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Trend of System on Panel

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Abstract

There has been a new trend to integrate various kinds of circuits by low temperature polycrystalline silicon thin film transistor(LTPS TFT) on insulator substrates to achieve System on Panel(SOP) for flat panel displays. In this paper, we will review the trend of the SOP and discuss the utility and future possibility of the SOP.

I. Introduction

The word of System on Panel(SOP) has been widely used and many people have expected that SOP can expand the application field of active matrix displays by integrating various kinds of circuits on an insulator substrate. However, there is no definition of SOP and there is little discussion about the necessity and utility of the SOP.

From the background above, we will review the trend of SOP and discuss the advantages and disadvantages of the SOP in this paper.

II. Design Rule Trend of TFT for displays

Figure 1 is the trend of typical design rule of MOS LSI and TFTs[1]. The first full color active matrix LCD product was commercialized by using high temperature polycrystalline silicon(poly-Si) TFTs in 1984. Since that time, the pixel pitch of the high temperature poly-Si TFT-LCDs has been continuously decreased until now while the mobility of the device has been remained under 100cm^2/Vsec. Therefore, we can say

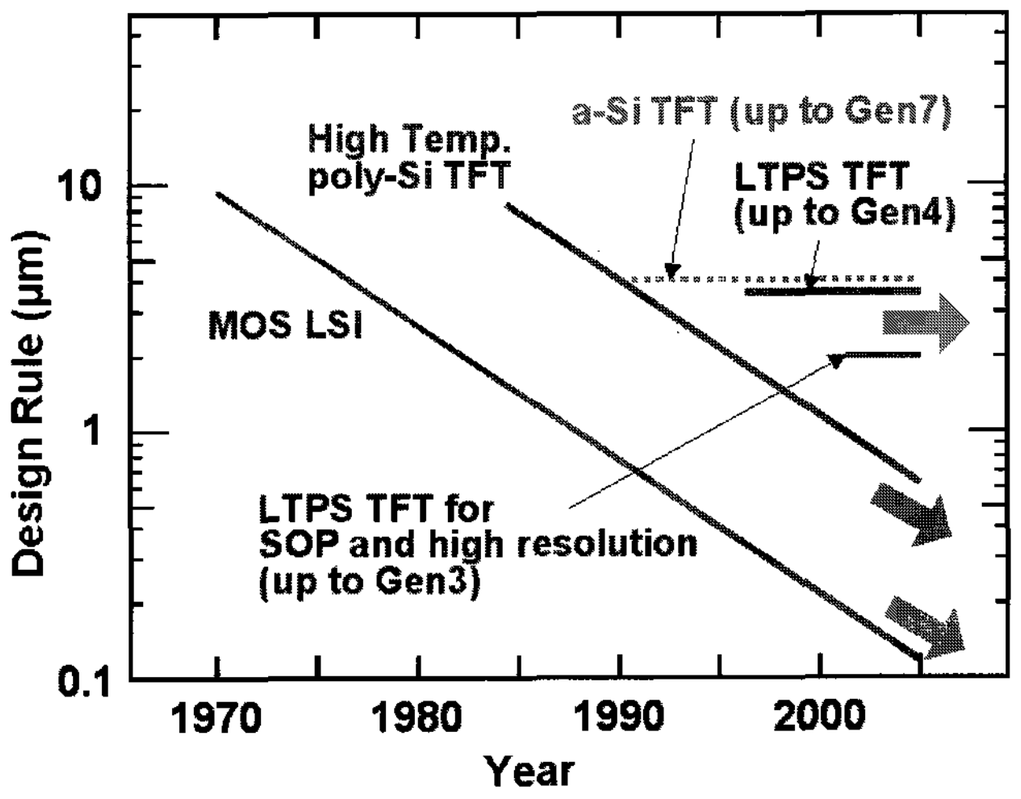

Fig. 1 Trend of typical design rule

that the high temperature poly-Si TFT has a similar trend of design rule reduction as MOS FETs. It has been achieved by the special application of transmissive light valve for LCD projector that can be only realized by the high temperature poly-Si TFTs.

