Reduced Swing Polarity Inversion Driving Method for a-Si:H TFT Based AMOLED

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Abstract

We have proposed a new driving method which improve the current stability of a-Si:H TFTs for AMOLED. It performs the negative bias annealing on driving TFTs during a certain period of a frame time. In the proposed method, the range of data signals is significantly reduced by modulating VSS.

1. Introduction

Hydrogenated amorphous silicon (a-Si:H) thin film transistors (TFTs) are attractive pixel elements for the large size active-matrix organic light-emitting diode (AMOLED) panel because its fabrication process is well-established so that the threshold voltages of its TFTs are quite uniform and its production cost is low [1-2]. However, its threshold voltage is seriously shifted from the initial value by an electrical stress on the gate electrode of the driving TFT [3-4]. When different voltage stress is given to each pixel so that the threshold voltage of each driving TFT is shifted differently, the illumination of OLEDs with same data voltage can not be equal with each other, and the screen uniformity is finally destroyed. In order to solve the problems, various threshold voltage compensation circuits have been reported [1-2]. But, the compensation schemes with memorizing the threshold voltage require additional components such as TFTs, capacitors or signal lines. Moreover, they would accelerate the degradation of a-Si:H TFTs by increasing gate voltage of the current driver TFT, which might lead into the linear region.

Recently, we have reported the driving methods to suppress the threshold voltage shift of the driving TFT by applying a negative bias to the gate electrode [5-9]. However, they included several problems such as the complexity increment of the pixel circuits or the large voltage swing of the data signal lines.

We present a new polarity inversion driving scheme which performs the negative bias annealing with positive data signals and their voltage swings are significantly reduced.

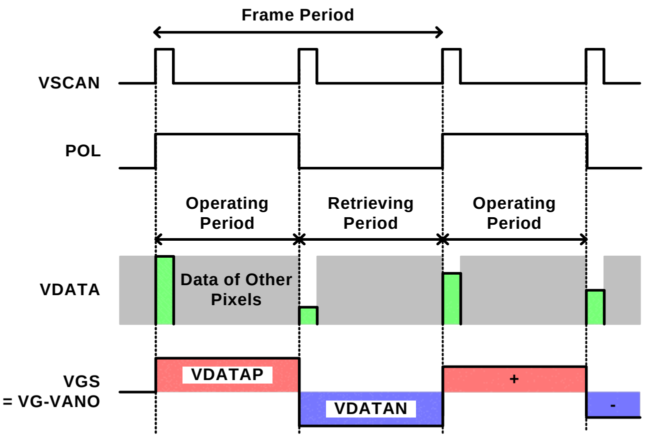


Fig. 1. Timing diagram of input signals and V_{GS} of a driver TFT

2. Polarity Inversion Driving

The proposed method named polarity inversion driving (PID) is basically a temporal interlacing scheme. It is said that threshold voltage shift of a-Si:H TFT is originated from the state creation in its bandgap [3-4]. Positive stress on the gate electrode leads to state creation, but negative bias leads to an overall reduction in the density of dangling-bond states [3]. It can be realized for threshold voltage to return to its initial value if created states can be removed by negative bias annealing. We have adopted these characteristics to PID. It utilizes one frame as two periods, which are the operating period and the retrieving period. An original positive analog voltage is applied in the operating period while a complementary positive voltage based on the original image data is applied consecutively in the recovering period. As shown in Fig. 1, the frame rate in the PID should be doubled and the positive pixel voltage, VDATAP and the negative voltage, VDATAN alternate according to the polarity selection signal, POL. VSS is ground in the first section of each frame, and it changes its voltage to high level in the second section of each frame as shown in Fig. 2. It helps VDATA swing range to be smaller than that of the previously proposed PID [8].

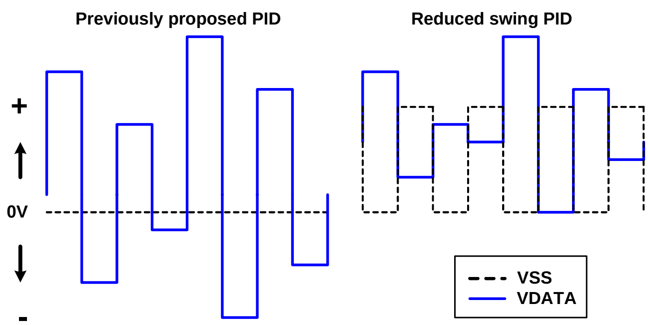


Fig. 2. Waveform diagrams for PID methods

Fig. 3 is the system configuration for the PID. A set of digital image data, G(n), is transmitted from the video signal processor to the frame memory at a rate of X frames per second (fps). After storing data more than one frame on the frame memory, it sends one set of the image data, G(n), to the look-up table twice as fast as the data sending rate from the video signal processor to the frame memory, 2X fps. The look-up table changes G(n) into Gn+ and Gn-.

