Design of Circuit for a Fingerprint Sensor Based on Ridge Resistivity

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Abstract—This paper proposes an advanced signal processing circuit for a fingerprint sensor based on ridge resistivity. A novel fingerprint integrated sensor using ridge resistivity variation resulting from ridges and valleys on the fingertip is presented. The pixel level simple detection circuit converts from a small and variable sensing current to binary voltage out effectively. The sensor circuit blocks were designed and simulated in a standard CMOS 0.35 μm process.

Index Terms—Ridge Resistivity, Fingerprint Sensor, CMOS integrated circuits, Ridge, Valley

I. INTRODUCTION

The fingerprint is known to be the most representative bio-metric for authentication of individual persons. Recently, some small, thin, and inexpensive direct-touch semiconductor fingerprint sensors have been proposed[2][3]. Some research organizations have published papers on semiconductor-based sensing schemes and demonstrated the possibility of a single-chip solution. The size and cost of the component make such a unit unsuitable for application to portable equipment.

For a decade, CMOS processes have been used to produce fingerprint sensor prototypes. Most of them rely on capacitive coupling between the finger and matrix of small metal plates to detect ridges and valleys on the finger surface. Each plate forms a pixel of the resulting image and requires circuitry to measure the capacitance using either DC [2] or AC [4] signals. Another sensing technique relying on thermal conduction of the finger's ridges and valleys has been developed [6].

These papers have described single chip sensing schemes based on capacitance variance measurement according to the distance from the chip's SiO_2 passivation layer to the ridges or valleys of the finger's skin. The main problems found by these approaches are the small capacitance variations versus the parasitic capacitance generated by the system's layers and the charge value uncertainty of the finger's skin. These problems are letting the finger's skin to touch a metal plate, which can in turn bring it to the desired potential before actual sensing is performed. Another advantage to use metal instead of SiO_2 is that the thickness of the material will not be a crucial issue, contrary it will enable to design the sensor foreseeing the normal worn-out that this type of sensor must withstand[5].

This paper proposes a sensor circuit where the property of human skin to conduct electricity is exploited to read fingerprints. Compared to the capacitive and thermal sensors, the skin resistivity method leads to a simpler pixel circuit while showing good sensitivity. The sensing scheme has a high sensitivity and a simple circuit structure for the restricted pixel area below a sensor metal.

The paper is divided as follows: section II presents the overall architecture of the sensor while section III followed by conclusions focuses on the proposed detection circuit blocks and simulation results, namely the pixel and the reading circuit.

II. SENSOR ARCHITECTURE

Present on the inner surface of the hands, fingers and the bottom area of the feet, is a type of skin which is different from the skin on other areas of the human body. This skin is corrugated, consisting of raised portions which are called ridges. These ridges do not run continuously from one side to the other, rather they curve, end, and split or divide in two or more ridges, that give every person and individual characteristic that is used for identification. As these ridges aid the fingers ability to grasp by increasing friction, this type of skin is known as friction skin.

On the tops of the friction skin ridges are very minute sweat pores which are constantly exuding perspiration. This perspiration adheres the outline of these ridges. Other substances, like oil from touching the face or hair, can also adhere to the ridges. This characteristic adherence, lead us to infer that the increased conductivity of this watery or oily outlined surface could be useful to sense the fingerprint with extra advantages to capacitance sensing scheme.

Fig 1 shows a resistivity sensor principle scheme. The fingerprint principle is based on the detection of the skin resistivity between the pixel pad selected by the shift register and the adjacent pixel pads connected to VDD.

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Skin resistivity varies from one person to another and depends also on skin humidity and mechanical pressure applied on the sensor. A skin resistivity varies from 1 MΩ to 8 MΩ in dry conditions. A resistivity of 100 KΩ has been measured in the case of humid skin. Therefore, the detection circuit must be able to detect skin resistivity varies from 100 KΩ to 8 MΩ[1].

