2D IRC Compensation Technology Research

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Abstract

AMOLED displays are widely used in smart phones, laptops, car and other scenes.With the continuous development of AMOLED technology, the performance requirements for display screens are becoming higher and higher, among which Luminance Uniformity and color difference (Delta-E) have become important indicators to measure the quality of AMOLED display screens.Due to the existence of IR Drop in the display screen, the resistance of the metal wire has a voltage drop and the difference between the input and output of the driver signal and the input and output of different pixel distances, resulting in uneven current distribution, which seriously affects the picture quality.

This paper presents a 2-D IRC(IR compensation) compensation technique.The compensation system integrates the compensation techniques of GIR(Global IR Drop), LIR (Local IR drop) and CUC(color uniformity compensation), and the Threshold voltage V_{th} (Threshold) of pixels in different areas within the surface voltage) to compensate.The compensation system compensates for Luminance Uniformity and Delta-E over a wide range of grey scales and backgrounds.This design scheme simplifies the in-plane regional current model, optimizes the current statistics scheme, optimizes the debugging scheme, and makes the 2-D IRC compensation technology have lower power consumption.

Author Keywords

Luminance Uniformity;Delta-E;GIR(Global IR Drop);LIR(Local IR drop);2-D IRC;CUC(color uniformity compensation);

1. Introduction

In recent years, the application scope of AMOLED displays has expanded to scenarios such as smartphones, laptops, and cars. The problem of decreased brightness uniformity caused by IR voltage drop becomes more prominent as panel size and brightness increase. In order to reduce the AMOLED IR Drop problem, measures such as optimizing circuit design, assisting cathodes, and improving ET resistance have been taken. Because these measures cannot meet the high demand for display quality, the IRDrop compensation algorithm has been developed in the Display Driver IC (DDIC) to meet the display quality requirements.

The principle of AMOLEDIR Drop compensation algorithm is mainly to partition the screen and then adjust the brightness of each partition separately to achieve overall brightness uniformity. Specifically, the algorithm will first partition the screen, with each partition containing a certain number of pixels. Then, the algorithm will count the voltage drop of each partition and calculate the brightness adjustment factor for each partition based on the measurement results. Finally, the algorithm will adjust the brightness of each pixel in each partition based on this coefficient to achieve overall brightness uniformity. The AMOLEDIR Drop compensation algorithm has been widely used in various AMOLED displays, including smartphones, tablets, televisions, and more. By applying this algorithm, the brightness uniformity and overall display effect of the screen can be significantly improved, enhancing the user experience.

The AMOLED IR Drop compensation algorithm is calculated using Ohm's law, where V=I * R, where V is the voltage drop (IR Drop), I is the current, and R is the resistance. The algorithm compensates by adjusting the Vdata voltage. Algorithm debugging method: Apply uniform voltage to the AMOLED panel, collect brightness and chromaticity distribution through a color analyzer and color camera, and repeatedly debug parameters until the specifications are met.

This article proposes a new 2-D IRC (IR compensation) compensation technique. Algorithm model $\triangle V=I * R+\triangle V_{th}$; This algorithm model includes two factors that affect panel uniformity, IR Drop and V_{th}. In AMOLED, TFT is used as a switching element, and the minimum gate voltage threshold voltage (V_{th}) required to start conducting in TFT (thin film transistor). Due to differences in manufacturing processes, different TFTs on the same AMOLED panel may have different V_{th} values. This will result in different brightness of pixels in different regions under the same input voltage, thereby affecting the display uniformity of the screen. The impact of IR Drop on different areas of AMOLED panels varies. The actual VDD voltage in each area is ELVDD-I * R, and IR also affects the uniformity of screen display. The IR Drop compensation algorithm compensates by measuring the uniformity of brightness in the measurement area, which is mainly affected by IR Drop and V_{th}. The traditional IR Drop compensation algorithm cannot solve the problem of uniformity reversal in many panels under different brightness levels because it cannot distinguish whether the brightness unevenness is caused by IR Drop or V_{th}.

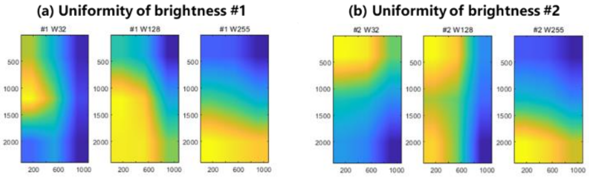

Figure 1. The trend of brightness uniformity varies under different brightness levels, Panel # 1 (a), Panel # 1(b).

