Design and Implementation of Readout Circuit on Glass Substrate for Touch Panel Applications

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***Abstract*—A readout circuit on glass substrate for touch panel application has been designed and fabricated in a 3-μm low temperature poly-silicon (LTPS) technology. In this work, the switch-capacitor (SC) technique is applied to amplify the small voltage difference from capacitance change due to the touch event on panel. In addition, the corrected double-sampling (CDS) technique is also employed to reduce the offset originated from LTPS process variation. The minimum detectable voltage difference of the proposed circuit is 40 mV. To further identify the different touch area during touch events, a 4-bit analog-to-digital converter is used to converter the output of readout circuit into 4-bit digital codes.**

***Index Terms*—Low temperature poly-silicon (LTPS), readout circuit, system-on-panel (SOP), touch panel.**

I. Introduction

Owing to the higher carrier mobility, lower threshold voltage, and higher stability of low temperature poly-silicon (LTPS) thin-film transistors (TFTs), some analog and digital circuits have been integrated on glass substrate in the active-matrix liquid crystal display (AMLCD) [1]–[3]. 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 panels [4]–[6].

Since some remarkable advances had been made for peripheral functional circuits, more kinds of circuits had been also implemented on the glass substrate for SOP applications [7]–[9]. In [10], a metal–nitride–oxide–silicon one-time-programmable cell with fast programming, high reliability, and fully process compatible to low-temperature polycrystalline-silicon panel had been reported for system-on-panel application.

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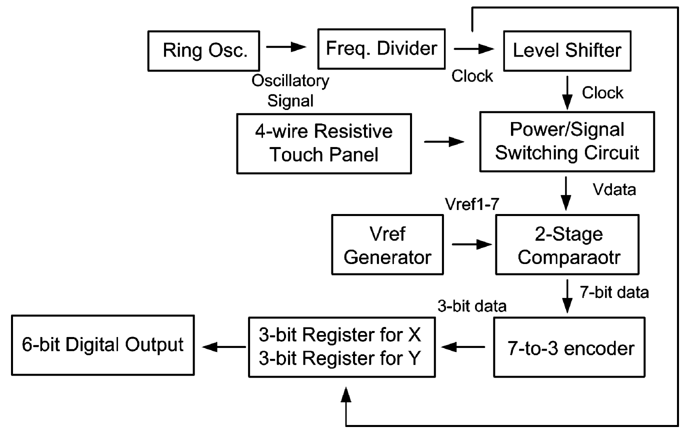

Fig. 1. Block diagram of touch panel controller [12].

Through channel FN programming, superior data retention and low-power operation were therefore achieved. In [11], an amplitude-shift-keying (ASK) demodulator implemented in LTPS technology for RF identification tags embedable on panel displays had been reported with the highest ASK modulated data rate of 100 kb/s.

Recently, touch sensing receives great demand on panel applications, 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 the touch sensing function is convinced to be one of the value-adding solutions that can be applicable to the present flat-panel displays (FPDs) [12]–[14]. Fig. 1 shows the block diagram of touch panel controller implemented with LTPS TFTs on a glass substrate to control a 4-wire resistive touch panel [12]. It induces voltage gradient across either plate of a 4-wire resistive touch panel, and senses the intermediate potential at the touch position. After that, the sensed potential is compared with seven reference voltages and the 7-bit output of the comparators is converted to two sets of 3-bit data for the x- and y-coordinates, respectively, by the encoder. According to the 6-bit data, the touch position in the x- and y-directions can be obtained.

Fig. 2 shows the readout circuit of the integrated long-side of the LCD driver IC (LDI) with readout function for touch–sensor–embedded display panels [13]. 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 C_i is shorted and $V_{\rm o\_op1}$ equals to $V_{\rm ref}$ and plus its own voltage corresponding to the given input current. This voltage, $V_{\rm r}$, is stored in $C_{\rm r}$ when SPL0 is set to low. When the Reset is low, the input current is converted into output voltage

