

32.2: An Innovative Pixel-Driving Scheme for 64-Level Gray-Scale Full-Color Active Matrix OLED Displays

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Abstract

Innovative pixel driving for active matrix OLED displays is described. A full-color display with a luminous deviation of less than 1.6%, which means a 6-bit or 64-level gray-scale accuracy, is shown. The driving is preferable for full-color video with gamma correction.

1. Introduction

Organic light emitting diode (OLED) displays are known to have a simple thin structure, fast response, wide viewing angle, and high contrast ratio. Adding to these merits, active matrix driving has lower power consumption than passive one because OLEDs can be driven using their more power-efficient condition. However, some challenges remain with active matrix OLED displays. Among them, inter-pixel uniformity is one of the most important for a picture quality as well as gamma correction.

Several pixel-driving methods have been proposed for suppressing inter-pixel non-uniformity, which is mainly caused by a deviation in poly-Si TFTs performance. The pixel circuit for V_{th} variation-compensation with autozero [1] was shown to suppress the V_{th} variation effectively, but it cannot compensate for a mobility variation [2]. Time-ratio gray scaling [3][4] performs very good uniformity because TFTs are driven only as switches. However, it is obvious that this digital driving method does not perform gamma correction, and frame memories are required in a sub-frame data generator [2]. Another driving method, such as adaptive current mode driving [2][5], requires the same characteristics in pair TFTs [6]. In this paper, we propose an innovative driving scheme named “clamped inverter driving” for active matrix OLED displays, which perform high inter-pixel uniformity and gamma correction, without the additional circuitry or twin TFTs.

2. Driving Scheme- “Clamped Inverter Driving”

Figure 1 shows a schematic diagram of the proposed pixel, which is composed of an OLED and a driving amplifier. Inter-pixel uniformity is accomplished because the OLED is driven by the “ON” and “OFF” states of the amplifier. The OLED is luminous during a continuous “ON” state period, and a gray-level is modulated with the “ON” state duration using the analog signal voltage.

The pixel circuit configuration is shown in Fig. 2, where the driving amplifier is a CMOS inverter. In the writing period, both an input gate (T1) and a reset gate (T2) are turned on, and the

analog signal voltage and the inverter’s reset voltage are applied to each node in a storage capacitor (C1). Here, the reset voltage is apparently a mean value of the inverter’s “ON” and “OFF” state voltages. Then, T1 and T2 are turned off. The above operation means that C1 has been charged as the inverter turns on or off when the same voltage of the written signal is applied to the pixel. After the writing operation, a sweep gate (T3) is turned on, and a triangle-shaped sweep voltage is applied to the pixel.

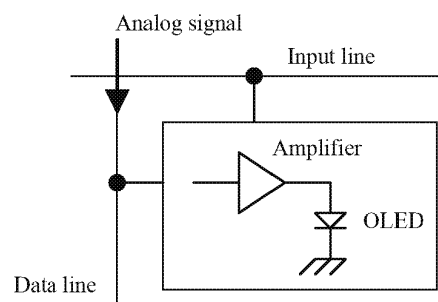


Figure 1. Schematic diagram of pixel.

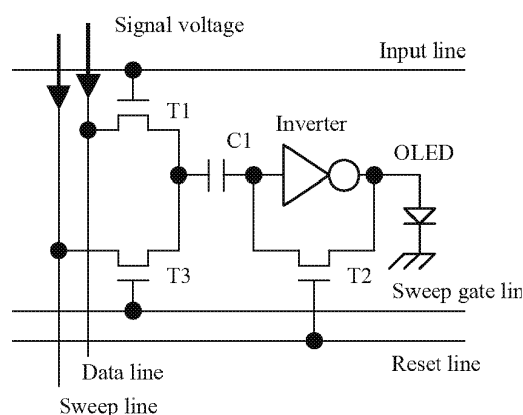


Figure 2. Circuit configuration of pixel.

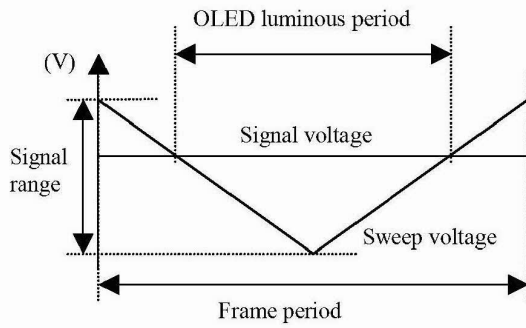


Figure 3. Timing chart of OLED driving.

