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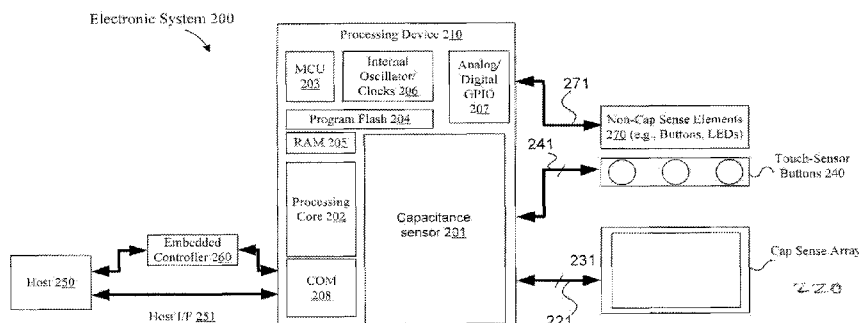
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(54) **Title:** SINGLE LAYER TOUCH SENSOR**FIG. 9**

(57) **Abstract:** Embodiments described herein provide touch sensor devices and methods for forming touch sensor devices. The touch sensor device includes a substrate having a central portion and an outer portion. A plurality of substantially co-planar electrodes are on the central portion substrate. A first plurality of conductors are on the substrate. Each of the first plurality of conductors has a first end electrically connected to one of the plurality of electrodes and a second end on the outer portion of the substrate. An insulating material is coupled to the second ends of the first plurality of conductors. A second plurality of conductors are coupled to the insulating material. Each of the second plurality of conductors is electrically connected to the second end of at least some of the first plurality of conductors and is insulated from the second end of the others of the first plurality of conductors.

## SINGLE LAYER TOUCH SENSOR

### RELATED APPLICATIONS

**[0001]** This application claims the benefit of U.S. Provisional Application No. 61/446,178, filed on February 24, 2011, the contents of which are hereby incorporated by reference herein.

### TECHNICAL FIELD

**[0002]** This disclosure relates to the field of touch sensors and, in particular, to capacitive sensors.

### BACKGROUND

**[0003]** In recent years, touch pads, or capacitive sensor devices, have become increasingly integrated in various industries and product lines. Often, these sensors have the ability to detect multiple objects (e.g., fingers) simultaneously.

**[0004]** Touch sensors are an expensive part of the user interface system. One reason for the high cost of touch sensors is that conventional sensors use either multiple layers of materials formed on multiple substrates or a single substrate with a series of "jumpers" to form electrical connection between the individual electrode segments and insulate them from the other electrodes that intersect them.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The present disclosure is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

[0006] **Figure 1** is a schematic plan view illustrating an embodiment of a touch sensor array;

[0007] **Figure 2** is a schematic plan view illustrating a portion of the touch sensor array of Figure 1 in greater detail;

[0008] **Figure 3** is a schematic plan view illustrating another embodiment of a touch sensor array;

[0009] **Figure 4** is schematic plan view illustrating a further embodiment of a touch sensor array;

[0010] **Figures 5, 6, and 7** are plan views illustrating an embodiment of portion of a touch sensor array during the formation thereof;

[0011] **Figure 8** is a plan view of a portion of a further embodiment of a touch sensor array; and

[0012] **Figure 9** is a block diagram illustrating an embodiment of an electronic system.

## DETAILED DESCRIPTION

**[0013]** Reference in the description to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The phrase “in one embodiment” located in various places in this description does not necessarily refer to the same embodiment.

**[0014]** In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the subject matter of the present application. It will be evident, however, to one skilled in the art that the disclosed embodiments, the claimed subject matter, and their equivalents may be practiced without these specific details.

**[0015]** The detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show illustrations in accordance with example embodiments. These embodiments, which may also be referred to herein as “examples,” are described in enough detail to enable those skilled in the art to practice the embodiments of the claimed subject matter described herein. The embodiments may be combined, other embodiments may be utilized, or structural, logical, and electrical changes may be made without departing from the scope and spirit of the claimed subject matter. It should be understood that the embodiments described herein are not intended to limit the scope of the subject matter but rather to enable one skilled in the art to practice, make, and/or use the subject matter.

**[0016]** Attempts have been made in the past to reduce the number of layers, and thus the manufacturing costs, of touch sensors. There are several single layer sensors available that are suited only for single touch reception. These

sensors typically use a series of electrodes the width of which linearly change from one end to the other end of the electrode. Using the signal variation along the electrode's length, the coordinate along the electrode's axis is determined. The coordinate in the perpendicular direction to the electrodes axis is determined by the conventional digitization method.

**[0017]** Another possibility for a single layer multiple-touch sensor uses an array of pads filling the sensor area, and sensing each of the pads (or electrodes) in a self capacitance sensing mode. However, such requires independent traces for each of the sensing pads and a very large number of measuring channels and pins on the controller chip to get an acceptable accuracy for even a small size sensor. Embodiments of the present invention allow for addressing the sensing pads without requiring a large number of measuring ports or pins on the controller. Additionally, a method of achieving multi-touch sensors with no bezel is disclosed herein, and the performance of such sensors is demonstrated.

**[0018]** Embodiments described herein provide a touch sensor device and a method for forming a touch sensor device that has a single layer active area. Additionally, the touch sensor device is provided with a wiring scheme that minimizes the number of wires, as well as the layers, (or traces) required to simultaneously detect multiple contact points (i.e., "touches"). As a result, overall manufacturing costs may be reduced.

**[0019]** In one embodiment, a touch sensor device is provided. The touch sensor device includes a substrate having a central portion and an outer portion. A plurality of substantially co-planar electrodes are on the central portion of a substrate. A first plurality of conductors are on the substrate. Each of the first plurality of conductors has a first end electrically connected to one of the plurality of electrodes and a second end on the outer portion of the substrate. An insulating material is coupled to the second ends of the first plurality of

conductors. A second plurality of conductors are coupled to the insulating material. The second plurality of conductors and the insulating material are configured such that each of the second plurality of conductors is electrically connected to the second end of at least some of the first plurality of conductors and is insulated from the second end of the others of the first plurality of conductors.

**[0020]** In another embodiment, a touch sensor device is provided. The touch sensor device includes substrate having a central portion and an outer portion. A first set of electrodes is formed on the central portion substrate. A second set of electrodes is formed on the central portion of the substrate. The second set of electrodes is arranged in a series of rows and substantially co-planar with the first set of electrodes. A first plurality of conductors is formed on the substrate. Each of the first plurality of conductors has a first end electrically connected to one of the first set of electrodes and a second end on the outer portion of the substrate. A second plurality of conductors is formed on the substrate. Each of the second plurality of conductors has a first end electrically connected to one of the second set of electrodes and a second end on the outer portion of the substrate. An insulating body is coupled to the second end of each of the first plurality of conductors and the second end of each of the second plurality of conductors. A third plurality of conductors is coupled to the insulating body such that each is electrically connected to one of the second end of one of the first plurality of conductors and the second end of the second plurality of conductors associated with only one row of the second set of electrodes and is electrically insulated from the second end of the others of the first set of conductors and the second end of the second plurality of conductors associated with the other rows of the second set of electrodes.

**[0021]** In a further embodiment, a method for constructing a touch sensor device is provided. A substrate having a central portion and an outer portion is provided. A plurality of substantially co-planar electrodes is formed on the central portion substrate. A first plurality of conductors is formed on the substrate. Each of the first plurality of conductors has a first end electrically connected to one of the plurality of electrodes and a second end on the outer portion of the substrate. An insulating material is formed on the outer portion of the substrate and coupled to the second ends of the first plurality of conductors. A second plurality of conductors is formed on the insulating material. The second plurality of conductors and the insulating material are configured such that each of the second plurality of conductors is electrically connected to the second end of at least some of the first plurality of conductors and is insulated from the second end of the others of the first plurality of conductors.