In early 1990's, the development target of amorphous silicon(a-Si) TFT-LCD had been set to note PC VGA displays. Since that time, the a-Si TFT glass substrate size has been continuously expanded until now to improve the productivity while the design rule has been remained at the same value. Gen7 lines are available now and Gen9 lines have been already planned. This is very clear strategy for cost reduction.

On the other hand, low temperature polycrystalline silicon(LTPS) TFT, which is the only candidate to realize SOP now, is halfway placement. It has both characteristics of a-Si TFTs and high temperature poly-Si TFTs. However, SOP will be mainly used for direct view displays applications. This means that the

main competitor of the SOP will be a-Si TFT-LCDs. Customers never allow us to shrink the display size to decrease the cost. Therefore, the LTPS TFT has to follow at least the same trend as a-Si TFTs in order to keep the cost competitiveness. Unfortunately, the maximum available glass substrate size for LTPS fabrication lines has still remained to Gen4 and it is limited to Gen3 in case of finer design rule.

From the discussion above, we can say that to pursue finer design rule or to pursue extremely higher performance of the TFT characteristics is not the solution for SOP. 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. The basic design rule available for SOP will remain around 2 micron for the present even though we use the special apparatuses for the finest design rule. In other words, the most important thing is how we can achieve the most proper functions in the integrated TFT circuits only on the available dead space of the display by using the conventional design rule and conventional TFT characteristics.

Ⅲ. Trend of SOP

Let us review the trend of SOP. We introduce 4 typical types of LTPS TFT displays and discuss advantage and disadvantage of them.

1. Point-a-time Analog Data Driver Type

Figure 2 shows a block diagram of the conventional LTPS TFT-LCD with integrated a point-a-time analog data driver[2]. This is the most commonly used conventional LTPS TFT-LCD module. The data driver consists of a shift register and analog switch array. The analog video data is sequentially sampled by the TFT switch array. The TFT controller is an external IC to supply the analog video signal, other digital signals, and power supply voltage. High through rate analog buffer for video signal that consumes much power is required in the TFT controller IC. Therefore, the consumed power in the external IC is a critical design issue of the system.

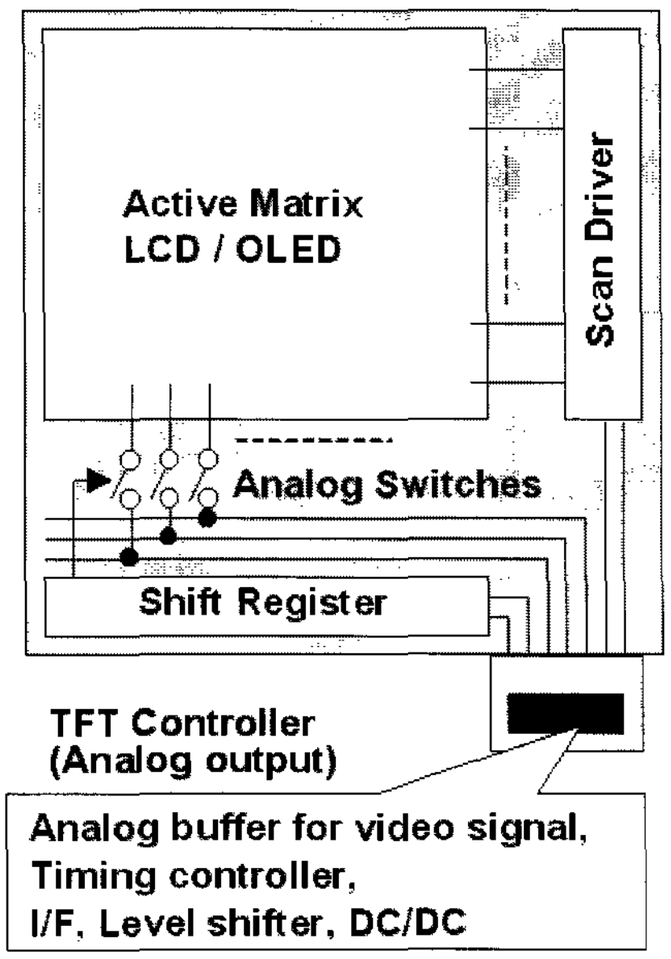

Fig. 2 Point-a-time analog drive panel

2. De-multiplexer with External Driver Type

In cellular phone applications, most of the users require the frame memory integration in the system to save power consumption in the character display mode that uses mostly static images. The de-multiplexer type as shown in Fig. 3 is suitable for the applications because the external driver IC in the figure has the integrated frame memory[3]. 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

