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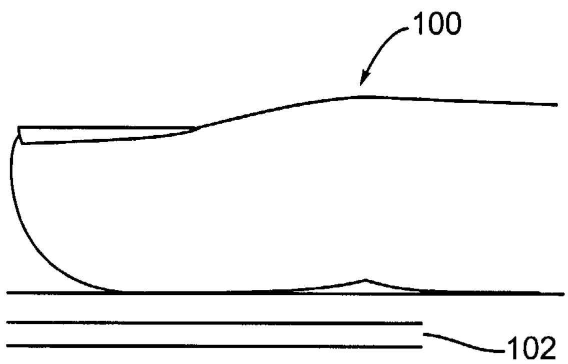
(54) Title: METHOD AND APPARATUS FOR DETECTING THE PRESENCE OF A FINGER ON A FINGERPRINT MINUTIAE-SENSING DEVICE



(57) Abstract: A method and apparatus for detecting the presence of a finger on a biometric minutiae sensor is disclosed. According to one embodiment, one or more capacitive sensing strips are disposed on a biometric minutiae sensor. A low frequency clock periodically charges and then discharges the one or more capacitive sensing strips. After a predetermined period, a charge remaining on the capacitive strips is sampled and then compared to a threshold charge. If the sampled charge exceeds the threshold charge then a switch enables a higher frequency clock so that the biometric minutiae sensor is enabled. A finger sensing electronics is also disclosed, which, in one embodiment, includes the one or more capacitive sensing strips and a frequency switch. In still another embodiment, the finger sensing electronics further includes a comparator configured to enable or disable the frequency switch.

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TITLE OF THE INVENTION

METHOD AND APPARATUS FOR DETECTING THE PRESENCE OF A FINGER ON A FINGERPRINT MINUTIAE-SENSING DEVICE

BACKGROUND

1. Field of the Invention.

The present invention relates generally to biometric sensors and, more particularly to a method and apparatus for detecting the presence of a finger on a biometric minutiae sensor.

2. Background Information.

Figure 1 illustrates a finger 100 being placed on a fingerprint minutia-sensing device 102. One such device is disclosed in U.S. Patent No. 5,325,442 by Knapp (the '442 patent).

A more detailed illustration of a solid state device 102 is shown in FIG. 2. Device 102 is a capacitive direct contact sensing device that consists of individual fingerprint minutiae detection sensors 200 arranged in rows 204 and columns 208 so as to form an array of m x n sensors 200. In one example of such a sensing device 102, each sensor 200 acts as one plate of a capacitor, while a finger 100 acts as the other plate. A passivation layer on device 102 acts as the dielectric between the two plates.

In operation of the device 102, a fingerprint image is captured one sensor 200 at a time. Typically, the sensor scans one row 204 at a time. The relative depth between ridges and valleys of the fingerprint can be determined using the equations:

$$C = k\frac{A}{d} \quad (1),$$

$$i = C\frac{dv}{dt} \quad (2), \text{ and}$$

$$v(t) = \frac{1}{C}\int_{-\infty}^{t} i(t)\cdot dt \quad (3).$$

Where C is the capacitance in farads; k is the dielectric constant of the passivation layer; A is the area of the plates forming the capacitor; d is the distance between the plates; i is the current; dv/dt is the change in voltage over the change in time; and t is a measure of time.

Accord to the ‘442 patent, the relative capacitance changes are measured by monitoring the charging current of each capacitor. The charging current of each capacitive element will vary, depending on the capacitance of that element as it charges to a particular value.

A drawback to the constant charging technique of ‘442 patent, or indeed any constant scanning technique is the power consumed while the device is scanning the biometric. For example, a typical array of sensors can be 300 by 300 sensors, thus comprising 90,000 individual sensors. Constantly scanning and measuring each sensor 200 can require a tremendous amount of power and processing overhead.

The problems discussed above are exacerbated by the wide variety of applications that use biometric sensing devices. As applications move to battery powered environments, the power consumption of the biometric sensing device becomes critical. Simply put, the power and processing overhead required to repetitively perform the constant scanning operations are wasted when a finger is not present.