**[0022]** In yet a further embodiment, a touch sensor device is provided. The touch sensor device includes a substrate having a central portion and an outer portion. A first set of electrodes is formed on the central portion substrate. A second set of electrodes is formed on the central portion of the substrate. The second set of electrodes is arranged in a series of rows and substantially co-planar with the first set of electrodes. A first plurality of conductors is on the substrate. Each of the first plurality of conductors has a first end electrically connected to one electrode of the first set of electrodes or the second set of electrodes and a second end on the outer portion of the substrate. A second plurality of conductors is coupled to the substrate. Each of the second plurality of conductors is electrically connected to at least one of the first plurality of conductors at a node that is external to the central portion of the substrate such that each of the second plurality of conductors is electrically connected to one

electrode of the first set of electrodes or a plurality of electrodes in one of the rows of the second set of electrodes.

**[0023]** **Figure 1** is a plan view illustrating a capacitive (or touch) sensor array 10 according to one embodiment. The touch sensor array 10 includes a substrate 12 having a central (or active) portion 14 and outer (or bezel) portions 16 on opposing sides of the central portion 14, near the edges of the substrate 12. In one embodiment, the substrate 12 is made of glass.

**[0024]** An array of electrodes is formed on the central portion 14 of the substrate 12, which includes a first set (or plurality) of electrodes (also, "first electrodes") 18 and a second set of electrodes (also, "second electrodes") 20. In the embodiment shown in **Figure 1**, the first electrodes 18 are substantially "comb" shaped having comb members facing down as shown in **Figure 1**. In the depicted embodiment, five first electrodes 18 are included, which are arranged horizontally (as shown in **Figure 1**) and substantially extend the entire width of the central portion 14 of the substrate 14.

**[0025]** Still referring to **Figure 1**, the second electrodes 20 are substantially "E" shaped having members extending upwards. In the embodiment shown, thirty second electrodes 20 are included which are arranged in rows (i.e., horizontal rows) 22, each of which is associated with one of the first electrodes 18, and columns (i.e., vertical rows) 24. As shown, each of the rows 22 includes six of the second electrodes 20, and each of the columns 24 includes five of the second electrodes 20. Within each row 22, the second electrodes 20 are mated with the respective first electrode 18 such that the members extending from the first electrodes 18 and the second electrodes 20 are inter-digitated.

**[0026]** As will be described in more detail below, the first electrodes 18 may be used as "transmitter" (TX) electrodes, and second electrodes 20 may be used as "receiver" (RX) electrodes.

[0027] Referring now to **Figure 2** in combination with **Figure 1**, the touch sensor array 10 also includes a (first) plurality of conductors, or primary traces, 26 formed on the substrate 12. In the example shown, the primary traces 26 extend substantially horizontally (as shown in **Figure 2**) across the substrate 12. As shown, each of the primary traces 26 is connected to, and thus in electrical contact with, a respect one of the first electrodes 18 or one of the second electrodes 20 at a first end thereof, and has a second end extending into one of the outer portions 16 of the substrate. The primary traces 26 may be considered to include a first set associated with (i.e., in contact with) the first electrodes 18 and a second set associated with the second electrodes 20.

[0028] The first electrodes 18, the second electrodes 20, and the primary traces 26 may be made of indium tin oxide (ITO) and may be formed in a substantially planar manner. That is, although not specifically shown, the first electrodes 18, the second electrodes 20, and the primary traces 26 may have substantially the same thickness (e.g., 300 Angstroms (Å)) and lay in substantially the same plane.

[0029] Still referring to **Figures 1** and **2**, an insulating material (or layer) 28 is formed on the outer portions 16 of the substrate 12. The insulating material 28 covers the ends of the primary traces 26 that extend onto the outer portions 16 of the substrate 12. The insulating material may be made of, for example, an epoxy or resin material and have a thickness of, for example, between 5 and 25 micrometers (μm). It should be noted that the insulating material (or insulating bodies) 28 do not extend over the central portion 14 of the substrate.

[0030] A (second) plurality of conductors, or secondary traces, 30 are formed on the insulating material 28 over both outer portions 16 of the substrate 12. In one embodiment, the secondary traces 30 are made of silver. Of particular interest is that each of the secondary traces 30 is electrically connected to either one (and only one) primary trace 26 associated with one of the first electrodes 18

or all of primary traces 26 associated with the second electrodes 20 in one (and only one) of the columns 24 of second electrodes.

[0031] For example, referring specifically to **Figure 2**, the "first" secondary trace 30 (i.e., counting from left to right in **Figure 2**) is electrically connected to the top-most first electrode 18 (though the appropriate primary trace 26), and the "fifth" secondary trace 30 is electrically connected to all of the second electrodes 20 in the left-most column 24 of second electrodes 20. The remaining electrical connections between the secondary traces 30 and the primary traces 26, and thus the remaining electrodes 18 and 20, are shown in **Figures 1 and 2**, and are similar in both outer portions 16 of the substrate 12.

[0032] The insulating material 28 electrically separates each secondary trace 30 from the other primary traces 26 (i.e., those to which that particular secondary trace 30 is not electrically connected). For example, in **Figure 2**, the insulating material 28 insulates the "fifth" secondary trace 30 from the primary traces 26 connected to the second electrodes 20 that are not in the left-most column 24 of second electrodes 20. That is, the primary traces 26 connected to the second electrodes 20 that are not in the left-most column 24 extend below the "fifth" secondary trace 26 without making an electrical connection to the "fifth" secondary trace 26.

[0033] As such, the secondary traces 30 provide unique electrical connections for each "pair" of the first electrodes 18 and the second electrodes 20 (i.e., one of the first electrodes 18 and one of the second electrodes 20 associated and inter-digitated with that particular first electrode 18). For example, referring again to **Figure 2**, one such pair of electrodes may include the top-most first electrode 18 and the left-most second electrode 20 in the top row 22. Through the secondary traces 30, this pair of electrodes is provided with electrical connections specifically through the "first" secondary trace 30 and the "fifth" secondary trace

30. However, the pair of electrodes that includes the top-most first electrode 18 and the next second electrode 20 to the right in the top row 22 is provided with electrical connections through the left-most secondary trace 30 and the "fourth" secondary trace 30 as shown in **Figure 2**.

**[0034]** It should also be understood that the touch sensor array 12 may include an additional set of traces not shown in the figures. This additional set of traces may be used to provide a ground for the first electrodes 18. As such, each of the ground traces may be electrically connected to one of the secondary conductors in a manner similar to the respective primary traces 26. The ground traces may be all connected to the same secondary trace that is used to connect them to the system ground.

**[0035]** In the particular example shown in **Figures 1 and 2**, thirty such pairs of electrodes are included, and unique electrical connections are provided to each of the pairs using twelve secondary traces 30, while the central (or active) portion 14 of the substrate 12 includes only a single layer of structures formed thereon.

**[0036]** In operation, the secondary traces 30 are coupled to (i.e., are in operable communication with) an electronic system (an example of which is described below). In general, the capacitive sensor array 10 is operated by providing a signal to one of the first electrodes 18 (i.e., TX electrodes) while grounding the other first electrodes 18. Signals are generated in the second electrodes 20 associated with the driven first electrode 18 by electrical coupling of the driven first electrode 18 to the second electrodes 20 associated with the driven first electrode 18. The signal induced in the second electrodes 20 may change due to the presence of an object (e.g., a finger) on, or near, that portion of the sensor array 10. The signal change in the second electrodes 20 is indicative of change in the capacitance between the second electrode 20 and the respective first electrode (i.e., "mutual capacitance"). This process is continuously repeated

for each of the first electrodes 18 and each of the associated rows of second electrodes 20.

[0037] **Figure 3** illustrates the touch sensor array 10 according to another embodiment of the present invention. Similar to the embodiment shown in **Figure 1**, the touch sensor array 10 shown in **Figure 3** includes a substrate 12 with an active portion 14 and a bezel portion 16. However, only one bezel portion 16 is included along the bottom (as shown in **Figure 3**) edge of the substrate 12. The touch sensor array 10 also includes an array of first electrodes 18 and second electrodes 20. The substrate 12 as shown in **Figure 3** has been rotated compared to that of **Figure 1** such that the columns 24 correspond to the first electrodes 18, and the rows 22 correspond to the second electrodes 20.

