A Novel Digital Driving Method for AM-OLED

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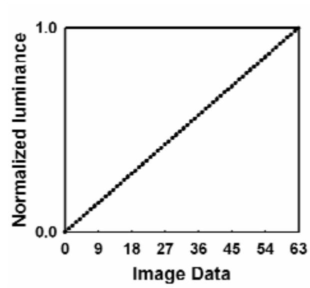
Abstract

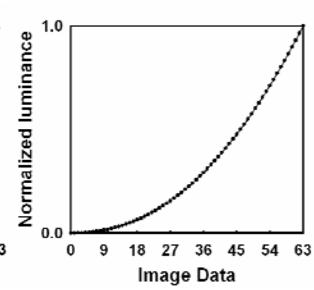
We propose a novel digital driving method for AM-OLED (Active Matrix-Organic Light Emitting Diode) display. Proposed method modulates V_{DD} so that luminance may be weighted in accordance with the bit significance. We can increase the minimum emission time or slower scan circuits are applicable by using proposed method.

1. Introduction

OLED (Organic Light Emitting Diode) display is widely being researched due to low power consumption and higher performances. For the driving circuitry of OLED, a-Si TFT has an advantage because of its good uniformity, But the characteristics of a-Si TFT change with time which results in reduction of life time. Therefore, a lot of researchers have been studying poly-Si TFT circuitry for OLED. However, poly-Si TFT also has a disadvantage of variation of threshold voltage (V_{th}). So, the non-uniform V_{th} variation should be compensated to get a uniform image quality [1]. There are two kinds of driving methods for AMOLED, which are voltage and current programming methods [3]. However, these circuits need a lot of TFTs and capacitors in a pixel to compensate the V_{th} variation resulting in reduced aperture ratio. Digital driving method was presented for a uniform image quality and a higher aperture ratio [1]. Luminance of OLED driven by the digital driving is proportional to a digital value as shown in Fig. 1 (a) but the luminance of an ideal display should be a power function of the digital data as shown in Fig. 1 (b). To implement the gamma characteristics as shown in Fig. 1 (b), more bits are necessary. Thus the number of sub-fields (SFs) should be increased. But, if the number of SFs increases, then minimum emission time decreases dramatically. In addition, if the resolution of OLED becomes higher, the total emission time decreases accordingly. For better image quality, it is necessary to keep or increase the shortest emission time.

In this paper, we will show a new digital driving method which can keep or increase the time even when the resolution of display becomes higher or the number of grayscale increases.





(a) AMOLED driven by digital driving (b) ideal display

Fig. 1 Luminance characteristics of (a) AM-OLED driven by a conventional digital driving and (b) an ideal display

2. Proposed Digital Driving Method

Figure 2 shows the conventional 2T1C pixel circuit for the digital driving. This pixel circuit is the same as that of the conventional voltage driving. However, two voltage levels are applied to the gate of driving TFT [2]. The anode voltage of OLED is almost same as V_{DD} because the driving TFT operates at a linear region. Thus, the digital driving technique shows a very good immunity to variations of carrier mobility and V_{th}. To display a various gray-scale, to display 8 bit time ratio digital gray scale method was presented as shown Fig. 3 [1]. One frame time is divided into 8 sub fields (SFs, SF7-SF0). Each SF is divided into a scan period (SP) and an emission period (EP). The length of each EP is decided according to the weight factor of the digital bit. During SPs, a high voltage is applied to the cathode of OLED.. During EB, a low voltage is applied to the cathode. To display 8-bit images on OLED driven by the digital driving, the total required number of bits is 10. Thus, the time for SF0 becomes 1/1023 of the total emission time (1 frame-the total time of SPs). As shown in Fig. 3, the time-ratio of all EPs is 128:64:32:16:8: 4:2:1. The assumption of the conventional method is the luminance of each EP is identical. But, if luminance of the first SF, SF7 becomes 2×, then the time for SF7 can be identical to that of SF6. This means that the minimum length of SF time can be increased by weighting luminance at different SFs. Fig. 4 shows one example of the proposed method. The luminance at three SFs (SF7, SF6, and SF5) is twice as high as that at the remainders. So, the time-ratio becomes 64:32:16:16:8:4:2:1. There are 3 luminance levels in example as shown Fig. 5. So, the time-ratio of the method the another (Fig.5) is 32:16:16:8:8:4:2:1. To obtain the luminance levels, V_{DD} should be modulated as shown in Fig. 5. The shortest times of the proposed methods (Fig. 4 and Fig. 5) are 1.78 t_0 and 2.93 t_0, respectively, where to is the shortest EP of the conventional method. Therefore, our proposed method can increase the minimum emission time. If the minimum emission time is maintained, then the scan time can be increased. Our method can slow down the scan circuits.

