" OPTOELECTRONIC FINGERPRINT SENSOR FOR MOBILE PHONES"

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ABSTRACT

A optoelectronic fingerprint ID solution has been developed for mobile phones. This rugged, ultra-miniaturized optical sensor can be configured to be installed in the corner of the cell phone case. Biometric fingerprint sensing will reduce cell phone theft, and allow user identity verification for financial transactions and database access. Multifunctionality is supported to allow cursor control, scanning of bar codes or scanning of URL addresses (for OCR reading). The proprietary sensor chip interfaces directly to the DSP microprocessor bus in the mobile phone.

Key words: ID, identity, fingerprint, biometric, sensor

BACKGROUND

The rapid evolution of mobile phone technology and the introduction of m-commerce and m-banking services has placed new emphasis on user ID technology. To access such services, a 4-digit PIN number provides only low security – and 6-8 digit PIN numbers (frequently changed) are too inconvenient. Alternatives such as voice recognition or dictating a pass-phrase are unreliable (due to background noise), awkward and too public. Several mobile phone manufacturers have concluded that miniature fingerprint sensors are the logical choice, and are planning to incorporate biometrics into high-end mobile phones in early 2003. Such widespread deployment of biometrics is unprecedented, and may enable the mobile web to leap ahead of the PC based Internet for financial transactions.

REQUIREMENTS

A fingerprint sensor designed for incorporation into a mobile phone must meet many demanding requirements. These include:

- Low cost < $5US
- Low profile <3mm
- Small area
- Low power
- Rugged (impact, moisture, ESD)
- Withstand temperature extremes
- High quality biometric
- Ease of use
- Works with dry or small fingers
- Difficult to spoof

TRADITIONAL OPTICAL FINGERPRINT SENSORS

Traditionally, an optical fingerprint sensor employs a prism platen that allows the fingerprint to viewed at a 45 degree angle, using LED illumination. A conventional lens system is used to focus a high contrast fingerprint image onto an area array sensor chip. Image processing software is used to extract features (typically minutiae – bifurcations & terminations of fingerprint ridges) from the fingerprint, which are then used for matching fingerprints. The advantage to an optical fingerprint sensor is that superior image quality is obtained. The disadvantage is the 'optical bulk' needed to obtain the proper focal length for the lens system – meaning that the optical sensor is too large for mobile phones.

MINIATURE OPTICAL SWEEP SENSOR

A new, miniaturized optical fingerprint sensor system (US Patent 6,259,108 and others) has been developed, where a linear array CMOS sensor is employed to image the fingerprint. To focus the fingerprint onto the sensor, a very small GRIN (gradient index) linear array lens system is used, which is similar to (but much smaller than) the lens array typically used in fax machines. The linear array fingerprint sensor system is thus dramatically reduced in size.

To use the sensor, the finger is swept across a "speed bump" platen (instead of being placed on an area platen). In practice, a desirable ergonomic design features the "speed bump" of the platen protruding from a slot in the panel surface, preferably in a slightly depressed groove to guide the finger motion.

Figure 1. Optical Sweep Sensor with Finger Guide

"PANEL SENSOR" for MOBILE PHONES

The "panel sensor" can be mounted in the front panel of a mobile phone case.

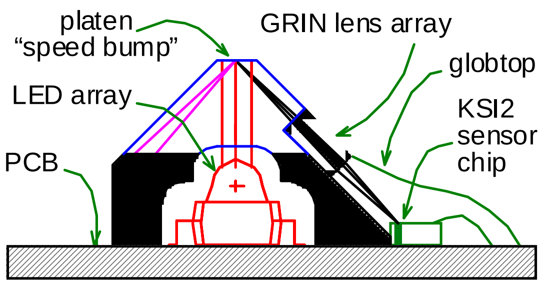

Figure 2. Diagram of Panel Sensor

Figure 2 shows a diagram of the Panel Sensor. The LED array shines straight upward, illuminating the skin of the finger. The GRIN lens array is focused on the platen; if a finger is present on the platen then glowing fingerprint ridges are imaged onto the linear array sensor chip; if no finger is present on the platen, only a black background is viewed.