[0038] Because there is only one bezel portion 16, all of the primary traces 26 extend from the first electrodes 18 and second electrodes 20 towards the bottom of the substrate 12, across the entire active portion 14. Within the bezel portion 16, the primary traces 26 are electrically connected to the secondary traces 30 in a manner similar to that described above (i.e., such that each electrode pair is provided electrical connections through a unique pair of the secondary traces 30).

[0039] One skilled in the art may appreciate that due to the electrical resistance of the traces, the embodiment shown in **Figure 3** may be more suitable for smaller devices (e.g., with diagonal lengths across the active area 14 of, for example, 10 centimeters or less).

[0040] **Figure 4** illustrates a touch sensor array 10 according to a further embodiment. Similar to the embodiment shown in **Figure 1**, the array 10 includes a substrate 12 with outer portions 16 on laterally opposing sides of the central portion 14, primary traces 26 extending from the first electrodes 18 and the second electrodes 20 into the outer portions 16, and secondary traces 30 connected to the primary traces 30 through an insulating material 28.

[0041] Of particular interest in the embodiment shown in **Figure 4** are the shapes and arrangement of the first electrodes 18 and the second electrodes 20. As shown, unlike the inter-digitated members shown in **Figures 1, 2, and 3**, the first electrodes 18 and the second electrodes 20 shown in **Figure 4** include "spiral" structures that are intertwined as indicated. However, it should be understood that the "comb" and "spiral" electrodes shown in Figures 1-4 are merely two examples of possible electrode configurations that may be used.

[0042] **Figures 5, 6, and 7** illustrate an outer (or bezel) portion 16 of the substrate 12 and a process for forming the connections between the primary traces 26 and the secondary traces 30 according to one embodiment. Referring now to **Figure 5**, the insulating material 28 is first deposited (e.g., using screen printing) on the outer portion 16 and over the ends of the primary traces 26 that extend onto the outer portion 16. The insulating layer 28 includes a series of via holes 32, with each of the via holes 32 being positioned over a respective one of the primary traces 26.

[0043] Referring now to **Figure 6**, the via holes 32 are then filled with, for example, a conductive paste to form a conductive via 34 in each of the via holes 32, which is in contact with the respective primary trace 26. Then, as shown in **Figure 7**, the secondary traces 30 are formed on the insulating material 28, with each secondary trace 30 extending over, and contacting, one (or more) of the conductive vias 34. Thus, each of the secondary traces 30 is electrically connected to one (or more) of the primary traces 26 through a conductive via 34. As such, the conductive vias 34 may represent contact points, or nodes, for the electrical connection of the secondary traces 30 to the respective primary traces 26. It should be noted that these contact points are external to (i.e., not positioned over) the central portion 14 of the substrate 12.

**[0044]** In one embodiment, the insulating material 28 is a dark ink that is used to conceal the secondary traces 30 (e.g., in an embodiment in which the substrate 12 and the electrodes 18 and 20 are transparent). In such an embodiment, the conductive paste used to form the conductive vias 34 may be a conductive, carbon ink, to hide the secondary traces 30 that may be otherwise visible through the via holes 32 from the back side of the substrate 12.

**[0045]** Such an embodiment is especially useful for the sensor on lens (SOL) touch sensors. SOL sensors are formed on the back of the overlay (usually glass) material and acts as the substrate for the sensor electrodes as well as the lens material to provide electrical insulation between the finger and the touch sensor electrodes. SOL sensors are often integrated into displays with the sensor side facing towards the display, and the plain side facing the user. In an SOL sensor using this embodiment, the order of materials on the bottom surface of the lens may be the electrode material, the insulating material 28, black Carbon ink, and the secondary traces 30, respectively. Using the method shown in **Figures 5, 6, and 7**, the insulating ink and the Carbon ink completely conceal the secondary traces from the user side of the touch sensor.

**[0046]** **Figure 8** illustrates a row of second electrodes 20, primary traces 26, and outer portion 16 of a touch sensor array according to another embodiment. As shown, the second electrodes 20 are provided with progressively increasing sizes farther from the outer portion 16, allowing for a reduction in the total space used by the primary traces 26 in the central portion 14. Additionally, as the primary traces 26 extend into the outer portion 16, the primary traces 26 “fan out.” Also of particular interest in the embodiment shown in **Figure 8**, is the particular shape (e.g., a “polygonal” shape) of the insulating material 28, which allows for the insulating material 28 to appropriately insulate and connect the primary traces 26 and the secondary traces 30 without via holes and/or

conductive vias being formed therein. More specifically, the insulating material 28 allows the secondary traces 30 to pass over, and remain insulated from, the appropriate primary traces 26. Additionally, in the embodiment shown in Figure 8, the ends of the primary traces 26 are “bent” in a direction substantially parallel to the direction in which the secondary traces 30 extend, thus allowing an increase in the contact area between the primary traces 26 and the secondary traces 30.

**[0047]** In another embodiment, the multi-layer routing of the traces may be accomplished by using a flexible printed circuit (FPC) tail, which includes a flexible insulating substrate (i.e., made of an insulating material) with a series of traces (i.e., secondary traces) formed thereon. In such an embodiment, the FPC tail may be coupled to the substrate (e.g., substrate 12) at the edge (or edges) of the active portion 14 and may be wrapped around the substrate 12, effectively eliminating the bezel portion 16 of the array.

**[0048]** In another embodiment, the sensor may be formed by disposing transparent conductive materials (such as ITO) on PET substrate. In yet another embodiment, the sensor may be formed by laying out the sensor electrodes using alternative conductive materials such as metal mesh. In this embodiment, the electrodes are formed by disposing metal mesh electrodes on PET substrate. In an alternative embodiment, the metal mesh electrodes may be disposed on glass substrate. In another embodiment, the electrodes may be formed with silver nano-wires on PET or silver nano-wire on glass substrate.

**[0049]** In other embodiments, the sensor may be made by using a SOL configuration where only a single sheet of glass is used as both the touch interface as well as the substrate for the conductive electrodes. In another embodiment, the sensor may be formed by bonding a glass (or other transparent insulating) lens onto another glass with the sensor pattern disposed on. In yet

another embodiment, the sensor may be formed by bonding glass (or other transparent insulating material) onto a sheet of PET containing the sensor pattern.

**[0050]** As such, embodiments described herein provide a capacitive sensor device with a single layer structure in the active portion of the device, while a multi-layer structure is used in the bezel portions for routing the traces. The multi-layer routing allows the repeated use of the traces so that the device uses the absolute minimum number of traces, and the minimum number of pins on the electronic system which drives the device.

**[0051]** With respect to the embodiments described above, the gap between the rows 22 (**Figure 1**) is determined by the maximum number of primary traces 26 extending into the bezel portion(s) 16. In the embodiment shown in **Figure 1**, there are three primary traces 26 routed to the bezel portions 16. If the thickness of each primary trace 26 is  $d$  and the minimum space between the primary traces 26 is  $s$ , the minimum distance (or gap) between the rows 22 is  $3(d + s) + s$ .

**[0052]** As will be appreciated by one skilled in the art, it is preferable to minimize the gap size by minimizing the trace widths and the space between the traces. The minimum trace width may be determined by the resistance of the traces and the limits of the process used to form the traces. The width of traces made of ITO may be minimized by lowering the sheet resistance of the ITO. For example, if the minimum line width and spacing of ITO on PET is 0.1 mm, the minimum gap between the rows in **Figure 1** when implemented on PET is 0.7 mm. In some embodiments, in order to avoid cross coupling between the first and second electrodes of the neighboring rows (or columns), a ground trace may be formed, which would increase the minimum gap size to 0.9 mm.

[0053] However, when the substrate is glass, rather than PET, lower sheet resistance of ITO and better trace width and spacing may be achieved, which leads to reducing the gap size between the neighboring electrodes.

[0054] Further, the pitch size (i.e., the distance between the centers of the two neighboring sensor cells or electrodes) may be adjusted by varying the pad size (i.e. the width of one of the second electrodes 20). However, it may be preferable to use a pitch of 6 mm or less.