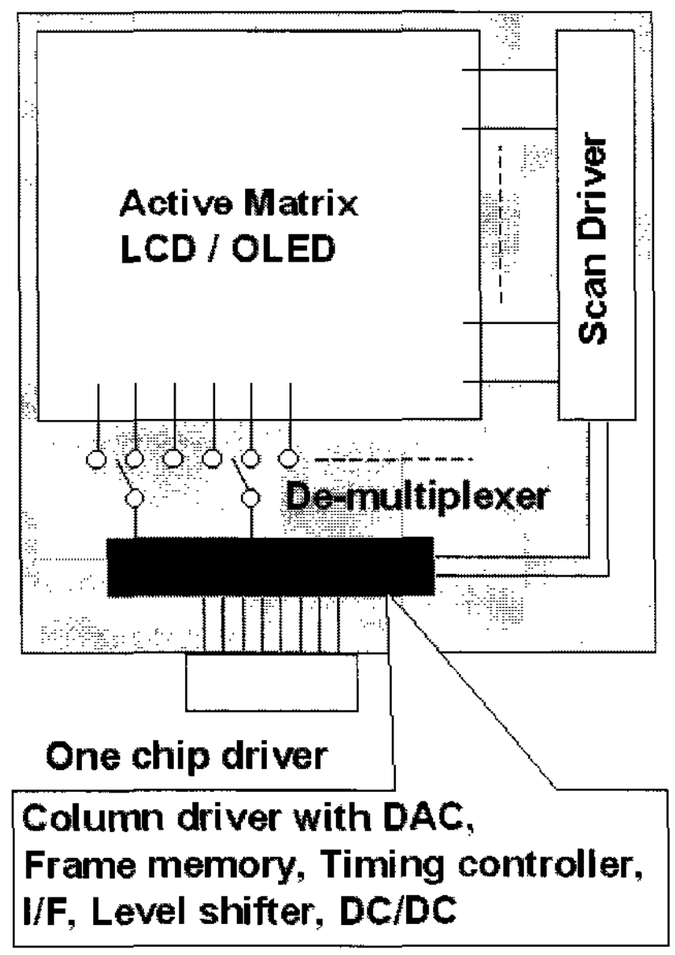

Fig. 3 De-multiplexer type panel

the TFT substrate for the driver IC assembly and expensive cost of the driver IC.

3. Partial SOP

In order to minimize the power consumption of the system in the Fig. 2, the digital data driver with D/A converter integration is one of the candidates. Figure 4 is an example of such case[4]. 5V digital I/F 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 I/F. 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.