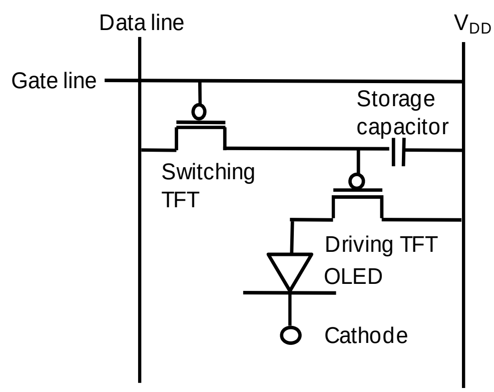


Fig. 2 Schematic of conventional 2T1C pixel circuit

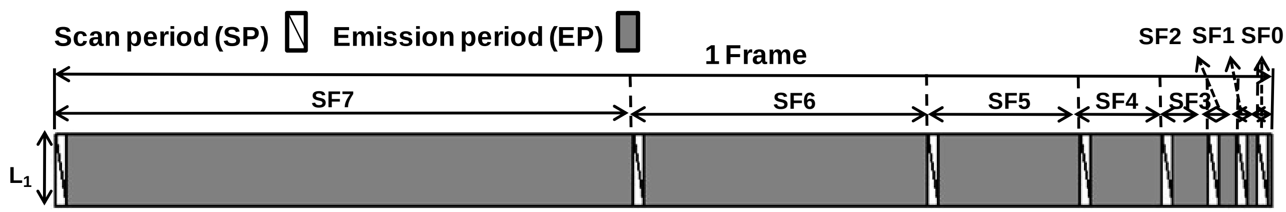


Fig. 3 Timing chart of a conventional 8 bit time ratio gray scale method.

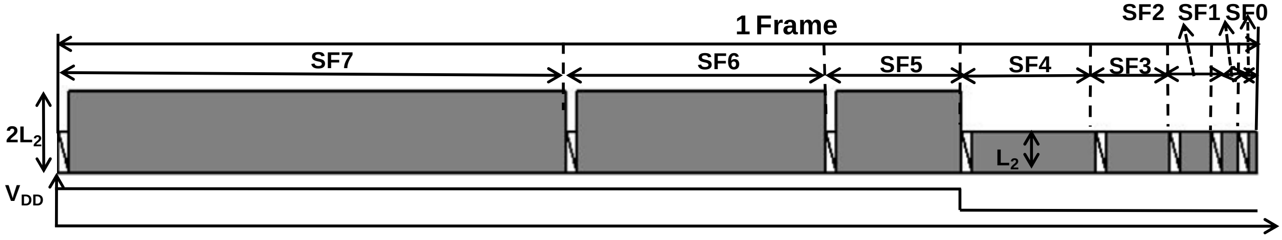


Fig. 4 Schematic of first proposed 8 bit time ratio gray scale method.

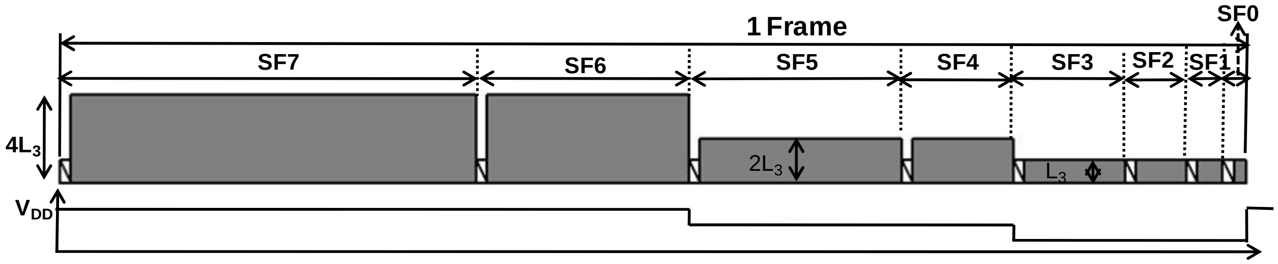


Fig. 5 Schematic of second proposed 8 bit time ratio gray scale method.

