Lifetime Compensation Scheme for Oxide Active Privacy Displays

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Abstract

The OLED industry has begun utilizing novel Indium Gallium Zinc Oxide (IGZO) technology to manufacture medium-sized display panels, integrating active privacy features to address automotive safety requirements and privacy needs in tablet-based office environments. However, the brightness lifetime curve of IGZO products exhibits an initial increase (exceeding 10%) within the first few hundred hours of operation this deviation fails to meet product shipment standards, necessitating brightness reduction compensation tailored to display duration. Conventional lifetime compensation schemes are only capable of brightness increase compensation. Leveraging collected module lifetime curves, we have designed a DBI algorithm that supports both brightness elevation and reduction, thus fulfilling the lifetime compensation requirements of diverse products. Active privacy displays split pixels of standard screens into two segments and integrate a light-shielding layer to regulate light exit angles, enabling active privacy protection. As display content differs between privacy and sharing modes, the SRAM must store distinct count values for each content type. Conventional compensation methods cannot accommodate this demand, so we developed a specialized DBI algorithm for dual-mode compensation: it separately accumulates degradation amounts for the two display modes, stores these values in Flash memory, and retrieves the corresponding count values from Flash to SRAM based on the active display mod thereby achieving effective lifetime compensation for active privacy displays.

Author Keywords

OLED; Burn in; IGZO; De-Burn in(DBI) Algorithm

1. Introduction

Active Matrix Organic Light-Emitting Diode (AMOLED), as a currently sought-after light-emitting display technology, has the advantages of being thin and light, low power consumption, high contrast, and high refresh rate due to its self-luminous characteristic without the need to carry a backlight panel. It is increasingly favored by people and has been widely applied in fields such as mobile communications, wearable displays, mobile office, vehicle mounted displays, and flexible displays. Currently, AMOLED still has some common technical problems. For example, slight differences in the manufacturing process can cause the threshold voltage drift of Thin-Film Transistors (TFT). Under the same driving voltage, TFTs will generate different driving currents. AMOLED controls the display brightness of pixels through different driving currents, so different driving currents will lead to inconsistent brightness of OLED displays at the same gray scale, resulting in display unevenness (Mura). During long-term use, OLED devices will undergo material aging, which is manifested in the display effect as a decrease in the luminous efficiency of the devices. The attenuation rates of device materials for red, green, and blue colors are inconsistent, so it is easy to form color deviation in the display. Different display contents lead to inconsistent luminous times of OLED devices in different areas, and the difference in pixel luminous efficiency leads to the formation of local residual images when displaying pure color images. These common problems affecting display image quality are all factors restricting the further development of AMOLED. To address these common image quality issues, the industry has carried out a large number of mechanism studies and completed the development of brightness attenuation compensation algorithms. However, the current DBI algorithms in the industry can only compensate for the attenuation trend of LTPO/LTPS, where the brightness gradually decreases from the initial moment. They statistically analyze the display content, calculate the attenuated brightness based on the display content, and then compensate the attenuated brightness to the initial brightness. In recent years, the industry has begun to take the IGZO route. The lifetime curve of metal oxide products is different from that of LTPO and LTPS products: the lifetime curve of IGZO products starts from the initial moment, the brightness gradually increases, the rising time exceeds 400 hours, the peak brightness exceeds 10% of the initial brightness, and then it starts to gradually decrease. This requires reducing the brightness compensation in the early stage and then increasing the brightness compensation in the later stage. Moreover, active privacy technology cannot be compensated by traditional DBI algorithms. This paper introduces the special brightness attenuation curve of IGZO oxide display screens, analyzes its aging compensation mechanism, introduces the implementation method of active privacy display, and proposes a DBI compensation architecture for active privacy display of medium-sized oxide products.