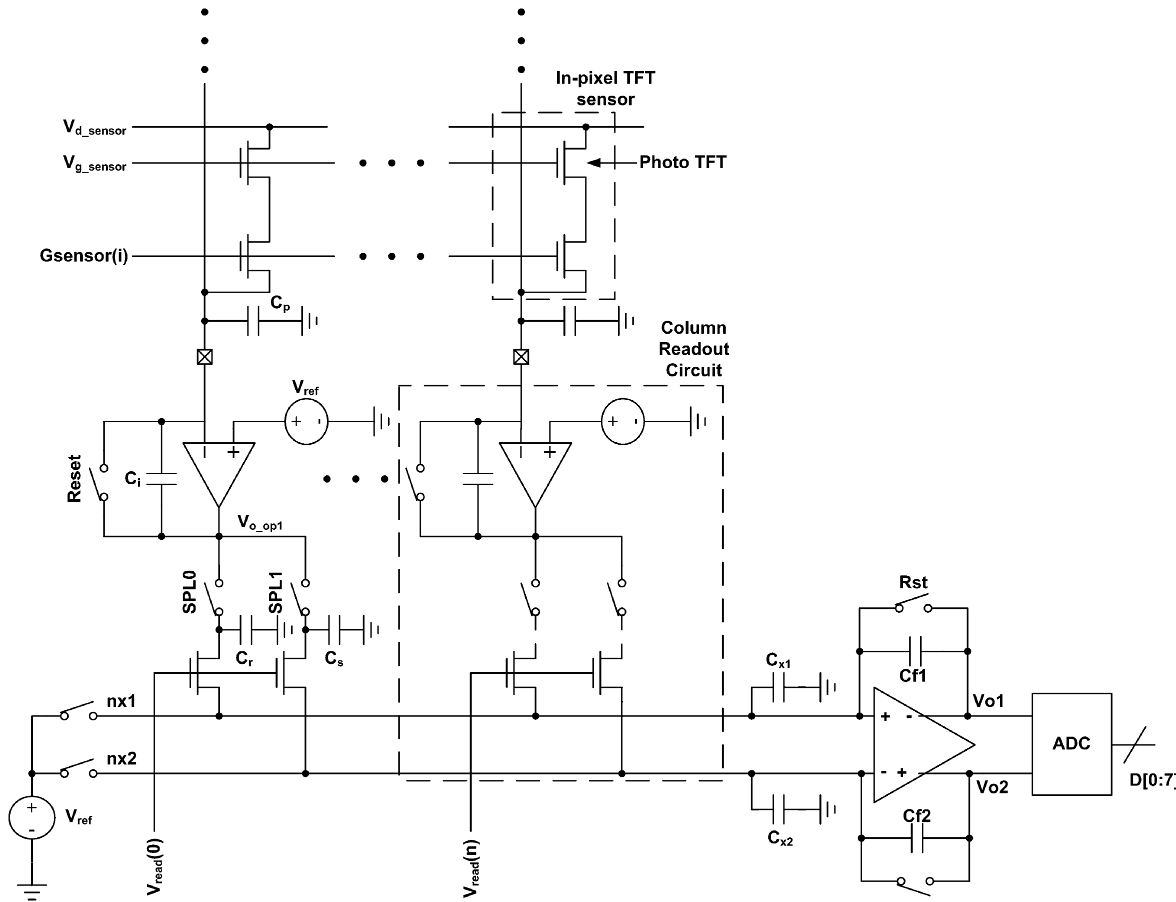

Fig. 2. Readout circuit of the integrated long-side of the LCD driver IC (LDI) with readout function for touch-sensor-embedded display panels [13].

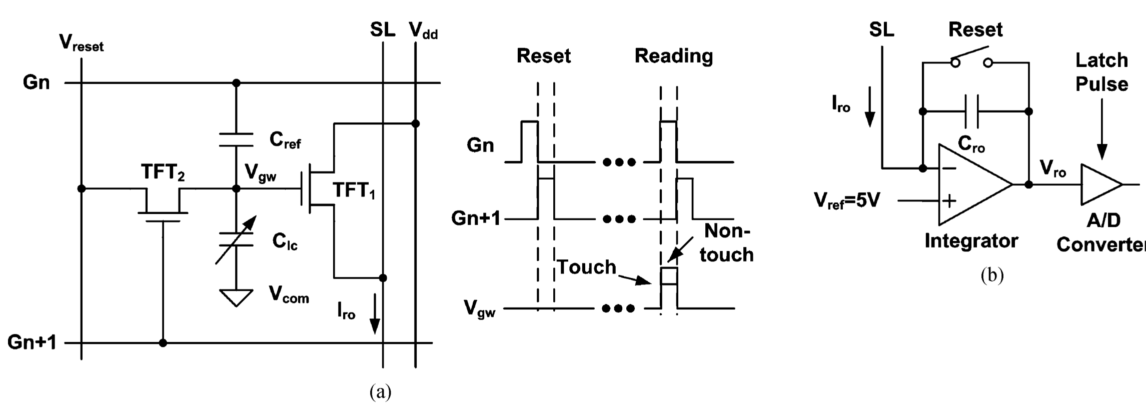

Fig. 3. (a) Liquid crystal capacitive sensor circuit. (b) Corresponding readout circuit [14].

by the integrator. The output voltage of $V_{\mathrm{o\_op1}}$ decreases with time and the voltage at the falling edge of SPL1, V_{s}, is stored on C_{s}. With global charge amplifier and ADC, the difference between V_{r} and V_{s} can be distinguished and digitalized into 8-bit digital codes [13].

Fig. 3 shows the embedded liquid crystal capacitive sensor and its readout circuit [14]. In Fig. 3(a), the voltage of V_{gw} is controlled by the coupling effect from Gn in the reading period. The liquid crystal capacitance (C_{lc}) 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 V_{gw} is decreased. The voltage difference at V_{gw} can be further amplified and converted into current signal ($\mathrm{I_{ro}}$) by TFT_1. Fig. 3(b) shows the readout circuit with the integrator and the A/D converter. The output voltage (V_{ro}) is reset to V_{ref} first. Due to the voltage difference from V_{gw}, $\mathrm{I_{ro}}$ in the non-touch state is larger than that in the touch state. By applying the A/D

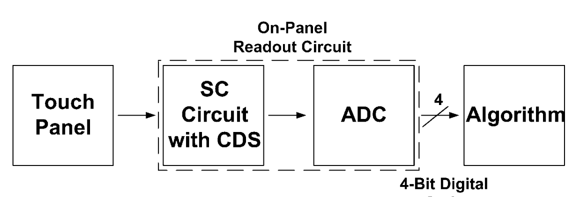

Fig. 4. Block diagram of touch panel system.

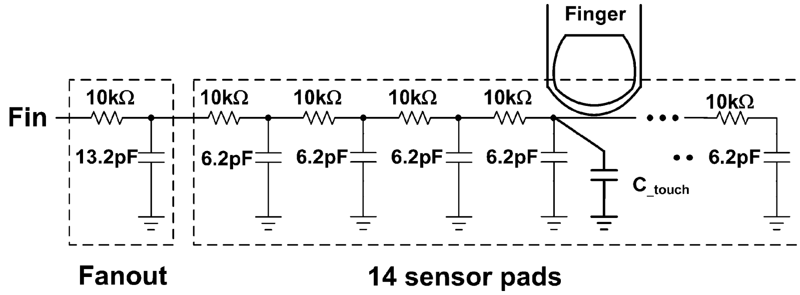

Fig. 5. Equivalent RC model of one capacitive sensor line on a 2.8-in panel.

