Required characteristics of poly-Si TFT's for analog circuits of System-on-Glass

Dae-June Kim, Kyun-Lyeol Lee, Changsik Yoo
Division of Electrical and Computer Engineering, Hanyang University
Haengdang-dong, Seongdong-gu, Seoul 133-791, Korea
Phone: +82-2-2290-0361, E-mail: csyoo@hanyang.ac.kr

Abstract

Required characteristics of poly-Si TFT's are investigated for the implementation of analog circuits to be integrated on System-on-Glass (SoG). Matching requirements on resistor values, threshold voltage and mobility of poly-Si TFT's are derived as a function of the resolution of display system. Effective mobility of poly-Si TFT's required for the realization of source driver is analyzed for various panel sizes.

1. Introduction

Since poly-Si TFT has much better performance than a-Si TFT which has been widely used for TFT LCD, there have been efforts to realize driver circuits and pixel array on a single glass substrate with poly-Si TFT [1-4]. The final goal of this effort is system-on-glass (SoG) which is expected to reduce the cost of flat panel display system and increase the yield through the PCB-less assembly and simple module process.

For SoG, various kinds of analog and digital circuits are required to be implemented with poly-Si TFT whose performance is still inferior to that of single-crystal transistors. Moreover, due to irregular grain boundaries of poly-Si, threshold voltage and mobility are not uniform and therefore the characteristics of analog circuits built with poly-Si TFT can be different from location to location in a panel [5], making it difficult to achieve high resolution display. In addition, the performance of analog circuits is likely to be poor due to the kink effects.

In this paper, allowable mismatch of poly-Si TFT characteristics is derived as a function of the resolution of display system. Effective mobility required for the realization of source driver is analyzed for various panel sizes. The results have been verified by HSPICE simulation.

2. Required resistance matching of resistor-string type digital-to-analog converter (DAC)

Resistor-string type DAC in Figure 1 is most widely used to convert the digital video data to analog video signal with gamma correction capability. With this type of DAC, the achievable resolution of display system is determined by the mismatches in the resistor values. The full scale analog voltage is 5.8V and thus the gamma-corrected 1/2-LSB values of 4-, 6-, and 8-bit DAC are 107.3mV, 25.4mV, and 3.7mV, respectively. These values are the allowable error in the output voltage of DAC. For the display resolution of 4-, 6-, and 8-bit, the required matching accuracy of resistor values is 12%, 4%, and 1%, respectively, according to the HSPICE simulation results as shown in Figure 2.