2. IGZO Characteristics & Compensation

IGZO oxide exhibits unique properties in the TFT field. Due to its high light transmittance, low leakage current, and low cost, IGZO-TFT has obvious advantages in medium and large-sized flexible displays with low power consumption and low refresh rate. It has been currently applied in medium-sized tablet displays. When collecting lifetime data of oxide display screens, we found some unique lifetime characteristics, manifested as brightness first increasing and then decreasing. We selected screens from different areas of the large panel for lifetime experiments, displaying pure white grayscales of 255, 192, 128, and 64 respectively. We measured the brightness of different grayscales at the initial moment, then measured the brightness attenuation of different grayscales at fixed intervals. The test duration exceeded 1500 hours. A 3500-hour brightness curve was fitted based on the test data, as shown in Figure 1 below. The horizontal axis represents time, the vertical axis represents normalized brightness.

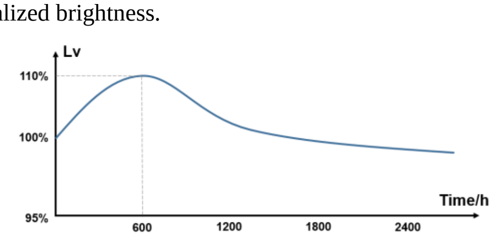

Figure 1. Brightness degradation curve of IGZO sample.

The data shows that the brightness keeps rising within 600 hours after the initial moment of lighting, with the maximum brightness exceeding 10% of the initial brightness. This phenomenon is due to the positive bias of Vth in Driver-TFT and Switch TFT in the pixel circuit, leading to a continuous increase in current. After 600 hours, the current tends to be stable, so the brightness shows an upward trend before 600 hours. After the current stabilizes, the brightness no longer increases, and then decreases due to the attenuation of OLED devices. The brightness of oxide products increases by more than 10% in the first 600 hours, so the products cannot meet customer specification requirements, and brightness compensation is needed. The traditional DBI algorithm predicts the brightness attenuation curve based on the SED model, as shown in Figure 2. Horizontal axis represents times, the vertical axis represents normalized brightness. The blue curve at the 1200-hour mark indicates the degradation trend for grayscale 64, the red curve for grayscale 128, and the yellow curve for grayscale 255. Calculates the required compensation value at different moments according to the attenuation curve, and performs brightness-increasing compensation, but it cannot perform early brightness-reducing compensation for oxide products. The formula of the SED model:

$$L_t = L_0 \exp(-(t/\tau)^{\beta}) \qquad (1)$$

$$L_0^n t_{1/2} = C \qquad (2)$$

Among them, L_0 is the initial brightness, t is the display time, L_t is the display brightness of t moment, τ is the coefficient related to the initial brightness, β is the factor related to the device structure and material characteristics, for the same batch of OLED samples, have the same C; n is the acceleration factor related to the decay rate. $t_{1/2}$ is the time and it takes for the initial brightness to fall by half.

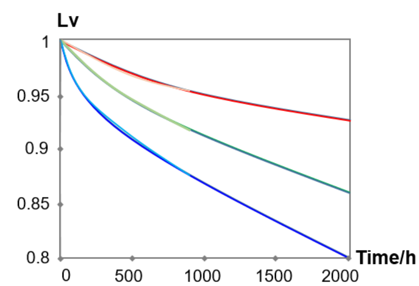

Figure 2. SED model fitting curves.

We improve the existing solution and propose a novel DBI compensation scheme that can meet the requirement of brightness reduction in the early stage and brightness increase in the later stage for oxide displays. The specific scheme is shown in Figure 3. Different count values represent the accumulated aging values at different times. Positive and negative values are designed in the compensation table to realize brightness-increasing compensation or brightness-reducing compensation for brightness with different attenuation trends. We collect screens from the same batch to obtain the brightness attenuation curves of different gray scales. A segmented compensation method is adopted: we fit the brightness curve of the early brightness rising stage based on the collected data, and calculate the required compensation values for different gray scales at different times according to the brightness curve. Positive and negative values are set in the DBI algorithm compensation table. A negative compensation value indicates gray scale reduction for brightness compensation, while a positive compensation value indicates brightness-increasing compensation. The compensation value for the oxide lifetime curve is negative in the first 600 hours and positive thereafter, realizing DBI compensation with brightness reduction in the early stage and brightness increase in the later stage.

