Design of Efficient CMOS Fingerprint Sensors Using MEMS Technology

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Abstract:

This paper describes the Performance of Efficient high speed and low cost fingerprint sensor system and reports on the development of a tactile fingerprint sensor made by a CMOS compatible front side bulk micromachining technology for high performance fingerprint sensor. And also this report deals with the field of micro-electromechanical systems or MEMS. MEMS encompass the process-based technologies used to fabricate tiny integrated devices and systems that integrate functionalities from different physical domains into one device. MEMS has evolved over the past decade and it has come out as a possible technology for mobile, satellite communication and wireless applications. And we also discuss about the general operating principle of the tactile fingerprint sensor in detail. The device enables the measurement of a fingerprint by the path of a mechanical scanning principle of the finger roughness. A modified circuit of charge sharing scheme is proposed, which demonstrates a decrease of power use of goods and services and better improvement of difference between a valley sensing and ridge voltage than typical system. In this paper also proposes an effective fingerprint identification system with hardware unit (thinning processor) for thinning stage processing of a verification algorithm based on minutiae.

I. INTRODUCTION

Traditional automatic personal identifications, such as personal identification numbers (PINs), identification cards, and keys are no longer satisfactory for recent security requirements. Biometrics, the automatic identification of a person on the ground of certain physiological or behavioural characteristics, is one of the technologies that can be utilized to the fulfilment of security requirements, because each person possesses unique features that are relatively invariant over time. Some research organizations have issued papers on semiconductor-based sensing schemes and demonstrated the possibility of a single-chip solution. A capacitive fingerprint sensor uses a capacitive sensor array to find fingerprints. The name 'capacitive' comes from the fact that the finger skin and the sensor electrode produce a capacitor whose capacitance is defined by the length from the chip surface to the finger skin A commission-sharing sensing scheme has a high sensitivity and a simple circuit structure for the restricted pixel area below a sensor plate. The paper proposed the removing of parasitic capacitance using unit-gain buffer, and paper proposed the improvement of difference between a ridge and valley detection voltage using a feedback resistor. This report offers a modified circuit for reduction of the static power dissipation. A fingerprint verification algorithm has two phases: enrolment and confirmation. In the offline enrolment phase, an enrolled fingerprint image is pre-treated, and the minutiae are extracted and laid in. In the on-line verification phase, the similarity between the enrolled minutiae and the input minutiae is examined.

In that respect are three steps involved in the confirmation process:

1) Image pre-processing and statistical analysis,
2) Minutiae extraction, and
3) Minutiae matching.

Conventional fingerprint authentication hardware and software system needs a high performance microcontroller such as 32-bit ARM7, or ARM9.

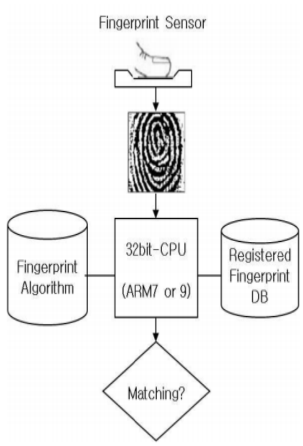

Figure 1 Typical fingerprint identification systems

This paper proposes an effective hardware unit for thinning stage processing of fingerprint identification from analyzing of algorithm cycle distribution. A thinning algorithm changes a binary fingerprint image to one pixel width. Hardware processing is more effective than software algorithm in speed, because a thinning algorithm is an iteration of simple instructions.

A. Biometrics

BIOMETRICS is the techniques used to identify an individual by the extraction of physical or behavioural parameters peculiar to him. Biometric recognition is envisaging new solutions using constant features of the user's body with the convenience that they cannot be misplaced, forgotten or stolen. Biometric techniques are for example the recognition of the human language; the features of the font or the hand, palm, the shape of the iris and of course the fingerprints

B. *Fingerprints*

Fingerprint recognition is the oldest biometric technique and criminal science has been using it for more than 150 years. A typical fingerprint includes several singular points so called minutiae (generally a figure from 12 to 30). These specific points correspond to the places of ending, bifurcation or crossover of ridges and vales of the finger.

