Circuit Design Technologies for System on Panel

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Abstract

System on Panel (SOP) can integrate many functions by Thin Film Transistor (TFT) circuits on an insulator substrate without using external driver LSIs. However, to make practical SOP has become more and more difficult because of rapid cost reduction of the driver LSIs. This paper will review the circuit design technology trend for SOP and introduce an example of a practical SOP, 2.0inch QVGA full color active matrix OLED with 8bit source driver.

1. Introduction

We believed that SOP (System on Panel) is one of the best methods to reduce manufacturing cost and get a high performance of flat panel display. Therefore many companies have researched to integrate various kinds of circuits such as DACs and DC/DC converter on glass substrate for TFT-LCD and AM-OLED application [1-2] However, the mobile digital-TV (DTV) and ubiquitous computing become more popular, the mobile flat panel display demand for high resolution, high color depth, low-power consumption, compact displays. As the requirement of mobile flat panel display progresses, the driving voltage and design rule should be decreased for lower power and a narrow picture frame. But it is very difficult to meet these requirements because poly-Si TFTs have higher threshold voltage, lower mobility and been fabricated with a larger design rule than single crystal silicon. Especially, design rule of single crystal silicon is more and more decreased to meet low power consumption and narrow picture frame. However, design rule for SOP still remained around 2 micron. Therefore, it is difficult to integrate fully SOP in the narrow pitch. The most important thing is how we can achieve the most proper function in the integrated TFT circuits only on the available dead space of the display by using the conventional design rule and conventional TFT characteristics. Also, we must develop novel circuit to meet high performance of flat panel display. In this paper, we review circuit design technologies trend for SOP and we introduce an example of SOP technology, 8bit source driver to be overcome high resolution, high color depth, low-power consumption and compact design.

2. Technology trend of SOP

We classified three typical types to explain technology trends of SOP. First, we explain de-multiplexer type. The de-multiplexer type is suitable for the applications because the external driver IC has the integrated frame memory. The advantage of the system is to minimize the power consumption and simplify the integrated TFT circuit configuration. The disadvantage of the system is rather larger dead space on the TFT substrate for the driver IC assembly and expensive cost of the driver IC.[3]

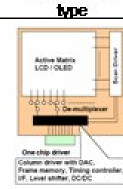
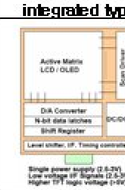
	De-multiplexing type	5V digital I/F type	Under 3V fully integrated type
SOP Type			
Dead space	Good	Good	Bad
TFT circuit simplicity	Good	Good	Bad
System customization	Easy	Not difficult	Very difficult
TFT power consumption	Small	Small	Large
Required TFT characteristic	Wide margin	Not so severe	Severe
TFT substrate cost	Good	Fair	Bad

Table 1 Comparison among the 3 type of SOP

Second, we explain 5V digital I/F type. This type is the digital data driver with D/A converter. 5V digital interface signals are used in the system because it doesn't require so precise LTPS TFT characteristic control in the fabrication process such as 3V digital interface. By removing high through rate analog circuits from the TFT controller, the chip size of the IC can be shrunk and power consumption can be drastically decreased. If the LTPS TFT fabrication yield is not so affected by the complexity of the integrated circuits, it can become one of the practical systems.[3]

Lastly, we explain fully integrated SOP. This type is an ideal SOP doesn't need any external ICs to driver the system. This SOP panel can be driven single power supply of 3V and low voltage digital interface signals of 2.5 to 3V. However, the power consumption is rather large because the integrated TFT circuits require at least 5V to operate in the required frequency and the poor efficiency of the LTPS TFT DC/DC converter makes loss. Furthermore, it requires precise control of LTPS TFT characteristics to keep low voltage interface and keep good efficiency of the DC/DC converter. It is also difficult to keep high yield of the LTPS TFT fabrication process because the complexity of the integrated circuits is very high, while process window is very narrow. Therefore, the ideal fully integrated SOP is very challenging target.

