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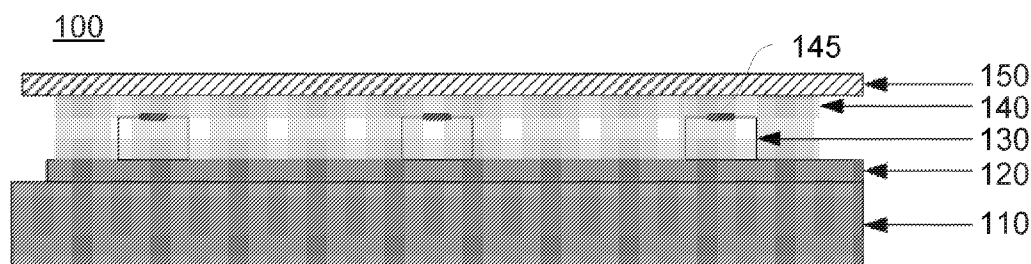


FIG. 1

(57) Abstract: A control panel device is disclosed herein. The control panel device includes a circuit board, an enclosure member (e.g., gasket), a top plate and one or more pressure sensors (e.g., MEMS microphones). The enclosure member is attached to the circuit board. The top plate is disposed on the enclosure member. The enclosure member defines one or more air chambers. The pressure sensors are attached to the circuit board and are configured to detect pressure changes of the air pockets of the respective air chambers and to generate signals corresponding to the pressure changes. The control panel detects a touch on the top plate based on one or more signals generated by at least one of the pressure sensors.



CONTACT INTERFACE DEVICE WITH TRAPPED AIR SENSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 62/550,319, filed August 25, 2017, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] This application relates generally to contact interface devices and more particularly to contact interface devices using sensors.

BACKGROUND

[0003] Existing contact interface technologies (e.g., touch screens) are used in various commercial, industrial, medical and/or military applications. However, those technologies pose several problems. For example, the environment may require using harsh or abrasive cleaners (e.g., acids or bleaches) and/or scrubbing to ensure a properly cleaning of a device, which can affect reliability. In particular, military applications can require touch-screen equipment to be functional in harsh climates and/or battlefield conditions (with, e.g., ice, snow, mud, sand, dust, etc.). For example, in some medical applications, the user may desire to wear gloves to interact with a human-machine interface of the device.

[0004] However, some of the existing touchscreen technologies do not operate with a gloved hand. And although some existing touchscreen technologies are compatible with gloves, those technologies typically need a plastic film disposed on the front of the device. The plastic film cannot withstand abuse of harsh cleaners, scrubbing, or abrasion. Some other existing touchscreen technologies compatible with gloves utilize infrared sensors. The infrared sensors are disposed on top of or above a top plate of the device. However, the infrared sensors are vulnerable to foreign materials that may block infrared light beams, and ambient light may disrupt the infrared sensors. Some other devices utilize mechanical buttons, which are moving parts that eventually wear out and are subject to contact contamination. Some touch panels are also designed to include a transparent liquid crystal

display (LCD) back panel, which is made of plastics or glass and is vulnerable to the environment and handling.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] For a more complete understanding of the disclosure, reference should be made to the following detailed description and accompanying drawings wherein:

[0006] FIG. 1 is a block diagram of a touch panel device including pressure sensors covered by a silicone over-mold, for illustrating some aspects of the present disclosure.

[0007] FIG. 2 is a block diagram of a touch panel device including pressure sensors enclosed in a gasket, according to exemplary embodiments of the present disclosure.

[0008] FIG. 3 illustrates measurements of a mechanical impact of the impact hammer and a corresponding pressure signal generated by a MEMS microphone pressure sensor.

[0009] FIG. 4 is a block diagram of a touch panel device including pressure sensors enclosed by a gasket, according to exemplary embodiments of the present disclosure.

[0010] FIG. 5 is a block diagram of a touch panel device including bottom-port MEMS microphones, according to exemplary embodiments of the present disclosure.

[0011] FIG. 6 is a block diagram of a touch panel device including bottom-port MEMS microphones, according to exemplary embodiments of the present disclosure.

[0012] FIG. 7 illustrates examples of control panel devices that include O-rings or bellows as enclosure members, according to exemplary embodiments of the present disclosure.

[0013] FIG. 8 illustrates examples of control panel devices with top panels that include air pockets, according to exemplary embodiments of the present disclosure.

[0014] FIG. 9 illustrates examples of control panel devices with curved top panels, according to exemplary embodiments of the present disclosure.

[0015] FIG. 10 illustrates examples of control panel devices that do not include backing material, according to exemplary embodiments of the present disclosure.

DETAILED DESCRIPTION

[0016] Skilled artisans will appreciate that elements in the figures are illustrated for

simplicity and clarity. It will further be appreciated that certain actions and/or steps may be described or depicted in a particular order of occurrence while those skilled in the art will understand that such specificity with respect to sequence is not actually required. It will also be understood that the terms and expressions used herein have the ordinary meaning as is accorded to such terms and expressions with respect to their corresponding respective areas of inquiry and study except where specific meanings have otherwise been set forth herein.

[0017] According to at least some embodiments of the present disclosure, a contact interface device (e.g., a control panel device or a human machine interface device) can withstand a harsh environment for various commercial, industrial, medical, and/or military applications. The disclosed device can interact with objects such as users' hands, with or without gloves, and can be mass-produced. The disclosed technology operates by detecting any object (including, e.g., a gloved hand) contacting a top plate of a device. The top plate may be made of any flat surface material such as metal, plastic, or glass. The device detects the contact by using sensors. The sensors can be mounted behind the top plate that isolates the microphones from the external environment. The sensors may be, e.g., pressure sensors, MEMS (microelectromechanical system) sensors (MEMS microphones as accelerometers), force sensors (e.g., piezo sensors), and/or strain sensors (e.g., strain gauge sensors). In some embodiments, a MEMS microphone is used as a capacitive pressure sensor. If properly constructed, other types of pressure sensors can perform the same function. Pressure sensors may be piezoresistive, capacitive, electromagnetic, electrostatic, piezoelectric, optical, and/or potentiometric.