[0055] **Figure 9** is a block diagram illustrating one embodiment of an electronic system 200 having a processing device for detecting a presence of a conductive object (e.g., a finger) on a capacitive sense array according to embodiments of the present invention. The electronic system 200 includes a processing device 210, a capacitive sense array 220, touch-sense buttons 240, a host processor 250, an embedded controller 260, and non-capacitance sense elements 270. The capacitive sense array 220 may include any of the arrays 10 shown in **Figures 1-4** and **8** and described above.

[0056] The processing device 210 may include analog and/or digital general purpose input/output ("GPIO") ports 207. The GPIO ports 207 may be programmable and may be coupled to a Programmable Interconnect and Logic ("PIL"), which acts as an interconnect between GPIO ports 207 and a digital block array of the processing device 210 (not shown). The digital block array may be configured to implement a variety of digital logic circuits (e.g., DACs, digital filters, or digital control systems) using, in one embodiment, configurable user modules ("UMs"). The digital block array may be coupled to a system bus. The processing device 210 may also include memory, such as random access memory ("RAM") 205 and program flash 204. RAM 205 may be static RAM ("SRAM"), and program flash 204 may be a non-volatile storage, which may be used to store firmware (e.g., control algorithms executable by processing core 202

to implement operations described herein). The processing device 210 may also include a microcontroller unit ("MCU") 203 coupled to memory and the processing core 202.

**[0057]** The processing device 210 may also include an analog block array (not shown). The analog block array is also coupled to the system bus. The analog block array also may be configured to implement a variety of analog circuits (e.g., ADCs or analog filters) using, in one embodiment, configurable UMs. The analog block array may also be coupled to the GPIO ports 207.

**[0058]** As illustrated, a capacitance sensor 201 may be integrated into the processing device 210. The capacitance sensor 201 may include analog I/O pins for coupling to an external component, such as the capacitive sense array 220, the touch-sense buttons 240, and/or other devices. As described above, in accordance with one aspect of the embodiments described herein, the number of I/O pins on the capacitance sensor 201 may be minimized due to the capacitive sense array described above. The capacitance sensor 201 and the processing device 210 are described in more detail below.

**[0059]** The embodiments described herein may be used in any capacitive sense array application. For example, the capacitive sense array 220 may be a touch screen, a touch-sense slider, or touch-sense buttons 240 (e.g., capacitance sense buttons). In one embodiment, these sense devices may include one or more capacitive sense elements. The operations described herein may include, but are not limited to, notebook pointer operations, lighting control (dimmer), volume control, graphic equalizer control, speed control, or other control operations requiring gradual or discrete adjustments. It should also be noted that these embodiments of capacitive sense implementations may be used in conjunction with non-capacitive sense elements 270, including but not limited to pick buttons, sliders (ex. display brightness and contrast), scroll-wheels, multi-

media control (ex. volume, track advance, etc) handwriting recognition and numeric keypad operation.

**[0060]** In one embodiment, the capacitive sense array 220 is coupled to the processing device 210 via bus 221. The capacitive sense array 220 may include a one-dimensional sense array in one embodiment and a two-dimensional sense array in another embodiment. Alternatively, the capacitive sense array 220 may have more dimensions. Also, in one embodiment, the capacitive sense array 220 may be sliders, touchpads, touch screens or other sensing devices.

**[0061]** In another embodiment, the electronic system 200 includes touch-sense buttons 240 coupled to the processing device 210 via bus 241. The touch-sense buttons 240 may include a single-dimension or multi-dimension sense array. The single- or multi-dimension sense array may include multiple sense elements. For a touch-sense button, the sense elements may be coupled together to detect a presence of a conductive object over the entire surface of the sense device. Alternatively, the touch-sense buttons 240 may have a single sense element to detect the presence of the conductive object. In one embodiment, touch-sense buttons 240 may include a capacitive sense element. Capacitive sense elements may be used as non-contact sense elements. These sense elements, when protected by an insulating layer, offer resistance to severe environments.

**[0062]** The electronic system 200 may include any combination of one or more of the capacitive sense array 220 and/or touch-sense buttons 240. In another embodiment, the electronic system 200 may also include non-capacitance sense elements 270 coupled to the processing device 210 via bus 271. The non-capacitance sense elements 270 may include buttons, light emitting diodes ("LEDs"), and other user interface devices, such as a mouse, a keyboard, or other functional keys that do not require capacitance sensing. In one embodiment,

busses 271, 241, 231, and 221 may be a single bus. Alternatively, these buses may be configured into any combination of one or more separate buses.

**[0063]** The processing device 210 may include internal oscillator/clocks 206 and a communication block ("COM") 208. The oscillator/clocks block 206 provides clock signals to one or more of the components of processing device 210. The communication block 208 may be used to communicate with an external component, such as a host processor 250, via host interface ("I/F") line 251. Alternatively, the processing device 210 may also be coupled to the embedded controller 260 to communicate with the external components, such as host processor 250. In one embodiment, the processing device 210 is configured to communicate with the embedded controller 260 or the host processor 250 to send and/or receive data.

**[0064]** The processing device 210 may reside on a common carrier substrate such as, for example, an integrated circuit ("IC") die substrate, a multi-chip module substrate, or the like. Alternatively, the components of processing device 210 may be one or more separate integrated circuits and/or discrete components. In one exemplary embodiment, processing device 210 may be the Programmable System on a Chip ("PSoC®") processing device, developed by Cypress Semiconductor Corporation, San Jose, California. Alternatively, processing device 210 may be one or more other processing devices known by those of ordinary skill in the art, such as a microprocessor or central processing unit, a controller, special-purpose processor, digital signal processor ("DSP"), an application specific integrated circuit ("ASIC"), a field programmable gate array ("FPGA"), or the like.

**[0065]** It should also be noted that the embodiments described herein are not limited to having a configuration of a processing device coupled to a host, but may include a system that measures the capacitance on the sense device and

sends the raw data to a host computer where it is analyzed by an application. In effect the processing that is done by processing device 210 may also be done in the host.

**[0066]** It is noted that the processing device 210 of **Figure 9** may measure capacitance using various techniques, such as self-capacitance sensing and mutual capacitance sensing. The self-capacitance sensing mode is also called single-electrode sensing mode, as each sensor element needs only one connection wire to the sensing circuit. For the self-capacitance sensing mode, touching the sensor element increases the sensor capacitance as added by the finger touch capacitance is added to the sensor capacitance. The mutual capacitance change is detected in the mutual capacitance-sensing mode. Each sensor element uses at least two electrodes: one is a transmitter (TX) electrode (also referred to herein as transmitter electrode) and the other is a receiver (RX) electrode. When a finger touches a sensor element or is in close proximity to the sensor element, the capacitive coupling between the receiver and the transmitter of the sensor element is decreased as the finger shunts part of the electric field to ground (e.g., chassis or earth).

**[0067]** The capacitance sensor 201 may be integrated into the IC of the processing device 210, or alternatively, in a separate IC. The capacitance sensor 201 may include relaxation oscillator (RO) circuitry, a sigma delta modulator (also referred to as CSD) circuitry, charge transfer circuitry, charge accumulation circuitry, or the like, for measuring capacitance as would be appreciated by one of ordinary skill in the art having the benefit of this disclosure. Alternatively, descriptions of the capacitance sensor 201 may be generated and compiled for incorporation into other integrated circuits. For example, behavioral level code describing capacitance sensor 201, or portions thereof, may be generated using a hardware descriptive language, such as VHDL or Verilog, and stored to a

machine-accessible medium (e.g., CD-ROM, hard disk, floppy disk, etc.). Furthermore, the behavioral level code can be compiled into register transfer level ("RTL") code, a netlist, or even a circuit layout and stored to a machine-accessible medium. The behavioral level code, the RTL code, the netlist, and the circuit layout all represent various levels of abstraction to describe capacitance sensor 201.

**[0068]** It should be noted that the components of the electronic system 200 may include all the components described above. Alternatively, the electronic system 200 may include only some of the components described above.

**[0069]** In one embodiment, the electronic system 200 is used in a notebook computer. Alternatively, the electronic device may be used in other applications, such as a mobile handset, a personal data assistant ("PDA"), a keyboard, a television, a remote control, a monitor, a handheld multi-media device, a handheld video player, a handheld gaming device, or a control panel.