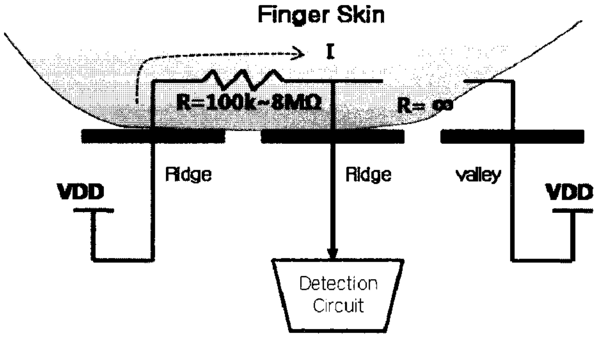

Fig. 1 Resistivity sensor principle scheme

There is a conventional ridge resistivity sensing circuit[1]. The conventional ridge resistivity sensing circuit has some problems. The reading bus output voltage cannot be uniformed by voltage drop in each pixel of wide sensor area. Also, the circuit includes a complex AGC(automatic gain controller), ADC and current mirror.

Fig. 2 shows the proposed bock diagram of a sensor array, the pixel plates are powered sequentially on a one by one and a row by biasis by two shift register blocks, so that only the inputs to the integrated sensor beside power will be clock and clear for the two shift register blocks. The output of the sensor metal will give a current level proportional to the conductivity of the watery or oily material that has been adhered to the ridge. As it will only touch the active plate, a current output will be available where a ridge is present. For a fingerprint ridge bridging the sensor metal2 to the sensor metal1, the current will flow from VDD to sensor metal2 via pass transistor, reaching the fingerprint ridge then entering to the sensor metal1. From there, the current will be steered to the pixel level detection circuit below the sensor metal via the transmission gate. The voltage obtained on the detection circuit will depend on the voltage drop caused by the skin resistivity which is the dominant resistance between VDD and the detection circuit. A transmission gate is used to connect a pixel pad to the detection circuit, in order to increase the voltage swing on the bus. At the beginning of the fingerprint sensing process, the fingertip will enter in direct contact with one or several pixel pads.

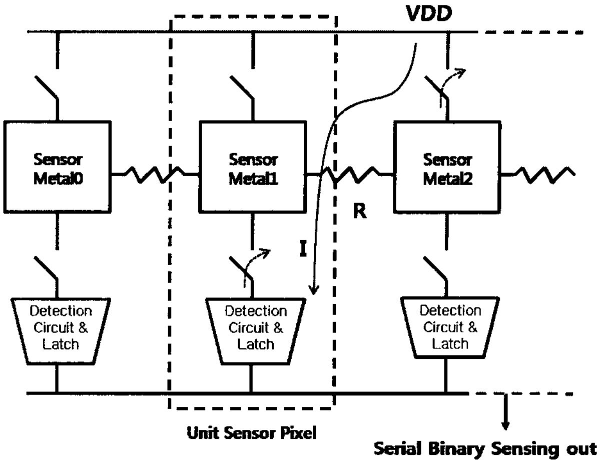

Fig. 2 Proposed resistivity sensor block diagram

A serial shift register toggles the sensor metal connections successively from VDD to the detection block. When a sensor metal is connected to the detection circuit block, a current flowing from the adjacent sensor metal connected to VDD, go through the surface of the skin and enter the selected sensor metal. The magnitude of this current will depend on whether a ridge or a valley of the fingerprint bridges the selected pixel to the adjacent ones. In the case of ridges, low skin resistance will be detected whereas for valleys nearly open circuits will be detected. The unit sensor pixel includes one sensor metal plate and detection circuit block. The detection circuit block is located below a sensor metal. A resistivity sensing scheme has a high sensitivity and a simple circuit structure for the restricted pixel area below a sensor plate.

III. DETECTION CIRCUIT DESIGN

Fig. 3 shows the proposed detection circuit. In a wet or dry ridge condition, the sensing current variation of 100 nA to 4 μA is obtained in node n1. The parasitic capacitance Cp includes a metal capacitance and gate capacitance of inverter and NMOS diffusion capacitance. Therefore, the voltage of node n1 is different in each fingerprint condition, wet or dry ridge. In this paper, we applied 100k ohm in a wet ridge and 8M ohm in a dry ridge and 1G ohm in a valley. Inverter of node n1 has low logic threshold voltage for a fast sensing in a dry ridge. Obtained sensing voltage is latched by signal ydec. The signal, xdec and ydec are generated from two shift registers. DRIVER drives a output voltage from a sensor pixel to tri-state BUS.