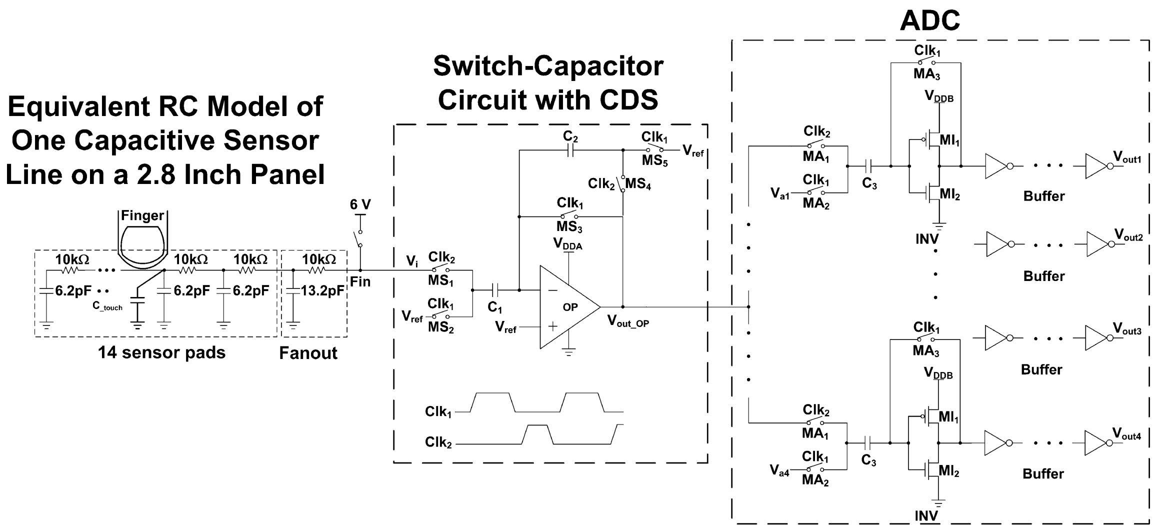

Fig. 6. New proposed on-panel readout circuit to sense the voltage change due to the capacitance change on the touch panel in a 3-μm LTPS technology.

converter, the touch and non-touch events can be converted to the digital output.

In this work, a new readout circuit on glass substrate for touch panel application has been designed and fabricated in a 3-μm low-temperature poly-silicon (LTPS) technology. Fig. 4 shows the block diagram of touch panel system. There are totally 14 and 8 capacitive sensor lines in the x- and y-directions, respectively, on the touch panel. When the touch panel is touched, the total capacitance of the capacitive sensor line will be changed. By applying the switch-capacitor (SC) circuit, the voltage difference from capacitance change due to the touch events can be amplified. In addition, the corrected double-sampling (CDS) technique is also employed to reduce the offset originated from process variation. To further identify the different touch area during the touch events, a 4-bit analog-to-digital converter (ADC) is used to converter the output of readout circuit into 4-bit digital codes. Finally, by analyzing the 4-bit digital codes, the corresponding functions, such as zoom in, zoom out, move, and so on, can be performed on the touch panel by the appropriate algorithm of software in the system.

II. New Proposed On-Panel Readout Circuit

A. Equivalent Model of the Capacitive Sensor Line

Fig. 5 shows the equivalent RC model of one capacitive sensor line on a 2.8-in touch panel provided by the panel manufactory with total R of 150 kΩ and C of 100 pF. The Fanout block is the equivalent parasitic RC network of the interconnect line between the sensor line to the output node Fin. The touch capacitor ($C_{\text{\_touch}}$) is varied from 0.5 to 2 pF according to the different touch area. When the sensor line is touched by the finger, $C_{\text{\_touch}}$ is added in parallel to the touched node and the total capacitance on the capacitive sensor line is also changed. In order to discriminate between the touch and non-touch events, that is, to detect the capacitance change from $C_{\text{\_touch}}$, each node on the sensor line is pre-charged to 6 V at the beginning. When the touch event happened, the voltage at the output node Fin (V_{Fin}) will be changed to

$$V_{\text{FIN}} = \frac{C_{\text{total}}}{C_{\text{total}} + C_{\text{\_touch}}} \cdot V_{\text{pre-charge}} \tag{1}$$

where $V_{\text{pre-charge}} = 6$ V, $C_{\text{total}} = 100$ pF, $C_{\text{\_touch}} =$ 0.5 to 2 pF. Therefore, the voltage level at output node Fin under the touch event can be derived from 5.88 to 5.97 V with the corresponding $C_{\text{\_touch}}$ value from 2 to 0.5 pF. For such a capacitive sensor line, the capacitance change due to the touch event can be indicated by the voltage change. So the on-panel readout circuit is designed to distinguish the voltage difference at the Fin node. In this work, the SC technique is applied to enlarge the voltage difference from capacitance change in the touch panel and the CDS technique is employed to reduce the offset owing to process variation. In addition, the different touch area is further identified by the 4-bit digital output code from on-panel ADC.

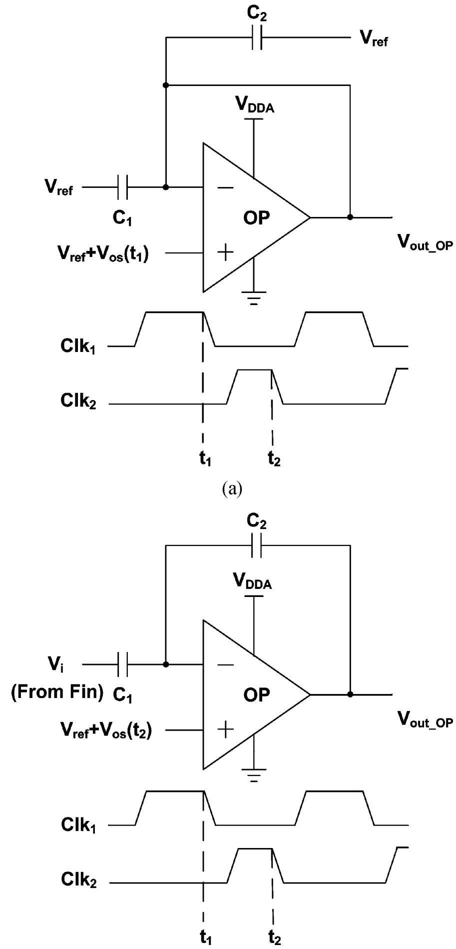

Fig. 7. Proposed switch-capacitor readout circuit with CDS during the logical high in (a) Clk_1 for reset with offset storage and (b) Clk_2 for amplification and offset cancellation.