**[0070]** Although the foregoing examples have been described in some detail for purposes of clarity of understanding, the invention is not limited to the details provided. There are many alternative ways of implementing the invention. The disclosed examples are illustrative and not restrictive.

## CLAIMS

What is claimed is:

1. A touch sensor device comprising:
  - a substrate having a central portion and an outer portion;
  - a plurality of substantially co-planar electrodes on the central portion substrate;
  - a first plurality of conductors on the substrate, each of the first plurality of conductors having a first end electrically connected to one of the plurality of electrodes and a second end on the outer portion of the substrate;
  - an insulating material coupled to the second ends of the first plurality of conductors; and
  - a second plurality of conductors coupled to the insulating material, wherein the second plurality of conductors and the insulating material are configured such that each of the second plurality of conductors is electrically connected to the second end of at least some of the first plurality of conductors and is insulated from the second end of the others of the first plurality of conductors.
2. The touch sensor device of claim 1, wherein the insulating material is formed on the outer portion of the substrate, and the second plurality of conductors are formed on the insulating material.
3. The touch sensor device of claim 1, wherein the insulating material is not formed over the central portion of the substrate.

4. The touch sensor device of claim 1, wherein the plurality of substantially co-planar electrodes comprises a first set of electrodes and a second set of electrodes, wherein the second set of electrodes is arranged in a series of rows.
5. The touch sensor device of claim 4, wherein the first plurality of conductors comprises a first set of traces and a second set of traces, wherein the first end of each of the first set of traces is electrically connected to one of the first set of electrodes and the first end of each of the second set of traces is electrically connected to one of the second set of electrodes.
6. The touch sensor device of claim 5, wherein the second plurality of conductors and the insulating material are configured such that each of the second plurality of conductors is electrically connected to the second end of a selected one of the first set of traces or the second ends of the second set of traces having first ends electrically connected to the electrodes in one row of the second set of electrodes.
7. The touch sensor device of claim 6, wherein the first set of electrodes and the second set of electrodes comprise a plurality of inter-digitated members.
8. The touch sensor device of claim 7, wherein the members of each of the first set of electrodes is inter-digitated with the members from more than one row of the second set of electrodes.
9. The touch sensor device of claim 6, wherein the first set of electrodes and the second set of electrodes comprise a plurality of intertwined spiral formations.

10. The touch sensor device of claim 8, wherein the plurality of electrodes and the first plurality of conductors comprises indium tin oxide.

11. A touch sensor device comprising:

a substrate having a central portion and an outer portion;

a first set of electrodes formed on the central portion substrate;

a second set of electrodes formed on the central portion of the substrate, the second set of electrodes being arranged in a series of rows and substantially co-planar with the first set of electrodes;

a first plurality of conductors formed on the substrate, each of the first plurality of conductors having a first end electrically connected to one of the first set of electrodes and a second end on the outer portion of the substrate;

a second plurality of conductors formed on the substrate, each of the second plurality of conductors having a first end electrically connected to one of the second set of electrodes and a second end on the outer portion of the substrate;

an insulating body coupled to the second end of each of the first plurality of conductors and the second end of each of the second plurality of conductors; and

a third plurality of conductors coupled to the insulating body such that each is electrically connected to one of the second end of one of the first plurality of conductors and the second end of the second plurality of conductors associated with only one row of the second set of electrodes and is electrically insulated from the second end of the others of the first set of conductors and the second end of the second plurality of conductors associated with the other rows of the second set of electrodes.

12. The touch sensor device of claim 11, wherein the first set of electrodes and the second set of electrodes comprise a plurality of inter-digitated members.

13. The touch sensor device of claim 12, wherein the members of one of the first set of electrodes are inter-digitated with the members from more than one row of the second set of electrodes.

14. The touch sensor device of claim 13, wherein the insulating body is formed on the outer portion of the substrate, and the third plurality of conductors are formed on the insulating body.

15. The touch sensor device of claim 14, wherein the insulating body and the third plurality of conductors are not formed over the central portion of the substrate.

16. A method for constructing a touch sensor device comprising:  
providing a substrate having a central portion and an outer portion;  
forming a plurality of substantially co-planar electrodes on the central portion substrate;

forming a first plurality of conductors on the substrate, each of the first plurality of conductors having a first end electrically connected to one of the plurality of electrodes and a second end on the outer portion of the substrate;

forming an insulating material on the outer portion of the substrate and coupled to the second ends of the first plurality of conductors; and

forming a second plurality of conductors on the insulating material, wherein the second plurality of conductors and the insulating material are configured such that each of the second plurality of conductors is electrically

connected to the second end of at least some of the first plurality of conductors and is insulated from the second end of the others of the first plurality of conductors.

17. The method of claim 16, wherein the insulating material and the second plurality of conductors are not formed over the central portion of the substrate.

18. The method of claim 17, wherein the plurality of electrodes and the first plurality of conductors each comprise indium tin oxide.

19. The method of claim 18, wherein the first plurality of conductors and the second plurality of conductors are substantially orthogonal.

20. The method of claim 19, wherein the substrate comprises glass.

21. A touch sensor device comprising:

a substrate having a central portion and an outer portion;

a first set of electrodes formed on the central portion substrate;

a second set of electrodes formed on the central portion of the substrate, the second set of electrodes being arranged in a series of rows and substantially co-planar with the first set of electrodes;

a first plurality of conductors on the substrate, each of the first plurality of conductors having a first end electrically connected to one electrode of the first set of electrodes or the second set of electrodes and a second end on the outer portion of the substrate; and

a second plurality of conductors coupled to the substrate, each of the second plurality of conductors being electrically connected to at least one of the

first plurality of conductors at a node that is external to the central portion of the substrate such that each of the second plurality of conductors is electrically connected to one electrode of the first set of electrodes or a plurality of electrodes in one of the rows of the second set of electrodes.

22. The touch sensor device of claim 21, wherein the second plurality of conductors does not extend over the central portion of the substrate.

23. The touch sensor device of claim 22, further comprising an insulating material coupled to the second ends of the first plurality of conductors and the second plurality of conductors, the insulating material electrically insulating each of the second plurality of conductors from the others of the first plurality of conductors.

24. The touch sensor device of claim 22, wherein the insulating material does not extend over the central portion of the substrate.