3. Design technology of 8bit source driver [4]

Until now, we explained SOP technology trend from example of 3 typical types. We can't easily decide that which is the best one because each of them has advantages and disadvantages. However, we believe that SOP is one of the effective approaches to decrease the cost of active matrix displays if we can optimize the system.

From now, we explain design technology of 8bit source driver applied 2.0-inch QVGA active-matrix OLEDs even though LTPS TFTs have threshold voltage variation and large design rules. Normally, sub pixel area of 2.0 inch QVGA display is only 42µm by 126µm. In such narrow pitch, we applied three technologies to integrate 8bit source driver. First, we developed a new 8bit DAC circuit that is applied to one-to-three DEMUX. Second, we propose new source driver structure to integrate 8bit DAC. Lastly, we also applied pre-charging method to overcome insufficient data line charging period, which is only one third of normal driving method due to the one-to-three DEMUX.

Generally, in the case of DAC, the area of it is larger square as 1bit increase. Therefore, the area of 8bit DAC becomes larger 4 times than 6bit DAC. However, we developed new small sized 8bit DAC because it is impossible to integrate 8bit DAC in the small area (126µm). Fig.1 shows the new 8bit DAC structure. As show in Fig.1, it is composed of top 4bit DAC and bottom 4bit DAC. In the case of top 4bit DAC is consist of 4bit decoder blocks, 9 reference voltage sources and reference voltage selection switches. On the other hands, bottom 4bit DAC is consist of 4bit decoder blocks, resistance selection switches and poly-resistance array. The most important feature of a new 8bit DAC is able to get 16 kinds of reference voltage source even though we used 9 kinds of reference voltage sources. Fig2. shows equivalent circuit of 8bit DAC. As show in Fig.2, top 4bit decoder is to select two neighboring nodes among 9 reference voltages. Then, two kinds of reference voltage pair are occurred by voltage drop of reference selection switches. One of reference voltage pair is for an odd gray level and the other is for an even gray level.

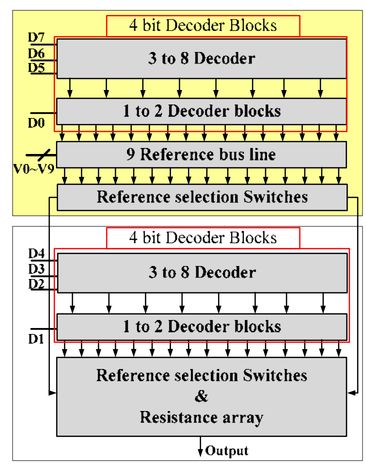


Fig. 1 8bit DAC structure.

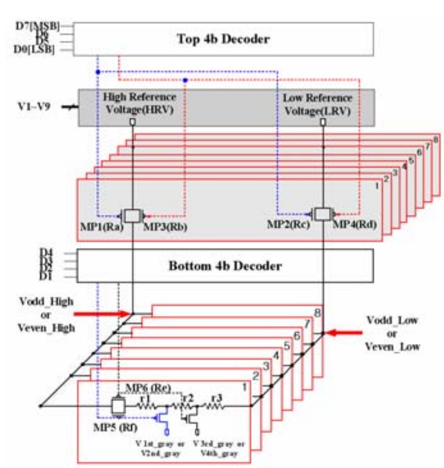


Fig. 2 Equivalent circuit of 8bit DAC.

On the other hands, the bottom 4bit decoder is to divide resistance string. That is, data voltage level is set by the ratio of resistance values between selected two reference voltage sources. Therefore, we can obtain 4 different voltage levels with the 4 combinations of top and bottom 4b decoders. Also, other 28 gray values can be calculated by ratio of different turn on switch and poly- resistance values. Since there are 9 references voltage levels and 32 gray values between two neighboring reference voltage levels, total 256 gray can be obtained.