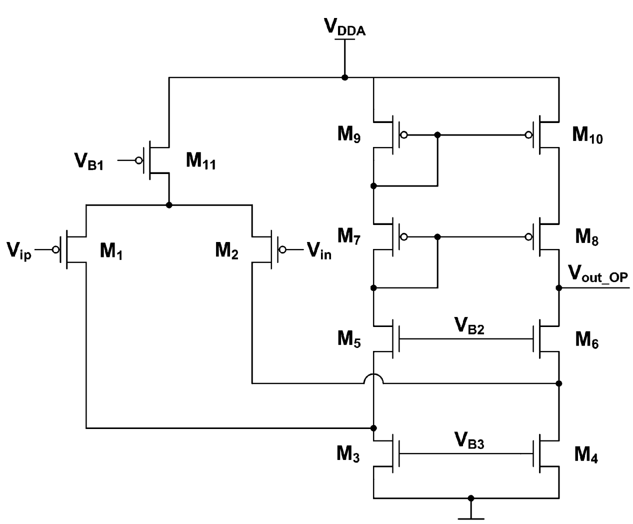

Fig. 8. Schematic diagram of the folded-cascode operational amplifier (OP).

B. Circuit Implementation and Simulation

Fig. 6 shows the new proposed on-panel readout circuit for touch panel applications in a 3-μm LTPS technology. The proposed circuit is designed to detect the capacitance change from

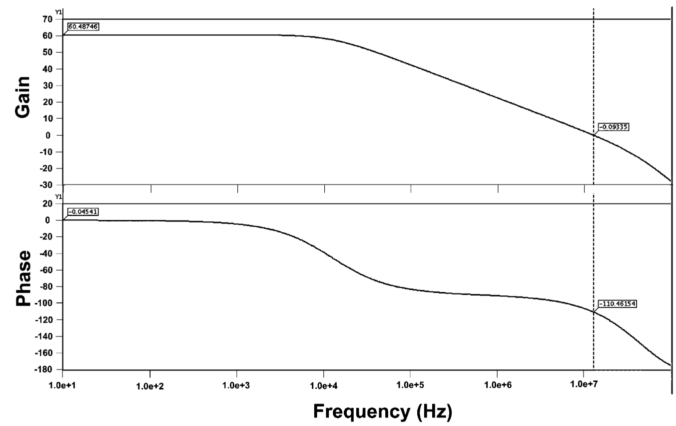

Fig. 9. Simulated frequency response of the folded-cascode operational amplifier in open-loop condition.

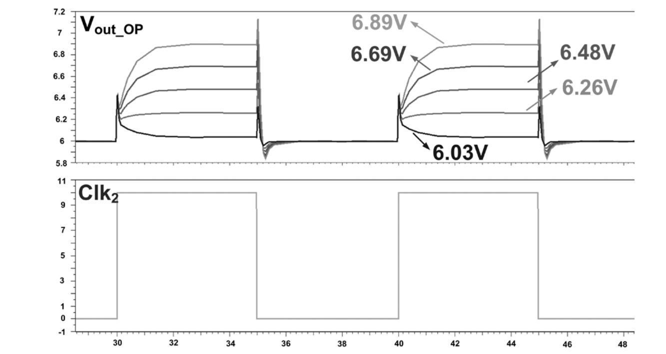

Fig. 10. Simulated output voltage of the switch-capacitor circuit with CDS with different input signals from V_i.

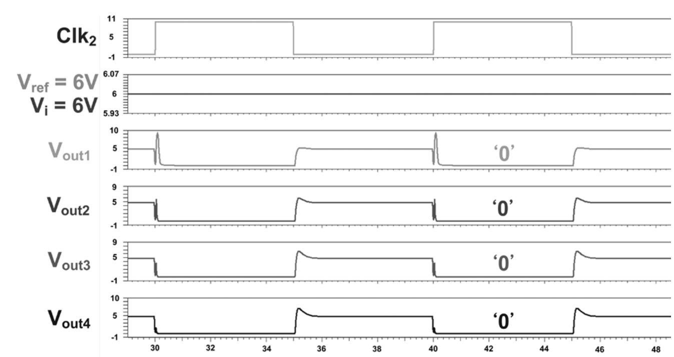

Fig. 11. Simulated result of the proposed circuit under the non-touch event with the digital output code of '0000'.

the capacitive sensor line shown in Fig. 5. The proposed circuit is composed of two parts. One is the SC circuit with CDS technique [15], and the other is on-panel ADC [16]. The SC technique is applied to amplify the small voltage difference between V_i and V_{ref} with the factor of C_1/C_2, where V_i is the voltage from the output node (Fin) of the sensor line. Since the TFTs suffer large device variation in LTPS process compared with that in CMOS silicon process, the CDS technique is utilized to eliminate the offset of operation amplifier (OP). The effect of the input offset can be modeled as an error voltage source (V_{os}) placed in series with the positive input of OP.