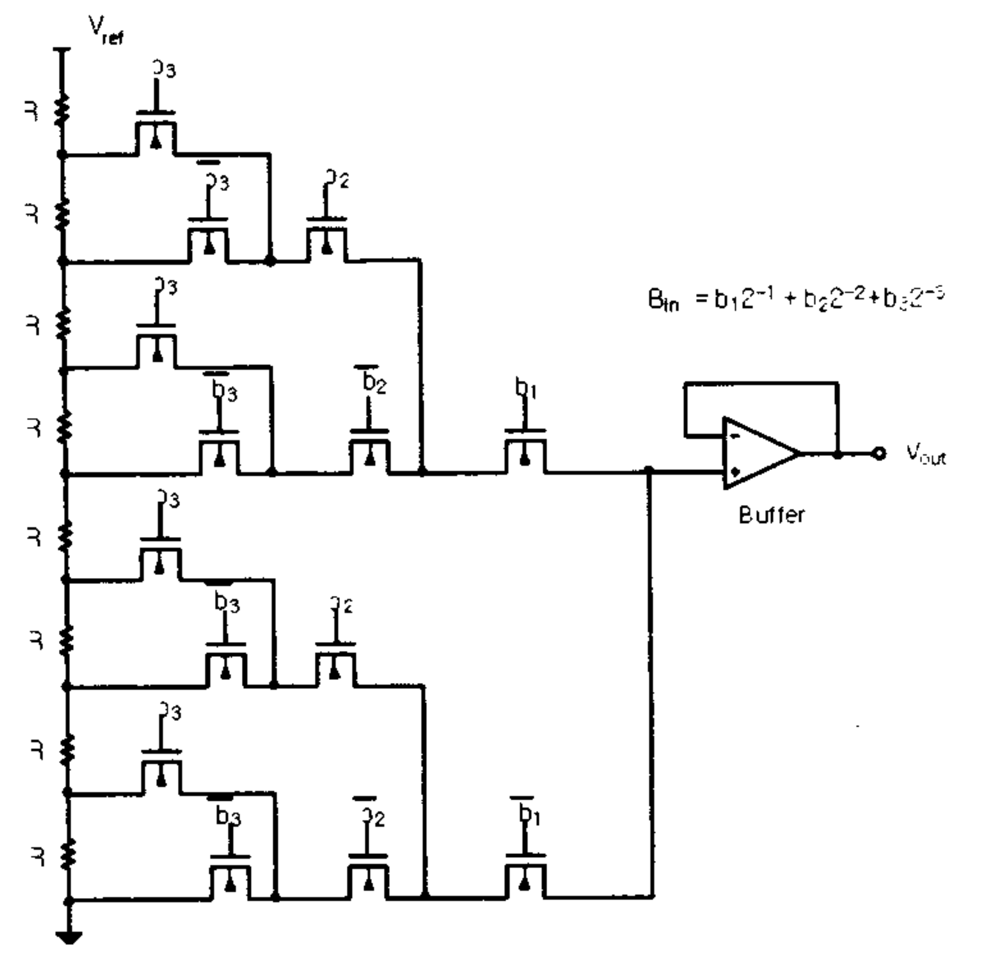
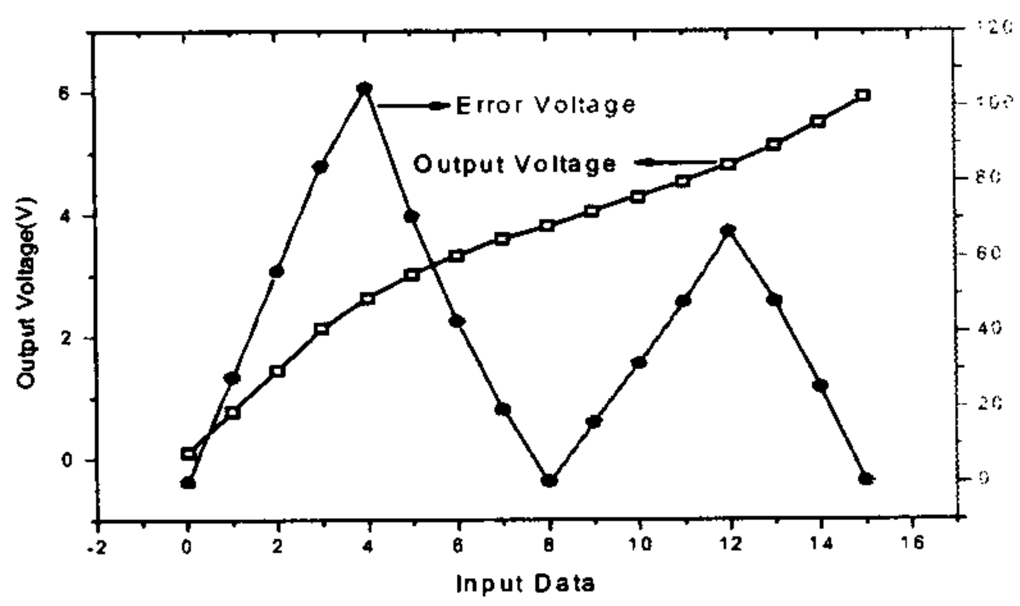
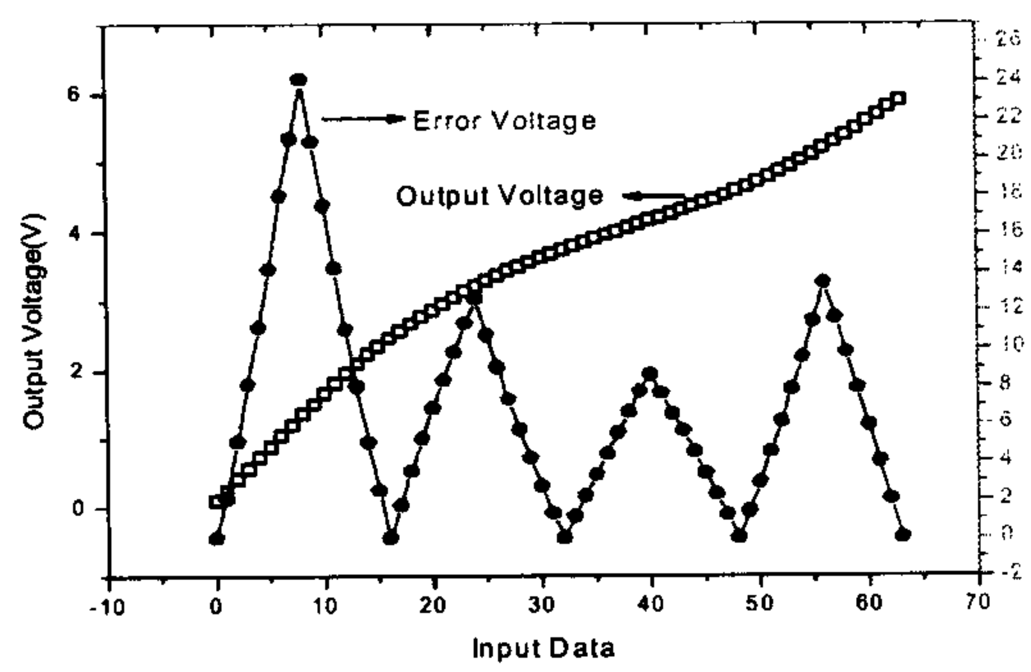