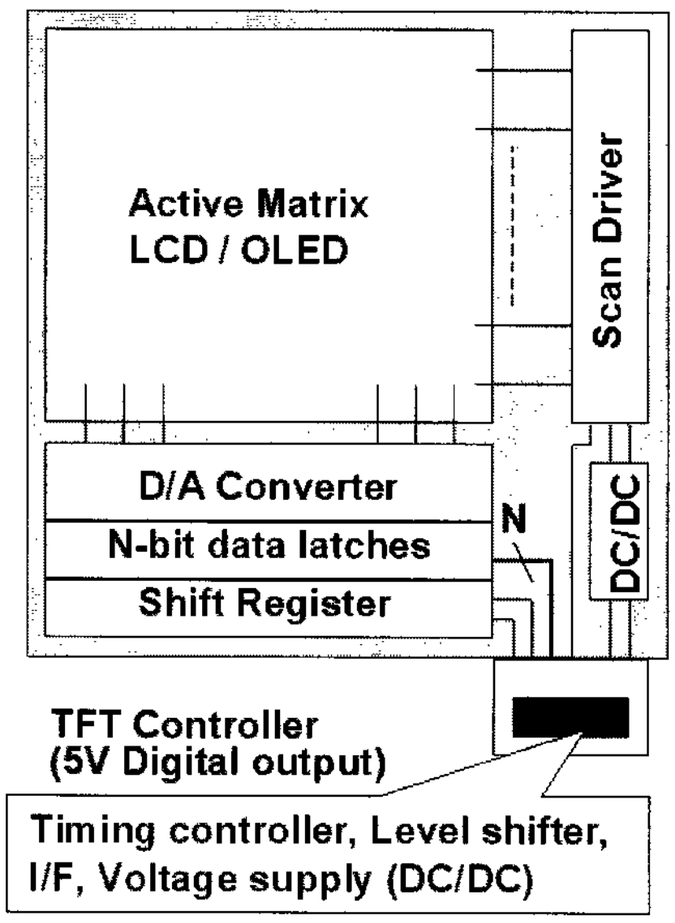

Fig. 4 5V digital drive panel

4. Fully integrated SOP

Figure 5 is an ideal SOP that doesn't need any external ICs to drive the system[5, 6]. This SOP panel can be driven single power supply of 3V and low voltage digital I/F 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 I/F and keep

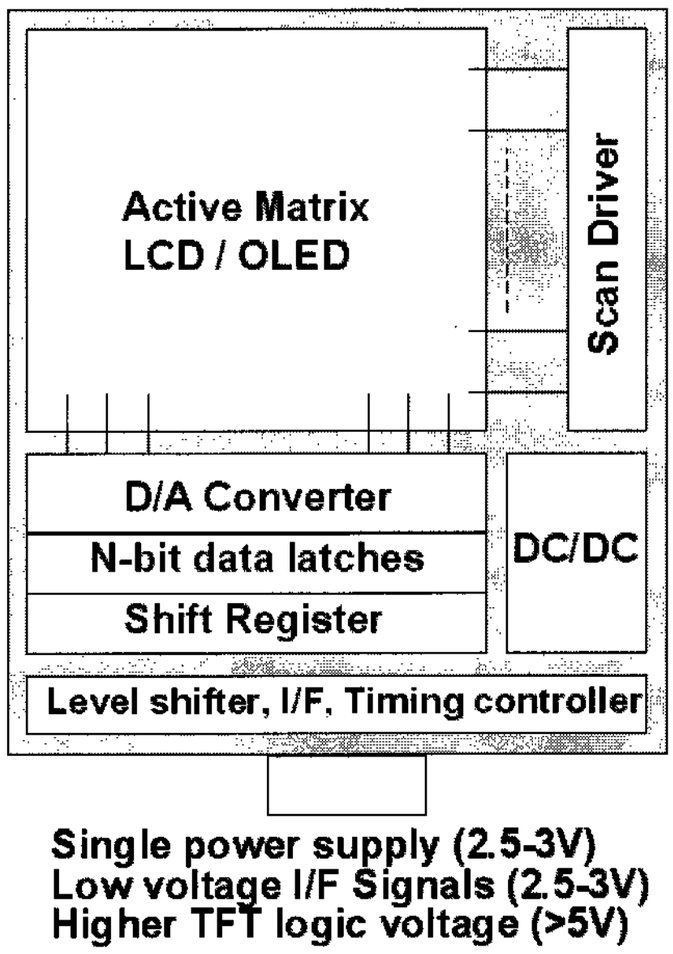

Fig. 5 Fully integrated SOP

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.

Table 1 is the comparison among the four types of active matrix devices. We can't easily say 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.

Table 1 Comparison among the 4 types of panels

	(a) Point a time analog	(b) De-multiplexing	(c) 5V digital I/F	(d) <3V fully integrated
Compactness	Good	Good	Good	Excellent
TFT circuit simplicity	Good	Good	Fair	Bad
System customization	Easy	Easy	Not difficult	Difficult
TFT circuit power consumption	Small	Small	Small	Large
External driver IC power consumption	Huge	Small	Small	—
Required TFT characteristics	Wide margin	Wide margir	Not so severe	Severe
TFT substrate cost	Good	Good	Fair	Bad
External driver IC cost	Fair	Fair	Good	—

Ⅳ. Example of SOP

We have already developed prototype of the SOP AMOLED panel[7]. Figure 6 is the block diagram of the panel. We have integrated digital data driver with 6-bit D/A converter, scan driver, DC/DC converter and timing controller. We have also succeeded to integrate individual gamma compensation circuits. We have used 5V I/F instead of 3V I/F to keep sufficient wide process window for LTPS TFTs.