[0018] For example, a touch control panel with one or more buttons (e.g., push buttons) may be realized by using an array of sensors (e.g., pressure sensors) and a detection circuit. Examples of detection circuits using pressure sensor signals are disclosed in U.S. Patent Application No. 15/382,591, filed December 16, 2016, which is incorporated herein by reference in its entirety. A top plate (also referred to as front plate or front panel) of the touch control device serves as the human-machine interface (HMI), and the material for the top plate may be selected to meet environment and use requirements of the device. The resulting touch control panel is inherently reliable because the pressure sensors are mounted behind the top plate and are isolated from the external environment. The design of the touch control panel utilizes the pressure sensors that are easy to assemble, characterize and test. The

touch control panel is suitable for high volume production.

[0019] According to at least some embodiments of the present disclosure, MEMS microphones are used as trapped air pressure sensors to detect a contact with a top plate (e.g., a touch or a tap to the top plate). Each pressure sensor is enclosed in a sealed microphone chamber. The sealed microphone chamber also includes a trapped air pocket around the microphone. The tap and/or touch motion applied to the panel compresses the microphone chamber (as well as the trapped air pocket). In turn, the compression of the microphone chamber causes a pressure change of the trapped air pocket, which leads to a corresponding output voltage generated by the pressure sensor indicating the pressure change. Because the pressure sensor in the chamber is not in direct contact with the chamber inner surface or the top plate, the tap or touch motion to the top plate does not directly compress or squeeze the pressure sensor. The resulting touch panel is easy to assemble and can be tested on a factory assembly line.

[0020] It is advantageous for the pressure sensors to detect pressure changes of the trapped air pockets around the pressure sensors. For example, the present applicants have observed that, if there is no trapped air pocket around the microphone package, the tap or touch motion may cause direct deformation of the microphone package itself. It is easier to detect pressure changes of the trapped air pockets instead of the deformation of the microphone package. The package deformation may be microscopic. The package deformation can also occur in three dimensions and may vary depending on how the pressure sensor is mounted.

[0021] FIG. 1 is a block diagram of a touch panel device including pressure sensors covered by a silicone over-mold, for illustrating some aspects of the present disclosure. The touch panel device 100 includes a backing 110, a printed circuit board (PCB) 120, one or more pressure sensors 130, a silicone over-mold 140, and a top plate 150 (also referred to as front panel or front plate).

[0022] The PCB 120 is disposed on the backing 110. Examples of backing mechanism and structures are disclosed in a co-pending U.S. Provisional Patent Application titled “BUTTON SENSOR ATTACHMENT FOR TOUCH PANEL, filed August 25, 2017, which is incorporated herein by reference in its entirety. The PCB may include a detection circuit for detecting the tap or touch motion based on the signals generated by the pressure sensors 130.

Examples of detection circuits for detecting tap or touch motion are disclosed in U.S. Patent Application No. 15/382,591, filed December 16, 2016, which is incorporated herein by reference in its entirety. In some other embodiments, detection modules other than the detection circuit can be used to detect the tap or touch motion. For example, a software detection module may run on a processor and detect the tap or touch motion. The pressure sensors 130 are disposed on the PCB 120 and are electrically connected to the PCB 120. The silicone over-mold 140 is placed on top of the pressure sensors 130. The top plate 150 is disposed on the silicone over-mold 140. In some embodiments, the top plate 150 may be made of, e.g., stainless steel, aluminum, or other metals or other solid materials. In some embodiments, the over-mold 140 can include materials other than silicone.

[0023] In some embodiments, the pressure sensors 130 are disposed such that the microphone ports of the pressure sensors 130 (e.g., top-port MEMS microphones) face towards the silicone over-mold 140. In some embodiments, the microphone ports of the pressure sensors 130 are in direct contact with the silicone over-mold 140. During an over-molding process, an over-mold is fabricated on the PCB after the PCB is manufactured. In other words, each over-mold is unique to individual instance of the PCB. In some other embodiments, there are additional seals 145 between the microphone ports of the pressure sensors 130 and the silicone over-mold 140. In other words, the microphone ports are positively sealed by the seals 145.

[0024] During operation, a user touches or taps the top plate 150, causing a deflection of the top plate 150 and the silicone over-mold 140. In turn, one or more pressure sensors 130 are deformed, which causes the air pressure inside of the pressure sensor 130 to change. The pressure sensor 130 generates a signal proportional to the change of the air pressure inside of the pressure sensor 130. The control panel device then detects a tap or touch motion based on the signal of the pressure sensor 130 using, e.g., a detection circuit. For example, in some embodiments, the location of one or more pressure sensors are known. The surface of the control panel can be divided into multiple areas that correspond to locations at which one or more pressure sensors are disposed. The control panel device can assume that a contact (e.g., a tap or touch motion) occurs in proximity to the location of the pressure sensor that collects the signal corresponding to the contact.

[0025] In the embodiments shown in FIG. 1, the pressure sensor 130 can be, e.g., plugged

MEMS microphones where the microphone ports are sealed. Examples of plugged MEMS microphones are disclosed in U.S. Patent Application No. 15/382,581, filed December 16, 2016, which is incorporated herein by reference in its entirety. The seal effectiveness may affect the deformation of the pressure sensor 130 as well as the signal output of the pressure sensor 130. The seal by the silicone over-mold 140 needs to be robust over time and temperature. With the silicone over-mold 140, the assembly of the control panel device involves an extra procedure for individually sealing each microphone port.