SUMMARY OF THE INVENTION

A method and apparatus for detecting the presence of a finger on a biometric minutiae sensor is disclosed. According to one embodiment, one or more capacitive sensing strips are disposed on a biometric minutiae sensor. A low frequency clock periodically charges and then discharges the one or more capacitive sensing strips. After a predetermined period, a charge remaining on the capacitive strips is sampled and then compared to a threshold charge. If the sampled charge exceeds the threshold charge then a switch enables a higher frequency clock so that the biometric minutiae sensor is enabled.

A finger sensing electronics is also disclosed, which includes, in one embodiment, the one or more capacitive sensing strips and a frequency switch. According to one embodiment, the finger sensing electronics further includes a comparator configured to enable or disable the frequency switch.

BRIEF DESCRIPTION OF THE DRAWINGS

In the figures of the accompanying drawings, like reference numbers correspond to like elements, in which:

FIG. 1 depicts a biometric minutiae sensing device.

FIG. 2 depicts a biometric minutiae sensing array.

FIG. 3 depicts an overview of the operation of a biometric minutiae sensing device according to one embodiment of the invention.

FIG. 4 depicts an embodiment of a biometric minutiae sensor including the finger sensing electronics.

FIG. 5 is an electrical schematic illustrating an embodiment of a finger sensing electronics.

FIG. 6 is flow diagram illustrating a method for detecting the presence of a finger on the biometric minutiae sensor.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 4 illustrates a portion of a biometric sensor 400, which comprises multiple arrays of sensors 406 as well as finger sensing electronics -- shown here as capacitive strips 402 and 404. Capacitive strips 402 and 404 are spaced within sensor 400 such that each area A, B, and C of sensor 400 is adequately spaced to detect a finger. In other words, if a finger is placed on a portion of the sensor 400, either area A or C will be sufficiently narrow (or wide) to ensure that the finger would still be detected by either capacitive strip 402 or 404. Similarly, if a finger is placed in the middle of sensor 400, area B is sufficiently narrow (or wide) to ensure that either capacitive strip 402, 404, or both detect the presence of the finger. The number and placement of the capacitive strips can thus be determined by taking the overall area of the sensor and dividing it by the minimum dimension that will ensure a finger is detected.

Moreover, according to one embodiment, one or more capacitive strips can be arranged in a manner so as to ensure proper alignment of a finger on the sensor 400. That is, the capacitive strips are arranged on the sensor 400 so that a superior scan of the ridges and valleys is achieved. For example, as is shown in optional horizontal capacitive strips 412, rather than being arranged in parallel, the capacitive strips can form a square or "detection grid" (as is shown with the combination of capacitive strips 402, 404 and 412) about the center of the sensor 400. An LED or other indicator, such as a software operated display notice, can be controlled by the capacitive strips and disposed on a sensor assembly or display device so as to indicate whether the finger is properly aligned on the sensor 400. In a like manner, the capacitive strips can be used to ensure that a finger is not aligned improperly or disproportionately over one portion of the sensor 400.

In one embodiment, the capacitive strips 402 and 404 are modeled from one or more arrays of sensors 406, e.g. one row 408 or one column 410. In an alternative embodiment, capacitive strips 402 and 404 are each formed from a single conductive plate. In the later case, each strip 402 and 404 is disposed between two or more arrays of sensors 406 as is shown in FIG. 4. For example, in an environment that includes a 300 x 300 array of sensors 406, each capacitive strip 402 and 404 can be approximately 15mm long and 50 microns wide.

FIG. 3 depicts a presently preferred biometric minutiae sensing device 300 (or "sensing chip"). Ridges 302 and valleys 304 on a finger will result in different capacitance values that can be used to measure the relative depth between the ridges 302 and valleys 304, or the "distance to valley" or "distance to ridge" values as measured between the skin and the capacitor plates 308.

In operation, the capacitor plates 308 are pre-charged to a fixed value, typically using a known voltage source. Next, the capacitor plates 308 are discharged using a current source. If the current source discharges at a fixed rate for a set period of time, then the voltage remaining on the capacitor plates after the set period of time can be measured. The remaining voltage is used to determine whether a ridge 302 or valley 304 was disposed over any particular capacitive plate. Precise measurements are not a necessity, as the relative values should differ enough in magnitude that a sufficient approximation of the ridge 302 and valley 304 locations can be made and the fingerprint minutiae can be mapped.