2. Methods

2.1 2-D IRC algorithm model

Compensation for IR drop is generally realized through circuit design [3][4][5] or data processing [1][6]. In the AMOLED display panel, according to the TFT saturation zone current and pixel circuit calculation formula:

$$\begin{aligned} \mathrm{I} &= 1/2 \times W/L \times C_{OX} \times \mu \times \left(V_{gs} - V_{th}\right)^2 \\ &= 1/2 \times W/L \times C_{OX} \times \mu \times (V_{DD} - V_{data} - V_{th})^2 \quad (1) \end{aligned}$$

In formula (1), Vdata is the input gray-level voltage, and the actual V_{DD} is affected by IR Drop, so the actual panel area V_{DD} =ELVDD-I*R. Because the V_{th} in different regions is inconsistent, resulting in the actual display of any gray level brightness will be affected by V_{th} uniformity, so the IR compensation model to add the threshold voltage V_{th} voltage compensation voltage $\triangle V_{th}$ in different regions. Thus, the current I_{ds} of sub-pixel units

$I_{ds} \propto (ELVDD-I*R-Vdata- V_{th} -\triangle V_{th})$. This scheme offsets the value of the voltage change caused by IR Drop and V_{th} by compensating Vdata. Compensating voltage $\triangle V=I*R+\triangle V_{th}$ for 2-D IRC.

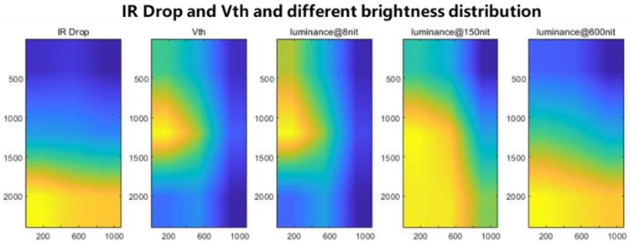

Figure 2. IR Drop and V_{th} distribution models, and their effects on different brightness levels.

From the compensation voltage formula of 2-D IRC, it can be seen that IR Drop mainly affects high current scenes with medium to high brightness, while ΔV_{th} has a significant impact on low brightness and medium to high brightness. After the superposition of V_{th} and IR voltage drops, the brightness of the panel is uneven and irregular as shown in Figure 3. It can be seen from this that the uniformity reversal problem of the panel has occurred at different brightness levels.

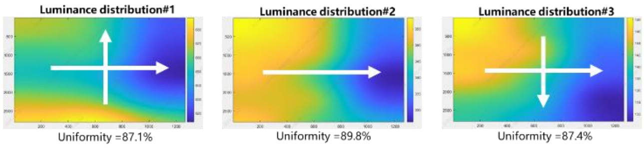

Figure 3. The irregular effects of IR Drop and V_{th} on brightness uniformity.

2.2 2-D IRC current statistical model

The 2-D IRC compensation algorithm and the traditional IRC compensation algorithm need to calculate the in-plane current sum. As input parameters to the compensation model , we use the current of all sub-pixel units in display area as the loading statistics in the area[7]. There is positive proportional coefficient relationship between the current and luminance of sub-pixel units (k_R, k_G, k_B), such as Figure 4 (b). The luminance and gray level of the sub-pixel units satisfy equation (2 – 4). Based on the above relationship, this scheme can calculate the current of R, G and B sub-pixel units according to gray level:

$$Pixel\_I_R = (gray\ level\_R/255)^{2.2} \times k_R \tag{2}$$

$$Pixel\_I_G = (gray\ level\_G/255)^{2.2} \times k_G \tag{3}$$

$$Pixel\_I_B = (gray\ level\_B/255)^{2.2} \times k_B \tag{4}$$

More often, the current of R, G and B sub-pixel units does not contribute same current amount to white screen, and there are coefficients I_R, I_G, I_B. Therefore, the above relationship can be used to calculate the current and loading of all sub-pixel units in the display screen:

$$Pixel\_I_{sum} = Pixel\_I_{R1} + Pixel\_I_{G1} + Pixel\_I_{B1} + Pixel\_I_{R2} + Pixel\_I_{G2} + Pixel\_I_{B2} + \dots \tag{5}$$

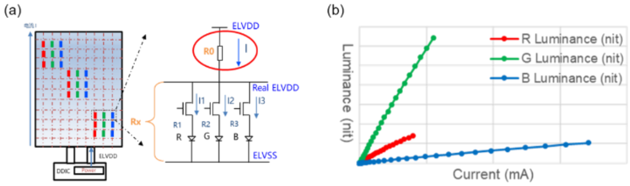

Figure 4. (a) Display the impedance model of the module, (b) Current-luminance curves of R, G, and B