Second, we propose new source driver structure. As shown in Fig.3 it has a top 4bit DAC(D7[MSB], D6, D5, D0[LSB]), a level shifter block, a S/H latch block, a shift register, a S/H latch block, a level shifter block, a bottom 4bit DAC(D4, D3, D2, D1) and a one-to-three DEMUX. We separated top 4bit DAC and bottom 4bit DAC to integrate 8bit DAC in small area. Using this structure reduces the 8bit source driver area by 40% compared to a conventional source driver.

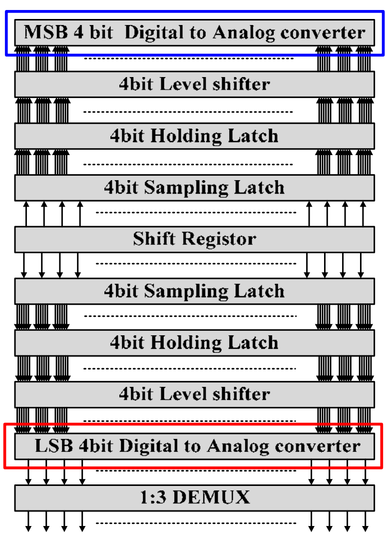


Fig. 3 8bit source driver structure.

Lastly, we also applied a pre-charging method to overcome the insufficient data line charging period, which is only one third of normal driving time due to the one to three DEMUX. Figure.4 shows the circuit simulation results for the 8bit DAC using pre-charging. The first 3μs are used for the pre-charge operation, which charges the high reference voltage level between the two neighboring nodes selected by the top 4b decoder. During the last 7μs the capacitor at the nodes will discharge and keep the actual data. We have achieved a data charging error less than 0.0025LSB even though the charging time of the data-line capacitor was reduced to 1/3 of the normal time.

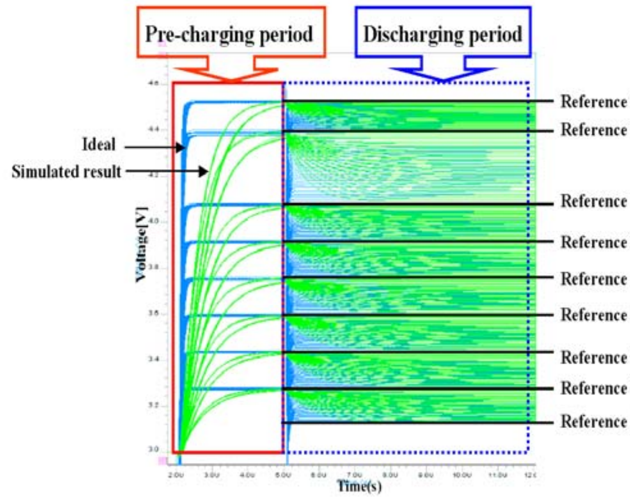


Fig. 4 Simulation results of 8bit DAC using pre-charging method.

Fig.5 shows ideal and measured RGB luminance from 0 to 255 gray levels with gamma value of 2.2. The output linearity of the source driver was calculated from each of RGB pixel luminance of developed 2.0 inch AMOLED panel. According to the calculated method, Fig.6 shows the measured DNL of RGB pixel luminance that is obtained from Fig.5 As shown in Fig.6 the maximum DNL is under 1LSB even though minimum gray step voltage is 4mV.