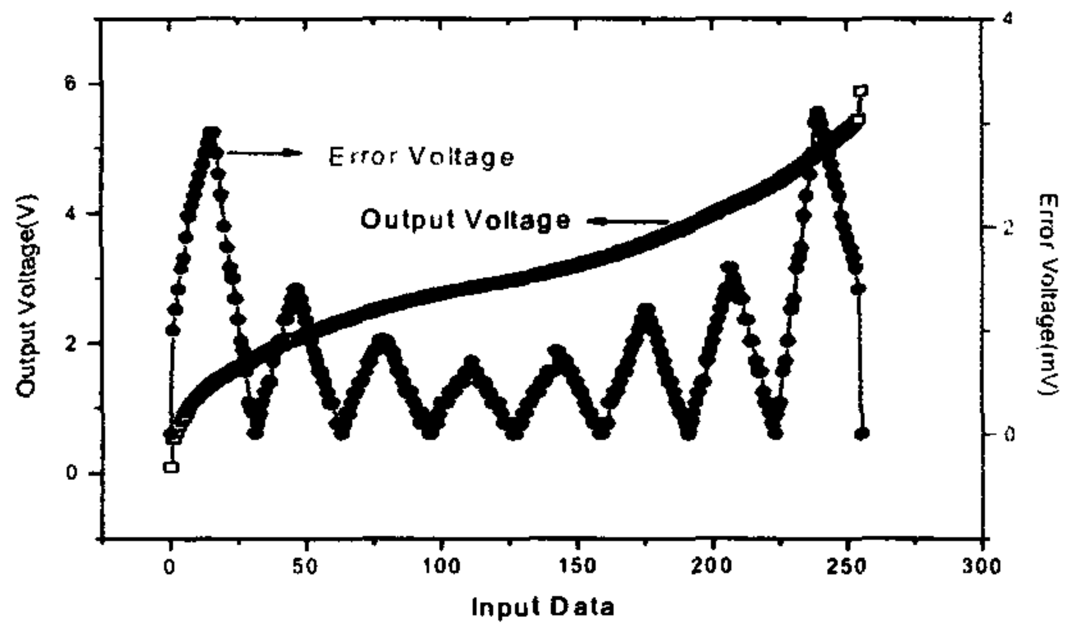
Figure 1. Resistor-string type 3-bit DAC



(a)



(b)



(c)

Figure 2. Simulation results of R-string DAC for (a) 4-bit with R-variation of 12%, (b) 6-bit with R-variation of 4%, and (c) 8-bit with R-variation of 1%.

3. Allowable mobility and threshold voltage mismatch of poly-Si TFT for source driver

For data line driving of LCD panel, operational amplifier (op-amp) implemented with single crystal transistor is widely used by configuring it as a unity gain buffer [6-7]. Two-stage op-amp in Figure 3 is the most popular circuit and therefore chosen as a reference circuit in deriving the required performance of poly-Si TFT. Op-amp built with poly-Si TFT has much larger offset voltage than the one on a single crystal substrate because of irregular grain boundaries. To compensate the offset, offset compensated unity-gain buffer in Figure 4 is used. During the offset detection period, the switches SW1 and SW3 are turned on and the offset voltage is stored in capacitor C_{offset}. During the driving period, the switches SW2 and SW4 are turned on and the output becomes $V_{in} + V_{offset} - V_{offset} = V_{in}$, which is independent of the op-amp offset voltage. Allowable mobility and threshold voltage mismatch with and without offset compensation are investigated as a function of display resolution assuming the total capacitance of data line is 30pF and video voltage range is 5V. Figure 5 shows the allowable variations of threshold voltage and mobility as a function of the display resolution.