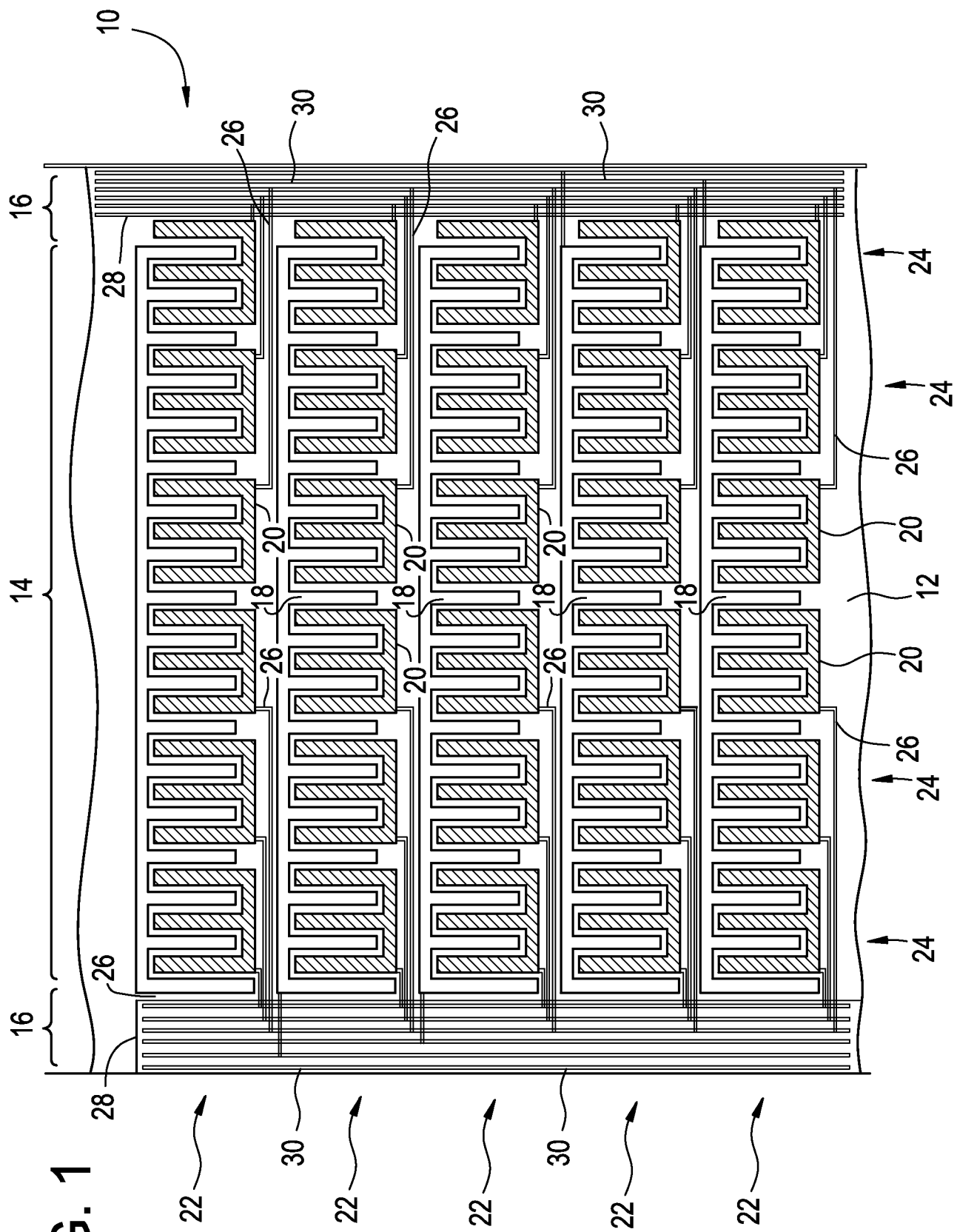
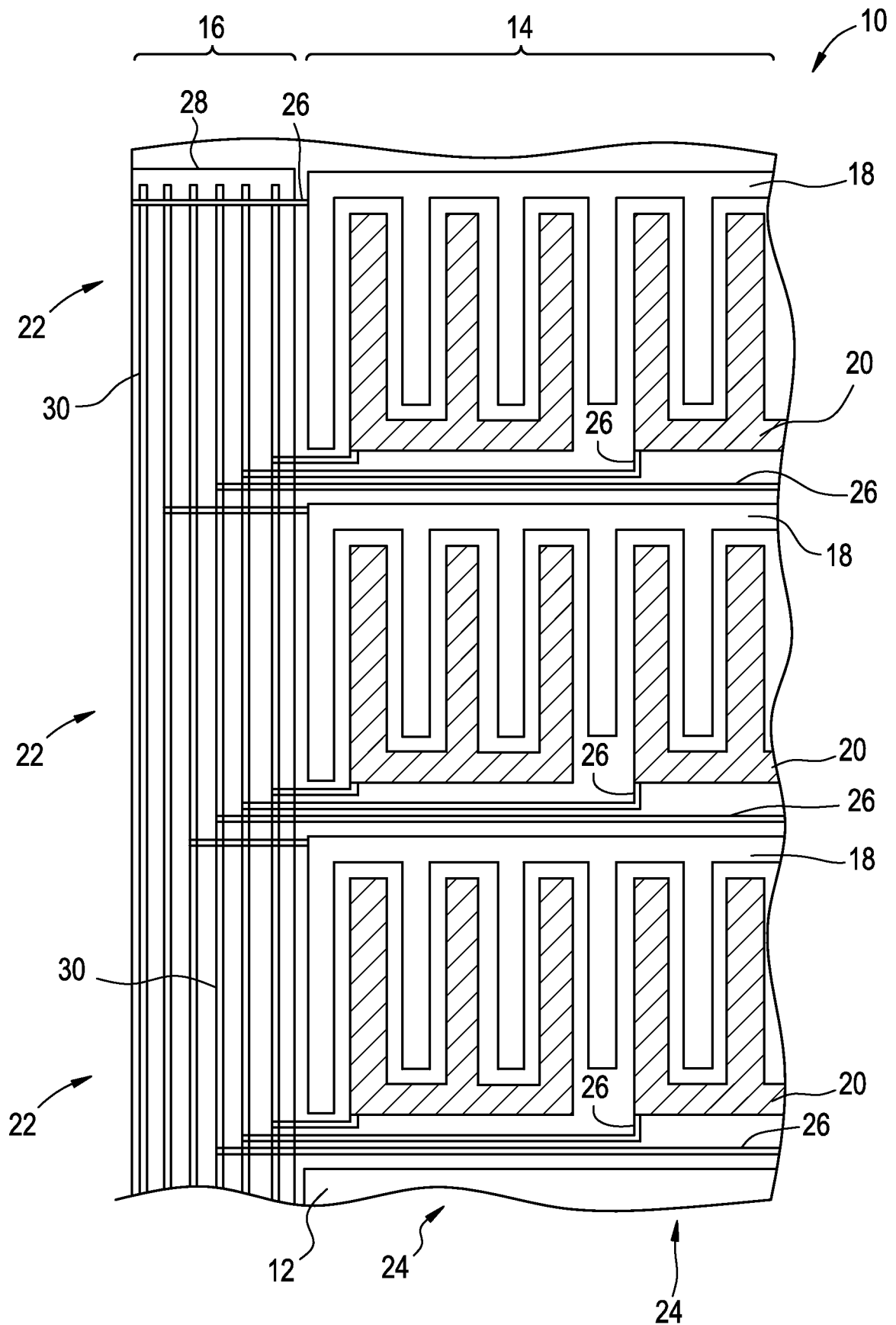


