P-178: Design of On-Panel Readout Circuit for Touch Panel Application

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Abstract

An on-panel readout circuit for touch panel application has been designed and fabricated in a 3-μm low temperature poly-silicon (LTPS) technology. The minimum detectable voltage difference of the proposed circuit is 30 mV. The switch-capacitor technique is applied to amplify the voltage difference from capacitance change due to touch panel. The corrected double-sampling (CDS) technique is also employed to reduce the offset originated from process variation.

1. Introduction

Low temperature poly-silicon (LTPS) thin-film transistors (TFTs) have been widely utilized in the active-matrix liquid crystal display (AMLCD) to integrate analog and digital circuits on glass substrate owing to its higher carrier mobility, low threshold voltage and high stability. By integrating peripheral functional circuits on the display panel, higher resolution, smaller size, and high reliability can be further achieved for the system-on-panel (SOP) application. Since the carrier mobility depends on the grain size of the active poly-Si layer, the deviation of the TFT characteristic is dependent on the quality of the poly-Si layer. The device variation compression is especially needed to be considered when the peripheral functional circuits are integrated on panel [1]-[2].

For SOP applications, more kinds of circuits had been implemented on the glass substrate. In [3], a metal-nitride-oxide-silicon one-time-programmable cell with fast programming, high reliability, and fully low-temperature polycrystalline-silicon panel compatible process had been reported for system-on-panel application. Through channel FN programming, superior data retention and low-power operation are therefore achieved. In [4], an amplitude-shift-keying (ASK) demodulator implemented in LTPS technology for RF identification tags embeddable on panel displays had been reported. The highest ASK modulated data rate was 100 kb/s.

Recently, touch sensing gets great demand on panel application such as PDA, tabled PCs, and smart phones, due to its intuitive operation and the advantages of easier and faster entry of the information. Integration of touch sensing function is convinced to be one of the value-adding solutions that can be applicable to the present flat panel displays (FPDs) [5]-[6]. Fig. 1 shows the block diagram of touch panel controller [5]. The touch panel controller has been implemented with LTPS TFTs on a glass substrate to control a 4-wire resistive touch panel. It induces voltage gradient across either plate of a 4-wire resistive touch panel, and senses the intermediate potential at the touch position.

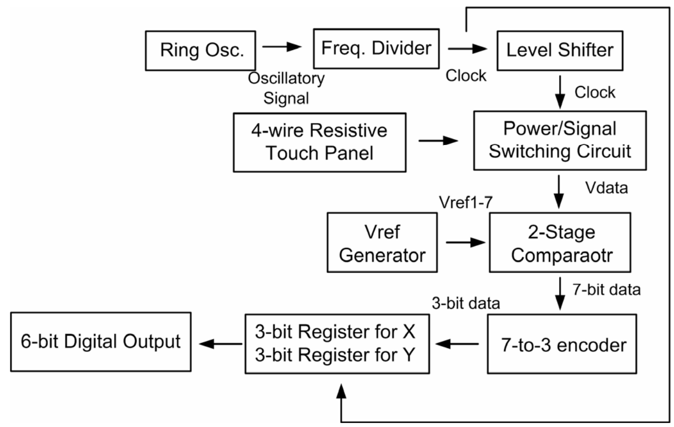


Figure 1. The block diagram of touch panel controller [5].

Fig. 2 shows the readout circuit of the integrated LDI with readout function for touch-sensor-embedded display panels [6]. An electric charge is generated in the photo TFT depending on the intensity of incident light. The input current is converted into voltage signal through the integrator. When the Reset is high, the feedback capacitor Ci is shorted and Vo_op1 equals to Vref and plus its own voltage corresponding to the given input current. This voltage, Vr, is stored in Cr as SPL0 is set to low. When the Reset is low, the input current is converted into output voltage by the integrator. The output voltage of Vo_op1 decreases with time and the voltage at the falling edge of SPL1, Vs, is stored on Cs. With global charge amplifier and ADC, the difference between Vr and Vs can be distinguished and digitalized into 8-bit digital codes [6].