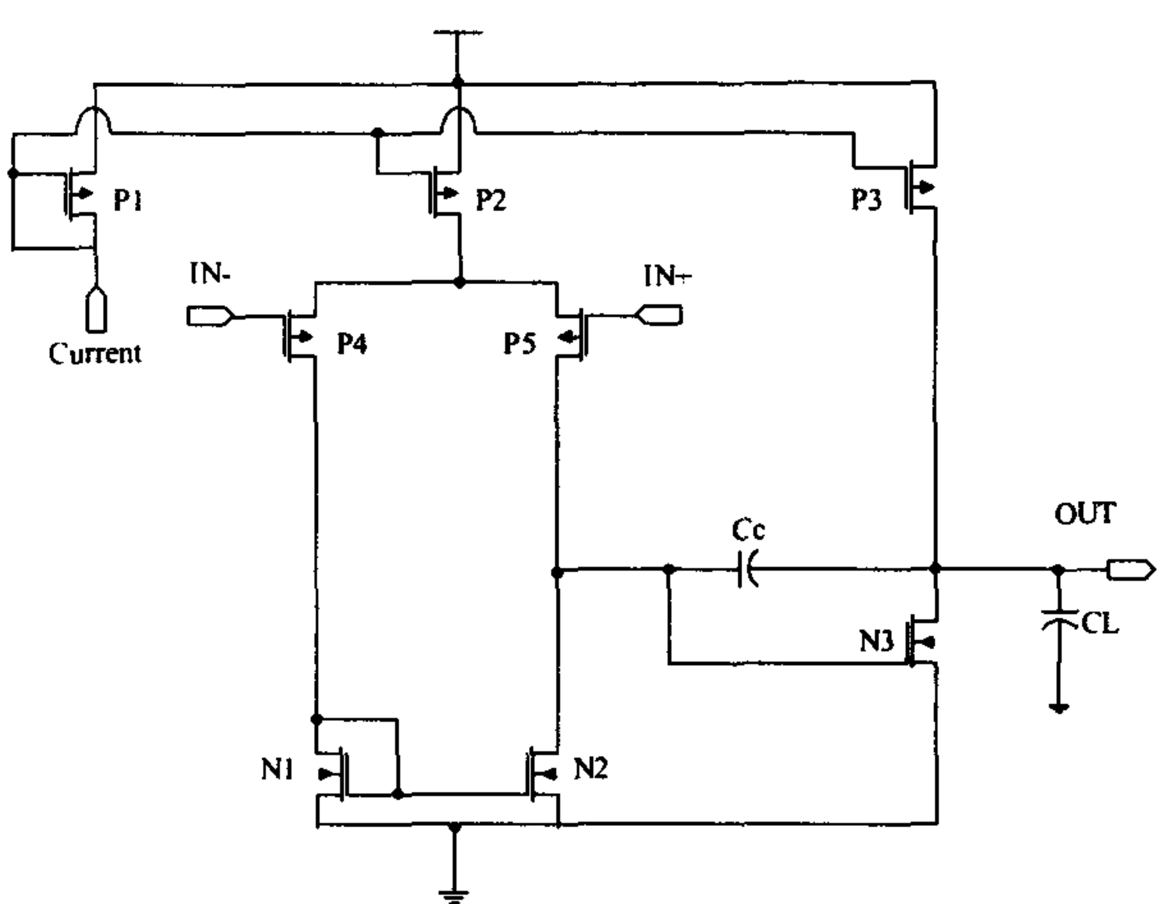


Figure 3. Two-stage op-amp

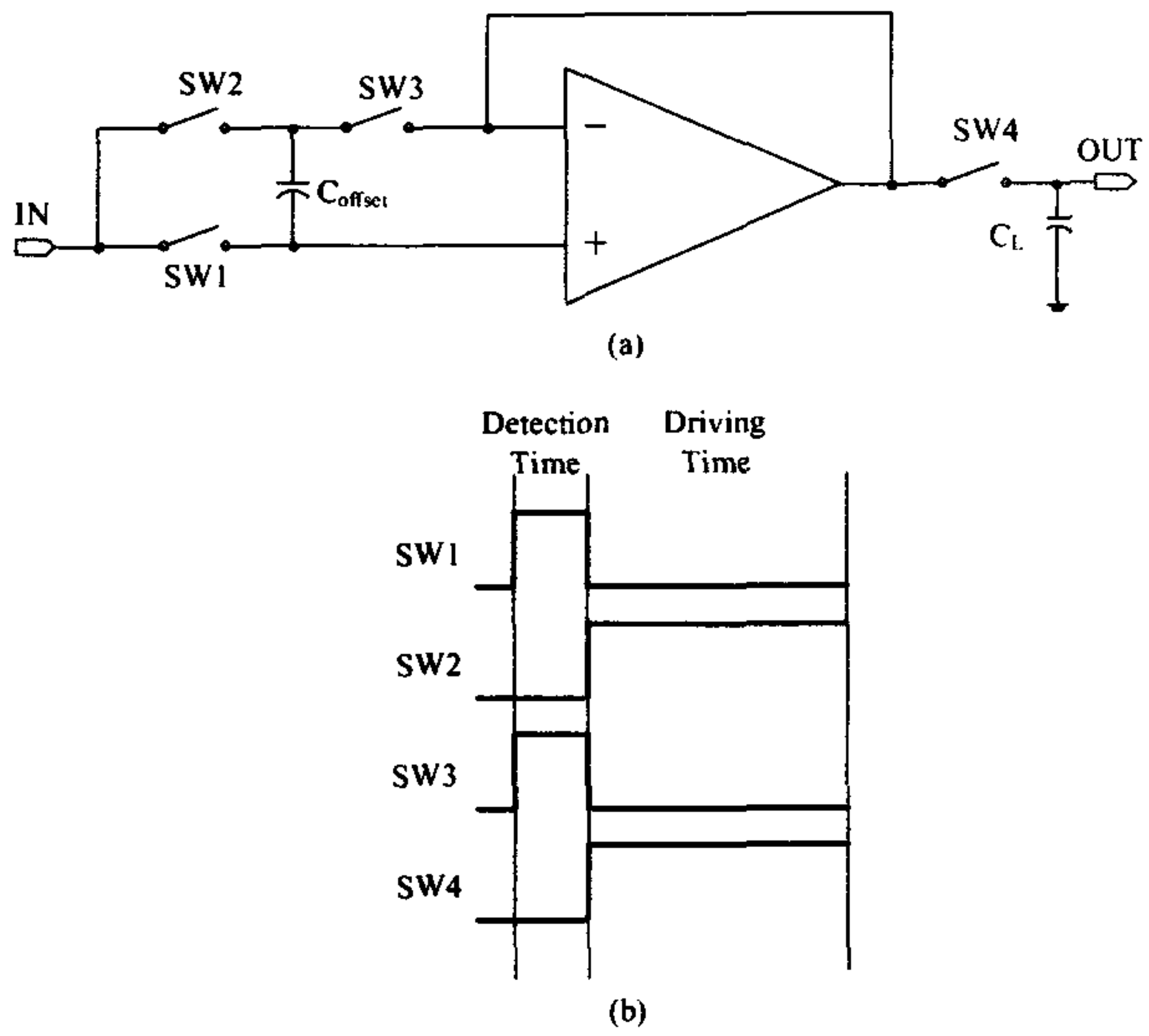


Figure 4. (a) Offset compensated unity-gain buffer and (b) its timing diagram