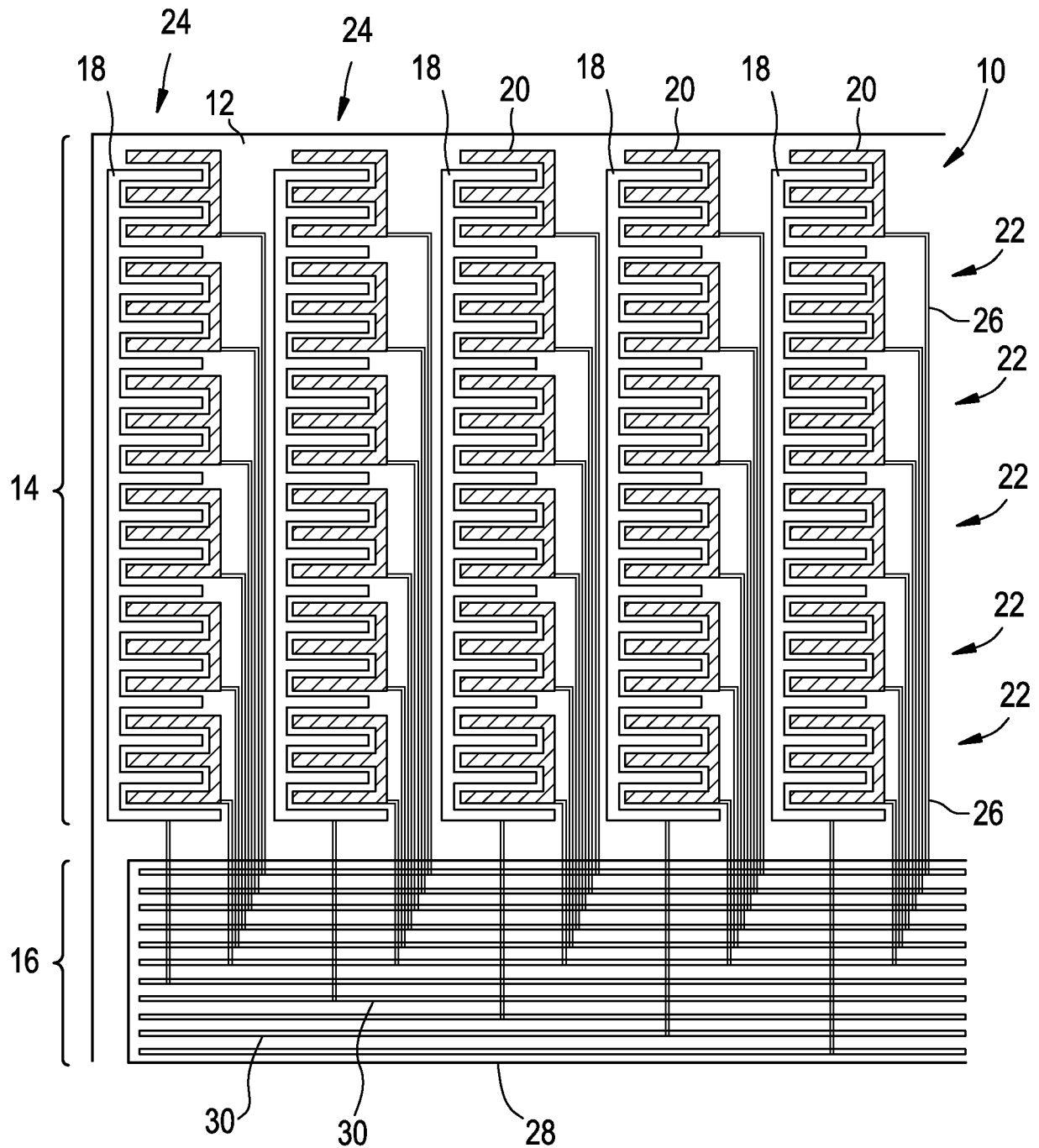
FIG. 1

FIG. 2

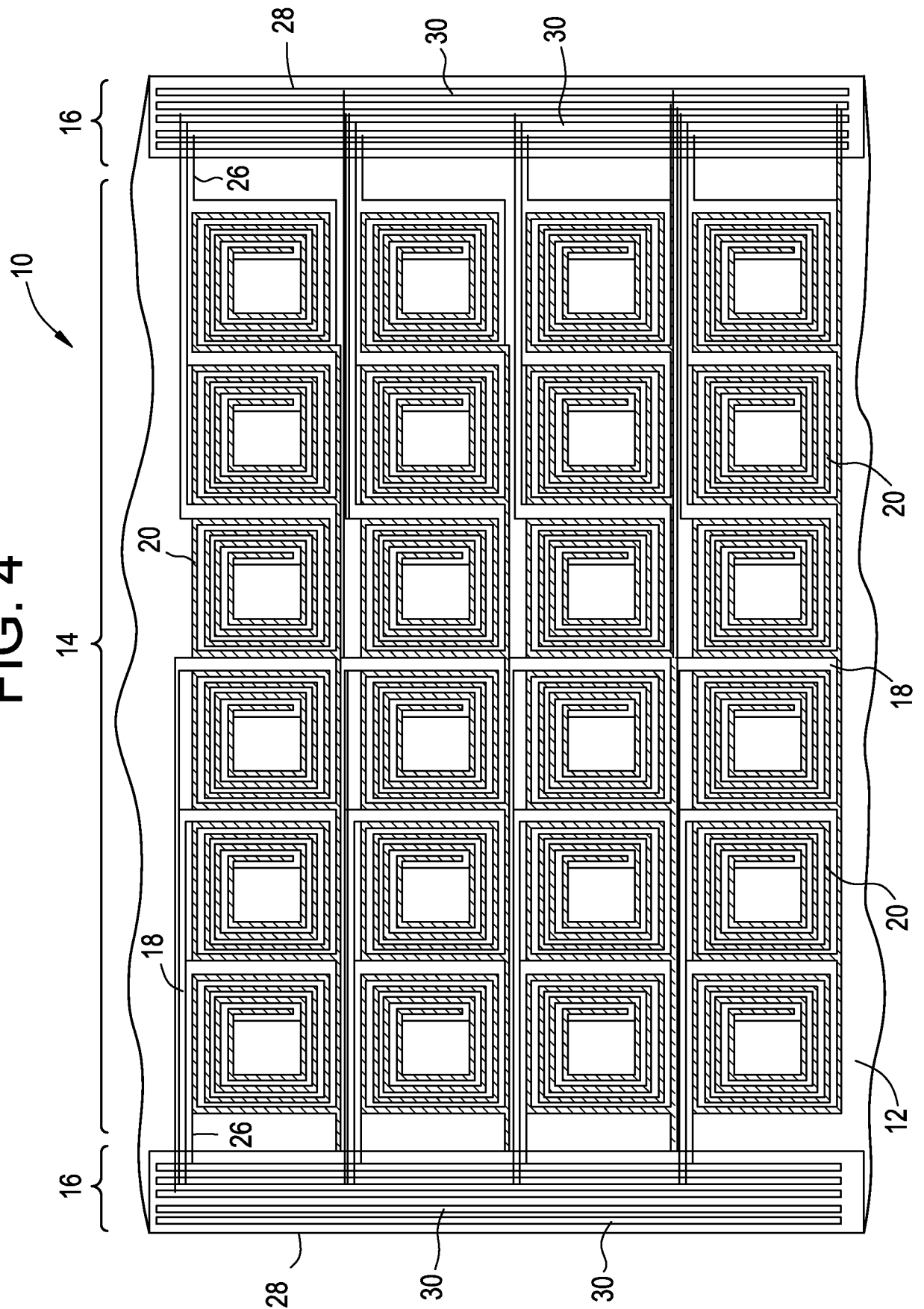


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FIG. 3



**FIG. 4**



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FIG. 5

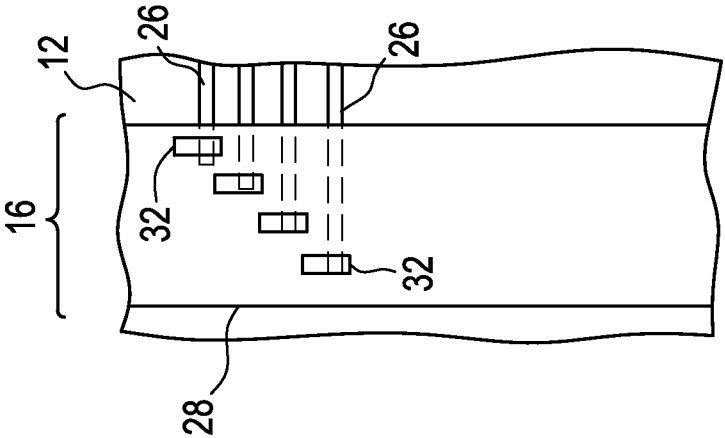


FIG. 6

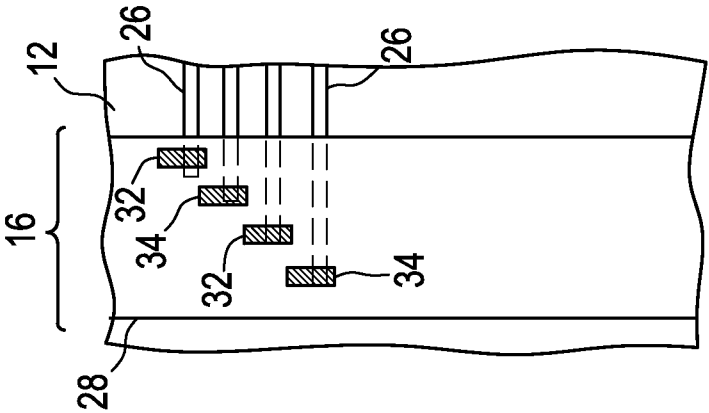


FIG. 7

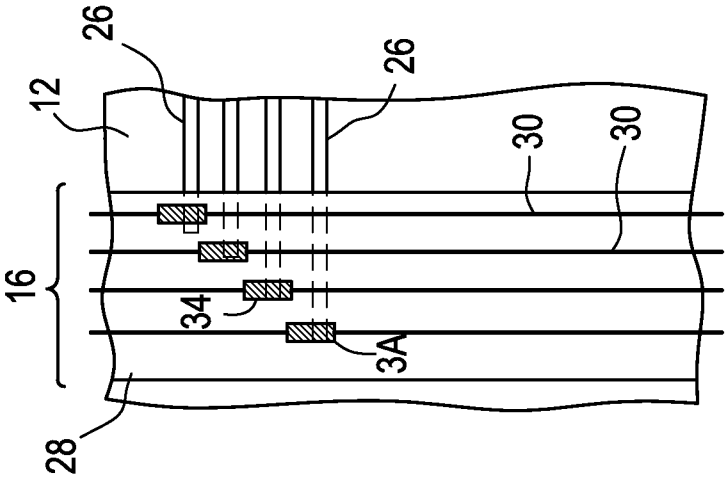
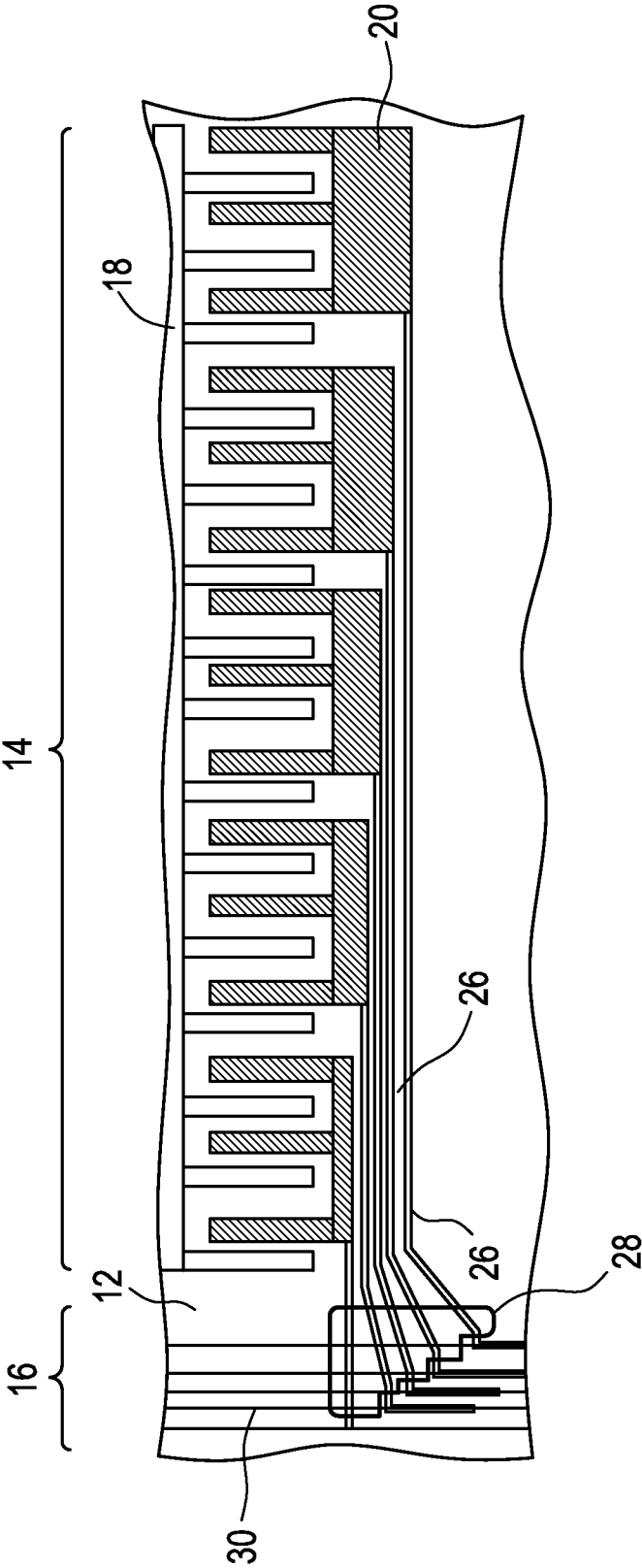


FIG. 8



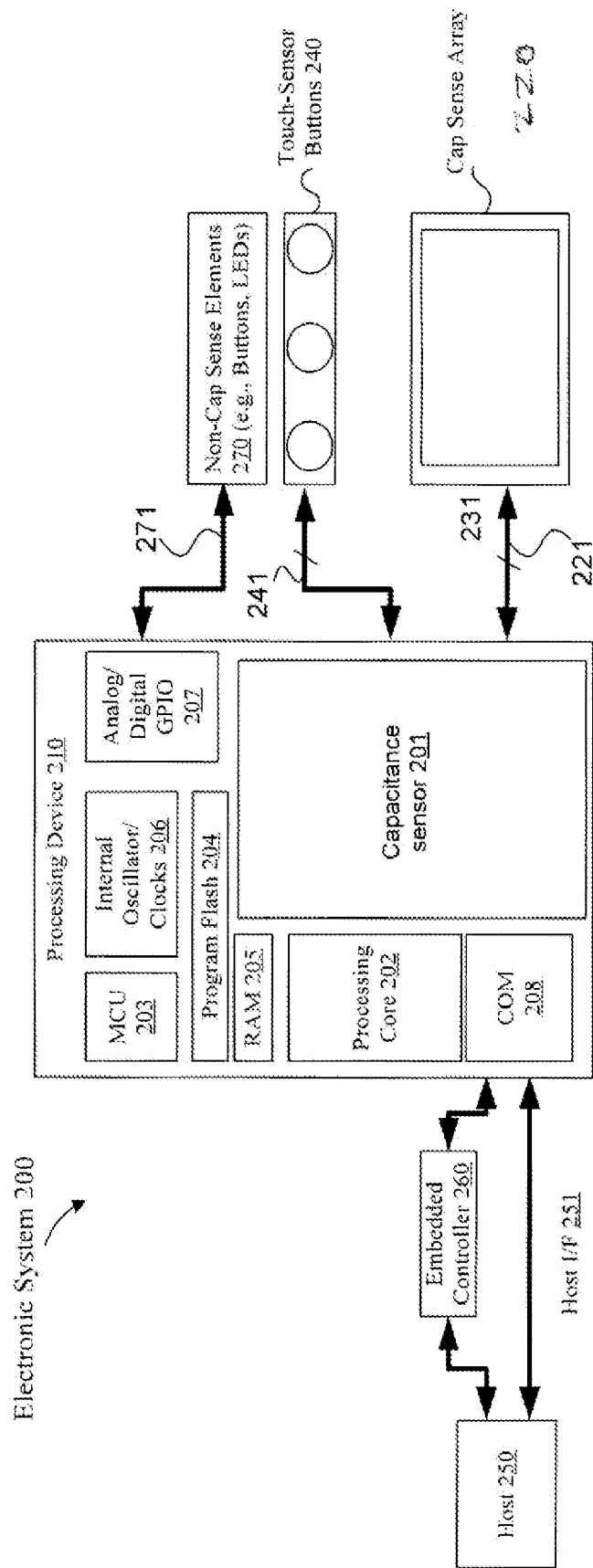


FIG. 9

**A. CLASSIFICATION OF SUBJECT MATTER*****G06F 3/041(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

G06F 3/041; B44C 1/22; G06F 3/045

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) &amp; Keywords:single layer,touch sensor,conductor,electrode

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                            | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | US 2009-0090694 A1 (HOTELLING STEVE PORTER et al.) 09 April 2009                                              | 21-22                 |
| Y         | See paragraphs[0026]-[0034] and figures 1B-2A.                                                                | 1-4, 16-20, 23-24     |
| Y         | JP 2010-205177 A (SHARP CORP) 16 September 2010<br>See paragraphs[0071]-[0102] and figure 2.                  | 1-4, 16-20, 23-24     |
| A         | US 2011-0018841 A1 (HRISTOV LUBEN) 27 January 2011<br>See paragraphs[0055]-[0056] and figures 7,8.            | 1-24                  |
| A         | US 2010-0220071 A1 (NISHIHARA KIYOSHI et al.) 02 September 2010<br>See paragraphs[0042]-[0046] and figure 1A. | 1-24                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

29 MARCH 2012 (29.03.2012)

Date of mailing of the international search report

**10 APRIL 2012 (10.04.2012)**

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Authorized officer

LEE, Hee Bong

Telephone No. 82-42-481-8120



**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2011/053916**

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