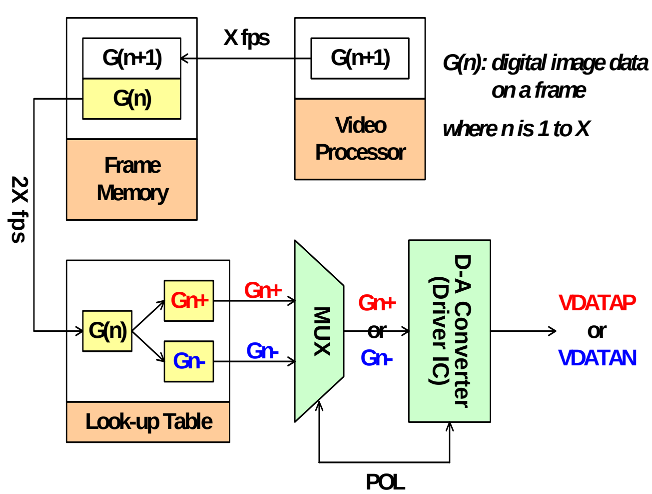


Fig. 3. System configuration for the PID method

Gn+ is for displaying an original image, and Gn-, the counterpart of Gn+, is for recovering the driving TFTs from the degradation. Gn+ and Gn- are transferred to the Digital to Analog Converter through the multiplexer (MUX). When POL is high, digital image data, Gn+, is transmitted and converted to analog signal VDATAP. When POL is low, Gn- is transmitted and converted to VDATAN.

3. Simulation and Analysis

We have verified the operation of the reduced swing PID method by simulating the conventional 2-TFT pixel circuit using SPICE. The schematic and the simulation conditions are shown in Fig. 4. It is assumed that signal data, VDATAP, from VDATA is 13V, and its annealing voltage, VDATAN is 6V in the first frame. VDATA in the next frame swings between 10V and 8V. According to each period, VSS also changes alternatively from 0V to 10V. The effective gate voltage stress on driving TFT, MDRV, is VG-VANO. During the operating period, the first part of each frame, the effective gate voltage is positive (about 7V at the first frame and 5V at the second frame) so that the original image would be displayed. These positive voltages are attributed to increasing threshold voltage of MDRV. However, its shift is recovered to the initial point by the negative voltage (about -7 at the first frame and -5V at the second frame) of the effective gate voltage during the retrieving period when the black image is displayed.

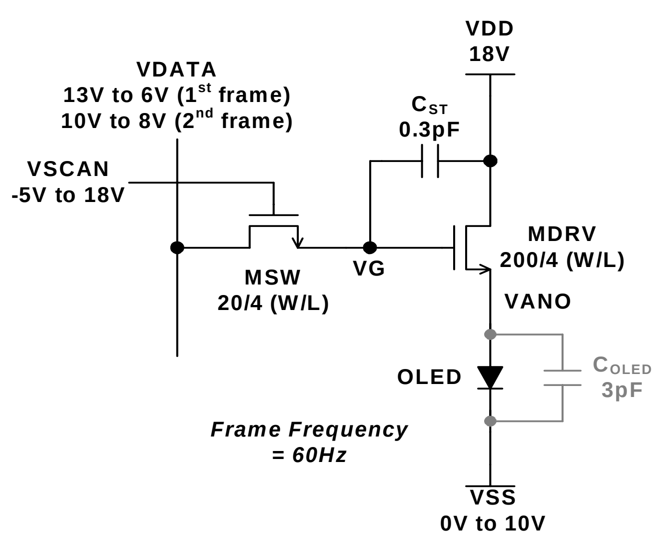
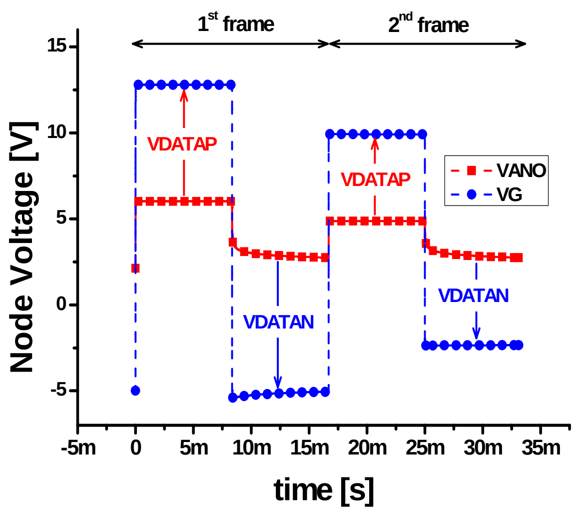
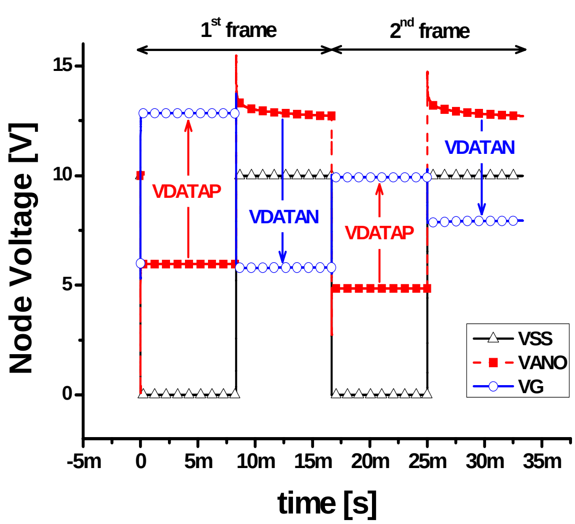