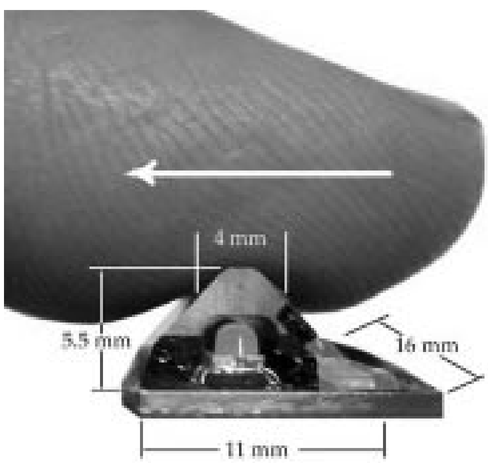

Figure 3. Photo of Panel Sensor

Figure 3 shows a photo of the Panel sensor. The narrow platen concentrates pressure on the skin of the finger, allowing good optical contact even for dry fingers.

Figure 4. Panel Sensor in Cell Phone Mockup

Figure 4 shows a mock-up photo of a panel sensor installation (in place of a roller cursor control) on a mobile phone. The fingerprint sensor can also perform pointer functions. In the hinge area of the phone is a finger groove, which helps guide the finger-sweep motion.

"CORNER SENSOR" for MOBILE PHONES

Since the new sweep sensor is optical, it can be designed in various form factors by folding the optical light path, to accommodate specific requirements. A new type of "corner sensor" has been designed which can be mounted in the corner of a mobile phone case, using a minimum of panel space. The corner sensor is manufactured in a vertical transfer mold with optically transparent epoxy encapsulating all components, forming a single sensor system for BGA SMT or flex cable attachment.

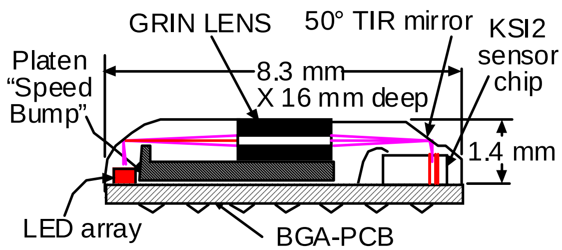

Figure 5. Diagram of Corner Sensor

Figure 5 shows a diagram of the Corner Sensor. In this configuration, the LED array reflects light off of the interior surface of the platen. where it is focused by the GRIN lens onto linear array sensor, providing a bright background when no finger is present. To make a low profile design, a 50 degree TIR (total internal reflection) mirror is used to reflect the image onto the linear array sensor chip.

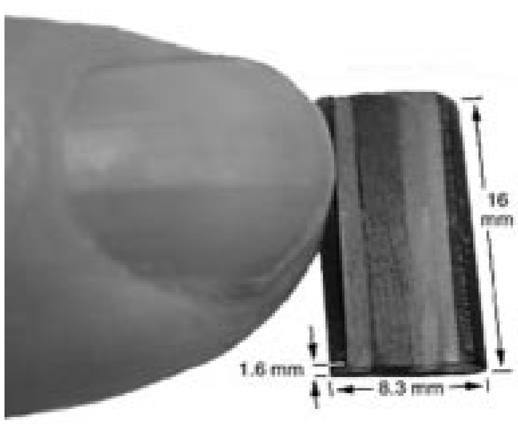

Figure 6. Photo of Corner Sensor

Figure 6 shows a photo of the corner sensor. For the corner sensor, the optical platen is at a 45 degree angle to the flat top of the sensor assembly.

Figure 7. Corner Sensor in Cell Phone Mockup

Figure 7 shows a mock-up photo of a corner sensor installation in a mobile phone. Fingerprint scanning is accomplished by sweeping the finger over the upper corner of the phone. In this configuration, the corner sensor can also be used for bar code or OCR scanning – by dragging the phone across the surface of the paper. .

IMAGE RECONSTRUCTION ALGORITHM

Since the finger is swept at a varying speed across the optic platen, the image will be distorted in the vertical direction, unless geometric correction is applied. A patented algorithm (US Patent 6,002,815 and others) is used for image reconstruction. The silicon sensor chip has two linear arrays, which are spaced apart. As the finger is swept across the sensor, image data appears first on linear array A and then subsequently on linear array B. A correlator is used to determine how long it takes for image data on A to re-appear on B (according to the scan rate clock), allowing an instantaneous calculation of finger sweep speed. The variations of finger sweep speed are then used to decimate unneeded image lines to produce a geometrically correct fingerprint image. Figure 8 provides a diagram of the image reconstruction algorithm.