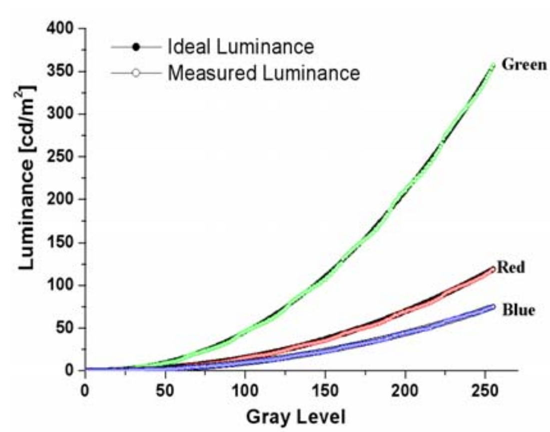


Fig. 5 Simulated DNL & INL of 8bit DAC

Fig.7 is a photograph of fully integrated 8bit source driver to operate 2.0 inch QVGA AMOLED panel. We have used 2μm line width and space LTPS TFT process. The heights of the DAC and digital logic part in the source driver are 2mm and 1mm, respectively.

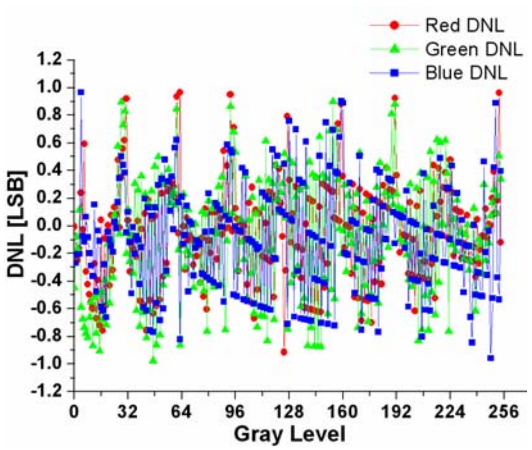


Fig. 6 Simulated DNL & INL of 8bit DAC

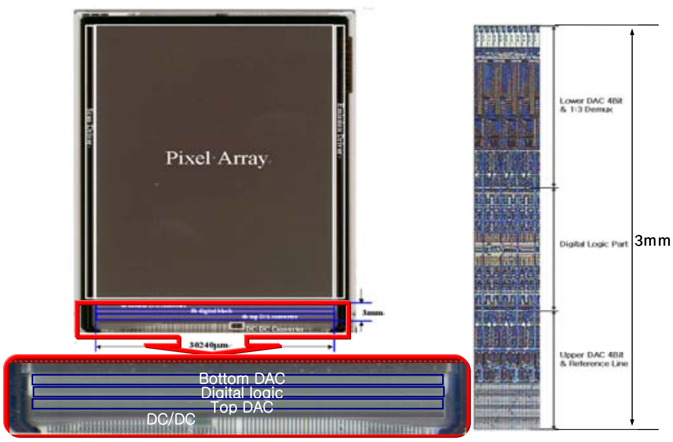


Fig. 7 Photograph of AMOLED backplane

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4. Summary

SOP is one of the effective approaches to decrease the cost of active matrix displays. However, the economical advantage of SOP strongly depends on the productivity of LTPS TFTs. In order to keep the competitiveness of the SOP to a-Si TFTs, innovative development of LTPS TFT fabrication process to improve the productivity is desired. However, to pursue finer design rule or to pursue extremely higher performance of the TFT characteristics is not the solution for SOP because the trend of the improvement of the TFT performance can never catch up with those of the MOS FETs. Therefore it is important to find appropriately optimized system for SOP from the present circumstances of LTPS TFT process. We introduced 8bit source driver as SOP technology from the present circumstance of LTPS TFT process. We applied three new technologies for high image quality and low power consumption into the developed 8bit source driver.

First, we applied new 8bit DAC architecture based on an R-string to achieve high image quality. Second, we applied new source driver structure and 1to3 Demux to achieve both high resolution and compacted design for 8bit D/A converter. Last, we applied our new pre-charge driving method to achieve high-accuracy D/A converter output. We achieved high image quality (256gray scale) using novel new 8bit D/A converter and high-accuracy(INL<1LSB) using new pre-charge driving method. We also achieved compact design(202ppi) using 1:3 Demux and novel new D/A converter architecture and power reduction using D/A converter without analog buffer and with 6V operation voltage.

5. References

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