Figure 7 shows typical characteristics of the LTPS TFTs we have used in the SOP AMOLED panel design. We have optimized the LTPS TFT fabrication process to keep good balance between p-ch and n-ch. We can use same dimension of W/L=4/4 TFTs for both p-ch and n-ch in typical 5V CMOS logic circuits. These TFT characteristics have enabled us to drive all TFT logics in the SOP by 5V with sufficient margin under a few MHz operation speed.

Figure 8 shows the photograph of the SOP AMOLED panel and Table 2 is the specifications of the panel. We have achieved correct operation of all TFT circuits and good image quality of the panel.

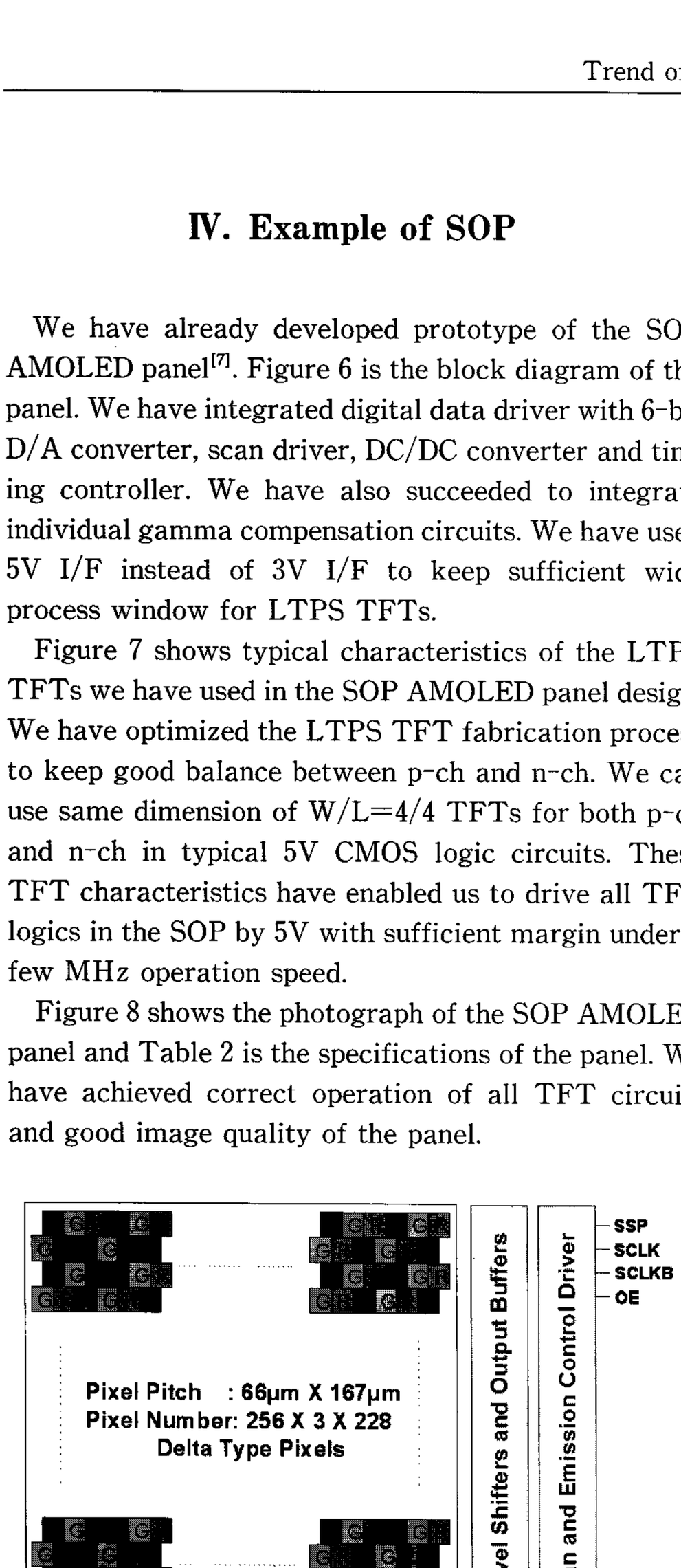

Fig. 6 Block diagram of the SOP AMOLED

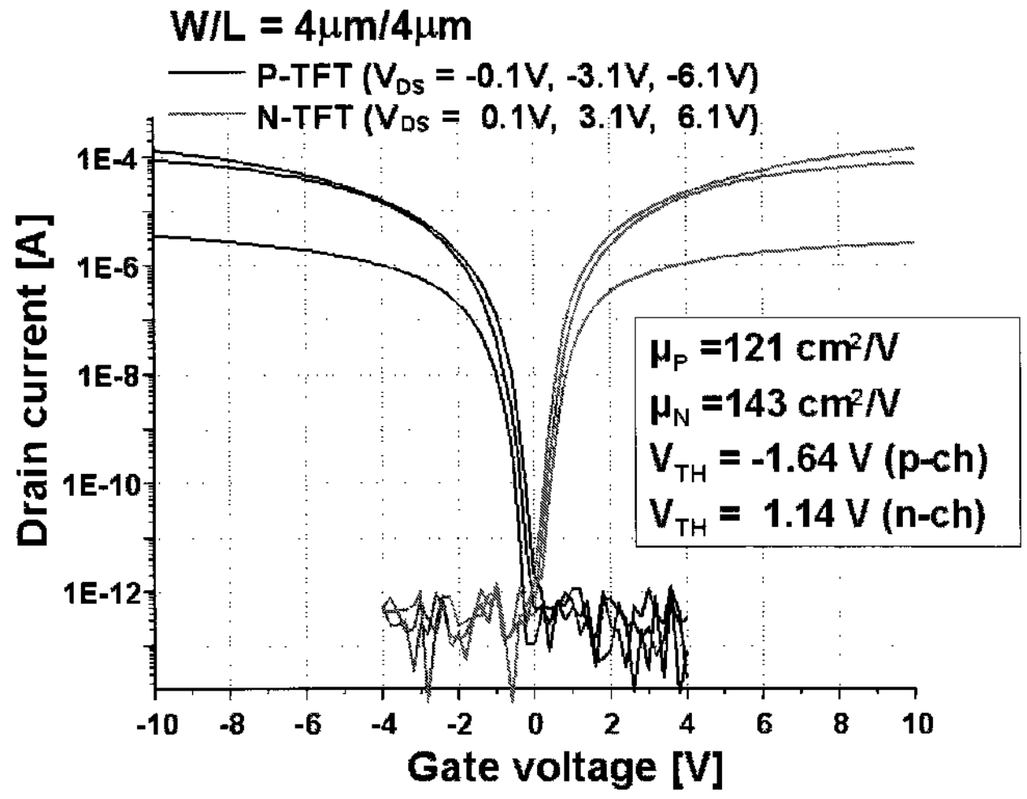

Fig. 7 Example of the LTPS TFT characteristics

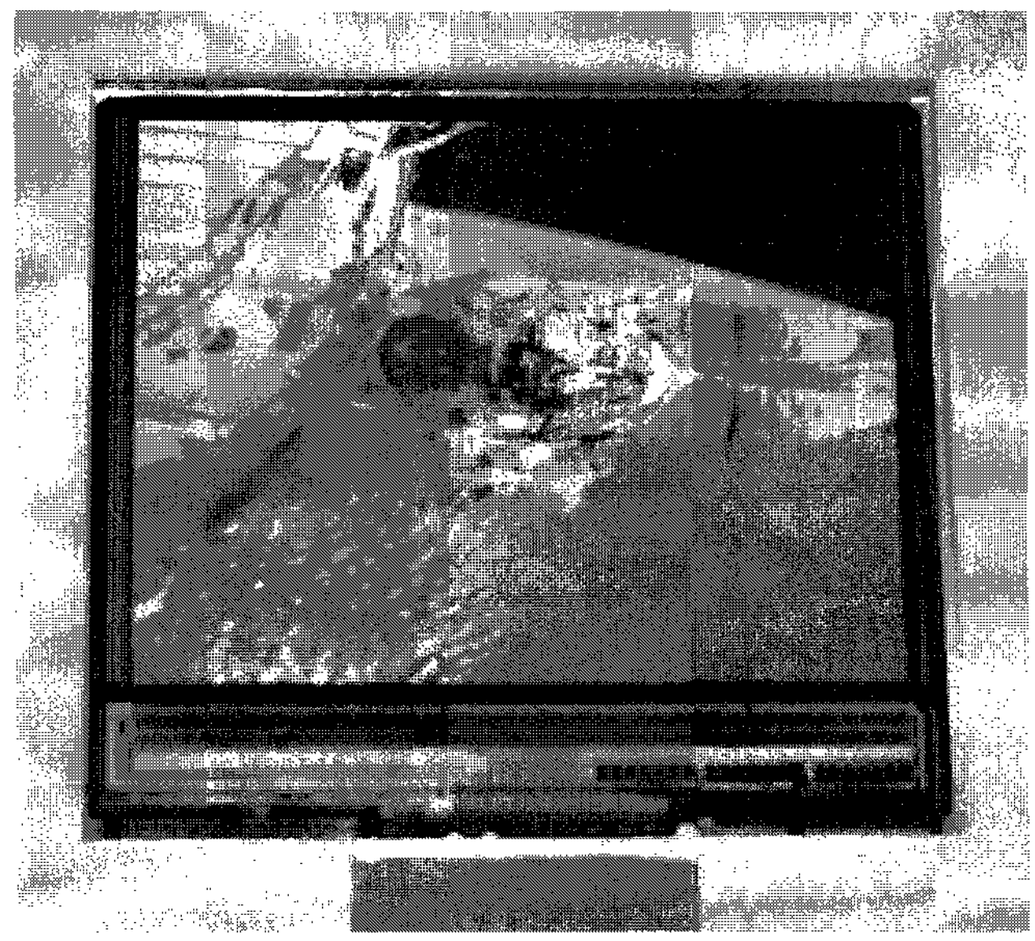

Fig. 8 Photograph of the developed SOP