2.3 2-D IRC in plane area Icompensation

In the traditional planar IRC model, due to the network structure of ELVDD power supply layout in the plane, the voltage drop generated by IR Drop is caused by the current of each pixel point in the region. Therefore, in traditional schemes, the current in different regions of the ELVDD plane varies, as shown in the model in Figure 5. The calculation formula for the voltage drop caused by IR Drop in each row from the 1st row to the nth row in terms of the unit of behavior is as follows:

$$V_{dd\_n} = V_{dd\_n-1} - I_n * R$$
$$V_{dd\_n-1} = V_{dd\_n-2} - (I_{n-1} + I_n) * R$$
$$\dots$$
$$V_{dd\_1} = V_{dd} - (I_1 + \dots + I_{n-1} + I_n) * R$$

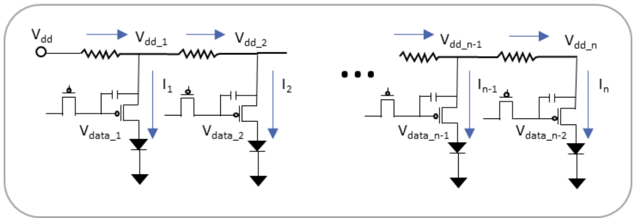

Figure 5. Traditional IR Drop Current Model.

It can be seen that the calculation and statistical formula of Vdd is very complex. It is difficult to achieve real-time Drop calculation in IC, and with the increase of panel size, the actual power supply Vdd input path is more, and the ELVDD line is more complex. The ELVDD Drop in two-dimensional plane cannot be calculated by the traditional model.

The simplified 2D IRC model in this scheme simplifies the ELVDD in-plane Drop model. When displaying a solid color image, the equivalent current distribution is uniform. The average current is $I_{everage}$, and the currents are approximately equal. $I_1=I_2=I_3 \dots =I_n$, and the impedance R distribution is uneven. The equivalent circuit model is shown in Figure 6. Therefore, the formula for calculating the equivalent V_{DD} is as follows:

$$V_{dd\_1} = V_{dd} - I_{everage} * R_1$$
$$V_{dd\_2} = V_{dd} - I_{everage} * R_2$$
$$\dots$$
$$V_{dd\_n-1} = V_{dd} - I_{everage} * R_{n-1}$$
$$V_{dd\_n} = V_{dd} - I_{everage} * R_n$$

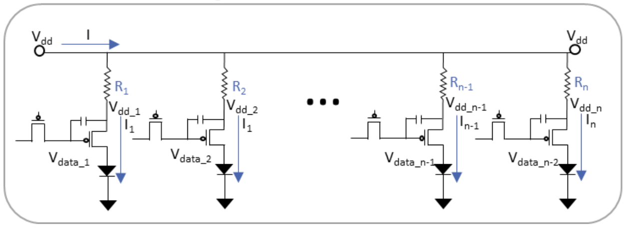

Figure 6. Improved equivalent IR Drop Current Model.

2.4 2-D IRC in-plane area V_{th} compensation

In the 2-D IRC model of this scheme, compensation △ Vth for the gate voltage threshold voltage Vth is introduced, and different △ Vth 1~△ Vth n are compensated in different regions. The formula for calculating V_{data} compensation in different regions is as follows:

$$\triangle V_{data\_1} = I_{everage} * R_1 + \triangle V_{th\_1}$$
$$\triangle V_{data\_2} = I_{everage} * R_2 + \triangle V_{th\_2}$$
$$\ldots$$
$$\triangle V_{data\_n-1} = I_{everage} * R_{n-1} + \triangle V_{th\_n-1}$$
$$\triangle V_{data\_n} = I_{everage} * R_n + \triangle V_{th\_n}$$

The traditional IRC commissioning process is divided into Global IR Drop commissioning process and Local IR drop commissioning process. Global IR Drop debugging process debugs parameters through color analyzer to full white and small white brightness and chroma equal. The Local IR drop debugging process collects the brightness and chrominance distribution through the color camera, and repeatedly adjusts the parameters until the brightness and chrominance specifications in different areas of the plane are consistent. As shown in Figure 7.