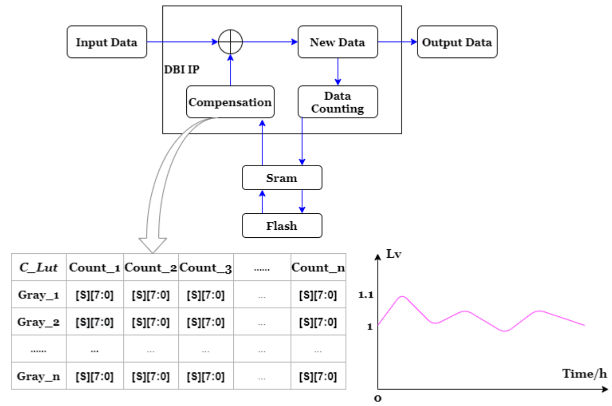

Figure 3. Improved DBI compensation architecture.

3. Active Privacy Display & Compensation

Active privacy has become a highly demanded feature in vehicle-mounted displays. The active privacy solution for displays achieves peeping prevention at a fixed angle by adding an privacy structural layer to adjust the propagation direction and intensity of light, thereby controlling the visible angle of the display, as shown in Figure 4 below.

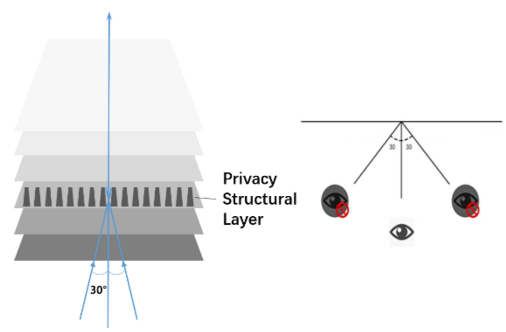

Figure 4. Active privacy display scheme.

The OLED active privacy screen splits one pixel originally driven by TFT into two. It controls the lighting of privacy pixels or shared pixels by switching between different display modes. As shown in Figure 5 below, there is an privacy structure around the privacy display pixels to limit the light-emitting angle.

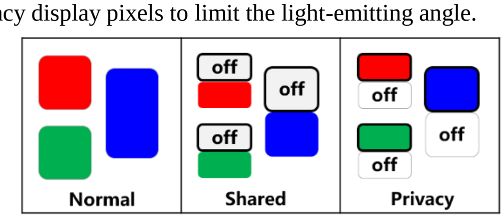

Figure 5. Pixel splitting in active privacy display.

The privacy display screen has two display modes. Obviously, the display contents in the two modes are different. The DBI algorithm needs to calculate the accumulated aging value based on the display content. The accumulated aging value is usually stored in SRAM and updated continuously. The count value in SRAM is updated to Flash at fixed intervals to prevent data loss due to power failure. The two display modes of the privacy display screen need to calculate and store the accumulated aging values of their respective display contents separately. Compared with conventional displays, this requires doubling the SRAM storage space, which is unacceptable from the perspective of production costs. We have designed a DBI algorithm that does not require increasing SRAM space to compensate for the aging caused by the two display modes of privacy display. The overall architecture is shown in Figure 6 below. Flash reserves spaces of the same size to store the accumulated aging values and compensation parameters respectively; According to the input value of Mode Select, SRAM determines to read data of the shared mode or the privacy mode from Flash.

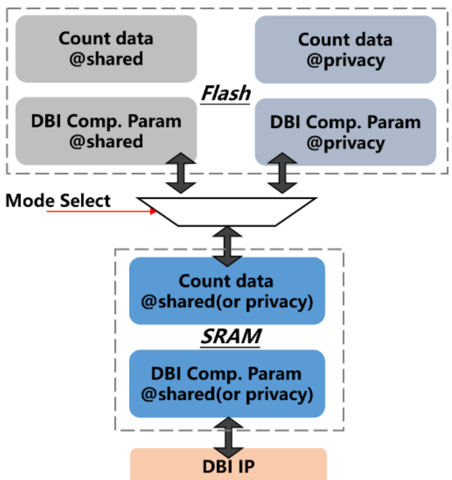

Figure 6. Schematic of DBI architecture for privacy display.

