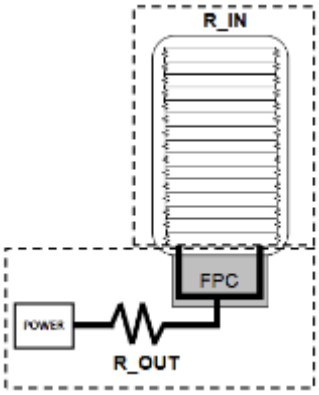

Fig. 1

In recent years, many scholars have made important contributions to the research of TFT device characteristics and pixel circuits, and have proposed threshold voltage compensation circuits [3]-[6] to improve current unevenness of OLED devices. Some scholars have proposed pixel circuits that can compensate for local IR drop [7]-[8]. Although this kind of circuit achieves good results, it has increased the complexity of the process. Joohyuk Yum et al. proposed a scheme that can compensate for both local and global IR drops through calculation and optical measurement to estimate IR drop [9]. However, the pure algorithm compensation method usually takes up a large amount of IC resources.

In order to minimize the changes in IC resources and processes, this paper has designed a detection circuit that can obtain the ELVDD of each row inside the display. Adjusting the V_{data} based on the detected voltage can improve the influence of local and global IR drop at the same time.

2. Project Introduction

2.1 Detection Circuit Design

The detection circuit is arranged on both sides of the display. In order to make the circuit simple and effective and avoid widening the width of the two sides, the detection circuit uses the original drive circuit Gate signal as control switch.

The detection circuit (red dotted area), shown in the figure below, is composed of PMOS devices and traces. Between the Gate circuit and the active area, a PMOS device is added to each row for detection. The gates of all PMOS are connected to the first-stage Gate signal of the corresponding row, the source is connected to the ELVDD corresponding to the row, and the drain is connected to a detection line which is connected to the IC.

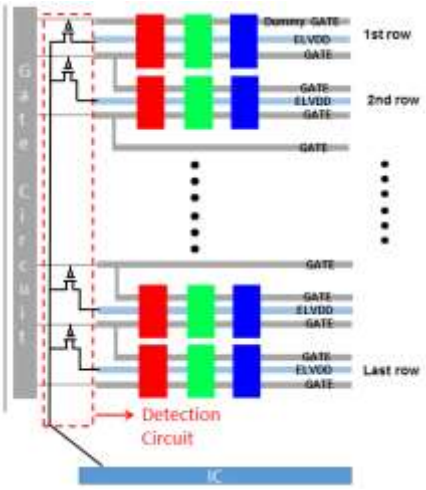

Fig. 2

Taking the 7T1C circuit as an example, the pixel circuit will experience the moment of T1 discharge and T2 charge. At time T1, the detection circuit PMOS is turned on, and the detection line obtains the ELVDD voltage through the source and drain and

feeds back to the IC terminal to adjust the V_{data}. At time T2, the adjusted V_{data} is charged to the pixel circuit. Since the display is driven row by row, the detection line obtain the ELVDD voltage of each row according to the drive circuit.

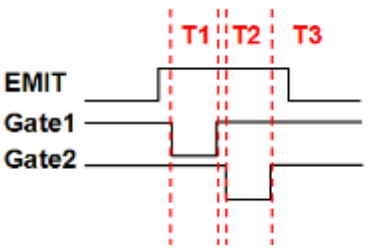

Fig. 3

2.2 Introduction of algorithm

The adjustment of V_{data} is done on the IC terminal. Generally, the value range of V_{data} is from the maximum value (VGMP) to the minimum value (VGSP). IC divides this range into several equal parts (N). The calculation formula of V_{data} is as follows:

$$V_{data} = VGSP + \left(\frac{VGMP - VGSP}{N}\right) * X \qquad (1)$$

X is adjusted according to gray scale brightness.

The adjustment of V_{data} in this scheme is achieved by adjusting the $VGMP_{row}$ and $VGSP_{row}$ of each row.

$$VGMP_{row} = ELVDD_{row} + X_1 \qquad (2)$$

$$VGSP_{row} = ELVDD_{row} - X_2 \qquad (3)$$

X1 and X2 in the formula are constants which can be set. Using a logic circuit, VGMP and ELVDD can maintain a fixed difference of X1, and VGSP and ELVDD can maintain a fixed difference of X2. In this way, VGMP, VGSP and ELVDD can keep in an interconnected relationship. As shown in Fig.5. $ELVDD_{row}$ of each row can be obtained by the detection circuit. Therefore, each row of pixels can have its own $VGMP_{row}$ and $VGSP_{row}$.