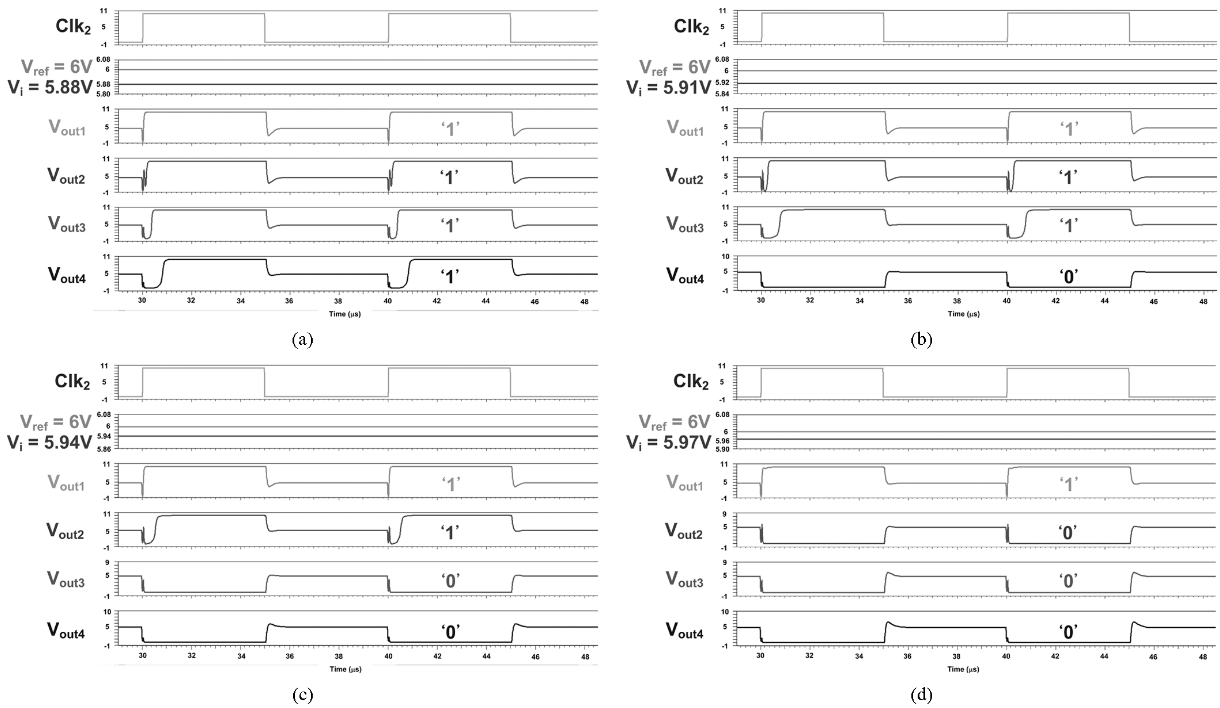

Fig. 12. Simulated results of the proposed readout circuit with (a) $V_i = 5.88$ V (digital output code: '1111'), (b) $V_i = 5.91$ V (digital output code: '1110'), (c) $V_i = 5.94$ V (digital output code: '1100'), and (d) $V_i = 5.97$ V (digital output code: '1000'), where the $V_{\rm ref}$ is kept at 6 V.

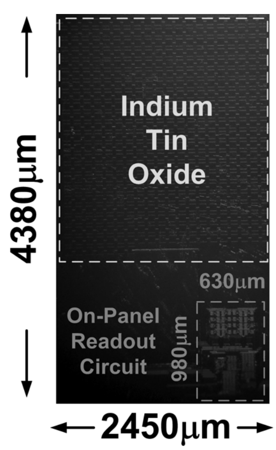

Fig. 13. Die photo of the fabricated readout circuit with ITO on glass substrate, where the ITO is utilized to verify the capacitive sensor line shown in Fig. 5.

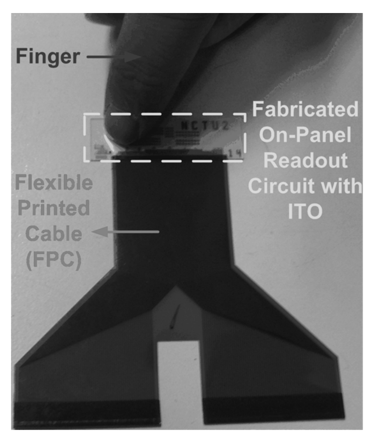

Fig. 14. Fabricated circuit on glass substrate with ITO to verify the readout function of the proposed circuit, when the ITO, which is utilized to verify the capacitive sensor line shown in Fig. 5, is touched by a finger.

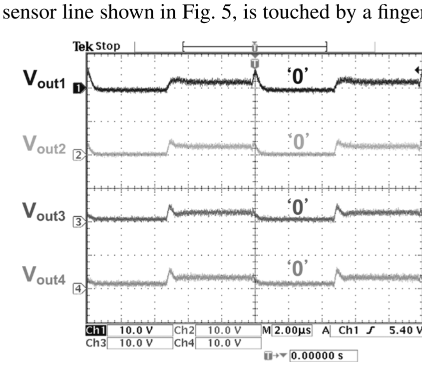

Fig. 15. Measured result of the fabricated circuit under non-touch event ($V_i =$ 6 V) with the output code of '0000'.

Fig. 7 shows the on-panel switch-capacitor circuit with CDS during the logical high in (a) Clk_1 and (b) Clk_2. In Fig. 7(a), the voltage across C_2 is reset and both the voltages across C_1 and C_2 are equal to the input offset of OP ($V_{\rm os}(t_1)$) at $t1$. In Fig. 7(b), V_i charges C_1 and the charging current flows across C_2. Consequently, the change in charge across C_1 equals to the change in charge across C_2. So, the output voltage ($V_{\rm out\_OP}$) at t_2 can be derived by

$$V_{\rm out\_OP}(t_2) = V_{\rm ref} + \frac{C_1}{C_2}\cdot(V_{\rm ref} - V_i) + [V_{\rm os}(t_2) - V_{\rm os}(t_1)]\cdot\left(1+\frac{C_1}{C_2}\right) \quad (2)$$

whereas the output voltage is only valid during the logical high in Clk_2. The offset voltage is also cancelled since the error voltage source was assumed to be independent of time.