Fig. 3 shows the embedded liquid crystal capacitive sensor and its readout circuit [7]. In Fig. 3(a), the voltage of Vgw is controlled by a coupling effect from Gn in the reading period. The liquid crystal capacitance (Clc) is defined by a sensor gap between the common electrode and sensor electrodes on a TFT substrate. The sensor gap is reduced when the sensor is touched. Therefore, the capacitance is increased as well as the voltage of Vgw is decreased. The voltage difference at Vgw can be further amplified and converted into current signal (Iro) by TFT1. Fig. 3(b) shows the readout circuit with the integrator and the A/D converter. The output voltage (Vro) is reset to Vref first. Due to the voltage difference from Vgw, Iro in the non-touch state is larger than that in the touch state. By applying the A/D converter, the touch and non-touch events can be converted to the digital output.

In this work, a new on-panel readout circuit for touch panel application has been designed and fabricated in a 3-μm low temperature poly-silicon (LTPS) technology. The switch-capacitor technique is applied to enlarge the voltage difference due to capacitance change of touch panel. The corrected double-sampling (CDS) technique is also employed to reduce the offset originated from process variation. The proposed on-panel readout circuit can detect the minimum voltage difference as small of 30 mV in the experimental measurement..

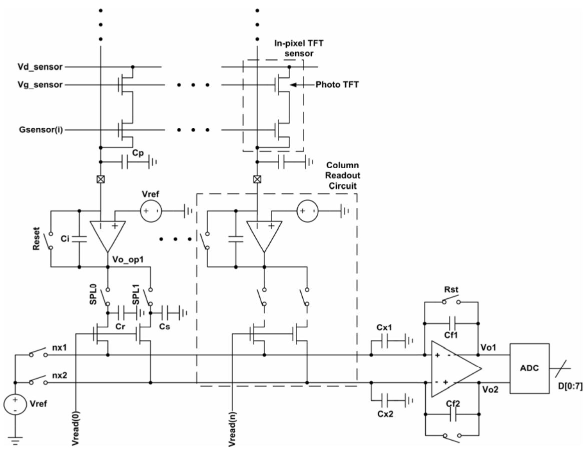
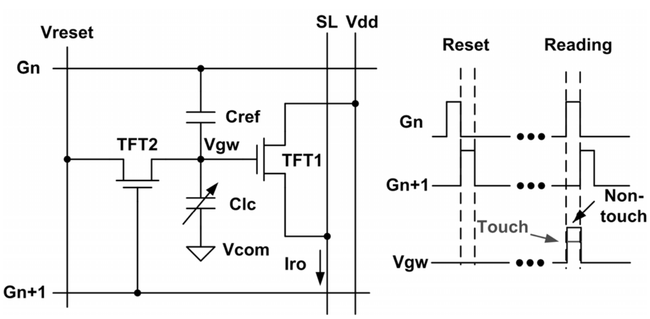


Figure 2. The readout circuit of the integrated LDI with readout function for touch-sensor-embedded display panels [6].



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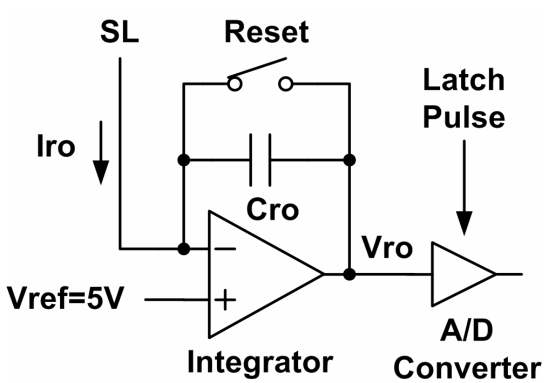


(b)

Figure 3. (a) Liquid crystal capacitive sensor circuit, and (b) the corresponding readout circuit [7].

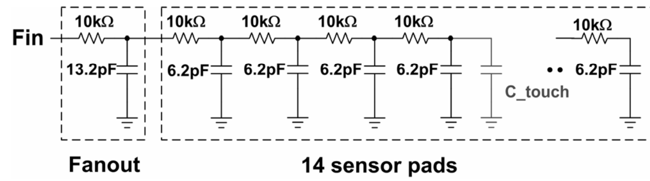


Figure 4. The equivalent RC model of one capacitive sensor line on the 2.8 inch panel.