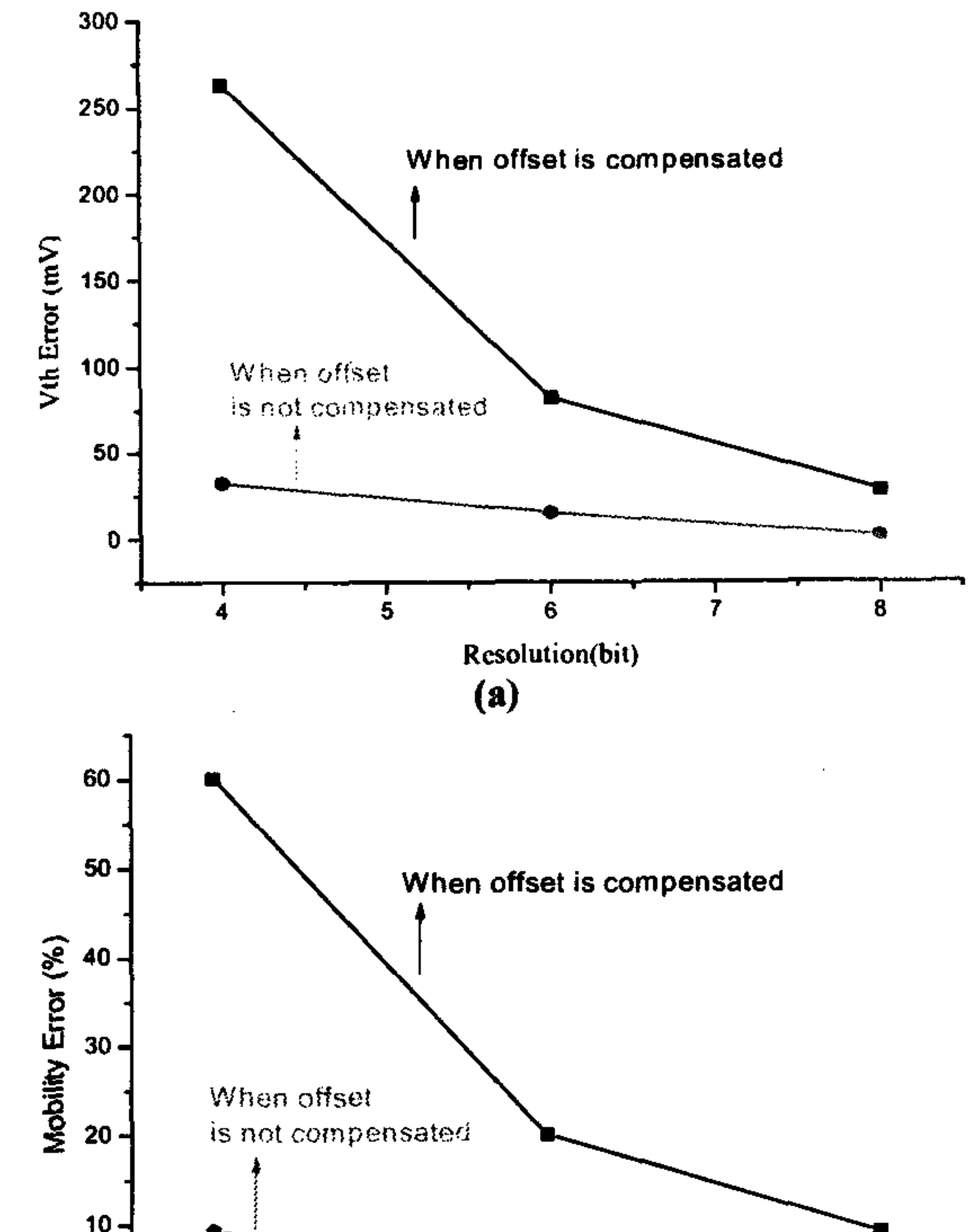


Figure 5. Allowable (a) threshold voltage and (b) mobility error with and without offset compensation

