A Novel Voltage-Programming Pixel with Current-Correction Method for Large-Size and High-Resolution AMOLEDs on Poly-Si Backplane

Hai-Jung In, Joon-Ho Bae, Jin-Sung Kang, and Oh-Kyong Kwon
Division of Electrical and Computer Engineering, Hanyang University, Haengdang-Dong, Seongdong-Gu, Seoul, 133-791, Korea
Ho-Kyoon Chung
R&D Center, Samsung SDI Co., Ltd, Yongin-City, Kyungki-Do, Korea

Abstract
A novel active matrix organic light diodes (AMOLEDs) voltage-programming pixel structure with current-correction method is proposed for large-size and high-resolution poly-Si AMOLED panel applications. The HSPICE simulation results shows that the maximum error of emission current in proposed pixel is 1.536%, 2.45%, and 2.97% with the ±12.5% mobility variation and ±0.3V threshold voltage variation for 30-, 40-, and 50-inch HDTV panels, respectively.

1. Introduction
Organic light emitting diodes (OLEDs) are expected promising flat panel display by its great features such as very thin, wide viewing angle, low power consumption, and fast response time [1]. Although a lot of efforts have been made to apply AMOLEDs to large-size applications, they are still used for small-size displays.

There are four kinds of prior poly-Si based AMOLEDs driving methods, which are voltage programming [2, 3], current programming [4-6], digitally driving [7], and PWM methods driving with ramp signal [8].

The digitally driving method may have the non-uniform image problem due to non-uniform electrical characteristics of pixel driving TFTs. The gray scale is expressed by the emission time, but the characteristics of TFTs and OLEDs varies from pixel to pixel and this causes the turn-on current variation of OLEDs. So, even if the emission time is same, the luminance of OLEDs should be different.

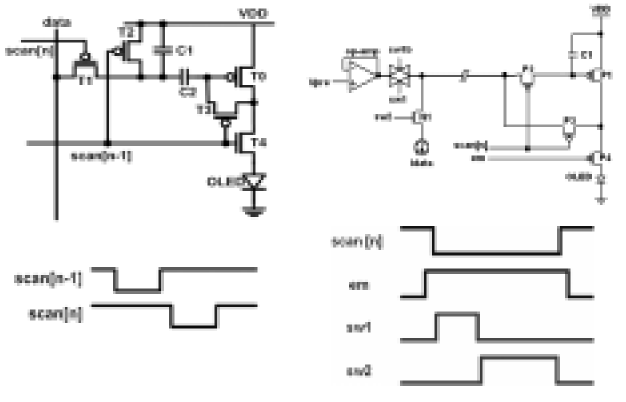
The PWM driving method with ramp signal has not only the same non-uniform picture quality problem as digitally driving method but also deformation problem of ramp signal due to the RC delay of ramp-signal line. As the panel size is increased, the line capacitance and resistance is increased. So, this makes hard to transmit ramp signal without deformation.

Voltage programming and current programming methods can be divided into voltage programming with current source pixel[2] and voltage programming with current mirror pixel[3], current programming with current source pixel[4,5] and current programming with current mirror pixel[6]. They usually employed threshold voltage compensation method in the pixel circuit in order to make better uniform image. Current mirror type pixel circuits are hard to apply to high-image-quality panels because they have electrical characteristic matching problem of mirror TFTs.

Mostly, voltage-programming methods can compensate threshold voltage variation of TFTs, but have the emission current variation problem from the mobility variation of the driving TFT. As the panel size is increased, required current for OLEDs is increased, and this increases emission current variation. In contrast, current-programming methods can compensate both threshold voltage and mobility variations of the driving TFT, but they have charging problem at low-level current. As the panel size and the resolution format increase, current programming methods become harder and harder to program at low gray-level video signals.

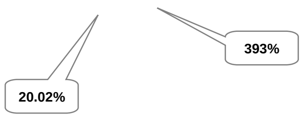
To analyze problems of prior pixels, the HSPICE simulations with large-size panel condition have been performed. Figure 1 shows a prior voltage-programming current-source pixel [9] and current-programming current-source pixel with a voltage pre-charging method [5].

In Figure 2 (a) and (b), the emission current errors of those pixel structures are plotted against gray-scale levels for the worst conditions of threshold voltage (±0.3V) and mobility (±12.5%) of the driving TFT in 30-inch HDTV.



(a) (b)

Figure 1. Schematic and timing diagram of (a) prior voltage-programming pixel and (b) current-programming pixel with voltage pre-charging method.