2. New On-Panel Readout Circuit

The equivalent RC model of one capacitive sensor line on the 2.8 inch panel provided by the foundry is shown in Fig. 4 with total R = 150 kΩ and C = 100 pF. Fanout is the equivalent parasitic RC of interconnect line between the sensor line to the output node Fin. When the sensor line is touched, one capacitor (C_touch) is added in parallel to the touched node and the capacitance of C_touch is varied from 0.5 pF to 2 pF depended on the touch area. In order to detect the capacitance change from C_touch, each node on the sensor line is pre-charged to 6 V at the beginning. After the touch event happened, the voltage level at output node Fin can be derived from 5.88 V to 5.97 V with the corresponding C_touch value from 2 pF to 0.5 pF. Therefore, the on-panel readout circuit for such a capacitive sensor line is required to distinguish at least 30-mV voltage difference at the Fin node. In this work, the switch-capacitor technique is applied to enlarge the voltage difference from capacitance change in the touch panel and the corrected double-sampling (CDS) technique is employed to reduce the offset owing to process variation.

Fig. 5 shows the new proposed on-panel readout circuit for touch panel application in a 3-μm LTPS technology. The proposed circuit is composed of two parts, one is the switch-capacitor (SC) circuit with corrected double sampling (CDS) technique [8] and the other is on-panel analog-to-digital (A/D) converter [9]. The SC technique is applied to amplify the small voltage difference between Vi and Vr with the factor C1/C2. The voltage across C2 is reset when the Clk1 is high. The input voltage (Vi) charges C1 and the charging current flows across C2 when the Clk2 is high. Consequently, the change in charge across C2 equals the change in charge across C1. So, the output voltage is related to the input voltage by Vout_OP = (C1/C2)*(Vi-Vr)+Vr at the end Clk2 at high.

Since the TFTs suffer worse device variation in LTPS process compared with that in CMOS silicon process. The corrected double sampling (CDS) technique is utilized to eliminate the offset of OPAMP. The effect of the input offset can be modeled as an error voltage source placed in series with the positive input of OP. When the Clk1 is high, the offset voltage is stored in C2. When the Clk2 is high, the offset voltage can be cancelled, and the output voltage is independent of the OP offset voltage.

The second part of the proposed circuit is the on-panel A/D converter. Since the voltage level at Vout_OP usually can not be directly applied for digital processing when the sensor line is touched, an on-panel A/D converter is needed. With different Va of reverence level, the output voltage (Vout_OP) can be digitalized according to the different input voltage (Vi). As the Clk1 is high, the threshold voltage of INV (Vt) is stored in C3 as well as Va. When the Clk2 is high, (Vout_OP+Vt-Va) is applied to INV. Hence, a comparison of Vout_OP and Va determines the output voltage Vout into digital code.

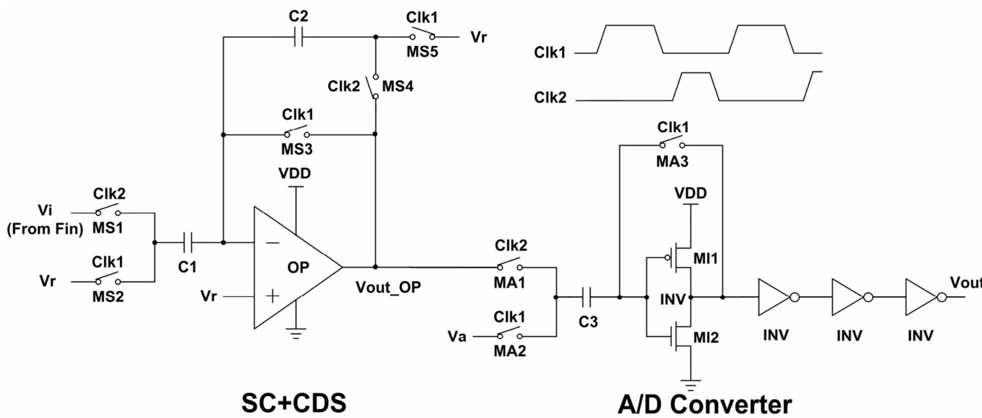
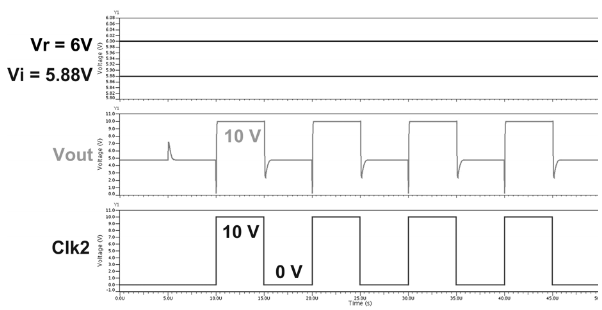