[0026] In some other embodiments, instead of using top port microphones, the pressure sensors may be bottom-port microphones. However, the assembly of the devices involves disposing solder seal around the bottom microphone ports of the bottom-port MEMS microphones where the ports make contact with the PCB.

[0027] The relationship between the characterization of the pressure sensor output versus the deformation (e.g., bending) of the panel may be a complicated issue, because the output of the pressure sensor is dependent on how the microphone package deforms as well as how well the seal holds up. For example, a change to the design of the microphone package or the seal may affect how the pressure sensor output responds to the panel deformation. Changes to the design of the control panel may also affect how the microphone itself deforms, which in turn affects how the pressure sensor output responds. As a result, the detection circuit of the control panel device needs a model of the relationship between the characterization of the pressure sensor output versus the bending of the panel. In addition, the characterization of the sensitivity of the control panel may be challenging if the deformation of the microphone package is included.

[0028] According to at least some embodiments of the present disclosure, at least some of the above issues may be solved by using pressure sensors enclosed in air chambers of a gasket. At least one advantage of the disclosed arrangement is that the detection sensitivity can be adjusted by changing material properties (e.g., hardness), independent of the pressure sensors. FIG. 2 is a block diagram of a touch panel device including pressure sensors enclosed in a gasket, according to exemplary embodiments of the present disclosure. The touch panel device 200 includes a backing 210, a PCB 220, one or more pressure sensors 230, a gasket 240, and a top plate 250 (also referred to as front panel or front plate).

[0029] The PCB 220 is disposed on the backing 210 and may include a detection circuit for detecting the tap or touch motion based on the signals generated by the pressure sensors 230. In some embodiments, components such as resistors or capacitors are disposed on the bottom side of the PCB 220. The top side of the PCB 220 has a relative smooth or flat surface for applying an adhesive or a sealant for the gasket 240 to be attached to.

[0030] The pressure sensors 230 are disposed on the PCB 220 and are electrically connected to the PCB 220. Unlike the touch panel device 100 of FIG. 1, the touch panel device 200 does not include a silicone over-mold, and instead includes a gasket 240. The gasket 240 defines one or more air chambers 245 for accommodating the one or more pressure sensors 230. The top plate 250 is disposed on the gasket 240. In some embodiments, the top plate 250 may be, e.g., a stainless steel top plate, an aluminum top plate, or a top plate including other types of metals and/or solid materials.

[0031] In some embodiments, the gasket 240 may be formed of, or includes, an open cell urethane foam material or a solid urethane material. The gasket 240 may be attached to the PCB 220 using an adhesive. The material of the gasket 240 may be selected such that the gasket hardness creates an optimal signal sensitivity for the control panel device, such that the sensitivity to user input is high relative to sensitive to external noise sources. In some embodiments, the gasket includes an absorptive material such that environmental vibrational noise are damped and not picked up by the pressure sensors. In some embodiments, the gasket has a vibration absorbing property. For example, in some other embodiments, the gasket includes a material with a hardness, e.g. a high durometer rubber, such that the environmental acoustic noise outside of the control panel device does not cause a pressure change inside of the air chambers, and thus is not detected, whereas the tap or touch motion on the plate will still cause a pressure change to be detected by the pressure sensors. In some embodiments, a durometer scale (a measurement of hardness) of the gasket material may be, e.g., from about Shore 60A to about Shore 90A. In some embodiments, the hardness of the gasket material may be selected depending on a geometry of the touch panel device as well as a desired level of noise reduction.

[0032] The air chambers 245 are enclosed by the gasket 240 and the top plate 250 and are airtight. In some embodiments, a width of the air chambers 245 is greater than a width of the pressure sensors 230. Thus, there is air between side surfaces of a pressure sensor 230 and inner side surfaces of the gasket 240. In some embodiments, a height of the air chambers 245

is greater than a height of the pressure sensors 230. Thus, there is air between the microphone port at the top of a pressure sensor 230 and the top plate 250.

[0033] The sealing of the air chambers 245 may be achieved over a large surface area by the gasket 240 and the top plate 250. The sealing may be robust over time and temperature. Where the pressure sensor is a MEMS microphone, the microphone port is left open and no additional seal is attached to the microphone during assembly. Thus, there is an air pocket sealed around the pressure sensor 230 inside of the air chamber 245.

[0034] In some embodiments, the pressure sensors 230 may be, e.g., top-port microphones. Thus, the assembly of the touch panel device 200 does not necessarily involve disposing a solder joint on the bottom port seal as would be used for a bottom port microphone.

[0035] During operation, a user touches or taps the top plate 250, causing a distortion of the top plate 250 and the gasket 240. In turn, one or more air chambers 245 are deformed, which causes the air pressure of the trapped air pockets inside of the air chambers 245 to change. Since the pressure sensors 230 are surrounded by the trapped air pockets, the packages of the pressure sensors 230 are not deformed. The pressure sensors 230 measure the pressure changes of the air pockets due to the changes of the volume of the trapped air pockets. In some embodiments, the shapes and volumes of the air pockets may be different from each other.

[0036] In some embodiments, the pressure sensor 230 generates a signal proportional to the change of the air pressure of the trapped air pocket inside of the air chambers 245. The control panel device then detects a tap or touch motion (as well as, e.g., a location and/or an intensity of the motion) based on the signals of the one or more pressure sensors 230.