(a) (b)

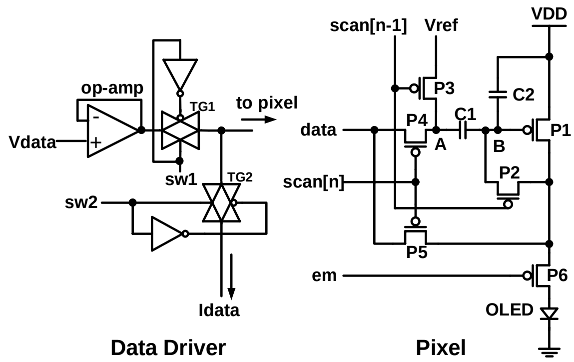
Figure 2. OLED emission current errors in 30-inch HDTV for the worst case of Vth and mobility variations of driving TFT of (a) voltage programming current-source pixel structure of figure 1(a) and (b) current-programming pixel structure of figure 1(b).

The maximum OLED-current error of voltage programming pixel [9] is 20.02%(52.87 LSB), and the maximum error of current programming pixel with voltage pre-charging method [5] is 393%(99.46 LSB), respectively. Simulation results indicate that it is hard to apply prior pixels to large-area high-resolution AMOLED panels.

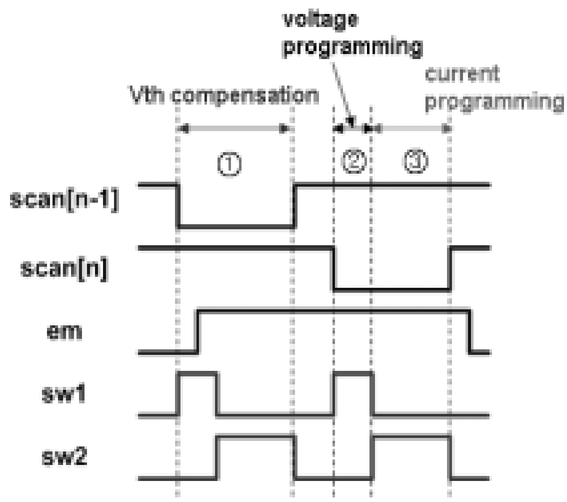
In this paper, to solve the previously mentioned problems, we proposed voltage-programming pixel structure with current correction method.

2. Proposed Voltage-Programming Pixel Structure with Current Correction Method

Figure 3 shows the schematic diagram and timing diagram of the proposed voltage-programming pixel structure with current correction method. The main idea of this method is using voltage programming with threshold voltage compensation first and current correction after the voltage programming for correcting the emission current deviation due to electrical characteristic variations of pixel driving TFTs.



(a)



(b)

Figure 3. (a) Schematic diagram and (b) timing diagram of the proposed voltage-programming pixel structure with current correction method.

When scan[n-1] is 'low' and em is 'high' P2 and P3 turn on and P6 turns off, so unwanted current is blocked to enter OLED during programming period. Because P1 is diode connected, the voltages of nodes A and B can be expressed by equation (1) and (2), repectively.

$$V_A = V_{ref} \quad (1)$$

$$V_B = VDD - |V_{thp,P1}| \quad (2)$$

When scan[n-1] goes 'high', P2 and P3 turn off and nodes A and B are floated. When scan[n] is 'low', P4 and P5 are turned on and data is programmed at the pixel. While sw1 is 'high', V_{data} is programmed at the node A, so the voltages of nodes A and B can be expressed by equation (3) and (4), respectively.

$$V_A = V_{data} \tag{3}$$

$$V_B = VDD - |V_{thp,P1}| - \frac{C1}{C1+C2}(V_{ref} - V_{data}) \tag{4}$$

The current of the driving TFT can be expressed by equation (5).

$$\begin{aligned} I_{P1} &= \frac{1}{2}\mu_p C_{ox}\frac{W}{L}\left(VDD - V_{G,p1} - |V_{thp,P1}|\right)^2 \\ &= \frac{1}{2}\mu_p C_{ox}\frac{W}{L}\left(VDD - \left(VDD - |V_{thp,P1}| - \frac{C1}{C1+C2}(V_{ref} - V_{data})\right) - |V_{thp,P1}|\right)^2 \\ &= \frac{1}{2}\mu_p C_{ox}\frac{W}{L}\left(\frac{C1}{C1+C2}(V_{ref} - V_{data})\right)^2 \end{aligned} \tag{5}$$

After voltage-programming sw1 becomes 'low' and sw2 becomes 'high', then the current flow out through P1, P5, data line, and TG2. By coupling effect of C1, the voltage of the node B is adjusted to flow I_{data} at P1.