Further details related to FIG. 3 are described in U.S. Patent No. 6,016,355, entitled "Capacitive Fingerprint Acquisition Sensor" and U.S. Patent No. 6,049,620, entitled "Capacitive Fingerprint Sensor With Adjustable Gain," filed May 13, 1997.

Each capacitive strip 402 and 404 is coupled to a finger detection circuit. FIG. 5 illustrates an example of a finger detection circuit 500. A capacitive strip 510 is coupled to a pre-charge switch 508. When the pre-charge switch 508 is closed, a voltage source 516 is connected to a capacitive strip 510. The voltage source 516 supplies a voltage (v_{ch2}) in order to charge the capacitor formed between plate 510 and finger 100, which is modeled as a virtual ground 514, to a predetermined charge. The finger detection circuit 500 also includes a discharge switch 506, which is connected, for example, to a constant current source 504. The discharge switch 506 couples the current source 504 to the capacitive plate 510, thereby allowing the capacitor to be discharged.

The finger detection circuit 500 is controlled or timed by a clock 512 that operates at a low frequency. For example, depending on the implementation, the operating frequency of finger detection circuit 500 may be in the range from 10KHz to 100KHz, however, the power savings will be most optimal at lower frequencies. Accordingly, one embodiment of the invention uses an operational frequency of 10KHz for the finger detection circuit 500. A sampling circuit 502 is used to sample the voltage on the capacitive strip 510. The output of the sampling circuit 502 is coupled to a high frequency switch 518 that is used to switch the sensor 400 to a high frequency mode. In one embodiment, the high frequency mode enables a clock that operates at 20MHz.

When the pre-charge switch 512 engages the voltage source 516, the discharge switch 512 disengages the current source 504. To this end, the same clock 512 can be used to operate both the pre-charge switch 512 and the discharge switch 506. However, if a different or non-proportional duty cycle is desired, then intervening electronics, such as a frequency divider (or multiplier) or a phase adjuster can be disposed between the clock 512 and the respective switch, or two different clocks can be employed.

A high frequency switch 518 is included to switch the biometric minutiae sensor 400 to the high frequency mode so that fingerprint minutiae can be detected. In one implementation, switching to the high frequency mode is accomplished by disabling a frequency divider that divides down the frequency of the higher frequency clock to the required lower frequency for the fingerprint sensing electronics 500 -- or low frequency mode. In an alternative embodiment, two different clocks are used, with each being enabled and/or disabled as required.

FIG. 6 illustrates a process by which a finger can be detected on the biometric minutiae sensor 400. It is assumed for this example that sensor 400 starts in the high frequency mode. However, the sensor 400 can always start in the low frequency mode from initial power up or activation so step 602 can be skipped.

In step 602, the sensor 400 switches from the high frequency mode to the low frequency mode. In the low frequency mode, the finger detection circuit 500 remains powered on and clock source 512 is enabled while the biometric minutiae detection elements are disabled or turned off. Due to the reduced amount of circuitry that remains powered on and the lower frequency of the clock source 512, a power reduction is achieved.

In step 604, the capacitive strip 510 is pre-charged to a predetermined level. The pre-charging step is accomplished by connecting the voltage source 516 to the capacitive strip 510 through the pre-charge switch 508. Then, in step 606, the charge on capacitive strip 510 is discharged for a fixed period of time (the discharge period). For example, the discharge switch 506 connects the constant current source 504 to the capacitive strip 510 for the discharge period.

After the capacitive strip 510 is discharged, the voltage remaining (v_{sense}) on strip 510 is sampled by the sampling circuit 500 in step 608. The sampled voltage is then compared to a threshold voltage in step 610. For example, in one implementation sampling circuit includes a comparator 502. The inputs to the comparator 502 are the sampled voltage (v_{sense}) and a threshold voltage (v_{th}). After the discharge period, a latch 520 is enabled by the clock 512, which captures the value from the comparator 502. The latched value is fed to the high frequency switch 518, thereby turning it on or off. The high frequency switch 518 can drive, for example, a fingerprint sensing element -- whereby once the fingerprint sensing element is enabled, an automatic gain controller is enabled. An exemplary automatic gain controlled is disclosed in co-pending U.S. Patent Application Serial No. 09/560,702 entitled "AUTOMATIC GAIN AMPLIFIER FOR BIOMETRIC SENSING DEVICE", filed on April 27, 2000.