[0037] Since there is no deformation of the pressure sensors 230, the relationship between the characterization of the pressure sensor output versus the deformation of the panel may be modeled without additional consideration of the potential pressure sensor package deformation. The model considers the distortions and/or compressions of the top plate 250 and the gasket 240, but does not need to consider the deformation of the pressure sensors 230. The compressibility data and/or hardness data of the gasket material is a known input for the model.

[0038] In some embodiments, a gasket may be manufactured in parallel with the PCB board

for ease of manufacturing. In other words, unlike an over-molding process wherein an over-mold is fabricated after the PCB is manufactured, the gasket and the PCB can be manufactured independently. There is no need to manufacture any gasket that is unique to individual instances of the PCB. Adhesive (in form of, e.g., a tape) may be applied to the gasket. When attaching the gasket to the PCB, a tape cover can be removed and the gasket is attached to the PCB board via the exposed adhesive.

[0039] In some embodiments, the performance of a control panel device may be tested using, e.g., an impact hammer. The impact hammer applies a stimulus at a surface of the top plate. FIG. 3 illustrates measurements of a mechanical contact by the impact hammer and a corresponding pressure signal generated by a pressure sensor. The curve 310 represents the mechanical pressure caused by the impact hammer. The curve 320 represents the pressure change of a trapped air pocket surrounding the pressure sensor. The air chamber including the trapped air pocket and the pressure sensor may be adjacent to the impact point on the top plate of the control panel. As shown in FIG. 3, the pressure sensor detects the impact motion instantly as the impact hammer contacts the control panel device. The X axis of curves 310 and 320 represents time. The Y axis of curve 310 represents the impact pressure caused by the impact hammer. The Y axis of curve 320 represents the air pressure change detected by the pressure sensor. As FIG. 3 shows, as soon as the impact hammer causes the mechanical pressure on the top plate of the control panel, the pressure sensor detects the air pressure change.

[0040] The gasket of the control panel device may have various configurations in different embodiments. FIG. 4 is a block diagram of a touch panel device including pressure sensors enclosed by a gasket, according to exemplary embodiments of the present disclosure. The touch panel device 400 includes a backing 410, a PCB 420, one or more pressure sensors 430, a gasket 440, and a top plate 450 (also referred to as front panel or front plate). The touch panel device 400 shown in FIG. 4 is generally similar to the touch panel device 200 shown in FIG. 2, except that the gasket 440 of the touch panel device 400 includes top portions 443.

[0041] Referring to FIG. 2, the gasket 240 includes through holes that define air chambers 245. To retain the trapped air pocket inside of the air chambers 245, the air chambers 245 of the gasket 240 are sealed at the top and bottom sides. For example, using adhesive and/or

sealant, the top side of the air chambers of the gasket 240 may be sealed to the top plate 250. Similarly, the bottom side of the air chambers of the gasket 240 may be sealed to the PCB 220.

[0042] Referring back to FIG. 4, because the gasket 440 includes top portions 443, the air chambers 445 of the gasket 440 no longer need to be sealed at the top side. As such only the bottom side of the air chambers of the gasket 440 needs to be sealed to the PCB 420, whereas the top side of the gasket 440 does not require an adhesive bond to the top plate 450. Consequently, the assembly process of the touch panel device 400 is simpler and the reliability of the device 400 increases, and it is also easier to replace the top plate 450 since the plate may only need to be mechanically pressed to the gasket 440. In some embodiments, the top plate 450 may be attached to the rest of the control panel device 400 using a mechanical mechanism, such as rivets, bolts, clips, etc.

[0043] In some embodiments, the control panel device can include bottom-port MEMS microphones instead of top-port MEMS microphones or other types of sensors. In some embodiments, the ports of the MEMS microphones are not sealed. FIG. 5 is a block diagram of a touch panel device including bottom-port MEMS microphones, according to exemplary embodiments of the present disclosure. The touch panel device 500 includes a backing 510, a PCB 520, one or more MEMS microphones 530, a gasket 540, and a top plate 550 (also referred to as front panel or top plate). In some embodiments, the backing 510 may be omitted. The touch panel device 500 shown in FIG. 5 is generally similar to the touch panel device 200 shown in FIG. 2, except that the bottom-port MEMS microphones 530 are disposed on the other side (bottom side) of the PCB 520 and enclosed by the backing 510 instead of the gasket 540.

[0044] As shown in FIG. 5, the gasket 540 of the touch panel device 500 may still define through holes 542. The top and bottom sides of the through holes 542 may be sealed against the top plate 550 and the PCB 520 respectively (using, e.g., adhesive or sealant). The air pockets of the through holes 542 communicate with the ports of the bottom-port MEMS microphones 530. The PCB 520 defines holes 522 for the air to travel through so that the bottom-port MEMS microphones 530 can measure the pressure changes of the air pockets of the through holes 542. The backing 510 includes places 515 for accommodating the bottom-port MEMS microphones 530. The bottom ports of the MEMS microphones 530 are sealed around the connections between the ports and the PCB 520. For example, solder may be

disposed around the ports where the ports make contact with the PCB 520.

[0045] In some embodiments, the places 515 may also include air around the microphones 530. However, the air chambers 515 do not communicate with the air in the through holes 542. In some other embodiments, the backing 510 may be omitted.

[0046] In some embodiments, the control panel device can include bottom-port MEMS microphones and does not include a gasket, and the sensor measures the pressure in the trapped air pocket of the hole 622. FIG. 6 is a block diagram of a touch panel device including bottom-port MEMS microphones, according to exemplary embodiments of the present disclosure. The touch panel device 600 includes a backing 610, a PCB 620, one or more MEMS microphones 630, an adhesive layer 680, and a top plate 650 (also referred to as front panel or top plate). The backing 610 includes places 615 for accommodating the bottom-port MEMS microphones 630. In some embodiments, the backing 610 may be omitted.