3. Simulation Conditions and Specifications

For the simulations of the proposed pixel and driving method, HSPICE[10] is used. Parasitic resistance and capacitance of column and row lines were extracted by using RAPHAEL[11] assuming the width of each line is 10μm. Table 1 shows panel parameters of AMOLED HDTVs and parasitic resistance and capacitance of column and row lines.

Table 1. Panel parameters of AMOLED HDTVs and parasitic resistances and capacitances

Panel Diagonal Size [inch]		30	40	50
Column Line	Width [μm]	10	10	10
	Resistance [kΩ]	10.56	14.08	17.60
	Capacitance [pF]	47.2	56.7	65.8
Row Line	Width [μm]	10	10	10
	Resistance [kΩ]	18.77	25.03	31.28
	Capacitance [pF]	204.6	250.8	308.6
VDD Line Width [μm]		12	20	30

The full white brightness of 600 cd/m^2 condition is applied for 30-inch, 40-inch, and 50-inch HDTV panels and the current requirements for each size are summarized in Table 2. Required maximum OLED-current for each size and color is calculated from the pixel size, resolution, and OLED-current efficiencies.

Table 2. Current requirements for AMOLED HDTVs

		R	G	B
Brightness [cd/m^2]		600		
Panel Brightness [cd/m^2]		536.0	874.9	389.0
OLED Brightness [cd/m^2]		1340.1	2183.3	972.6
Current Efficiency [cd/A]		8.4	22.0	5.6
Pixel Size [μm^2]	30-inch	115.3×345.9		
	40-inch	153.7×461.2		
	50-inch	192.2×576.5		
Required Maximum Current [μA]	30-inch	6.348	3.965	6.927
	40-inch	11.284	7.048	12.312
	50-inch	17.637	11.017	19.244

4. Simulation Results and Discussions

Figure 4 plots the driving-TFT current during programming time of proposed voltage-programming pixel structure with current correction method. Mobility of driving TFT is varied from 70cm^2/Vs to 90cm^2/Vs with the step of 10 cm^2/Vs.

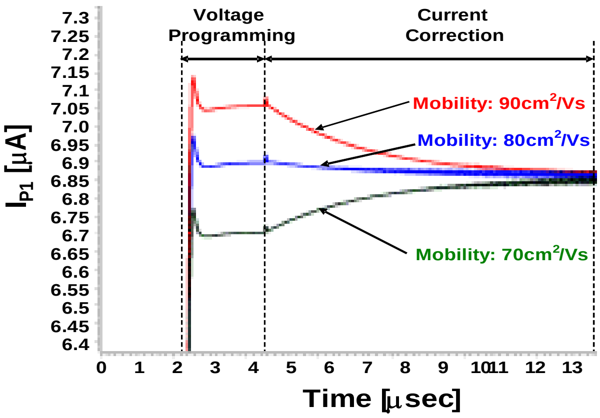
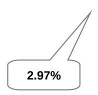


Figure 4. Flowing currents in driving TFT of the proposed voltage-programming pixel structure with current correction method at 30-inch panel with mobility variation of pixel driving TFTs.

Simulation results indicate that current of driving TFT of voltage programming time is different from expected current due to the mobility variation of pixel driving TFT, but it is adjusted to the target current by current correction. Figure 5 plots the emission current error of the proposed voltage-programming pixel structure with current correction method with respect to the gray scale in 30-, 40-, and 50-inch full HDTVs, respectively, where ±12.5% mobility variation and ±0.3V threshold voltage variation are applied.

(a) (b)



(c)

Figure 5. The emission current error of the proposed voltage-programming pixel structure with current correction method with respect to the gray scale of (a) 30-inch, (b) 40-inch, and (c) 50-inch full HDTVs.

6. Conclusions

A new driving method and a pixel circuit for large-area large-size and high-resolution AMOLEDs are proposed. The maximum error of emission currents in the proposed voltage-programming pixel structure with current correction method are 1.536%, 2.45%, and 2.97% for 30-inch, 40-inch, and 50-inch full HDTVs, respectively, when ±12.5% variation of mobility and ±0.3V variation of threshold voltage are assumed. The proposed pixel improves emission current uniformity by compensating not only threshold voltage but also mobility of pixel driving TFTs and overcomes the charging problem because it basically uses voltage-programming methods. It is expected that proposed driving method can be applicable at large-area full HDTV applications.

7. References

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