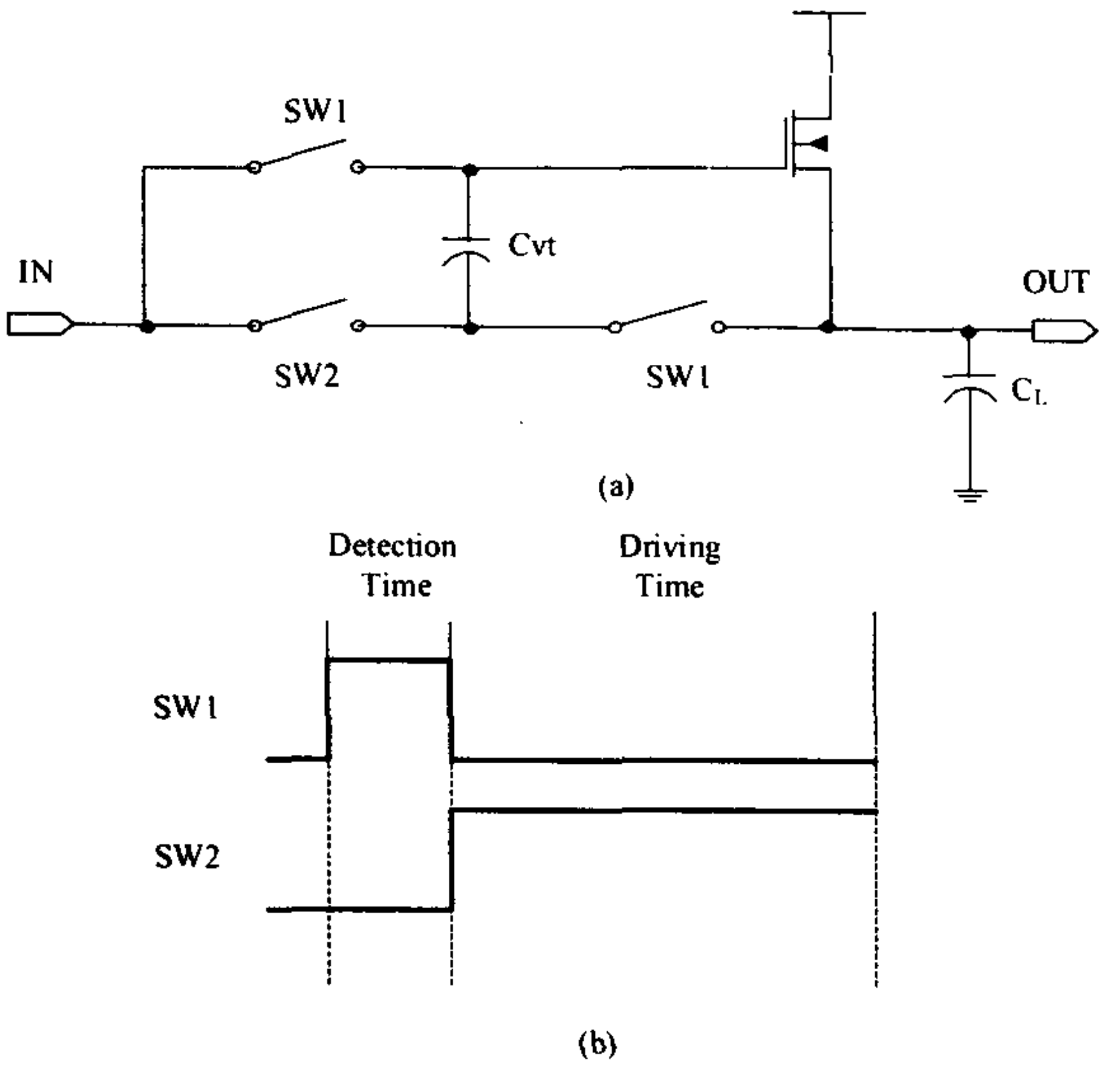


Figure 6. (a) Vth-mismatch compensated analog buffer and (b) its timing diagram

4. Required effective mobility

For larger panel size and better resolution format, the performance requirements on source driver become much more stringent. The most critical performance parameter is the data line charging time because with larger panel size and better resolution format, line time becomes shorter while the data line loading gets heavier. Required effective mobility of poly-Si TFT is analyzed for two types of source driver; (1) offset compensated unity-gain buffer in Figure 4 and (2) Vth-mismatch compensated analog buffer in Figure 6.

4.1 Unity-gain buffer as source driver

Slew rate of op-amp in Figure 3 is the maximum achievable time derivative of the output voltage variation and determined by the maximum current available to charge or discharge the load capacitance. In order to drive the signal lines of an LCD panel, the slew rate of op-amp should be larger than maximum video signal range divided by one row line time. It is evident the bias current of op-amp used as source driver should be increased for larger panel size and/or better resolution format. Therefore, the bias current of input differential stage of op-amp, which is the current in P2 in Figure 3, can be calculated by the equation (1), where C_c is the compensation capacitor whose value is chosen to be $0.22C_L$ for enough phase margin.

$$\left[SlewRate = \frac{I_{BIAS}}{C_C}\right] \geq \left[\frac{GrayFullSwingRange}{LineTime}\right]$$
$$I_{BIAS} \geq \left[\frac{GrayFullSwingRange}{LineTime}\right] \cdot C_C \qquad (1)$$

Larger bias current can be obtained by larger device size, but since a source driver should fit in one pixel pitch, maximum device size is limited. For the integration of op-amp in one pixel pitch, the widths of the transistors of op-amp should be decreased when necessary. With smaller transistor width, the effective mobility of transistors should be improved for larger bias current. For a given panel size and resolution format, the device size is increased until either it is limited by the one pixel pitch or the required bias current is obtained. If the resultant bias current is yet to be increased, the effective mobility is increased till the required bias current is obtained. Required effective mobility is calculated by the equation (2), where α is ratio of effective mobility to be increased and β is ratio of op-amp transistor width to be decreased.