To address the aforementioned challenges, two groups of display screens were respectively switched to the privacy mode and the shared mode. Lifetime attenuation curves under different gray scales were acquired, and corresponding compensation tables and sampling tables were established for each curve. These two sets of tables were then stored in DBI registers. In practical applications, the register value to be queried was determined based on the display mode switch. The accumulated aging value under the current mode was calculated and temporarily stored in SRAM, with periodic updates to Flash. Two spaces of equal size were reserved in Flash to store the accumulated aging values for the privacy mode and the shared mode, respectively. If the current display state was the privacy mode and a switch to the shared mode was required at the next moment, the accumulated aging value of the shared mode stored in Flash would replace that of the privacy mode in SRAM during the switch, and compensation was performed using the replaced value in SRAM. In this way, lifetime compensation for the two display modes of active privacy was achieved without increasing the SRAM space.

4. Algorithm Compensation Effect Verification

To verify the compensation accuracy of the DBI algorithm, 13.2 inch sample screens from the same batch as the data collection samples were subjected to actual aging for over 1000 hours. The Burn image shown in Figure 7(a) was displayed continuously. The ambient temperature was set to 50° C to accelerate aging, and the brightness was set to 600nit at the 255 gray scale. After 1000 hours of actual lighting, the screen was switched to a solid-color display. After 1000 hours of fixed lighting of Figure (a), the display effect of the W96 gray-scale white screen is presented in Figure 7(b). Obvious burn-in residuals can be observed, including the RGB color blocks at the bottom of the screen and the white circle burn-in located at the lower left of the center. We simulated the compensation effect using the optimized algorithm model. A compensation table was constructed based on the previously obtained lifetime data curve. The accumulated aging value was calculated according to the ambient temperature and aging time, and the compensation value required for each pixel was derived from this accumulated aging value. A compensation image was generated for display, as shown in Figure 7(c). It can be seen that the burn-in effect at the bottom of the screen is significantly improved after compensation, and there is no over-compensation phenomenon.

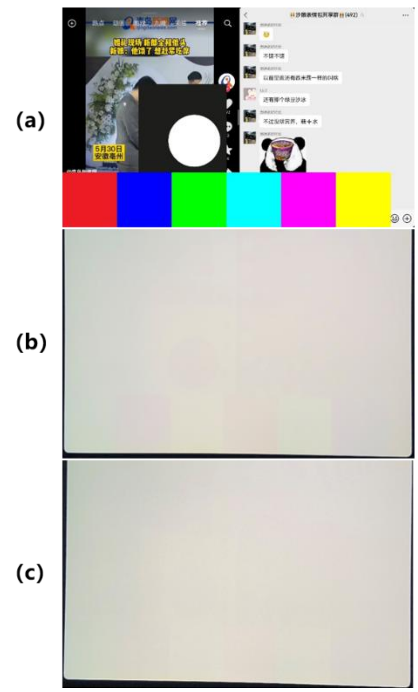

Figure 7. DBI Compensation effect diagram.

5. Conclusion

This paper proposes a lifetime compensation scheme for medium -sized active privacy displays based on oxides. This scheme can solve the problems that conventional DBI cannot perform brightness-reducing compensation and cannot compensate active privacy displays. By setting positive compensation values in the compensation table for brightness increasing compensation and negative compensation values for brightness reducing compensation, the issue of inconsistent attenuation curve trends in the early and late stages of IGZO oxide products is resolved. Two sets of compensation tables for the privacy and shared modes are stored in DBI registers, and the accumulated aging value is calculated and compensated according to the display content for each mode. When switching modes, the accumulated aging value stored in Flash is updated to SRAM, enabling aging compensation for active privacy screens. Through actual aging tests on 13.2-inch displays and verification of the compensation effect using the optimized lifetime compensation algorithm, the post compensation effect meets expectations. The lifetime compensation scheme proposed in this paper can effectively extend the lifetime of oxide OLED active privacy screens.

6. References

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