The second part of the proposed circuit is the on-panel ADC. Since the voltage level at $V_{\rm out\_OP}$ with analog signals usually can not be directly applied for digital processing when the

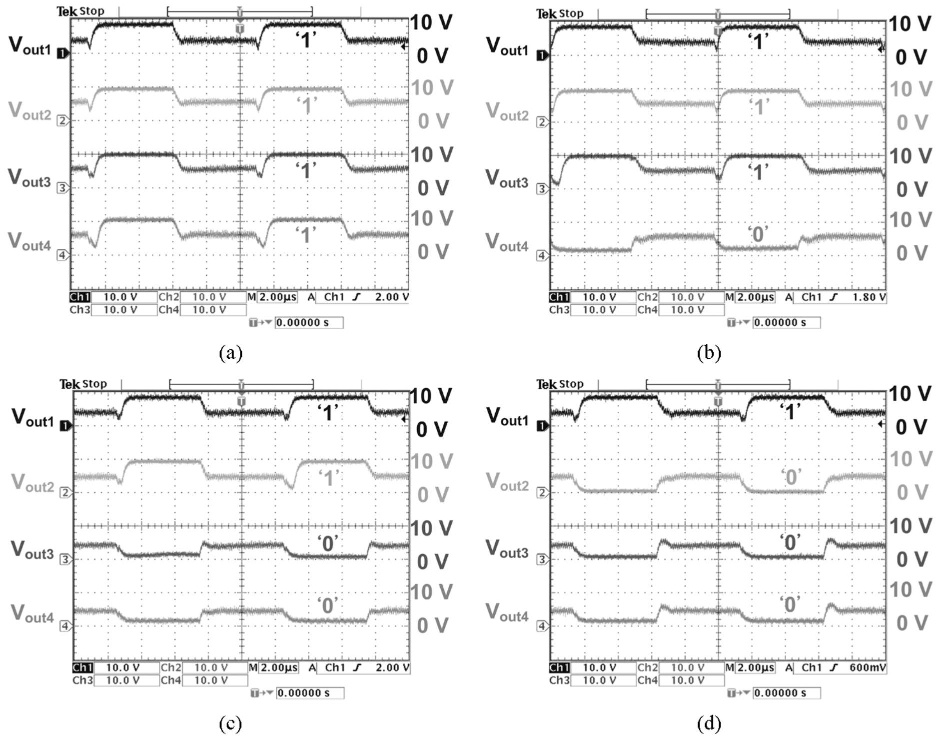

Fig. 16. The measured results of the fabricated readout circuit verified with the applied V_i signal of (a) 5.88 V (digital output code: '1111'), (b) 5.9 V (digital output code: '1110'), (c) 5.93 V (digital output code: '1100'), and (d) 5.96 V (digital output code: '1000'). The corresponding digital codes can be successfully generated at the output $V_{\rm out1}$, $V_{\rm out2}$, $V_{\rm out3}$, and $V_{\rm out4}$.

sensor line is touched, an on-panel ADC is required. Furthermore, with different $V_{\rm a}$ ($V_{\rm a1}$ to $V_{\rm a4}$) of reference voltage, the output voltage of OP ($V_{\rm out\_OP}$) can be digitalized according to the different input voltage (V_i). As the $\rm Clk_1$ is high, the logical threshold voltage (V_t) of the inverter (INV) is stored in C_3 as well as $V_{\rm a}$. When the $\rm Clk_2$ is high, ($V_{\rm out\_OP} + V_t - V_{\rm a}$) is applied to the input of INV and the logical threshold voltage (V_t) of the INV can be further cancelled. Therefore, the output of ADC depends only on ($V_{\rm out\_OP} - V_{\rm a}$) and it shows logical high when the sensor line is touched. Finally, the different touch area can be indentified by the 4-bit digital output ($V_{\rm out1}$ to $V_{\rm out4}$) from on-panel ADC.

The schematic diagram of the folded-cascode operational amplifier (OP) used in this work is shown in Fig. 8. Compared with the traditional two stage operational amplifier, this architecture exhibits better input common mode range, power supply rejection ratio, larger gain, and easier frequency compensation [15]. The proposed circuit has been simulated by the Eldo simulator in a 3-μm LTPS technology [17]. The simulated frequency response of the folded-cascode OP in open-loop condition is shown in Fig. 9 under the supply voltage ($V_{\rm DDA}$) of 10 V. The DC gain and the phase margin are 60.5 dB and 70°, respectively. The simulated unit gain bandwidth is 12.8 MHz. Fig. 10 shows the simulated output voltage of the switch-capacitor circuit with CDS. The output voltage shows 6.89, 6.69, 6.48, 6.26, and 6.03 V under $V_i = 5.88, 5.91, 5.94,$ and 5.97 V, respectively. The output voltage is only valid when the $\rm Clk_2$ is high.

Fig. 11 shows the simulated result of the proposed circuit under the non-touch event with $V_{\rm DDA} = V_{\rm DDB} = 10$ V, $V_{\rm ref} = 6$ V, $V_{\rm a1} = 6.15$ V, $V_{\rm a2} = 6.36$ V, $V_{\rm a3} = 6.6$ V, $V_{\rm a4} = 6.8$ V, $\rm Clk_1 = Clk_2 = 100$ kHz, $C_1 = 8$ pF, and $C_2 = 1$ pF.

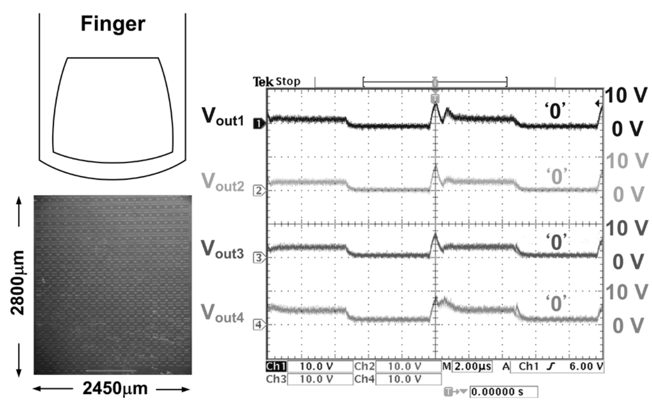

Fig. 17. Measured result of the fabricated circuit under non-touch event.