$$I_{BIAS} = \frac{1}{2}(\alpha\mu_p C_{ox})\left(\frac{W}{L}\right)_2 \beta(V_{GS2} - V_{tp})^2$$
$$\alpha = \frac{2 \cdot I_{BIAS}}{\mu_p C_{ox}\left(\frac{W}{L}\right)_2 \beta(V_{GS2} - V_{tp})^2} \qquad (2)$$

$\mu_p C_{ox}$ is a constant determined by the processing technology whose nominal value of the reference technology is $1.33\mu A/V^2$. The aspect ratio and overdrive voltage of P2 in Figure 3 are (540/8), 1.54V, respectively. The values of I_{BIAS} obtained by the equation (1) and the value of β are listed in Table 1. Then, α is calculated by the equation (2). Finally, the required effective mobility is determined by $\alpha\mu_p$, where μ_p of the reference technology is $12cm^2/Vs$. The result is shown in Figure 7.

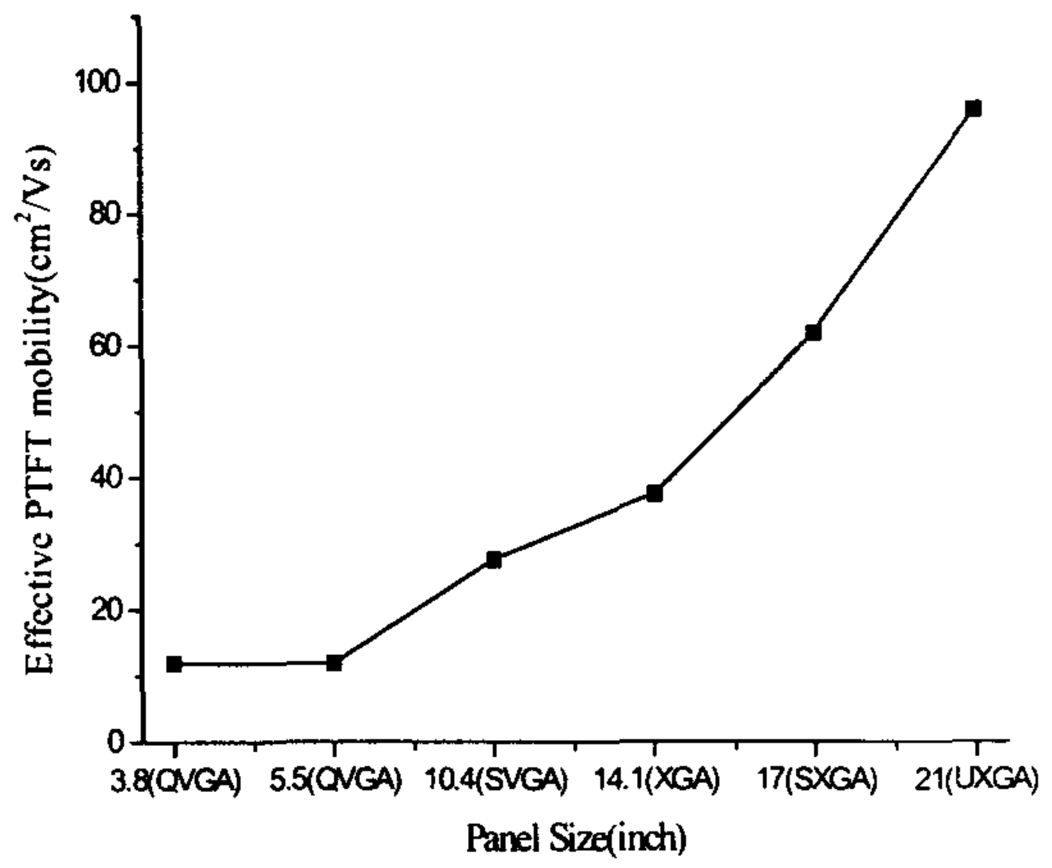


Figure 7. Mobility vs. panel size when unity-gain buffer in Figure 4 is used as source driver