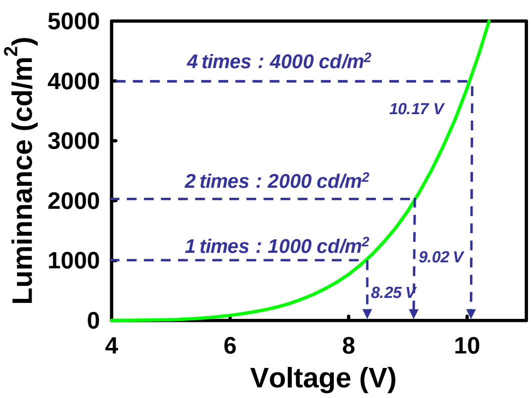


Fig. 6 Luminance characteristics of OLED with varying applied voltage.

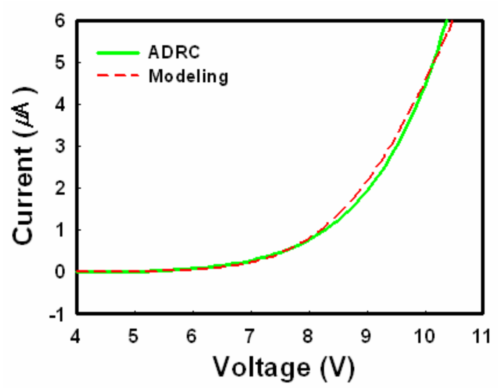


Fig.7 I-V characteristics of OLED (solid line: the measured data, dotted line: model)

3. Result

Fig. 6 shows luminance characteristics of OLED fabricated in our lab. 8.25 V, 9.02 V and 10.17 V of V_{DD} provide 1000 cd/m^2, 2000 cd/m^2 and 4000 cd/m^2, respectively as shown in Fig. 6. We modeled current-voltage characteristics of OLED as shown Fig. 7. We simulated the proposed driving method with V_{th} variation of ±3 V, as shown in Fig. 8. From the simulated results, we can see that the current errors are less than ±0.1 % when V_{th} varies by ±1.5 V.

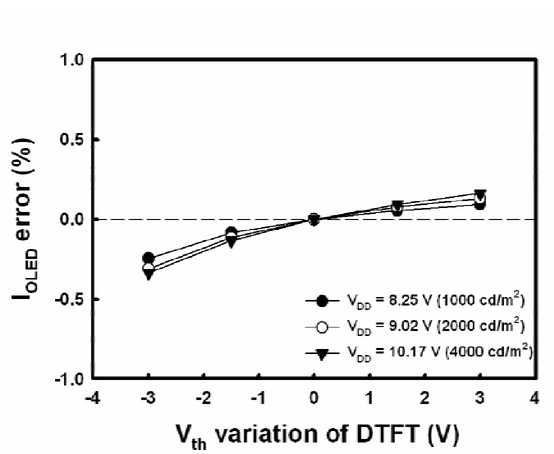


Fig. 8 Current error with V_{th} variation of Driving TFT

Fig. 9 shows that OLED current error percentage of driving TFT is about 0.1 %, when mobility varies from -20 to +20 cm^2/Vs. We can realize that the proposed digital driving method has a good immunity to the mobility variation of TFTs as shown in Fig. 9.

4. Conclusions

We proposed a new digital driving method here. The method modulates V_{DD} so that luminance may be weighted in accordance with the bit significance. By this method, we can increase the minimum emission time or slower scan circuits are applicable.

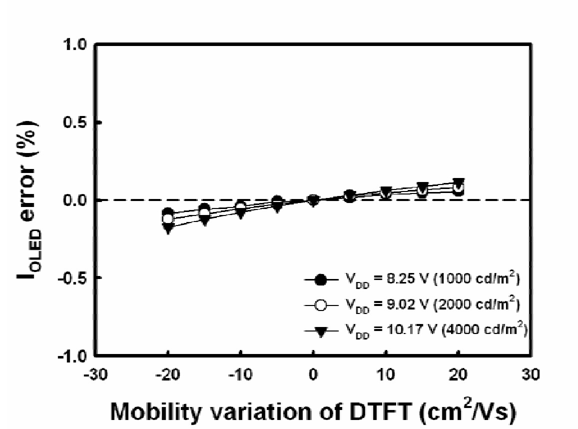


Fig. 9 Current error with mobility variation of Driving TFT

In conclusion, our proposed method has better performances in image quality and poly-Si circuit design.

5. Reference

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