This relationship is real-time. Hence, the $VGMP_{row}$ and $VGSP_{row}$ curves can be parallel to the detected $ELVDD_{row}$ curve. According to formula (1), we can see that the V_{data} curve also maintains a parallel relationship with $ELVDD_{row}$. In this way, the V_{data} of each row is adjusted according to the detection voltage, and the IR drop problem is solved. The theoretical relationship curve is shown in Fig. 6.

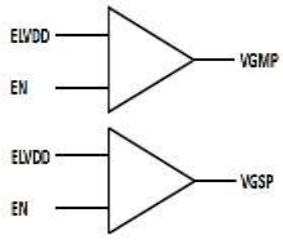

Fig. 5

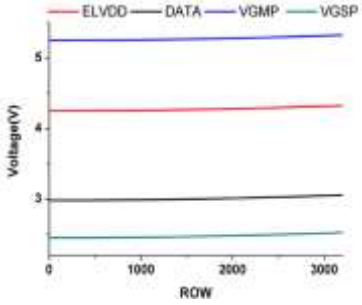

Fig. 6

3. Product Testing and Result Analysis

Based on the scheme in this article, we designed a 6.53-inch product with a resolution of 1440 * 3200 for research.

3.1 Detection Circuit Test

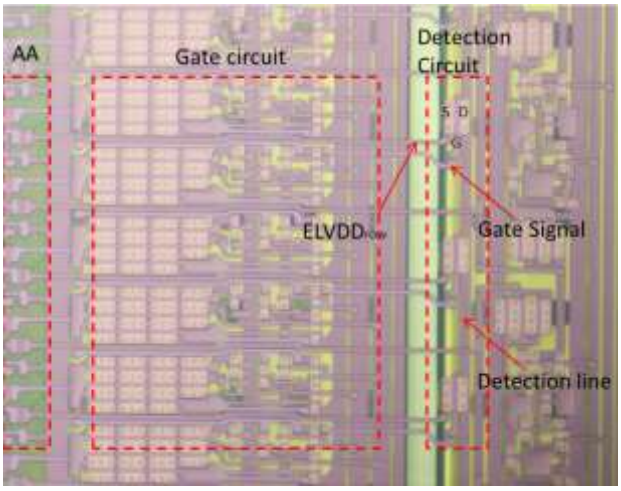

Fig. 7

Fig. 7 is the physical picture of the detection circuit under the microscope. Consistent with the design principle, the Gate signal is used to control the detection circuit switch. The detection voltage is fed back to the IC through a Detection Line.

The product has several bright lines in the vicinity of 1st row, as shown in Fig.8. Measurement Wave of the Detection line shows that ELVDD-Test is in the floating state in the front and back porch. In the active area, ELVDD-Test is a gradually rising curve with a maximum voltage drop of about 100mV. Compared with the ELVDD capacitor voltage on the FPC, the bonding voltage drop is about 250mV. As shown in Fig.9.

Fig. 8

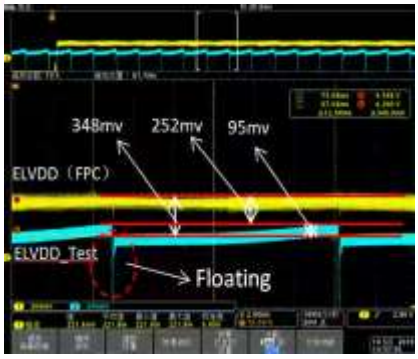

Fig. 9

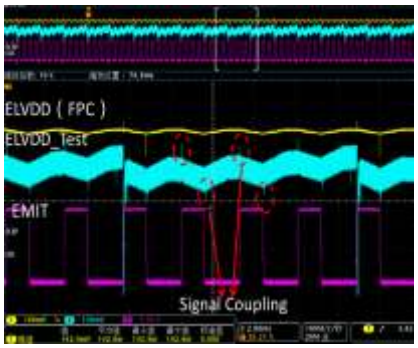

Fig. 10

In the PWM mode, it is found that the detected voltage is coupled with the edge of the EMIT signal, which generates a distorted voltage. The IC then outputs the wrong V_{data}. Changing the duty, the coupling voltage is still aligned with the edge of the EMIT signal. See Fig.10.