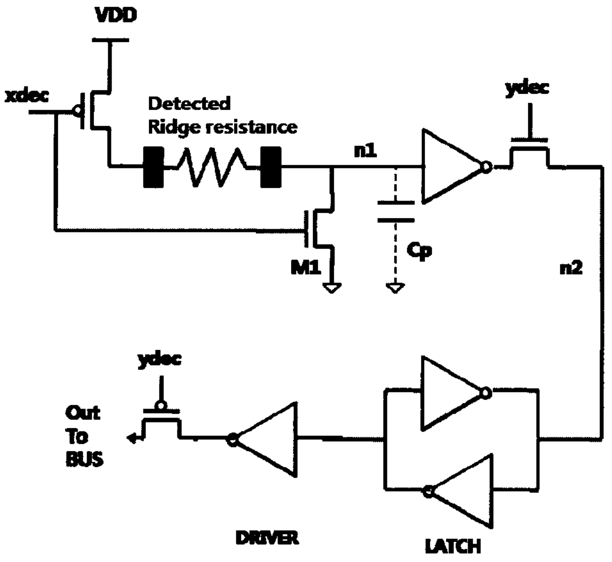

Fig. 3 Proposed detection circuit

Fig. 4 shows a timing diagram of the detection circuit. When xdec signal is high, node n1 is precharged to 0 voltage. When xdec signal is low, node n1 is charged to a ridge voltage slowly. Sensing time Ts is longer in a dry ridge because of the big skin resistance. When ydec signal is low, valid output value is generated. In a ridge, output is low and high in a valley. External microcontroller can control an image quality by data transfer time Td adjustment.