Figure 5. New proposed on-panel readout circuit to sense capacitance change in a 3-μm LTPS technology.



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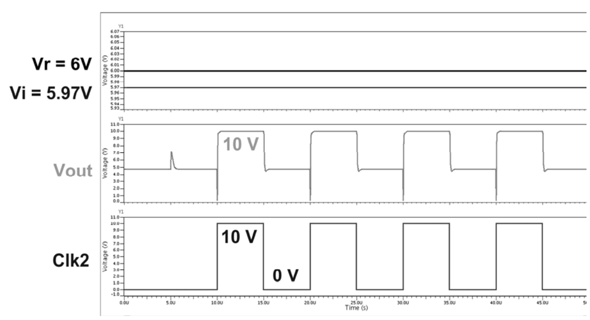

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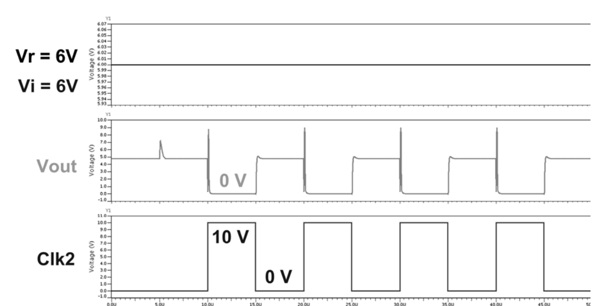
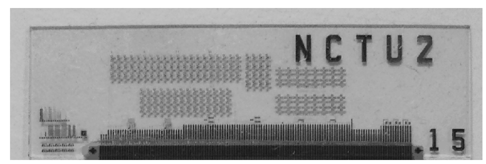


(c)

Figure 6. The simulated results of the proposed readout circuit with (a)Vi = 5.88 V, (b) Vi = 5.97 V, and (c) Vi = 6 V, where the Vr is kept at 6 V.



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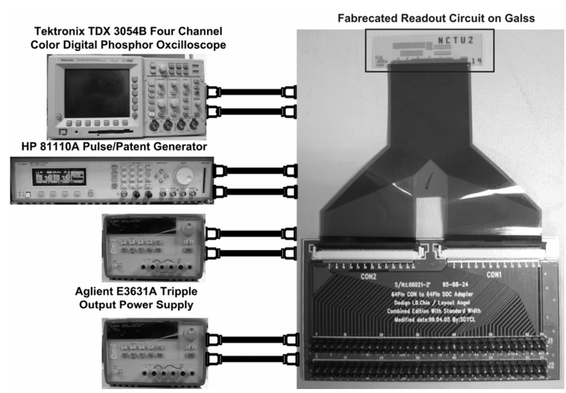


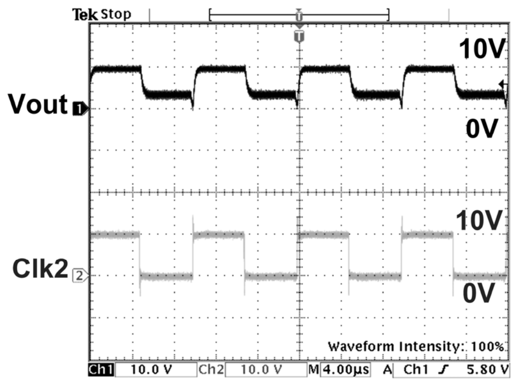
(b)

Figure 7. (a) The fabricated circuits on glass substrate to verify the readout function of the proposed circuit and (b) its corresponding measurement setup.