After analysis, it is found that the detection circuit only detected the active area. But in fact, a frame time also includes front and back porch. In order to avoid the floating state of the detection voltage in the front and back porch, we added T0 and T1 to optimize the detection circuit and redesigned a product with a resolution of 3200 * 1400. As shown in Fig.11.

The gate of T0 is connected to the IC terminal, and its switch is controlled by the IC. The source is connected to the ELVDD of the last row, and the drain is connected to the detection line. The gate of T1 is connected to the Dummy Gate signal before 1st row. The source is connected to ELVDD in the 1st row, and the drain is connected to the detection line.

Fig.12 shows the timing of T0 and T1. The function of T0 is to keep the voltage of the detection line stable at the ELVDD of the last row during back and front Porch. The function of T1 is to make the voltage of the last row steadily transition to the voltage of the 1st row. It is recommended to add two rows of Dummy before the 1st line, and the turn-on time of T0 does not include T1.

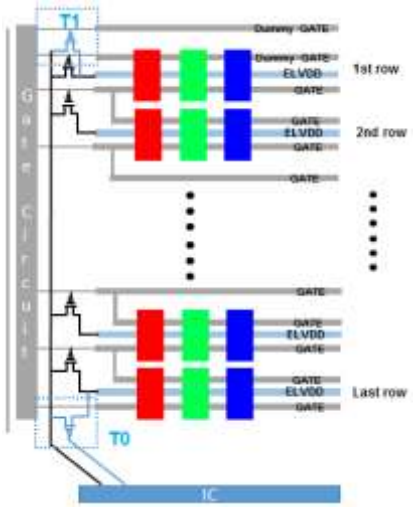

Fig. 11

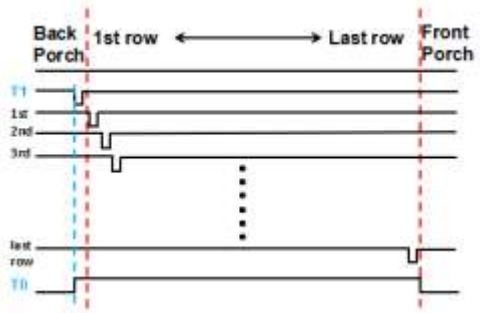

Fig. 12

Fig.13 is the detected voltage waveform of the front and back porch when T0 and T1 are turned on. It can be observed that the detected voltage is stable and exactly the same as the turn-on time of T0. The transition area is composed of two rows of Dummy, and the detected voltage transition is stable.

Fig. 13

In this product design, the source of the T0 device is connected to the ELVDD trace in the bonding area, so there is a voltage drop on the waveform. According to T0 design requirements, the source which connected to the last line of ELVDD will make the waveform more stable. The bright line on the product disappears, as shown in Fig.14. In addition, the new design optimizes the circuit routing to avoid the coupling of the Emit edge and the detection voltage, as shown in Fig.15.

Fig. 14

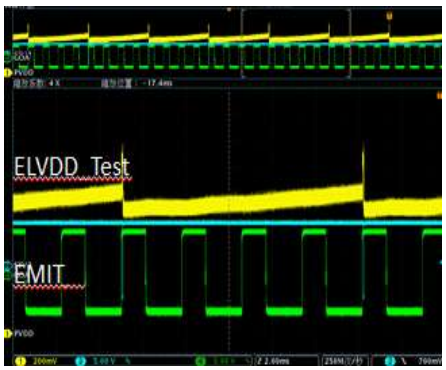

Fig. 15

3.2 Product Optical Test

According to the optical test specification, we conducted a 13-point brightness uniformity test on the product. The result is shown as follows:

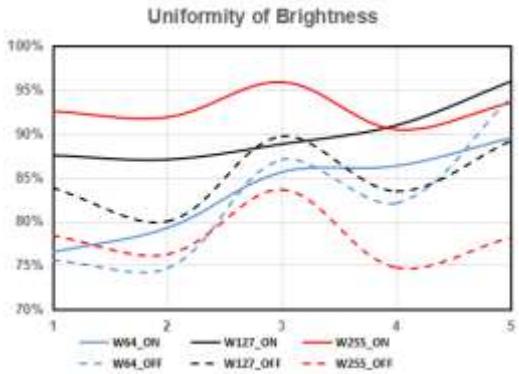

Fig. 16

Fig.16 shows the 13-point brightness uniformity of the three gray levels (255, 127, and 64), under the circumstance of white screen display and switching On/Off in this scheme. The solid line indicates that the detection function is on, and the dotted line

indicates that the detection function is off. The brightness uniformity at 255 gray levels exceeds 90%, increasing about 15%.The brightness uniformity at 127 gray levels exceeds 85%.The brightness uniformity of 64 gray scales is not obvious due to the small current, but can be improved by De-mura at low brightness level.

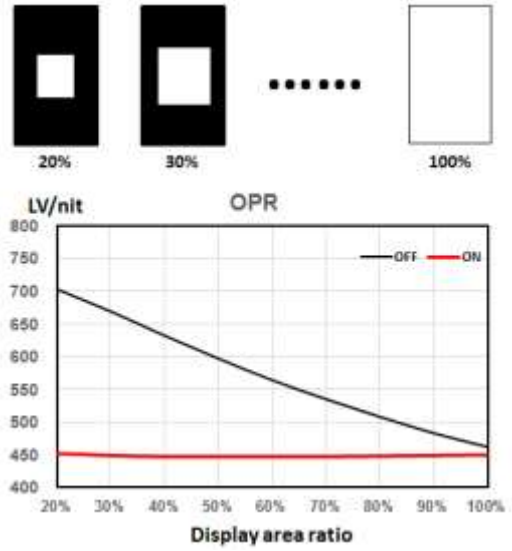

Fig. 17

Fig.17 shows the effect of global IR drop. When the detection circuit is turned off, the brightness of the center point of the display increases as the OPR decreases. As shown in the black curve. When the detection circuit is turned on, the brightness of the center point of the display is basically unchanged. As shown in the red curve.

Theoretically, the white brightness (W) is equal to the sum of R / G / B brightness. Due to the different luminous effects of OLED materials, the effect of IR drop in different colors is different. Therefore, W brightness is usually less than the sum of R / G / B brightness. We set ratio to indicate this gap:

$$\text{ratio} = (R + G + B) / W - 100\% \quad (4)$$

	Detection On					*Detection Off*				
	W	**R**	**G**	**B**	**ratio**	**W**	**R**	**G**	**B**	**ratio**
1	**427**	**105**	**302**	**33**	**3%**	**433**	**141**	**446**	**40**	**44.8%**
2	**428**	**105**	**302**	**33**	**2.8%**	**429**	**141**	**437**	**40**	**44%**
3	**434**	**107**	**305**	**34**	**2.7%**	**438**	**145**	**436**	**41**	**42%**
4	**434**	**106**	**306**	**33**	**2.5%**	**433**	**137**	**433**	**40**	**40.8%**
5	**431**	**107**	**303**	**32**	**2.5%**	**431**	**139**	**430**	**38**	**40.8%**

Test results show that this scheme can make the sum of R / G / B brightness closer to W brightness.

4. Other considerations

There are other details in the design of the detection circuit that need to be considered. For example, the selection of the ground capacitor of the detection circuit and how the trace is arranged to avoid crosstalk of other signals.

This scheme detects voltage in units of rows, so there is no compensation for horizontal IR drop. Since the IR drop in the horizontal direction is small, the brightness change caused by it can be ignored.

5. Conclusion

This scheme adjusts the V_{data} in real time based on the real ELVDD inside the display, which effectively improves the display problems caused by global and local IR drop. This scheme is simple, effective and suitable for all OLED products. The optical characteristics have been significantly improved, especially for large-size, large-resolution and high-brightness OLED displays. Since this scheme adjusts the V_{data} based on the real voltage of the product, some uncertain factors between different products can be avoided.

6. Reference

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