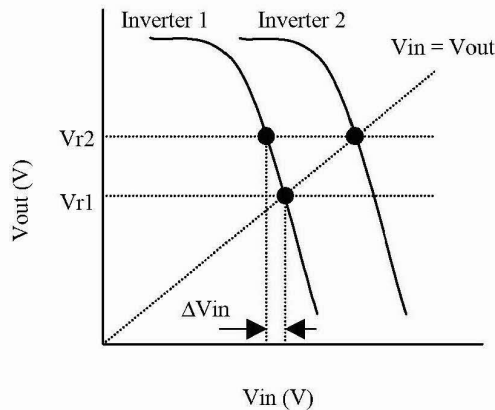


Figure 4. Characteristics of pixel inverter.

voltage, and OLED luminous period. The sweep voltage travels through a whole range of the signal voltage, and the OLED is luminous while the sweep is less than the written signal. Gamma correction is easily realized by modulating the analog signal level steps.

Some non-uniformity remains in this driving scheme due to the deviation in the transfer characteristics of the real inverter circuit. Figure 4 illustrates the characteristics of pixel inverters. As shown, the inverters' reset voltages (V_{r1} , V_{r2}) are different between the two inverters. Then, if these inverters' characteristics are normalized to "Inverter 1", the difference in the reset voltages is referred to ΔV_{in} as an equivalent input voltage variation. This means that as the inverter's voltage gain increases, the equivalent input voltage variation ΔV_{in} decreases. The CMOS inverter's gain G is described as

$$G = \frac{g_{mn} + g_{mp}}{g_{dn} + g_{dp} + g_{oled}}, \quad (1)$$

where, g_{mn} and g_{mp} are the transconductances of nMOS and pMOS transistors, g_{dn} and g_{dp} are their channel conductances, and g_{oled} is a conductance of an OLED, respectively. Equation (1) shows that the inverter's deviation can be suppressed by designing the inverter's TFTs with higher transconductance and lower channel conductance. The transistors should be designed in optimum channel length.

Figure 5 shows simulation results of the OLED current deviation caused by a variation in the pMOS transistor characteristics. The equivalent input voltage variation ΔV_{in} is limited to 100 mV even under 1.5 V of the V_{th} shift and 40% of the mobility deviation. This means that a 6-bit accuracy, which is a 64-level gray-scale, is available in this case if a range of the inverter's input signal is more than 6.4 V.

3. Experiments

The circuit diagram of the OLED display panel is shown in Fig. 6. The analog signal voltage was fed into the pixel-matrix using a horizontal scan circuit, and a vertical scan circuit selected a row of pixels to be written. The same sweep voltage was applied to all pixels in parallel.

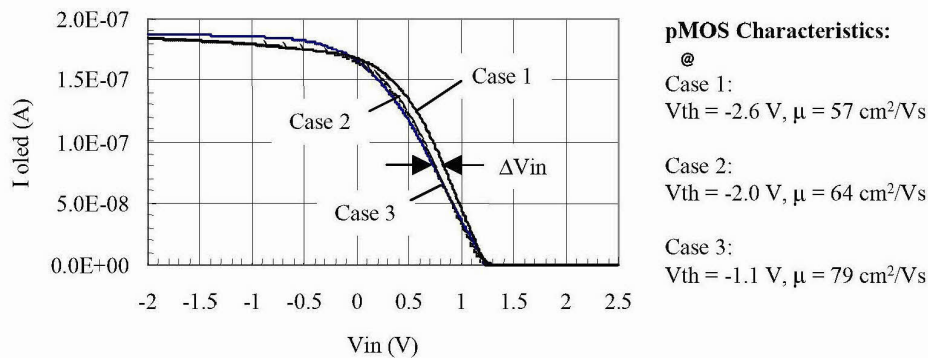


Figure 5. Simulation of OLED current.