C. *Fingerprint Sensors*

Typical fingerprint recognition systems are based on an optical measurement of the finger. On these systems, the digit is identified along a transparent prism and the picture is brought through a camera.

The measurement principle is the detection of a deviation of electrical capacity between contact and non contact parts of the finger on the gimmick. Some alternative techniques using optoelectronic, pyroelectric, thermal or ultrasonic transduction mechanisms have also presented interesting results.

D. *Sweeping Mode Fingerprint Sensors*

Solid state fingerprint sensors that require direct contact with the finger must be of large surface which is a disadvantage in terms of price. Sweeping mode fingerprint sensors, like the sensor presented in this paper, is a expert solution to create some compact and low cost devices. Most sweeping mode sensors use a partial matrix containing a concentrated number of seams (typically 40 courses). The final picture is then recomposed using a superposition technique.

D. *Micro Electro Mechanical Systems (MEMS)*

MEMS is a process technology used to create the tiny mechanical devices or systems, and as a result, it is a subset of Micro System Technology. And is traditionally defined as Combination of mechanical and electrical components which provide a completely functional system In the context of emerging technologies, MEMS products were initially centred on technology-product paradigms rather than product-market paradigms. Consequently, MEMS devices have found numerous applications across a diversity of industries.

E. *MEMS Technology Platforms*

Especially for products aiming at high volume electronic markets such as consumer electronics, manufacturers continuously try to refine production methods to deliver highly reliable products, while meeting pricing pressures. They have adopted a variety of strategies to use as much as possible the already available, well established, reliable and cost-effective technologies used in high volume electronics and combine them with MEMS technologies.

i. Bulk Micromachining (based on KOH etching)

ii. Surface Micromachining Based on Polysilicon

iii. Surface Micromachining Based on SOI

iv. Surface Micromachining Based on Metal Thin Films

II. FINGERPRINT SENSOR DESIGN

The finger is modelled as the upper electrode of the condenser, and the metal plate in the sensor cell as the lower electrode. These two electrodes are separated by the passivation layer of the silicon chip and air. The series -connected capacitor CF is composed of a capacitance between the metal shell and chip surface and another one between the chip surface and the finger skin. As the length between the chip surface and the finger's skin increases, the capacitance becomes smaller.

III. TACTILE FINGERPRINT SENSOR

a) Working Principle

The sensor presented here has two main features with respect to standard industrial solutions: it is a sweeping sensor and it is a tactile, e.g., mechanical sensor. The tactile measurement is based on the use of piezoresistive microbeams (cantilevers).

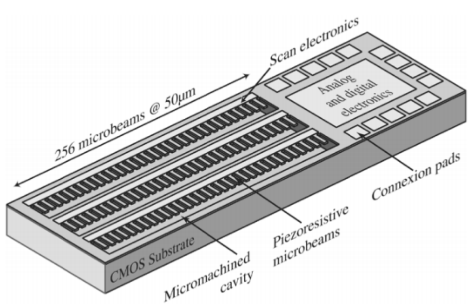

Fig.2 Schematic view of the tactile fingerprint sensor

Such micro beams have been successfully employed in several applications such as magnetic field sensing or gaseous chemical species detection. It takes three lines of sensing elements placed besides the electronic components and the bonding pads. The process of fingerprint acquisition with this sensor is shown in Fig. 2. First, the user sweeps its finger on the sensing element, placed perpendicularly to the focal point of the trend. During this step, the ridges and the valleys that compose the fingerprint will induce deflections in the different microbeams of each line of the sensor. The resistance variation of each piezoresistive gauge is transformed into a voltage variation. A shift register placed on tip of each row will switch the signal created by the microbes to a transmission line that feeds the analogy amplification chain.