[0047] The touch panel device 600 shown in FIG. 6 is generally similar to the touch panel device 500 shown in FIG. 5, except that the touch panel device 600 does not include a gasket and instead includes an adhesive layer 680 disposed between the PCB 620 and the top plate 650.

[0048] In some embodiments, the adhesive layer 680 includes a soft, non-hardening adhesive. The PCB 620 defines holes 622. When the top plate 620 is being contacted (e.g., a tap or touch motion by a user), at least a portion of the adhesive may be compressed and expands into the holes 622 of the PCB 620. The volumes of the holes 622 may change due to the compressed and expanded adhesive, and/or due to bending of the top plate 650.

[0049] In some embodiments, the gasket can be replaced by other enclosure members such as one or more O-rings (individual or an array), one or more bellows (individual or an array), one or more air pockets inside the panel, or a combination of two or more thereof. Enclosure members that are flexible components can be attached to the panel or the board to create one or more air chambers using an adhesive (or other sealant materials) or a mechanical configuration.

[0050] FIG. 7 illustrates examples of control panel devices that include O-rings or bellows as enclosure members. For example, compared to the control panel device 600 as shown in FIG.

6, the control panel device 710 replaces the adhesive layer 680 with a plurality of adhesive dots. The adhesive dots may have various shapes. The bottom port microphones can detect the pressure change of the air enclosed in the holes of the PCB. The control panel device 720 includes a plurality of O-rings. The O-rings, along with the top plate and the circuit board, form air chambers in which the top port microphones are disposed. The control panel device 730 includes a plurality of bellows. The bellows, along with the top plate and the circuit board, form air chambers in which the top port microphones are disposed.

[0051] FIG. 8 illustrates examples of control panel devices with top panels that include air pockets. The control panel device 810 includes a plurality of air pockets for accommodating the sensors. The air pockets may be sealed and/or air-tight, because the top panel is attached to the circuit board using, e.g., adhesive or gasket. The air pockets in the top panel, along with the circuit board, form air chambers in which the top port microphones are disposed. The control panel device 820 is similar to the control panel device 810, except that the control panel device 820 includes O-rings that are disposed in grooves of the top panel. The O-rings are pressed against the circuit board such that the air chambers defined by the air pockets are air-tight. The control panel device 830 is similar to the control panel device 820, except that the O-rings of the control panel device 830 are disposed in grooves defined by the circuit board, instead of the top panel.

[0052] In some embodiments, the top plate may be any suitable sheet material (e.g., sheet metal or sheet plastic). The top plate may be, e.g., flat or curved. FIG. 9 illustrates examples of control panel devices with curved top plates. The control panel device 910 includes a curved top plate and a plurality of bellows below the curved top plate. The bellows, along with the curved top plate and the circuit board, define the air chambers in which the pressure sensors are disposed. The shapes and volumes of the air chambers may be different from each other. The control panel device 920 is similar to the control panel device 910, except that the control panel device 920 includes a gasket below the curved top plate, instead of bellows. The control panel device 930 is similar to the control panel device 920, except that the control panel device 930 includes bottom port microphones instead of top port microphones. The bottom port microphones are disposed on the other side of the circuit board, similar to the bottom port microphones 630 shown in FIG. 6.

[0053] In some embodiments, the device may include a secondary plate behind the panel.

The secondary plate may include a hard material (e.g., metal or plastic). There may be a softer gasket material on each side of the secondary plate to accommodate the imperfections between plates and/or to seal the enclosures of the sensors (e.g., microphones). The sensors may be, e.g., top port microphones or bottom port microphones. The gasket material may include one or more gasket or O-rings. The gasket material may be attached using adhesive or a mechanical configuration.

[0054] FIG. 10 illustrates examples of control panel devices that do not include backing material. The control panel device 1010 includes a top plate and a backing plate below the top plate. There are gaskets disposed between the top plate and the backing plate, as well as gaskets between the backing plate and the circuit boards. The gaskets, along with the top plate, backing plate and the circuit board, define air chambers in which the top port microphones are disposed. The control panel device 1020 is similar to the control panel device 1010, except that the control panel device 1020 includes O-rings instead of gaskets to ensure that the air chambers are sealed and/or air-tight. The control panel device 1030 is similar to the control panel device 1020, except that the control panel device 1030 includes bottom port microphones instead of top port microphones. The bottom port microphones are disposed on the other side of the circuit board, similar to the bottom port microphones 630 shown in FIG. 6. The control panel device 1040 is similar to the control panel device 1030, except that the control panel device 1020 includes gaskets instead of O-rings to ensure that the air chambers are sealed and/or air-tight.

[0055] As used herein, the singular terms “a,” “an,” and “the” may include plural referents unless the context clearly dictates otherwise.

[0056] Spatial descriptions, such as “above,” “below,” “up,” “left,” “right,” “down,” “top,” “bottom,” “vertical,” “horizontal,” “side,” “higher,” “lower,” “upper,” “over,” “under,” and so forth, are indicated with respect to the orientation shown in the figures unless otherwise specified. It should be understood that the spatial descriptions used herein are for purposes of illustration only, and that practical implementations of the structures described herein can be spatially arranged in any orientation or manner, provided that the merits of embodiments of this disclosure are not deviated by such an arrangement.