By applying the SC and CDS technology, the output voltage of the proposed circuit ($V_{\rm out1}$ to $V_{\rm out4}$) is only valid when the $\rm Clk_2$ is high. Therefore, the non-touch event of the proposed circuit shows the digital output code of '0000' when the $\rm Clk_2$ is high. Fig. 12 shows the simulated results under different V_i. The digital code of ADC presents '1111,' '1110,' '1100,' and '1000' under $V_i = 5.88, 5.91, 5.94,$ and 5.97 V, respectively.

III. Experimental Results

The new proposed circuits have been designed and fabricated in a 3-μm LTPS technology. Fig. 13 shows the die photo of the fabricated readout circuit with indium–tin–oxide (ITO) on glass substrate, where the ITO is utilized to verify the capacitive sensor line shown in Fig. 5. The ITO is drawn with the equivalent resistance of 150 kΩ in the square form instead of a

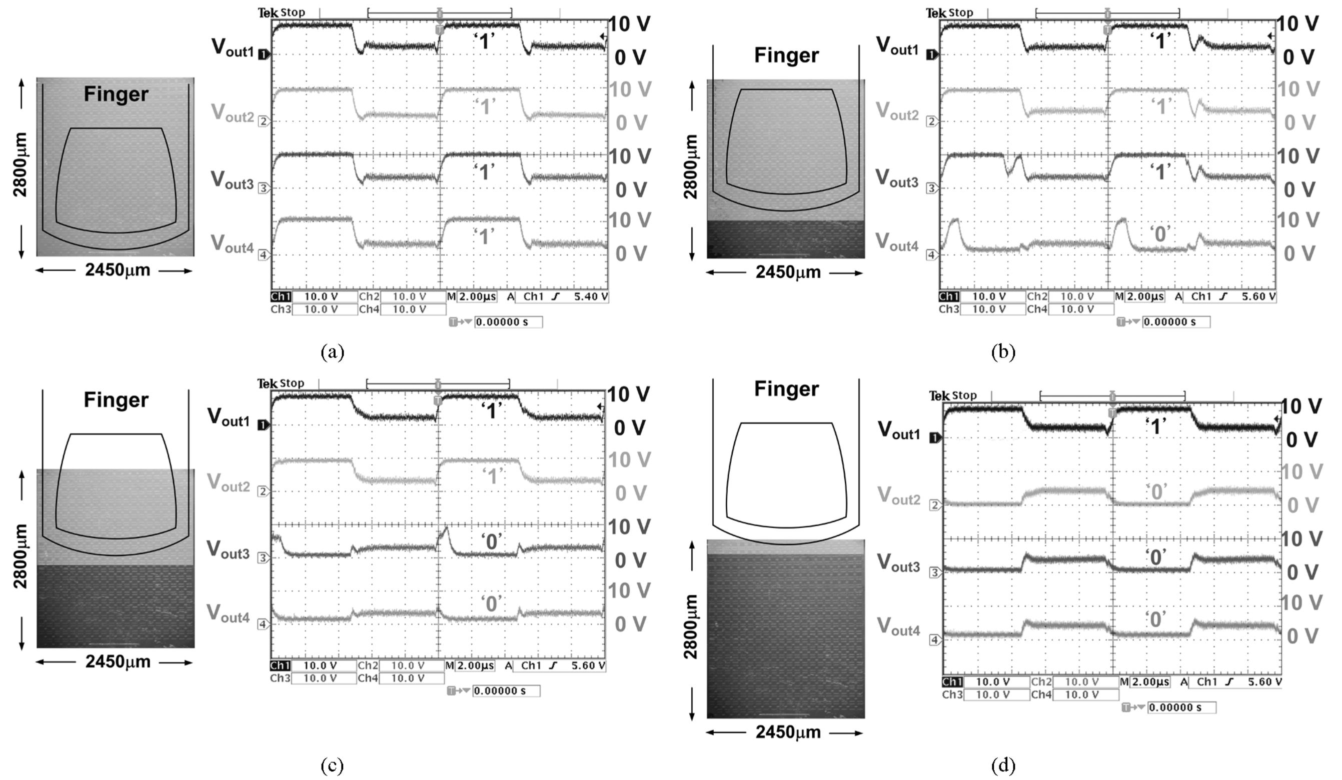

Fig. 18. Measured results of the fabricated readout circuit under the touched area by finger covered with: (a) full; (b) 3/4; (c) 1/2; and (d) less than 1/4 of the ITO area.

line in Fig. 13 due to the limitation of layout area in the experimental chip. The area of ITO is 2800 μm× 2450 μm and the area of on-panel readout circuit is 980 μm×630 μm. Fig. 14 shows the fabricated circuit on glass substrate with ITO to verify the readout function of the proposed circuit, when the ITO, which is utilized to verify the capacitive sensor line shown in Fig. 5, is touched by a finger. The 4-bit digital output code is utilized to identify the different touch area and to enhance the resolution of the touch panel.

The fabricated readout circuit is first verified with the externally applied input signals (V_i). Fig. 15 shows the measured result of the fabricated circuit under non-touch event ($V_i = 6$ V), where the digital output code is '0000.' Fig. 16 shows the measured results of the fabricated circuit under different V_i. The digital output code shows '1111,' '1110,' '1100,' and '1000' under $V_i = 5.88, 5.9, 5.93,$ and 5.96 V, respectively. Since the TFTs may suffer large device variation in LTPS process compared with that in CMOS silicon process, the minimum detectable voltage difference is 40 mV in the measured results. After the successful verification of readout function, the fabricated chip is measured by the different touch area of the finger with a 100-pF capacitor connected to the V_i node, which is used to simulate the touching event modeled in Fig. 5. The different digital output codes are confirmed according to the different touch area of ITO. Fig. 17 shows the measured result of the fabricated circuit under non-touch event, where the digital output code is'0000.' Fig. 18 shows the measured results of the fabricated circuit under different touch area. The digital output code shows '1111,' '1110,' '1100,' and '1000' when the touched area by finger is covered with full, 3/4, 1/2, and less than 1/4 of the ITO area, respectively. By further analyzing the 4-bit digital codes, the corresponding functions, such as zoom in, zoom out, move, and so on, can be performed on the touch panel by the appropriate algorithm of software in the system.