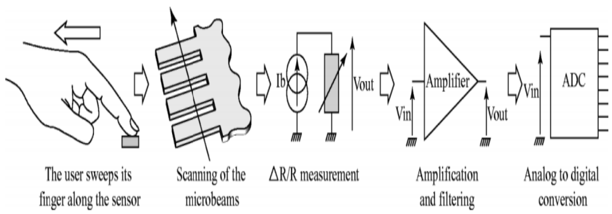

Fig. 3. Fingerprint sensor working principle.

b) Tactile Measurement

Unlike many other integrated fingerprint sensors, the device presented here employs a mechanical measurement principle. Some old works have shown tactile fingerprint sensors using an array of capacitive pressure sensors or tactile sensors. The finger is pressed and swept along the sensor with user defined pressure and speed. A thin polymer film is placed along the airfoil of the sensor for protection against pollution and erosion. This film acts as an significant function in the transduction, since it will smooth the profile of the finger. Elasticity, thickness and the nature of polymer/skin contact will affect the global sensitivity of the gimmick

At the conclusion of the transduction chain, the microbeams stiffness and the gauge sensitivity (discussed in Section II-C) will occupy an important role in the global sensitivity. The resulting image given by the sensor will be the convolution of the real finger surface through this transduction chain

IV. MEMS- CMOS COMPATIBLE BULK MICROMACHINING TECHNOLOGY

A versatile MEMS process which can be easily combined with standard CMOS processes. The sensor is made by means of CMOS-compatible front side bulk micromachining (FSBM) technology. With this process some relatively simple but robust products such as pressure sensors and accelerometers, micro mirrors, flow sensors and bolometer can be fabricated. Although this technology platform has the advantage that it does not need large equipment investments, the technology is difficult to integrate with CMOS, it is time consuming, and the fragile wafers are difficult to handle. The FSBM technique consists in designing openings through the different CMOS layers so as to obtain naked silicon areas. This stable low-cost MEMS technology allows integrating the sensor part and electronic circuits in the same chip.

V. MEMS FINGERPRINT SENSOR

We propose the MEMS fingerprint sensor as shown in Fig. 1. A finger touches the sensor surface where a large number of small pixels are arrayed. The detailed structure of the sensor is shown in Fig.4 (a). The pixels have MEMS structures stacked on the sensing circuits. Each MEMS structure comprisesa protrusion, a cavity, a pair of electrodes, and a grounded wall. The upper electrode and sealing layer are made of metal and dielectrics, respectively, and are deformable thin films. The protrusions are also made of dielectrics. The upper electrode is grounded through the grounded wall. The sensor works as follows.

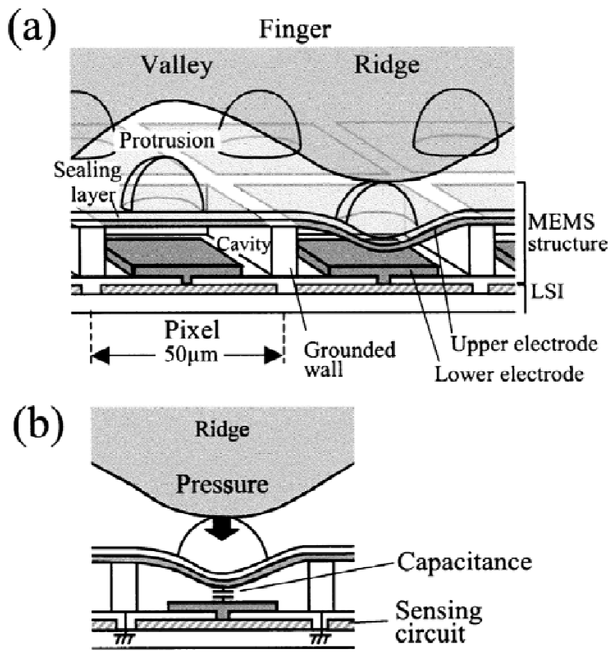

Fig. 4. (a) MEMS structure with cavity in the MEMS fingerprint sensor. (b) Its sensing mechanism.