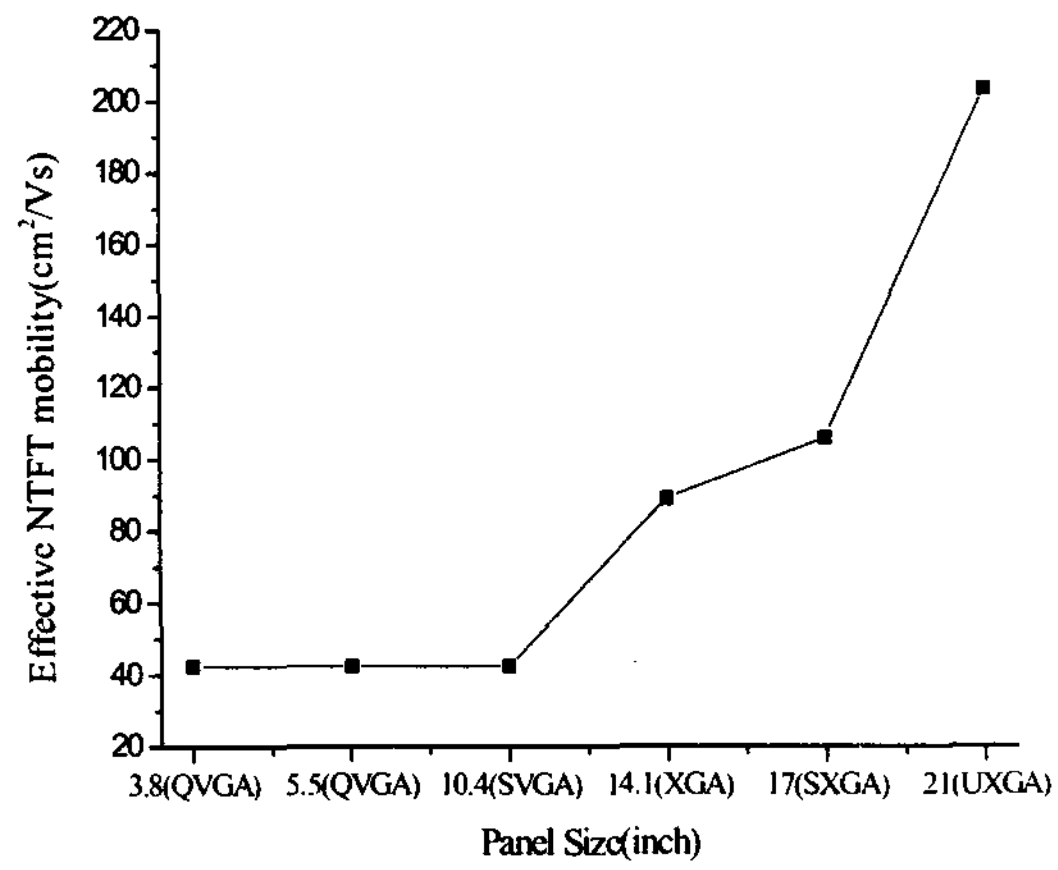


Figure 8. Mobility vs. panel size when analog buffer in Figure 6 is used as source driver

Table 1. Bias current and the ratio of op-amp transistor width to be decreased according to panel size and resolution format

Panel size (inch)	Resolution format	Line time (μs)	Compensation capacitor Cc (pF)	Load capacitor C_L (pF)	**Bias current I_{BIAS} (μA)**	Sub-pixel pitch (μm)	Source driver area for op-amp (μm^2)	Area of op-amp (μm^2)	**Ratio of op-amp transistor width to be decreased β**
3.8	QVGA (320*240)	69	6.6	30	**12.5**	80	28,000	172320	**1/6.2**
5.5	QVGA (320*240)	69	8.8	40	**16.6**	116	58,000	172320	**1/3**
8.4	VGA (640*480)	34	15.4	70	**62.8**	88	67,760	172320	**1/2.6**
10.4	SVGA (800*600)	27	22	100	**117**	88	84,216	172320	**1/2.1**
14.1	XGA (1024*768)	21	33	150	**237**	94	122,012	172320	**1/1.5**
17	SXGA (1280*1024)	16	42.46	193	**433**	87	135,720	172320	**1/1.27**
21	UXGA (1600*1200)	13	61.38	279	**834**	88	170,210	172320	**1/1.02**

4.2 Analog buffer as source driver

As is evident from the result in the previous section, it is difficult to use unity-gain buffer as source driver with poly-Si. An alternative to the unity-gain buffer is a simple analog buffer. Various kinds of V_{th}-mismatch compensated analog buffer [8-11] have been proposed among which the one in Figure 6 [8] is chosen to derive the required effective mobility of poly-Si TFT. The analog buffer shown in Figure 6 has two-phase clocks; SW1 and SW2. When SW1 is high, the voltage across the capacitor C_{vt} is V_{th} because the transistor is turned off during that period. When SW2 goes high, the output becomes $V_{in} + V_{th} - V_{th} = V_{in}$, that is, the output has the same value as the input regardless of the value of V_{th}.

For a given panel size and resolution format, required effective mobility is obtained by HSPICE simulation assuming the supply voltage and load capacitance of data line are 15V and 30pF, respectively. Figure 8 shows the result. Comparing the results in Figure 7, the required effective mobility is about two times larger for the case of analog buffer used as source driver. This is because the driving source impedance of the analog buffer in Figure 6 becomes very large as the output voltage approaches the final value, which is the inherent characteristic of source follower.

5. Conclusion

Characteristics of poly-Si TFT required for the implementation of analog circuits for SoG are described. For SoG, it requires that poly-Si TFT technology has higher effective mobility, lower threshold voltage and finer design rule and uniformity characteristics from location to location in a panel. Also, the performance of analog and digital circuit is required to be immune to the variation of poly-Si TFT parameter.

The research on the SoG with poly-Si TFT is gaining its popularity due to its feasibility of much cheaper flat panel display system. The work reported in this paper can be a guideline in developing poly-Si TFT devices targeting SoG.

6. References

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