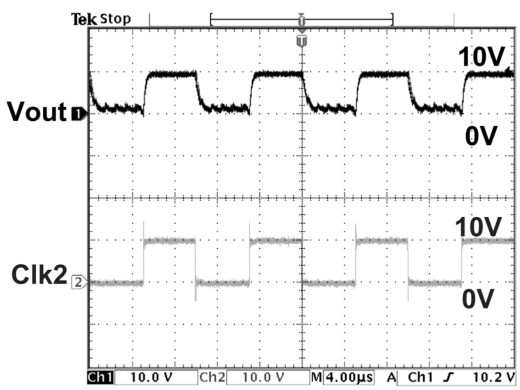
3. Experimental Results

The proposed circuit has been simulated by the eldo simulator in a 3-μm LTPS technology. Fig. 6 shows the simulated results under three different Vi with VDD = 10 V, Vr = 6 V, Va = 6.15V, Clk1 = Clk2 = 100 kHz, C1 = 8 pF, and C2 = 1 pF. By applying the switch-capacitor technology and on-panel A/D converter, the output voltage (Vout) is only valid when the Clk2 is high. In Figs. 6(a) and 6(b), with the input voltage (Vi) of 5.88 V and 5.97 V, the output voltage (Vout) is 10 V (VDD) as the Clk2 is high. In Fig. 6(c), with the input voltage of 6 V, which is non-touch event, the output voltage (Vout) is 0 V (GND) as the Clk2 is high.

The new proposed circuit has been fabricated and verified in a 3-μm LTPS technology. Figs. 7 show the fabricated on-panel readout circuit for touch panel application and its corresponding measurement setup. Aglient E3631A tripple output power supply is utilized to supply VDD, Vi, Vr, and Va. HP 81110A pulse/patent generator is applied to generate Clk1 and Clk2. Fig. 8 shows the measured results of the proposed circuit under different Vi. In Figs. 8(a) and 8 (b), with the input voltage (Vi) of 5.88 V and 5.97 V, the output voltage (Vout) is 10 V (VDD) as the Clk2 is high. In Fig. 8(c), with the input voltage of 6 V, which is non-touch event, the output voltage (Vout) is 0 V (GND) as the Clk2 is high. From Figs. 6 and Figs. 7, the experimental results show well consistent with the simulated results, that is, the proposed on-panel readout circuit can detect the minimum voltage difference as small of 30 mV.



(a)



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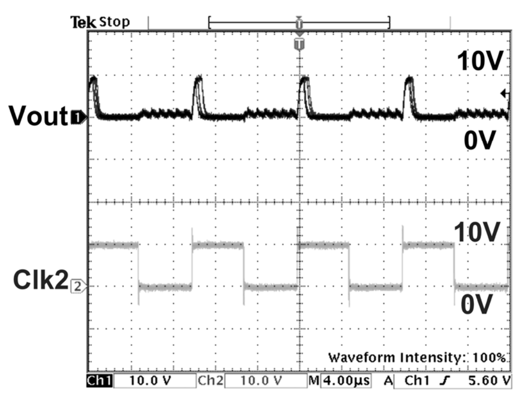

(c)

Figure 8. The measured results of the proposed readout circuit with (a)Vi = 5.88 V, (b) Vi = 5.97 V, and (c) Vi = 6 V.

4. Conclusion

A new on-panel readout circuit for touch panel application has been designed and fabricated in a 3-μm low temperature poly-silicon (LTPS) technology. The switch-capacitor (SC) technique is applied to enlarge the voltage difference from the capacitance change of touch panel and the corrected double-sampling (CDS) technique is also employed to reduce the offset owing to process variation. The minimum detectable voltage difference of the proposed circuit is 30 mV. More on-panel readout circuits can be integrated on the display panel to sense where is touched on the panel.

5. Acknowledgment

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