[0057] As used herein, the terms “approximately,” “substantially,” “substantial” and “about”

are used to describe and account for small variations. When used in conjunction with an event or circumstance, the terms can refer to instances in which the event or circumstance occurs precisely as well as instances in which the event or circumstance occurs to a close approximation. For example, when used in conjunction with a numerical value, the terms can refer to a range of variation less than or equal to $\pm 10\%$ of that numerical value, such as less than or equal to $\pm 5\%$, less than or equal to $\pm 4\%$, less than or equal to $\pm 3\%$, less than or equal to $\pm 2\%$, less than or equal to $\pm 1\%$, less than or equal to $\pm 0.5\%$, less than or equal to $\pm 0.1\%$, or less than or equal to $\pm 0.05\%$. For example, two numerical values can be deemed to be “substantially” the same if a difference between the values is less than or equal to $\pm 10\%$ of an average of the values, such as less than or equal to $\pm 5\%$, less than or equal to $\pm 4\%$, less than or equal to $\pm 3\%$, less than or equal to $\pm 2\%$, less than or equal to $\pm 1\%$, less than or equal to $\pm 0.5\%$, less than or equal to $\pm 0.1\%$, or less than or equal to $\pm 0.05\%$.

[0058] Additionally, amounts, ratios, and other numerical values are sometimes presented herein in a range format. It is to be understood that such range format is used for convenience and brevity and should be understood flexibly to include numerical values explicitly specified as limits of a range, but also to include all individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly specified.

[0059] While the present disclosure has been described and illustrated with reference to specific embodiments thereof, these descriptions and illustrations do not limit the present disclosure. It should be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the true spirit and scope of the present disclosure as defined by the appended claims. The illustrations may not be necessarily drawn to scale. There may be distinctions between the artistic renditions in the present disclosure and the actual apparatus due to manufacturing processes and tolerances. There may be other embodiments of the present disclosure which are not specifically illustrated. The specification and drawings are to be regarded as illustrative rather than restrictive. Modifications may be made to adapt a particular situation, material, composition of matter, method, or process to the objective, spirit and scope of the present disclosure. All such modifications are intended to be within the scope of the claims appended hereto. While the methods disclosed herein have been described with reference to particular operations

performed in a particular order, it will be understood that these operations may be combined, sub-divided, or re-ordered to form an equivalent method without departing from the teachings of the present disclosure. Accordingly, unless specifically indicated herein, the order and grouping of the operations are not limitations of the present disclosure.

CLAIMS

What is claimed is:

1. A control panel device, comprising:
 - a circuit board;
 - an enclosure member attached to the circuit board, the enclosure member defining one or more air chambers;
 - a top plate disposed on the enclosure member; and
 - one or more pressure sensors attached to the circuit board and disposed respectively in the air chambers, wherein each air chamber includes an air pocket at least partially surrounding a corresponding pressure sensor.
2. The control panel device of claim 1, wherein the pressure sensors are configured to detect pressure changes of the air pockets of the air chambers and to generate signals corresponding to the pressure changes.
3. The control panel device of claim 1, wherein the enclosure member includes at least one of a gasket, an O-ring, or a bellows.
4. The control panel device of claim 1, wherein the top plate and the enclosure member are configured to cause a deformation of at least one of the air chambers in response to an external contact to the top plate.
5. The control panel device of claim 1, wherein the circuit board includes a detection circuit configured to detect a touch on the top plate based on one or more signals generated by at least one of the pressure sensors.
6. The control panel device of claim 5, wherein the detection circuit is further configured to detect a location or an intensity of the touch on the top plate based on the one or more signals generated by the one or more pressure sensors.
7. The control panel device of claim 1, wherein the pressure sensors are

microelectromechanical system (MEMS) microphones.

8. The control panel device of claim 1, wherein the pressure sensors are top-port microphones that include top ports facing away from the circuit board, and at least a portion of the air pockets are between the top ports and the top plate.

9. The control panel device of claim 1, wherein the enclosure member includes a gasket, the gasket defines one or more through holes, and the gasket, the circuit board and the top plate enclose the air chambers at locations of the through holes.

10. The control panel device of claim 9, wherein a top side or a bottom side of at least one of the air chambers is sealed by an adhesive or a sealant disposed between the top plate and the gasket or between the gasket and the circuit board.

11. The control panel device of claim 9, wherein the gasket includes top portions covering top sides of the air chambers, the gasket and the circuit board enclose the air chambers, and a bottom side of at least one of the air chambers is sealed by an adhesive or a sealant disposed between the gasket and the circuit board.

12. The control panel device of claim 9, wherein the gasket includes a material with a vibration absorbing property.

13. A control panel device, comprising:

- a circuit board defining one or more holes, the circuit board having a top surface and a bottom surface;

- a gasket or an adhesive layer attached to the top of the circuit board;

- a top plate disposed on the gasket or the adhesive layer; and

- one or more pressure sensors attached to the bottom surface of the circuit board, the pressure sensors including ports facing towards the holes of the circuit board.

14. The control panel device of claim 13, further comprising: a backing disposed on the bottom surface of the circuit board, the backing defining one or more air chambers at least

partially surrounding the pressure sensors.

15. The control panel device of claim 13, wherein the pressure sensors are bottom-port MEMS microphones.

16. The control panel device of claim 13, wherein the gasket defines one or more through holes in communication with the holes of the circuit board.

17. The control panel device of claim 13, wherein the adhesive layer is configured to be compressed and extend into the holes of the circuit board in response to an external contact to the top plate.

18. An input device, comprising:

- a circuit board;
- one or more pressure sensors electrically connected to the circuit board;
- a flexible enclosure member attached to the circuit board and defining one or more air chambers, the one or more air chambers enclosing the one or more pressure sensors; and
- a top plate disposed on the flexible enclosure member, wherein the one or more air chambers are configured to deform in response to an external contact to the top plate.

19. The input device of claim 18, wherein the one or more pressure sensors are configured to detect air pressure changes due to the deformation of the one or more air chambers.

20. The input device of claim 18, further comprising:

- a detection module configured to detect a location or an intensity of the external contact to the top plate, based on signals generated by the one or more pressure sensors.