Fig. 4. A 2-TFT pixel circuit employing the newly proposed method



(a)



(b)

Fig. 5. Waveforms of VG and VANO using SPICE simulation (a) without VSS modulation and (b) with VSS modulation

The purpose of PID method is that the driving TFT of each pixel should be retrieved as much as it suffers from the stress while OLED illuminates. Because each of them experiences different analog image data in a frame, retrieving process should apply differently. As shown in Fig. 5 (b), the effective gate voltage stress is alternating from positive voltage to negative voltage in each frame. The amount of negative voltage is determined by the positive voltage of original image data for each frame. Fig. 5 (a) shows the waveforms of previously proposed PID. As comparing both waveforms, it can be easily observed that the VDATA swing range (from 13V to 6V at the first frame, from 10V to 8V at the second frame) of newly proposed PID is reduced much more than its range (from 13V to -5V at the first frame, from 10V to -2V at the second frame) of the previously proposed one. By changing VSS in the retrieving period, it pushes the potential of OLED's anode up so that the effective gate voltage stress can be negative with not negative data voltage but positive data voltage as well as the swing range of VDATA can be reduced considerably.

The brightness of OLED is determined by the current which is driven from the driving TFT. As shown in Fig. 6, even though VSS switches from 0V to 10V, the current of OLED is not affected by its modulation.

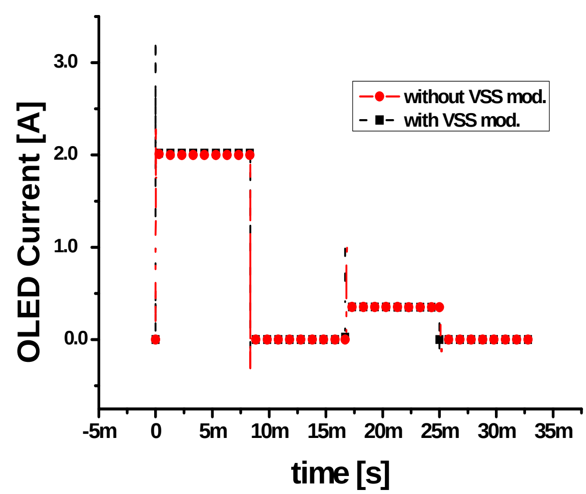


Fig. 6. OLED current using SPICE simulation of previous PID method and proposed one

This is a signal-oriented retrieving scheme: Gn-, which is converted to VDATAN, is the complementary part of Gn+ converted to VDATAP. It is an imaginary data for the threshold voltage of driving TFT to return its initial value from the shifted threshold voltage. Therefore, the good screen uniformity as well as the stable pixel characteristics can be realized without any threshold voltage compensation circuit. Thanks to the VSS modulation, the swing range of VDATA can be reduced more than the half of the previously reported one. It helps the system to lower its production costs. It could also suppress the motion blur effect due to the insertion of the black image between frames.

4. Summary

A new reduced swing polarity inversion driving (PID) scheme, which is the signal-oriented recovering method, has been proposed and verified by simulating the conventional 2-TFT pixel circuit using SPICE. In the proposed PID pixel circuit, there is no requirement of additional signals or pixel components. By the modulation of VSS, the data voltage signal can be reduced. PID can guarantee longer lifetime and better performance by minimizing the degradation of a-Si:H TFT and providing the good uniformity without any threshold voltage compensation scheme.

5. References

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