Table 2 Specifications of the developed SOP

Display size	2.5-in diagonal
Number of pixels	256 x RGB x 228 (delta type)
Pixel pitch	66μm x 167μm
Pixel circuit	Voltage programming type
Emission type	Bottom emission type
Input data	6-bit digital RGB (5V)
Gamma compensation	3 types are available for each color
Voltage generator for the Gamma compensation	Integrated (9 x 3 sets)
DeMUX of D/A output	1 to 2
Timing controller	Integrated (for timing signals)

V. Possibility of Frame Memory and Other Function Integration

If we target SOP device for cellular phone applications or any other mobile applications, we should integrate frame memory in the SOP[8, 9]. However, it is extremely difficult to integrate full frame memory by LTPS TFT without sacrificing the space in the glass substrate. The trend of the required frame memory bit number has been increased year by year. Unfortunately, LTPS TFT can never catch up with the trend.

Figure 9 shows the example of SOP AMOLED circuits with frame memory. If we integrate 6-bit QCIF frame memory, the memory area width reaches a several mm even though we use both top and bottom side of the active matrix with the finest available design rule of 2μm. In case of 6-bit QVGA, the memory area width reaches more than 10mm. It is clear that LTPS TFT is not a suitable device to pursue the volume of memory.

One of the practical solutions for the frame memory integration may be to limit the stored bit, for example one bit frame memory for character display mode.

Recently, other function such as touch sensor has been successfully integrated on AMLCD[10]. If the new function can be integrated by LTPS TFTs without sacrificing the yield or system performance, it may be a practical candidate for new applications.