If a finger is present, it will raise the capacitance of the capacitive strip 510. Therefore, if a finger is present, the remaining voltage as measured on strip 510 will be greater than if a finger is not present. The value of threshold voltage (v_{th}) is predetermined so that if the sampled voltage (v_{sense}) is greater than the threshold voltage (v_{th}), then the output of the sampling circuit 500 will turn active, which indicates the present of a finger. As shown in step 512, this will cause the biometric minutia sensing elements of the sensor 400 to be enabled through the high frequency switch 518.

According to one embodiment, the biometric minutia sensing elements (sensors 406) of the sensor 400 remain enabled until no minutiae or no change in the minutiae previously read is detected in step 616. If step 616 indicates that no minutiae are detected, then the process returns to step 602, whereby the sensor 400 returns to a low frequency mode. Otherwise, the sensor 400 remains in its normal frequency mode (as indicated by "step" 620) until no minutiae (or at least no new minutiae) are detected.

Power and resource savings can be achieved with the present invention, as biometric minutiae scanning does not have to be constantly performed. Accordingly, the present invention is particularly useful when incorporated into battery operated electronic devices that require interaction with a person, such as a personal digital assistant, a laptop computer, and a wireless communication device. For instance, an embodiment of the present invention can be incorporated into a wireless telephone to not only enable scanning of biometric minutiae information, but to power on the wireless telephone, or to enable the collection of biometric minutiae information so that a challenge or transaction can be digitally signed. Such a system is disclosed in U.S. Patent Application Ser. No. 09/536,242, filed March 27, 2000, entitled "BIOMETRIC SENSING AND DISPLAY DEVICE".

While various embodiments of the present invention have been shown and described above, it should be understood that they have been presented by way of example and not by way of limitation. For example, while the figures illustrate capacitive strips interposed between sensors 406, the capacitive strips may be formed by electrically connecting an array of sensors 406. Similarly, while the finger sensing circuitry and biometric minutiae sensing elements have been described in some embodiments as operating in a mutually exclusive mode, they can both be active at the same time. For example, the finger detection circuitry can be constantly operational, while the high frequency mode corresponding to actual minutiae detection is selectively engaged or disengaged by the finger detection circuitry. These and other embodiments of the invention will be apparent to one of skill of the art upon review of the written description and accompanying drawings.

CLAIMS

What is claimed is:

1. A finger sensing electronics comprising:
a capacitive strip;
a voltage source coupled to said capacitive strip, said voltage source configured to periodically charge said capacitive strip to a predetermined charge;
a current source coupled to said capacitive strip, said current source configured to periodically drain a portion of said predetermined charge from said capacitive strip;
a sampling circuit coupled to said capacitive strip, said sampling circuit configured to measure a remaining charge in said capacitive strip after said current source has drained a portion of said predetermined charge; and
a frequency switch coupled to said sampling circuit, said frequency switch configured to enable biometric minutiae sensing electronics when said remaining charge is greater than a threshold value.

2. The finger sensing electronics of claim 1, further comprising multiple arrays of capacitive fingerprint detection elements.

3. The finger sensing electronics of claim 2, wherein said capacitive strip is modeled from a plurality of said fingerprint detection elements.

4. The finger sensing electronics of claim 2, wherein said capacitive strip is formed of a continuous conductive strip disposed between at least two of said multiple arrays of fingerprint detection elements.

5. The finger sensing electronics of claim 2, further comprising a high frequency clock coupled to said capacitive fingerprint detection elements.

6. The finger sensing electronics of claim 5, further comprising a low frequency clock coupled to said voltage source, said low frequency clock configured to control said periodic charging of said capacitive strip when said low frequency clock is enabled.

7. The finger sensing electronics of claim 6, further comprising a frequency divider coupled to said high frequency clock, said frequency divider configured to generate said low frequency clock from said high frequency clock.

8. The finger sensing electronics of claim 6, wherein said frequency switch is configured to disable said low frequency clock and enable said capacitive fingerprint detection electronics by enabling said high frequency clock when said remaining charge is greater than said threshold value.