IV. Conclusion

A new on-panel readout circuit for touch panel applications has been designed and fabricated in a 3-μm LTPS technology. The SC technique is applied to enlarge the voltage difference from the capacitance change of touch panel, and the CDS technique is also employed to reduce the offset owing to process variation. The minimum detectable voltage difference of the proposed circuit is 40 mV, and the different touch area can be identified by the 4-bit digital output. The proposed readout circuit for touch panel application on glass substrate can be integrated in the active-matrix LCD (AMLCD) panels to increase the sensing resolution of touch panel for SOP applications.

References

[1] K.-H. Lim, H.-W. Kim, J.-S. Kang, Y.-C. Sung, and O.-K. Kwon, "A novel 2-stage analog amplifier with self-compensated current loads using low temperature poly-si TFTs for flat panel displays," in *SID Dig. Tech.*, 2008, pp. 541–544.

[2] J.-S. Yoon, J.-S. Kang, and O.-K. Kwon, "High efficient p-type only cross-coupled DC-DC converter using low temperature poly-si TFTs for mobile display applications," in *SID Dig. Tech.*, 2008, pp. 545–548.

[3] H.-J. Chung and Y.-W. Sin, "Low power level shifter for system-on-panel applications," in *SID Dig. Tech.*, 2008, pp. 1231–1234.

[4] T.-M. Wang, M.-D. Ker, and S.-C. Chen, "Design of analog output buffer with level shifting function on glass substrate for panel application," *J. Display Technol.*, vol. 5, no. 9, pp. 368–375, Sep. 2009.

[5] H. Nakatogawa, T. Tsunashima, Y. Aoki, T. Motai, M. Tada, A. Ishida, and H. Nakamura, "3.5 inch VGA TFT LCD with system-on-glass technology for automotive applications," in *SID Dig. Tech.*, 2009, pp. 387–390.
[6] Y.-H. Tai, S.-C. Huang, W.-P. Chen, Y.-T. Chao, and G.-F. Peng, "A statistical model for simulating the effect of LTPS TFT device variation for SOP applications," *J. Display Technol.*, vol. 3, no. 4, pp. 426–433, Dec. 2007.
[7] M.-D. Ker, C.-K. Deng, and J.-L. Huang, "On-panel output buffer with offset compensation technique for data driver in LTPS technology," *J. Display Technol.*, vol. 2, no. 2, pp. 153–159, Jun. 2006.
[8] J.-S. Chen and M.-D. Ker, "New gate-bias voltage-generating technique with threshold-voltage compensation for on-glass analog circuits in LTPS process," *J. Display Technol.*, vol. 3, no. 3, pp. 309–314, Sep. 2007.
[9] Y.-S. Park, D.-Y. Kim, K.-N. Kim, Y. Matsueda, J.-H. Choi, H.-K. Kang, H.-D. Kim, H.-K. Chung, and O.-K. Kwon, "An 8 b source driver for 2.0 inch full-color active-matrix OLEDs made with LTPS TFTs," in *IEEE Int. Solid-State Circuits Conf. Dig. Tech. Papers*, 2007, pp. 130–132.
[10] T.-Y. Lee, C.-C. Chiu, Y.-C. Liu, C.-C. Liu, Y.-C. King, and C.-J. Lin, "A new embedded one-time-programmable MNOS memory fully compatible to LTPS fabrication for system-on-panel applications," *IEEE Electron Device Lett.*, vol. 29, no. 8, pp. 906–908, Aug. 2008.
[11] Y.-H. Yu, Y.-J. Lee, Y.-H. Li, C.-H. Kuo, C.-H. Li, Y.-J. Hsieh, C.-T. Liu, and Y.-J. Chen, "An LTPS TFT demodulator for RFID tags embeddable on panel displays," *IEEE Trans. Microw. Theory Tech.*, vol. 57, no. 5, pp. 1356–1361, May 2009.
[12] J.-E. Pi, C.-S. Pyo, B.-H. Kim, Y.-I. Kim, J.-H. Eom, J.-B. Choi, S.-I. Park, B.-W. Lee, Y.-G. Hwang, and C.-W. Kim, "Touch-panel controller implemented with LTPS TFTs," in *SID Dig. Tech.*, 2009, pp. 443–446.
[13] Y.-K. Choi, H.-R. Kim, W.-G. Jung, M.-S. Cho, Z.-Y. Wu, H.-S. Kim, Y.-H. Lee, K.-M. Kim, K.-S. Lee, J.-S. Kim, and M.-H. Lee, "An integrated LDI with readout function for touch-sensor-embedded display panels," in *IEEE Int. Solid-State Circuits Conf. Dig. Tech. Papers*, Feb. 2007, pp. 134–135.
[14] S. Takahashi, B.-J. Lee, J.-H. Koh, S. Saito, B.-H. You, N.-D. Kim, and S.-S. Kim, "Embedded liquid crystal capacitive touch screen technology for large size LCD applications," in *SID Dig. Tech.*, 2009, pp. 563–566.
[15] D. Johns and K. Martin*, Analog Integrated Circuit Design*. : Wiley, 1997.
[16] T. Nakamura, H. Hayashi, M. Yoshida, N. Tada, M. Ishikawa, T. Motai, and T. Nishibe, "A touch panel function integrated LCD including LTPS A/D converter," in *SID Dig. Tech.*, 2005, pp. 1054–1055.
[17] Mentor Graphics Corp., Warren, NJ, "Eldo simulation," 2007.

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