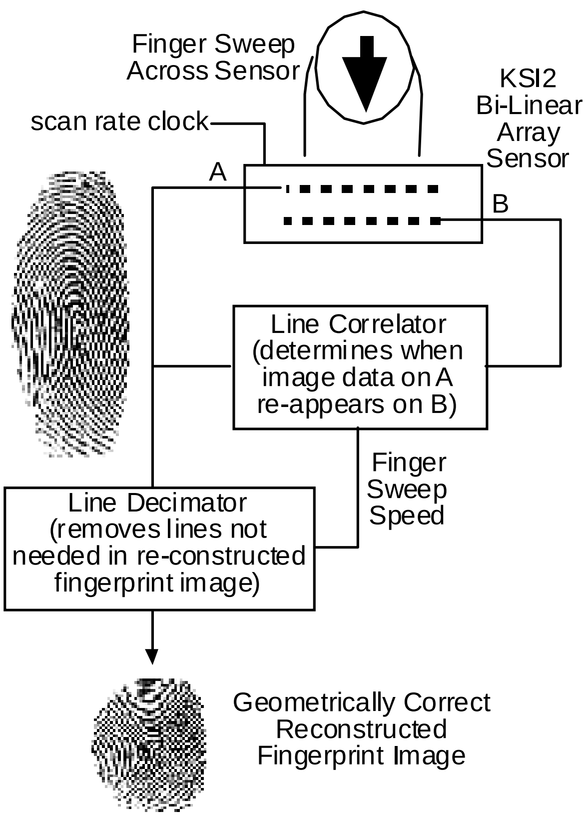

Figure 8. Image Reconstruction Algorithm

AGC & AUTOMATIC RESOLUTION SWITCHING

Automatic gain control (AGC) is essential to handle the very wide range of finger types, from moist (dark) to dry (faint). The AGC algorithm measures the gray scale distribution in the image (as the finger is being swept across the platen) and accommodates a dynamic range of 20:1 analog gain adjustment in real time.

The historic FBI standard for fingerprint images is 500 dpi. For the optical sweep sensor, automatic resolution switching is used to view small fingers at higher resolution – typically 750 dpi. This is especially helpful for reliable recognition of children and Asian women, who may have fingerprints with 25% the area of a Caucasian male.

INTEGRATION OF SENSOR IN MOBILE PHONE

The linear array sensor chip is designed to interface to an 8 bit microprocessor data bus as if it were memory (tri-state logic on outputs). No additional "glue logic" is required. The sensor chip has a 2KB FIFO buffer, which allows the microprocessor in the mobile phone to demand data from the sensor when it is ready to receive it (instead of being "data driven" by the sensor). The linear array sensor chip is controlled by a SPI interface from the microprocessor. Variables such as integration time, analog gain, and resolution can be controlled in real time by the microprocessor in the phone.

The physical integration of the fingerprint sensor assembly in the mobile phone can be either a panel sensor (Figure 3) or a corner sensor (Figure 6). For the panel sensor, the speed bump of the platen protrudes above the case of the phone. For the corner sensor, the speed bump of the platen is incorporated into corner of the cell phone case. Many other form factors are possible, depending on product requirements.

FINGERPRINT MATCHING

Biometrics depends on measurement and statistical matching of specific natural characteristics of an individual. Fingerprint feature extraction and matching can occur either locally in the mobile phone, or remotely over a network identity server – or both. The matching process can be either identification (selecting the correct person from a group) or verification (checking that a single person is really who he claims to be). Fingerprint feature extraction is the process of selecting minutiae (bifurcations and terminations of fingerprint ridges) or by templates (shape patterns) which carry sufficient unique identifying information. Usually feature extraction is computationally intensive, while matching is quick. For user acceptance, feature extraction and matching should take less than 1 second. For mobile phones, the local microprocessor can perform feature extraction and matching, and/or the microprocessor can also encrypt the feature set and transmit it to a remote identity server for matching. Many mobile phone manufacturers have developed their own feature matching and extraction software.

SUMMARY

A novel optical fingerprint sensor has been demonstrated, which uses finger-sweep motion to present the entire fingerprint to a linear array sensor. High quality, high contrast optical fingerprint images are obtained, which can be at 1000, 750, 500 or 250 dpi with 8 bits of gray scale. The sensor is exceptionally rugged, can stand immersion, impact, 27 KV ESD, and +60 to –20 degrees C. The optical design allows flexible form factors for panel and corner sensors. The CMOS sensor chip is compatible with most microprocessors.

CONCLUSION

Verification of identity using fingerprint sensing is now a practical, rugged, low cost option for mobile phones.