The ridge of a finger surface pushes the protrusion down, and the protrusion deflects the upper electrode as shown in Fig.4(a). The protrusion transfers the pressure from a finger to the center of the upper electrode. The deflection of the upper electrode increases the capacitance between it and the lower electrode. Then, the capacitance is converted into the output voltage of the sensing circuit just under the lower electrode. The value of the output voltage is translated into digitized signal levels.

On the other hand, the valley of a finger surface does not push the protrusion, and the capacitance is kept small. Therefore, the Capacitance under a ridge is larger than that under a valley. These values of the capacitance are translated into the digitized signal levels. With this sensing, the detected signals from all the pixels generate one fingerprint image. We had to design the MEMS structure and determine the structural parameters so that the sensor would produce the maximum capacitance change for a certain pressure from a finger surface. We also had to develop a new sensor fabrication process because the MEMS structure is stacked on the sensing circuits and has a cavity. It is necessary to fabricate the MEMS struc ture without damaging the underlying sensing circuits and seal the cavities to keep the water and contaminants out of the cavities. Next, we describe the structural design and the fabrication process of the MEMS fingerprint sensor.

VI. IDENTIFICATION ALGORITHM AN THINNING PROCESSOR DESIGN

Micro electro-mechanical devices allow engineers to make extremely tiny silicon switches. When a ridge touches a switch, it closes. But the coating remains a significant problem, and moreover, a binary image is the result, leading to minimal information. No further development has been done with this technique beyond the laboratory

A fingerprint image obtained from a fingerprint sensor has the picture distortion and noise in it. Gabor filter is strongly urged to get improved image and reduce a noise level. It arrived at the image more effective to take out the minutiae from it. Before it is applied to the image, frequency and direction of the icon should be calculated to emphasize unique features and make ridge clear. A one-pixel wide skeleton image is brought forth by changing thick ridge pattern to a one-pixel line, which is called thinning stage. Minutiae mean ridge ending or bifurcation of fingerprint images. Later all the true minutiae of the image are detected, these characteristics are stored in a pattern file.

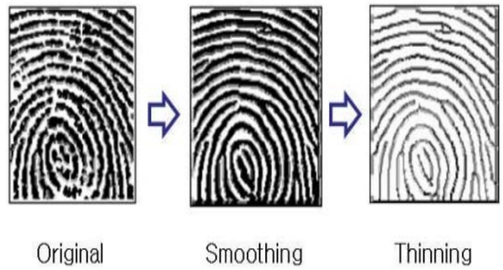

Fig.5 Fingerprint image pre-processing stages

This report suggests an effective hardware scheme for thinning stage processing of a fingerprint recognition based on minutiae from analyzing of algorithm cycle distribution. The cycle distribution of each algorithm step is analyzed in FPGA environment. Hardware processing is more effective than software one in speed, because a thinning algorithm is an iteration of simple instructions

a. Measured Fingerprints

A first analysis of these images indicates the high dividing line (nearly black and white) obtained with the detector. The crack of a bug may pass during the manufacturing process, primarily in the anisotropic etching post process or during the operation when the protective film is transferred from the airfoil. The detector does not require any background cancellation procedure or calibration step. Some other tip that appears on these images is the non uniformity of the front of the finger that is the primary problem of one row sensors. This problem can be resolved by performing a measurement of the finger speed either by including a specific device on the sensor or by utilizing the three rows and an additional computing step to rebuild the icon.

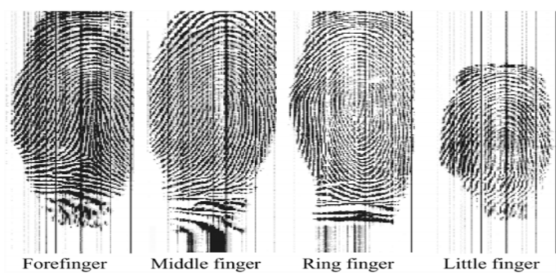

Fig.6 Rough images measured from the sensor for the digits

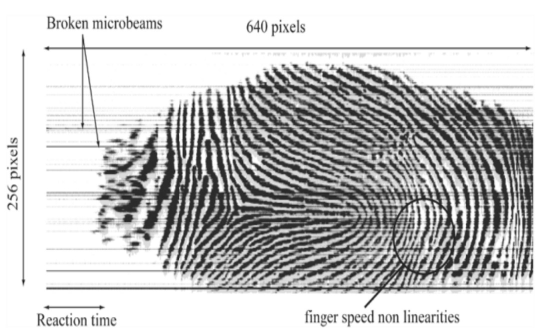

Fig. 7 Measured fingerprint of the forefinger.