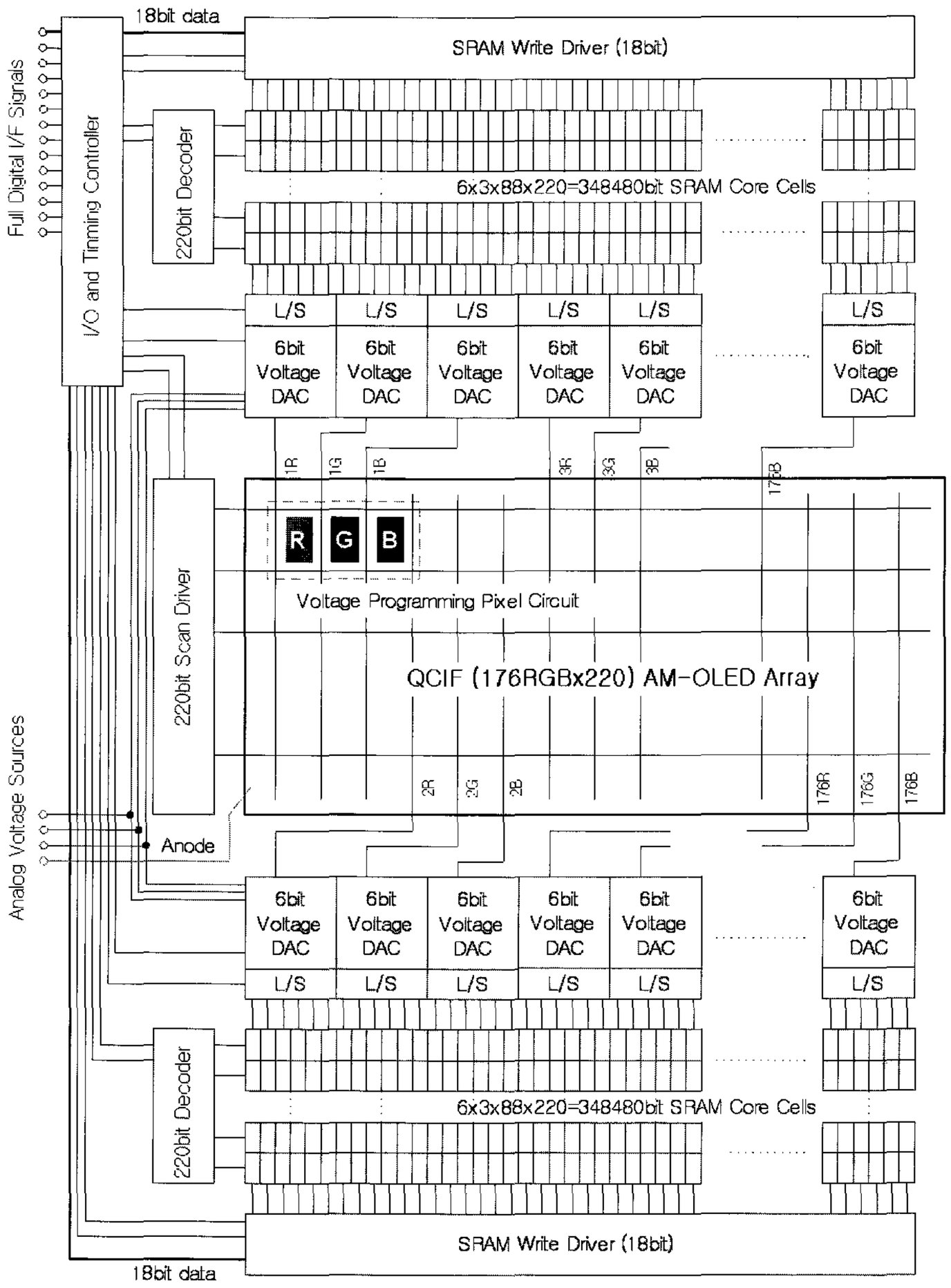

Fig. 9 Block diagram of an SOP with frame memory

VI. Conclusion

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.

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.

We have developed a proto-type of SOP AMOLED panel. We believe that SOP can be applied to any kind of active matrix displays.

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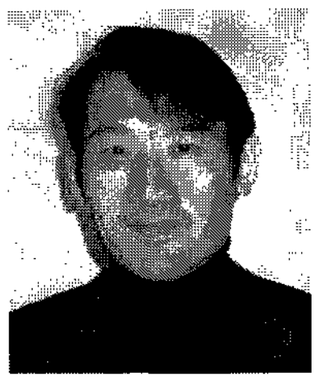

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