9. The finger sensing electronics of claim 6, wherein said frequency switch is configured to enable said low frequency clock and disable said high frequency clock when said remaining charge is less than said threshold value.

10. The finger sensing electronics of claim 2, wherein said multiple arrays of capacitive fingerprint detection elements are configured to enable said finger sensing electronics when a number of fingerprint minutiae detected are less than a threshold number.

11. A biometric minutiae sensor comprising:

a biometric minutiae sensing element;

a high frequency clock coupled to said biometric minutiae sensing element, said high frequency clock configured to provide an operating signal to said biometric minutiae sensing element;

a high frequency switch coupled to said high frequency clock;

a finger sensing electronics coupled to said high frequency switch, said finger sensing electronics configured to determine whether said high frequency switch should enable said high frequency clock; and

a low frequency clock coupled to said finger sensing electronics, said low frequency clock configured to provide an operating signal to said finger sensing electronics.

12. The biometric minutiae sensor of claim 11, wherein said biometric minutiae sensing element comprises two or more arrays of capacitive fingerprint sensors.

13. The biometric minutiae sensor of claim 12, wherein said finger sensing electronics comprises:

a capacitive plate disposed between at least two of said two or more arrays of capacitive fingerprint sensors, said capacitive plate configured to accept a finger; and

a comparator coupled to said capacitive plate, said comparator configured to detect whether a finger is placed near said capacitive plate.

14. The biometric minutiae sensor of claim 13, wherein when said comparator detects that a finger is placed near said capacitive plate, said comparator generates a signal directed to said high frequency switch, said signal causing said high frequency clock to engage said two or more arrays of capacitive fingerprint sensors.

15. The biometric minutiae sensor of claim 14, wherein when said two or more arrays of capacitive fingerprint sensors fail to detect a fingerprint from the finger, a second signal is created, said second signal causing said high frequency clock to disengage said two or more arrays of capacitive fingerprint sensors.

16. In a biometric minutiae sensor, said biometric minutiae sensor including a finger detection electronics coupled to a low frequency clock, and a biometric minutiae detection element coupled to a high frequency clock, a method for detecting a finger comprising, under control of said low frequency clock:

pre-charging a capacitive strip to a predetermined level;

discharging said capacitive strip for a fixed period of time;

sampling a remaining charge on said capacitive strip after said step of discharging;

comparing said remaining charge to a threshold charge; and

enabling a high frequency clock when said remaining charge is greater than said threshold charge.

17. The method of claim 16, further comprising disabling said low frequency clock after enabling said high frequency clock.

18. The method of claim 17, further comprising, under control of said high frequency clock, enabling said low frequency clock when said biometric minutiae detection element fails to detect biometric minutiae.

19. The method of claim 16, wherein said biometric minutiae detection element is a capacitive fingerprint sensor.

20. A computer software product configured to cause one or more processors to perform the steps in any of above claims 16-19.