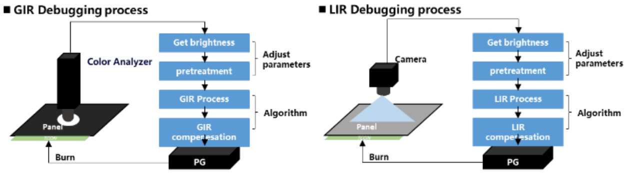

Figure 7. GIR and LIR debugging process.

The reason for introducing Δ V_{th} in the 2-D IRC compensation model is that traditional IRC cannot distinguish the brightness and color tone changes caused by threshold voltage Vth and IR Drop when compensating for brightness and chromaticity in different regions. They are all compensated according to IR Drop, which can result in poor compensation effect at other brightness levels. To solve the problem of poor IRC compensation under other brightness levels, this solution improves the Local IR drop debugging process in the 2-D IRC in-plane compensation debugging workflow by first capturing low brightness to compensate for V_{th}, and then capturing high brightness to compensate for IR drop.

3. Methods Verification and test results

The experimental part used a AMOLED module display to test the compensation performance of 2-D IRC, as shown in Figure 8, which showed good consistency in the brightness and color coordinates of the central area under different backgrounds.

	100% W	5% W + Tiktok background	5% W + Smile background	10% W + Black background	5% W + 24 color background
Lv (nit)	386.15	387.68	386.29	385.93	388.40
x	0.313	0.314	0.314	0.313	0.313
y	0.327	0.329	0.329	0.330	0.330

Figure 8. 2-D IRC compensation in the central region under different backgrounds.

Select two panels with poor in-plane brightness uniformity distribution, as shown in Figure 9. After 2-D IRC compensation, the brightness uniformity is over 95%, and there is also a significant improvement in uniformity for special backgrounds, as shown in Figures 10 and 11.

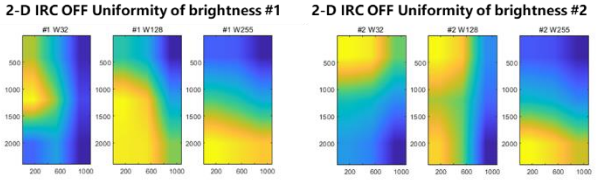

Figure 9. 2-D IRC OFF Uniformity of brightness.

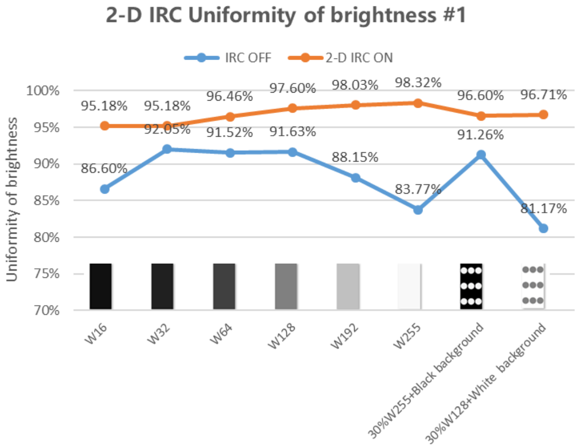

Figure 10. 2-D IRC Uniformity of brightness #1.

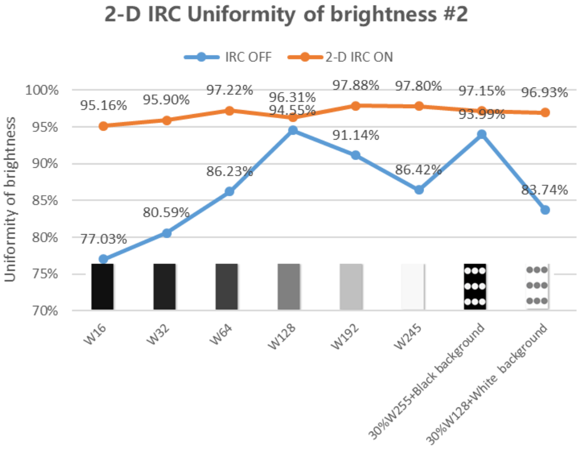

Figure 11. 2-D IRC Uniformity of brightness #2.

4. Conclusion

This scheme is based on the 2-D IRC compensation model of AMOLED. It integrates the compensation techniques of GIR (Global IR Drop), LIR (Local IR Drop), and CUC (Color Uniformity Compensation), and compensates for the threshold voltage Vth of pixels in different regions within the face. This compensation system is capable of compensating for brightness uniformity and color differences (Delta-E) across a wide grayscale range and different backgrounds. And the 2-D IRC compensation technology has lower power consumption.

5. Reference

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