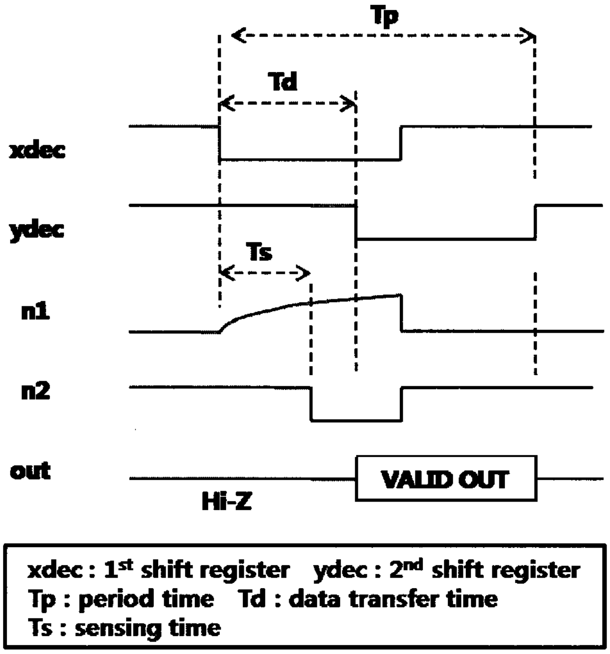

Fig. 4 Timing diagram

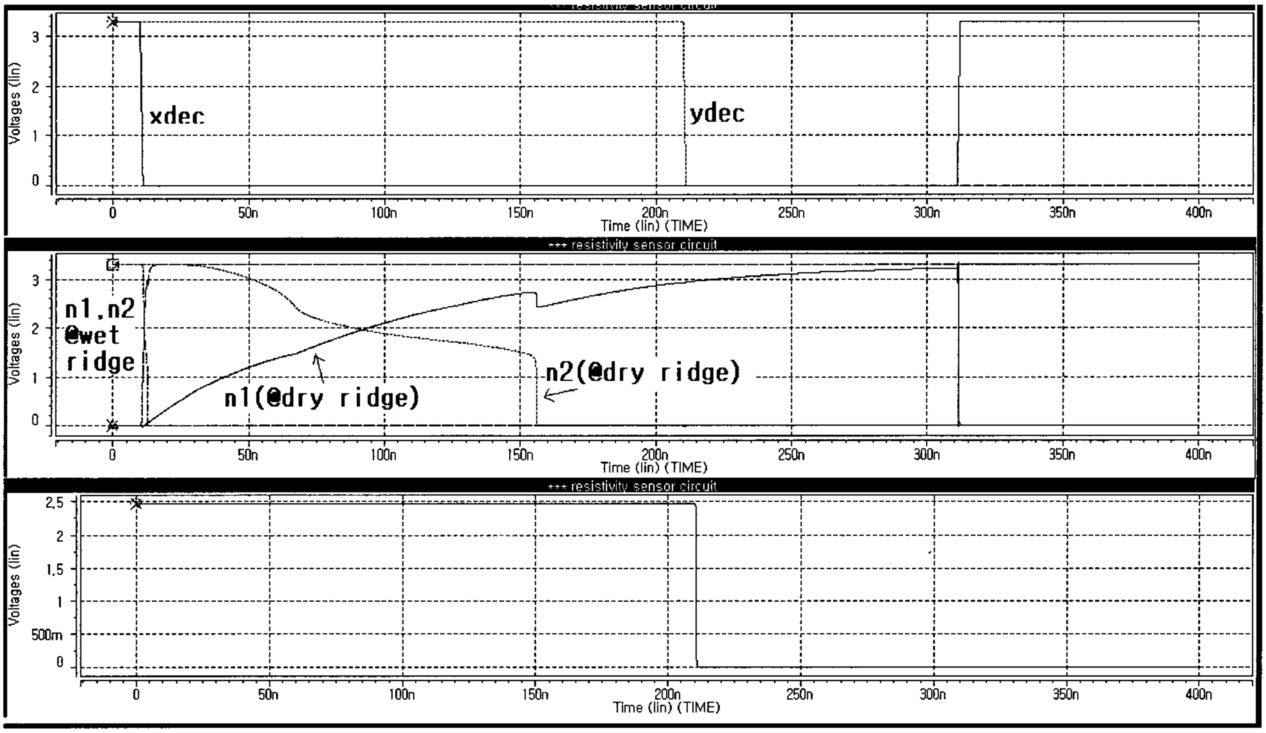

Fig. 5 Simulation result of detection circuit(at ridge condition)
(3.3V typical process of 0.35um CMOS)