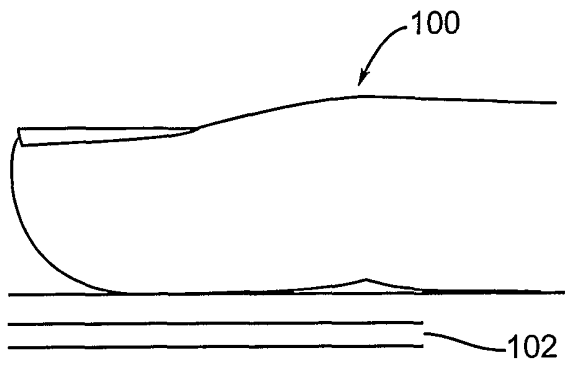


Fig. 1

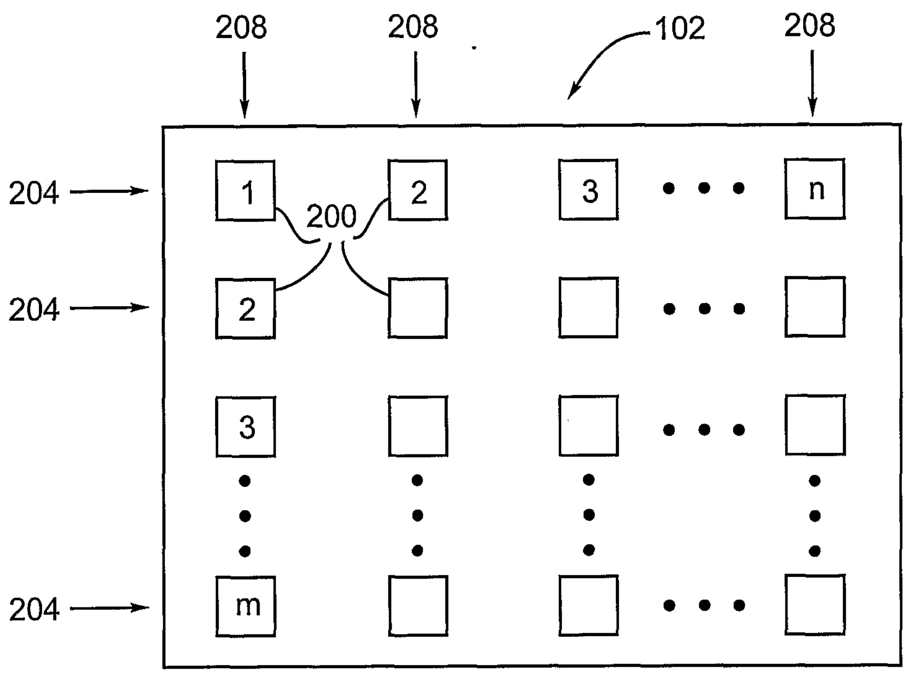


Fig. 2

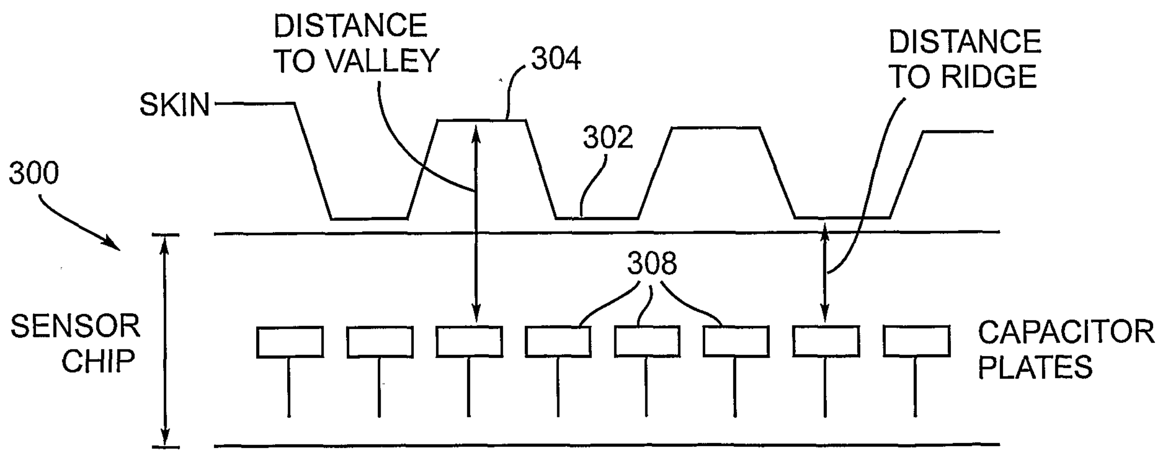


Fig. 3

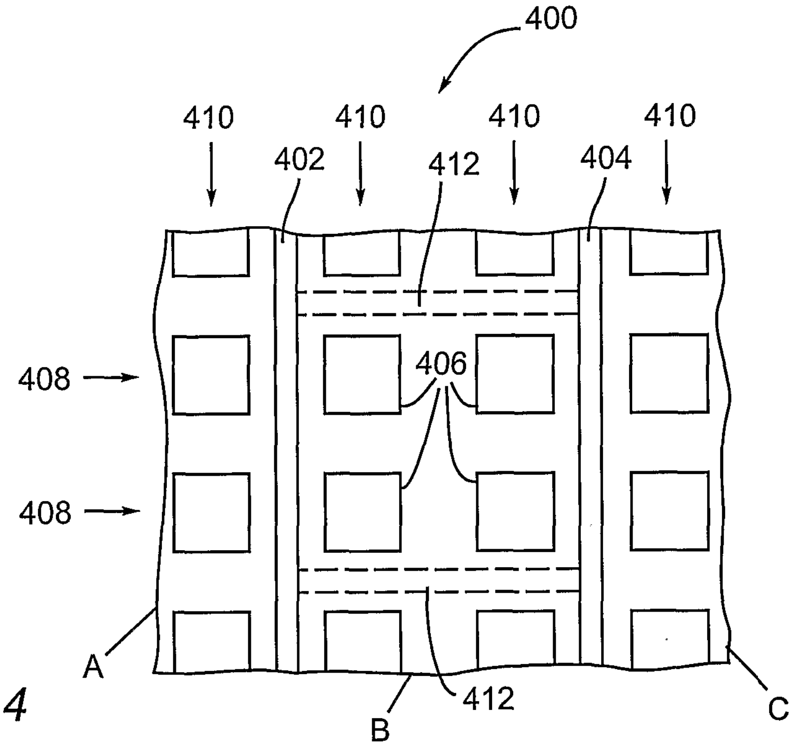

400
410
410
410
410
402
412