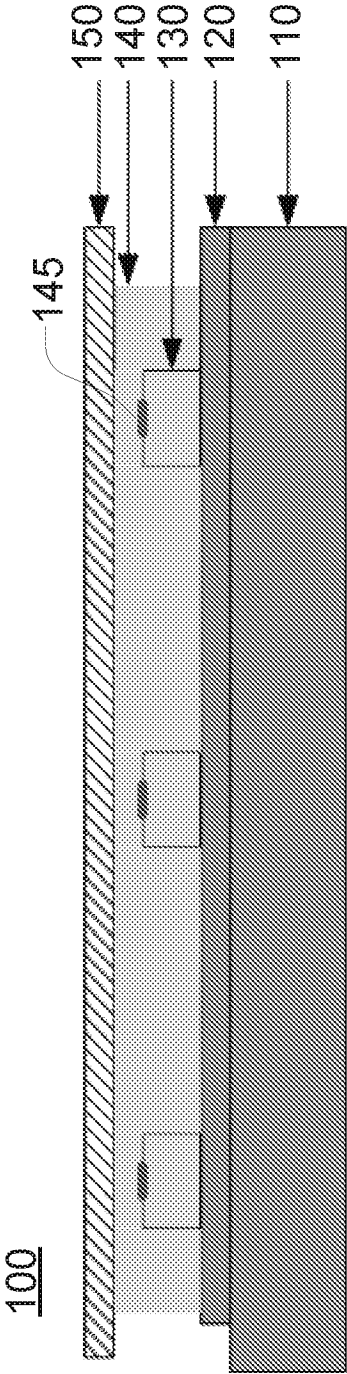


FIG. 1

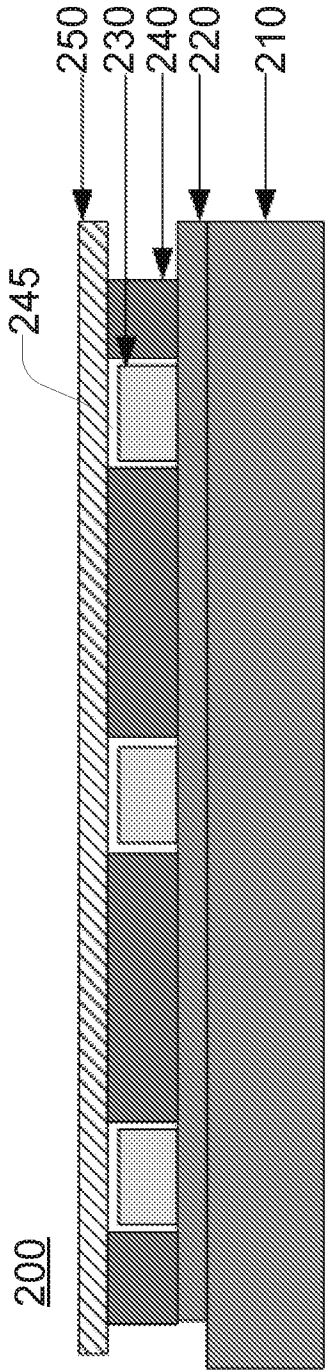


FIG. 2

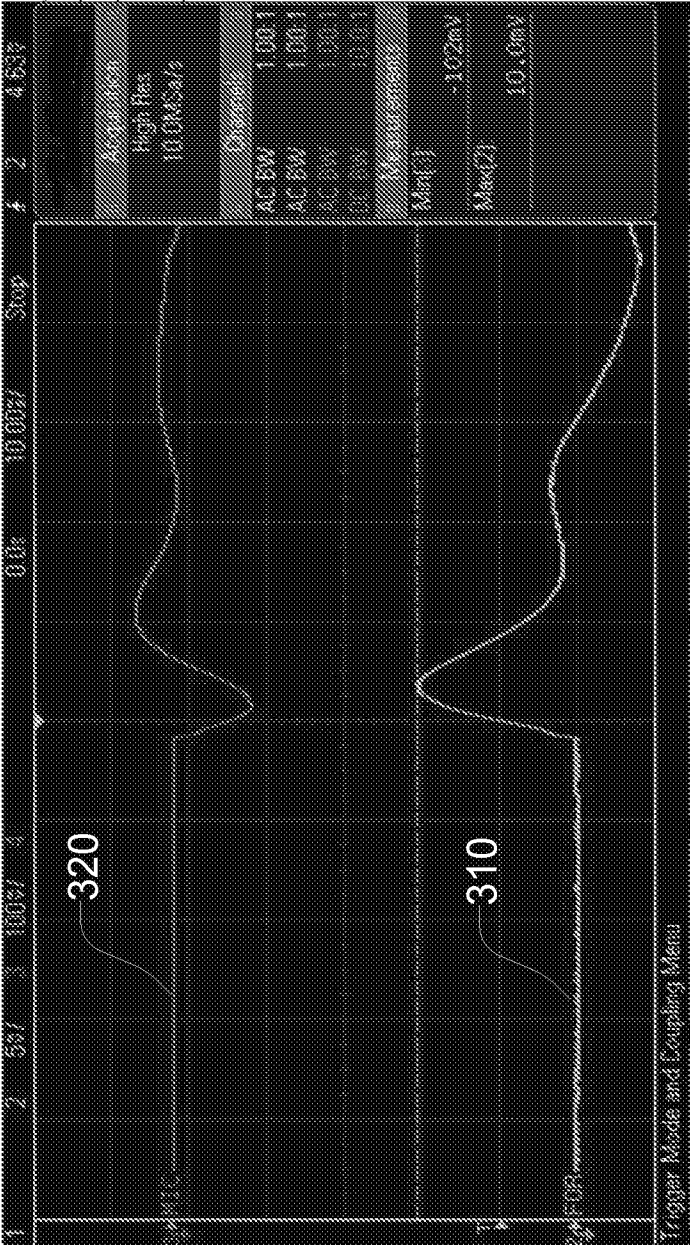


FIG. 3