b. Analysis of Algorithm

We implemented general purpose ARM7 compatible RISC microcontroller by FPGA to verify proper operation of the proposed fingerprint algorithm. The checkpoint routines successively turn on one of 8 LEDs on the emulation board. We finally confirmed that our embedded 32-bit RISC core successfully carried out the fingerprint authentication algorithm.

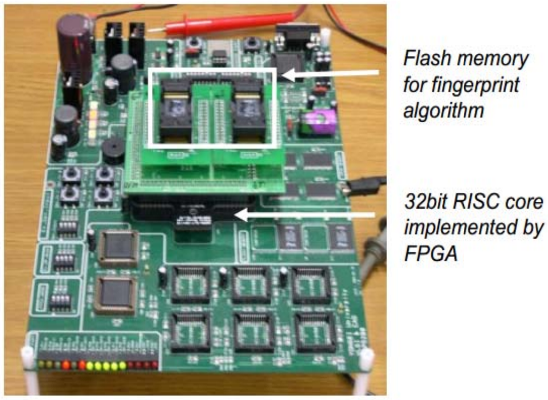

Fig. FPGA Emulation Board For Verifying The Algorithm

c. Thinning Processor Design

A thinning algorithm changes a binary fingerprint image to one pixel width. Hardware processing is more effective than software algorithm in speed, because a thinning algorithm is an iteration of simple instructions. In the past several decades, many thinning algorithms have been broken. In parliamentary law to cut the amount of information minimally, a thinning algorithm plays an important role in recognition of fingerprint images. The well-proved thinning algorithms are ZS (Zhang and Suen).

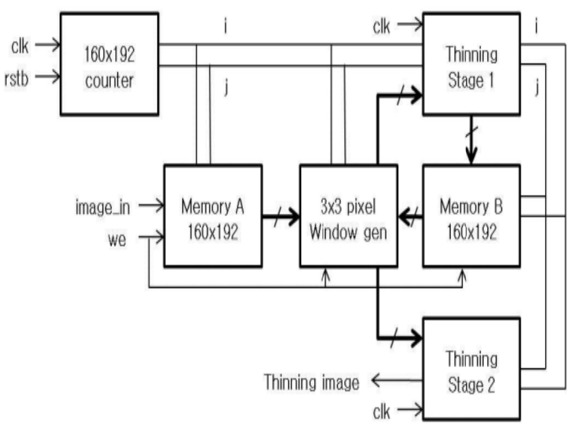

Figure. Block diagram of thinning processor

VII. CONCLUSION

We have presented in this paper the design and test of an integrated tactile fingerprint sensor made with a CMOS compatible bulk micromachining technology for the proposes the modified scheme of capacitive charge-sharing fingerprint sensors for low power use. The monumental nature of sensor allows the integration in the same silicon substrate of MEMS microstructures and the signal conditioning analogue interfaces together with digital cores. The modified capacitive detection circuit of charge sharing scheme includes the logic gate with a small size transistor to accelerate fast sensing of comparator. This high degree of integration offers many advantages such as low cost, reproducibility and miniaturization. Further works will target the driving of the sensor by a microcontroller and the carrying out of the dedicated algorithms for the signal conditioning, fingerprint identification, enrolment and matching that are in development at the lab. We expect approximate maximum 40% improvement of algorithm speed and replacement 32bit CPU by 16 or 8bit CPU, low power consumption and small size fingerprint system from the result.

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