Figure 3 shows a timing chart of the signal voltage, sweep

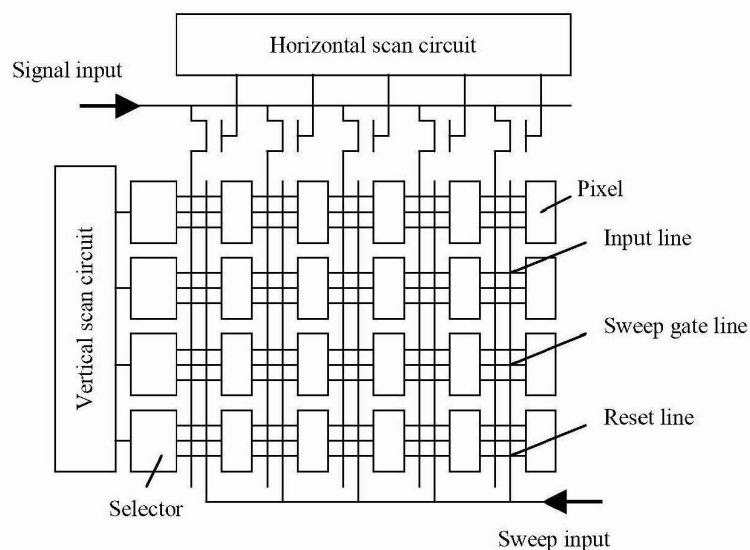


Figure 6. Circuit diagram of OLED display panel.

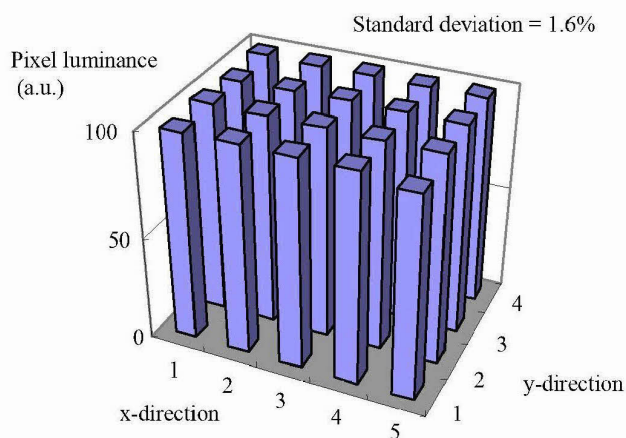


Figure 7. Inter-pixel Luminance variation.

Figure 7 shows an inter-pixel luminance variation in the panel when the input signal range was 6.0 Vpp. The non-uniformity was 1.6%, as measured using a standard deviation at 50 cd/m². We thus achieved 6-bit accuracy. An example of a full-color image is shown in Fig. 8.

4. Conclusion

Clamped inverter driving for active matrix OLED displays was proposed. The inter-pixel uniformity was effectively achieved by using a driving amplifier in each pixel. The gamma correction was also applicable because the gray-level was controlled by the amplifier's "ON" state duration, which was modulated using an analogous signal voltage. No special circuitry such as a sub-frame data generator was required. A full-color display that had 6-bit accuracy was shown.



Figure 8. Full-color image.

5. References

- [1] R.M.A. Dawson, Z. Shen, D.A. Furst, S. Connor, J. Hsu, M.G. Kane, R.G. Stewart, A. Ipri, C.N. King, P.J. Green, R.T. Flegal, S. Pearson, W.A. Barrow, E. Dickey, K. Ping, C.W. Tang, S. Van Slyke, F. Chen, J. Shi, J.C. Sturm, and M.H. Lu, Proceedings of SID 98, p. 11 (1998).
- [2] A. Yumoto, M. Asano, H. Hasegawa, and M. Sekiya, Proceedings of Asia Display / IDW '01, p. 1395 (2001).
- [3] M. Kimura, H. Maeda, Y. Matsueda, S. Miyashita, T. Shimoda, S.W.B. Tam, P. Migliorato, J.H. Burroughes, C.R. Towns, and R.H. Friend, Proceedings of IDW '99, p. 171 (1999).
- [4] K. Inukai, H. Kimura, M. Mizukami, J. Maruyama, S. Murakami, J. Koyama, T. Konuma, and S. Yamazaki, Proceedings of SID 00, p. 924 (2000).
- [5] T. Sasaoka, M. Sekiya, A. Yumoto, J. Yamada, T. Hirano, Y. Iwase, T. Yamada, T. Ishibashi, T. Mori, M. Asano, S. Tamura, and T. Urabe, Proceedings of SID 01, p. 384 (2001).
- [6] Press Release, Sony Inc., Feb. 7/2001, (2001)