404
408
406
408
A
412
B
C

Fig. 4

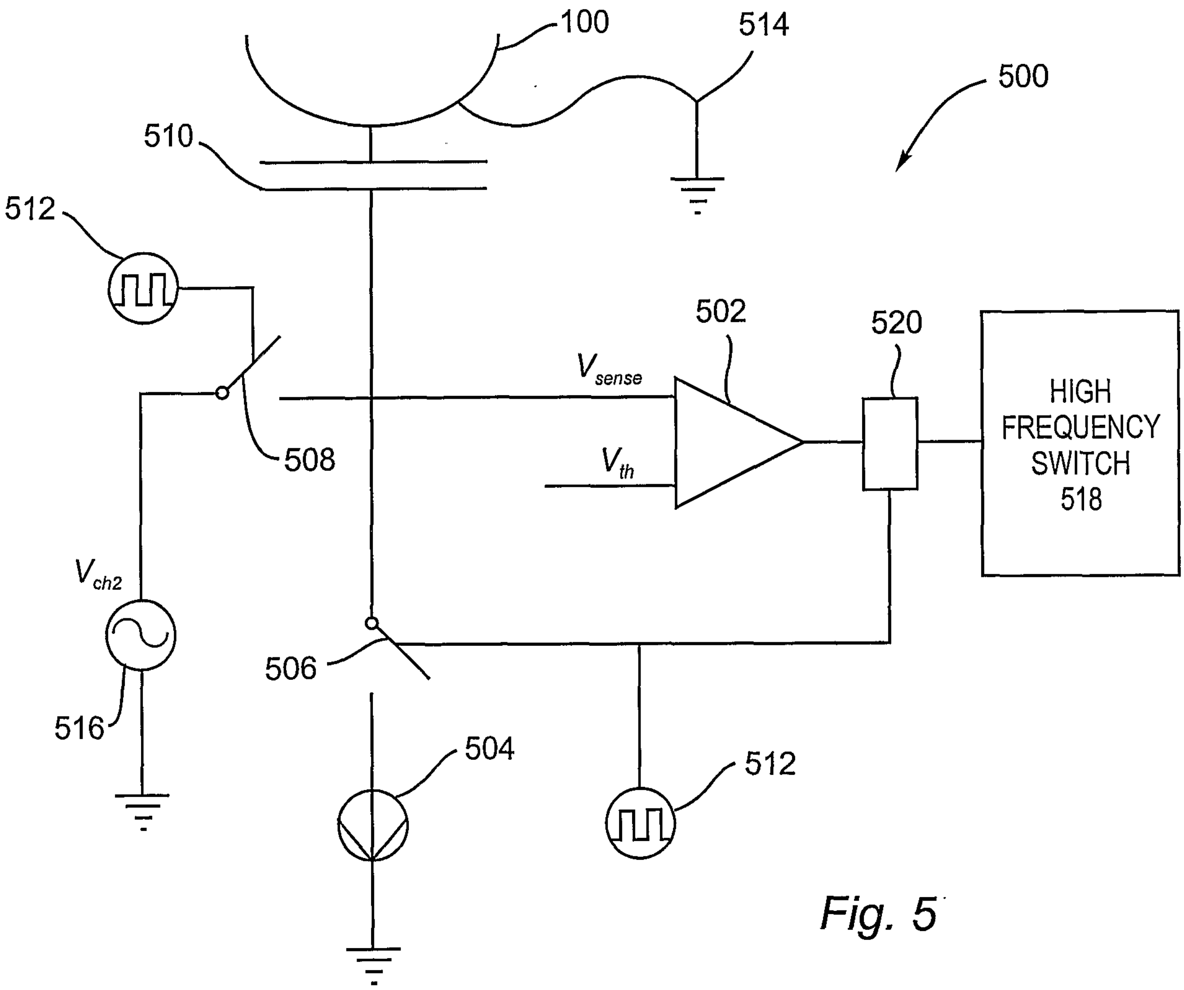
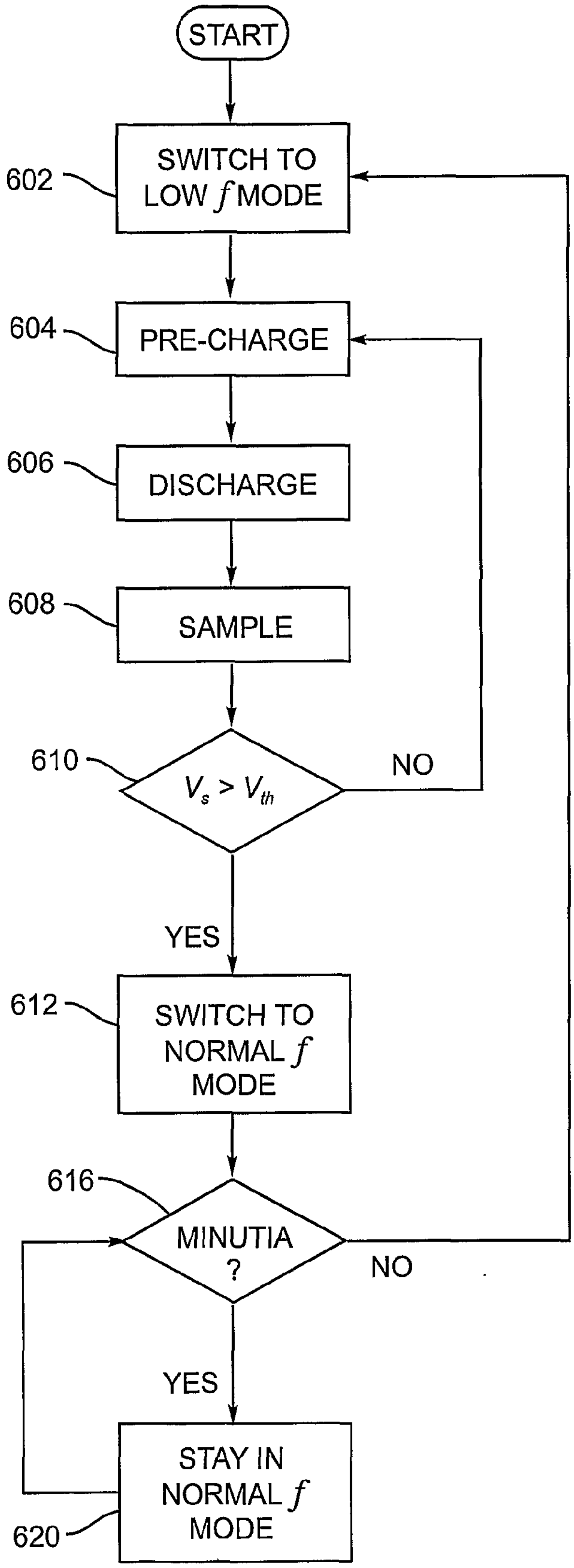

100
514
500
510
512
502
520
V_{sense}
HIGH FREQUENCY SWITCH 518
508
V_{th}
V_{ch2}
506
516
504
512

Fig. 5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SWITCH TO LOW f MODE
602
PRE-CHARGE
604
DISCHARGE
606
SAMPLE
608
$V_s > V_{th}$
610
NO
YES
SWITCH TO NORMAL f MODE
612
MINUTIA ?
616
NO
YES
STAY IN NORMAL f MODE
620

Fig. 6