Chapter 1

Introduction

1.1 Background

At present, active matrix liquid crystal display (AMLCD) or active matrix organic light emitting diode (AMOLED) display requires a large number of interconnections between the panel and the external driving circuit. In order to reduce cost, integrating the driver circuit onto the panel is a good solution as it can reduce the number of connections between external circuit and the panel. To realize a compact size display, the "system-on-panel (SoP)" technology by polycrystalline silicon (poly-Si) thin-film transistors (TFTs) offers a promising solution because the poly-Si devices allow integration of the driver on glass. Therefore, the poly-Si TFT is a good candidate with its higher carrier mobility and better reliability than the amorphous silicon (a-Si) TFT.

One of the most promising approaches is to use excimer laser to recrystallize amorphous silicon (a-Si), the poly-Si TFTs can have very high performance. However, the resulting poly-Si TFTs have poor uniformity and suffer from huge variations due to the narrow laser process window for producing large-grained poly-Si thin film. The fluctuation of pulse-to-pulse laser energy and non-uniform laser beam profile make laser energy density hard to hit the super lateral growth regime everywhere. The random grain boundaries and traps exist in the channel region [1]. This will lead to many problems in real product applications such as output variation in analogue circuit, and thus non-uniform brightness in panel. Since the device-to-device uniformity is difficult to control, it would be essential to develop circuits to compensate the variation.

1.2 Motivation

Poly-Si TFT displays with integrated driving circuits have recently been developed. At present, the poly-Si TFT is the best candidate to realize SoP and is widely considered for AMLCDs and AMOLEDs. Gate driver circuits are completely integrated in the poly-Si TFT displays. However, data driver circuits such as analogue switches and shift registers are integrated only partially. Many researchers have been trying to integrate more complicated analogue driving parts, such as analogue buffers and pixel circuits. Analogue buffers are indispensable to drive the load capacitance of the data buses in the panel. To realize a good image quality using the poly-Si process, pixel circuits with compensating methods are necessary.

Until now, however, these attempts appear to be unsuccessful in the display application due to the problems in poly-Si TFTs. Especially, the poly-Si TFT suffers from significant variation in the threshold voltage and the mobility due to the nature of the polysilicon crystal growth and represents different electrical characteristics with their locations in panel. In addition, kink effects make it hard to implement analogue circuits. The threshold voltage variation could even as large as 1V in some high performance TFT devices across as a large substrate area. This results in the output non-uniformity in analogue circuits such as analogue buffers and pixel circuits over the whole panel. There are methods proposed previously to solve this problem [2-4]. However, these methods require complex external compensating circuits and low immunity to the variation of poly-Si TFT characteristics.

The function of the analogue buffer in the data driver is to act as a buffer to drive the load capacitance of the data bus in the panel. When the output signal of a digital-to-analogue (D/A) converter is not sufficient for driving the load capacitance of the data bus, an analogue buffer is used to enhance the driving capability of the D/A converter. As the panel size increases, a larger analogue buffer is necessary. The purpose of the analogue buffer is to quickly charge or discharge the load capacitance, so that the voltage across the load capacitance becomes equal to the input voltage, which is the output voltage of a D/A converter. We can sample the input data with a smaller capacitor instead of charging a larger capacitor of the data bus by the D/A converter directly. Accordingly, the effective loading for the D/A converter can be reduced.

To implement the analogue buffer circuit with poly-Si devices, several critical issues must be considered, such as output voltage accuracy, driving capability, layout area and power consumption, and so on. An operational-amplifier-type (op-amp-type) analogue buffer using poly-Si TFTs has been reported by Itou [2]. It consists of an operational amplifier (op-amp) which is generally used in the single crystal Si MOSFETs. Although the op-amp is usually connected as a unit-gain buffer, the op-amp using poly-Si TFTs shows a very large variation of the output voltage due to the large variation of poly-Si TFT characteristics. In addition to the large variation of the output voltage, an op-amp needs many transistors, which occupy a large area. As there are several hundreds of analogue buffers used in an active matrix display, these circuits will use up a lot of area and increase cost. Thus, it is necessary to develop an analogue buffer which not only has high immunity to the variation of poly-Si TFT characteristics but also a very simple configuration for high resolution displays.

Some researches on poly-Si TFT analogue circuits have been tried to realize a buffer that can operate insensitively on the poor characteristics of poly-Si TFTs, and the source-follower-type analogue buffers are representative results of those efforts [5-15]. Especially, the output deviation was decreased about 20 mV by employing so-called “double offset canceling” in the Sony’s report [7]. However, it requires many control signals and TFTs. Also, two capacitors are required for one analogue buffer.

The source-follower-type analogue buffer uses an n-type driving TFT to charge the load capacitor. In general, when the voltage drop $|V_{GS}|$ between the gate and the source of the driving TFT reaches the threshold voltage of the driving TFT, the source follower will stop charging. However, the sub-threshold characteristics of poly-Si TFTs are rather poor compared with single crystal Si MOSFETs, so that the sub-threshold current of poly-Si TFTs should not be ignored. In this case, when the voltage of the load capacitor approaches near a target voltage, the driving TFT is operating in the sub-threshold region and there is still a sub-threshold current of the driving TFT to charge the load capacitor. This poor sub-threshold characteristic of the poly-Si TFT causes the final output voltage not to be kept constant for different charging times. Besides, its current driving capability is also reduced so that the output voltage is not settled within a line time. This is the critical drawback for application to large-sized and high-resolution displays.

AMOLED displays have attracted public attention due to their high brightness, high efficiency, fast response time and wide viewing angle. Although the poly-Si TFT is considered as the mainstream technology for AMOLED displays, pixel-driving scheme is still one of the most critical issues. The simple 2T1C pixel circuit [16] suffers from the pixel to pixel luminance non-uniformity due to the variation of poly-Si devices. The problem would become serious, especially when the display size becomes large. To overcome this non-uniformity issue, several technologies [17-91] have been proposed to compensate for the variation in the poly-Si TFT performances. The pixel circuits of AMOLED displays can be classified into voltage driving [17-60], current driving [61-82] and digital driving [83-91] methods. Even though the current driving method can be applied to achieve an excellent image quality, its panel driving speed is too slow to implement high resolution displays. Digital driving method can reduce the threshold voltage sensitivity of display images, but it needs very fast addressing speed so that it may not be the good solution for high gray-scale displays. The voltage driving method can compensate for the variation of the threshold voltage and is more attractive to integrate poly-Si TFT data drivers on the display panel. Therefore, the voltage driving method would have been considered as an attractive solution to eliminate the variation of poly-Si devices.

This thesis describes the analogue circuit techniques to reduce the threshold voltage and the mobility variations, which cause the non-uniformity of the displays.

The purpose of this thesis is to propose an analogue buffer and a voltage driving pixel circuit which not only has high immunity to the variation of poly-Si TFT characteristics but also a very simple configuration for high-resolution displays.

1.3 Thesis organization

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Chapter 2 Analogue Buffer Circuit

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2.3.1 Simple analogue buffer

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2.4.1 Match-TFT analogue buffer

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2.5 Conclusions