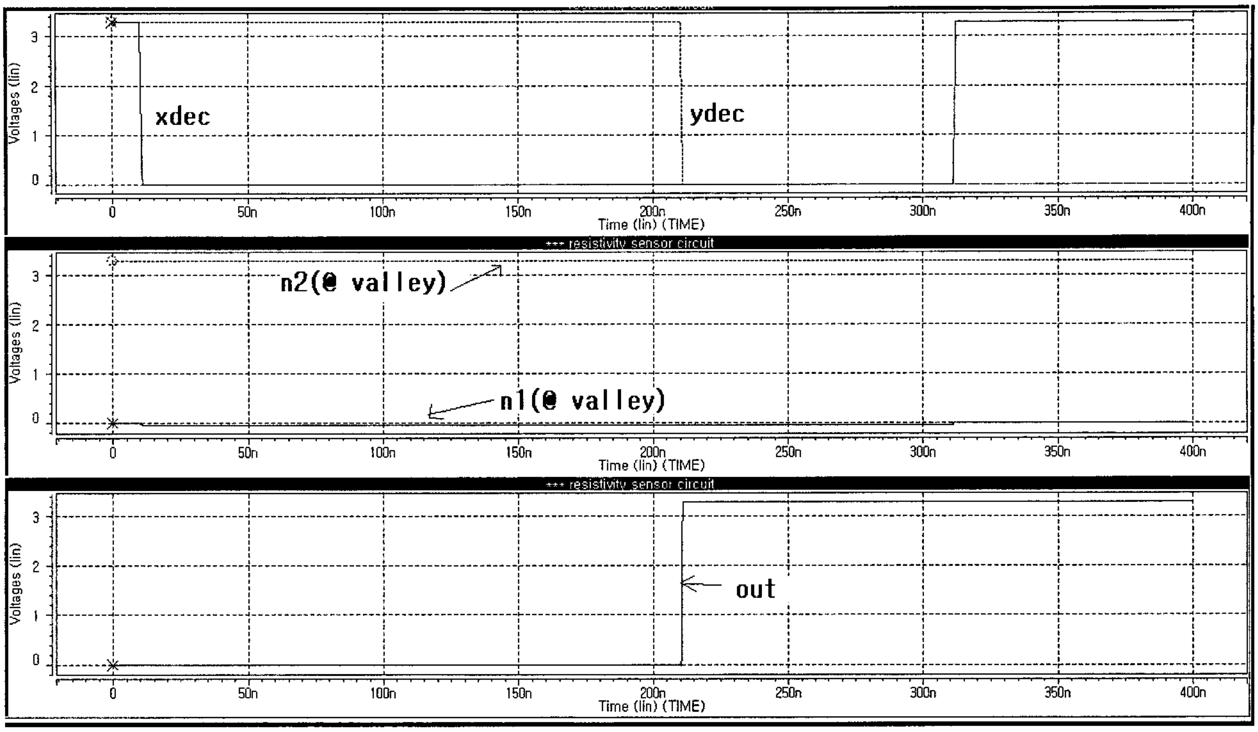

Fig. 6 Simulation result of detection circuit(at valley condition)
(3.3V typical process of 0.35um CMOS)

SPICE simulations were performed on the whole sensing circuit. Fig. 5 shows a simulation result of detection circuit in a ridge condition. The n1 voltage is charged slowly because of the big dry ridge skin resistance. Sensing time Ts is about 155ns. The total scan time will be less than 10ms in the 250x200 pixel array size of a conventional sensor. Therefore, Ts is not dominant in a fingerprint full sensing time. In general, a fingerprint sensing time is less than 1 second. Fig. 6 shows a simulation result of detection circuit in a valley condition. There is no transition in node n1 because of open circuit.

IV. CONCLUSIONS

A novel fingerprint sensor based on the principle of skin resistivity variation due to a ridge and valley of the fingertip contacting a metal tip has been presented. A serial shift register toggles the sensor metal connections successively from power to the detection block. When a sensor metal is connected to the detection circuit block, a current flowing from the adjacent sensor metal connected to power, go through the surface of the skin and enter the selected sensor metal. The simple and effective detection circuit is designed. The detection circuit is composed of sensing inverter, latch, precharge transistor, switching transmission gate and driver. External microcontroller can control an image quality by data transfer time Td adjustment. HSPICE simulations are performed with the model file of the CMOS 0.35 μm process have shown the proper functionality for skin resistivity varying from 100 KΩ to 8 MΩ. Sensing time Ts is 155ns. The total scan time is expected less than 10ms in a 250x200 pixel array size of conventional sensor. The image identification algorithm is under development and full chip implementation will be the topic of a future paper.

ACKNOWLEDGMENT

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REFERENCES

[1] Yves Audet, Laurent Aubray, Dominique Blouin, “A CMOS Fingerprint Sensor Based on Skin Resistivity,” Circuits and Systems, 2006 IEEE North-East Workshop on Volume, Issue , pp269 – 272, June 2006.

[2] S.-M. Jung, J.-M. Nam, D.-H. Yang, and M.-K Lee “A CMOS Integrated Capacitive Fingerprint Sensor With 32-bit RISC Microcontroller,’’ IEEE Journal of Solid-State Circuits, vol. 40, no. 8, pp. 1745–1750, Aug. 2005.

[3] R. Hashido, A. Suzuki, A. Iwata, T. Okamoto, Y. Satoh, A. Inoue, “A capacitive fingerprint sensor chip using low-temperature poly-Si TFTs on a glass substrate and a novel and unique sensing method”, IEEE J. of Solid-state circuits, vol. 38, No. 2, pp274 – 280, Feb. 2003

[4] O. Vermesan, K. H. Riisnaes, L. Le Pailleur, J. B. Nysaether, M. Bauge, H. Rustad, S. Clausen, L.-C. Blystad, H. Grindvoll, R. Pederson, R. Pezzani, and D. Kaire, "A 500-dpi AC Capacitive Hybrid Flip-Chip CMOS ASIC/Sensor Module for Fingerprint, Navigation, and Pointer Detection With On-Chip Data Processing", IEEE Journal of Solid-State Circuits, vol. 38, no. 12, pp. 2288-2296, Dec. 2003.

[5] Olavarrieta Fritsche, G., Nakano Miyatake, M., "A simple fingerprint sensor based on ridge conductivity," Design of Mixed-Mode Integrated Circuits and Applications, 1999. Third International Workshop on, Volume , Issue , 1999, pp207–209, 1999.

[6] http://www.atmel.com/products/Biometrics

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