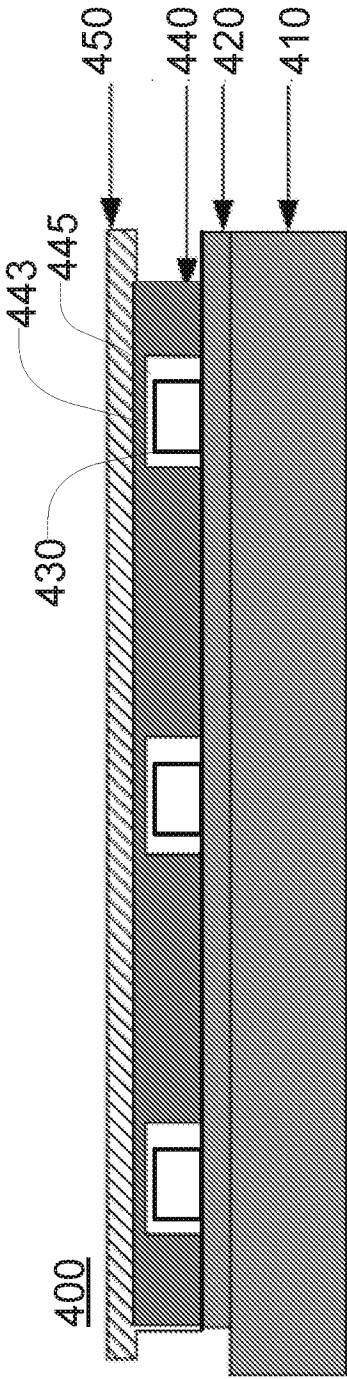


FIG. 4

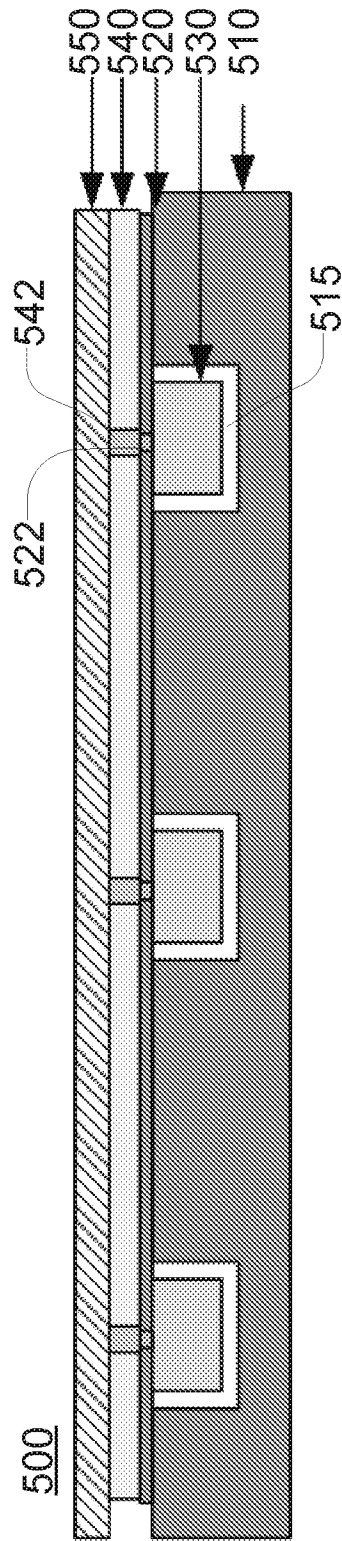


FIG. 5

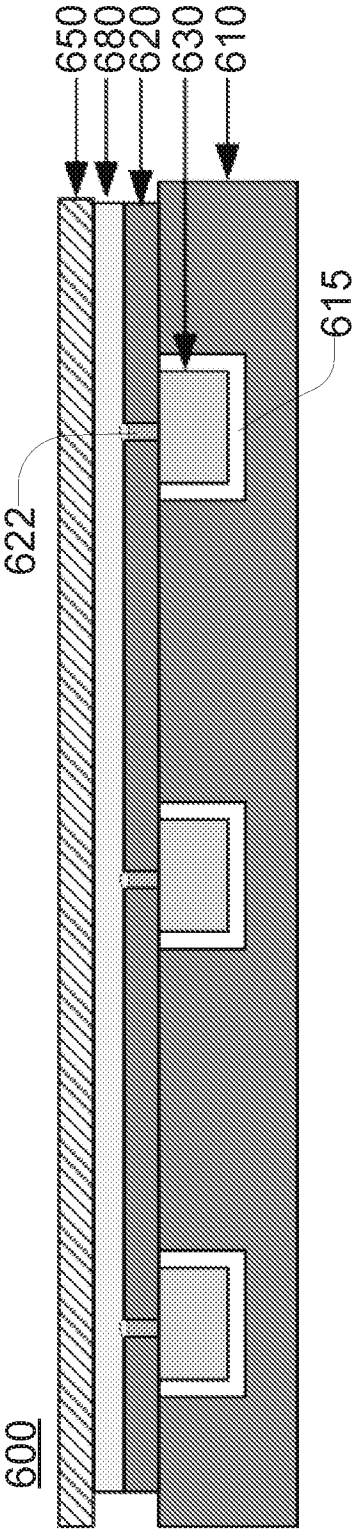


FIG. 6

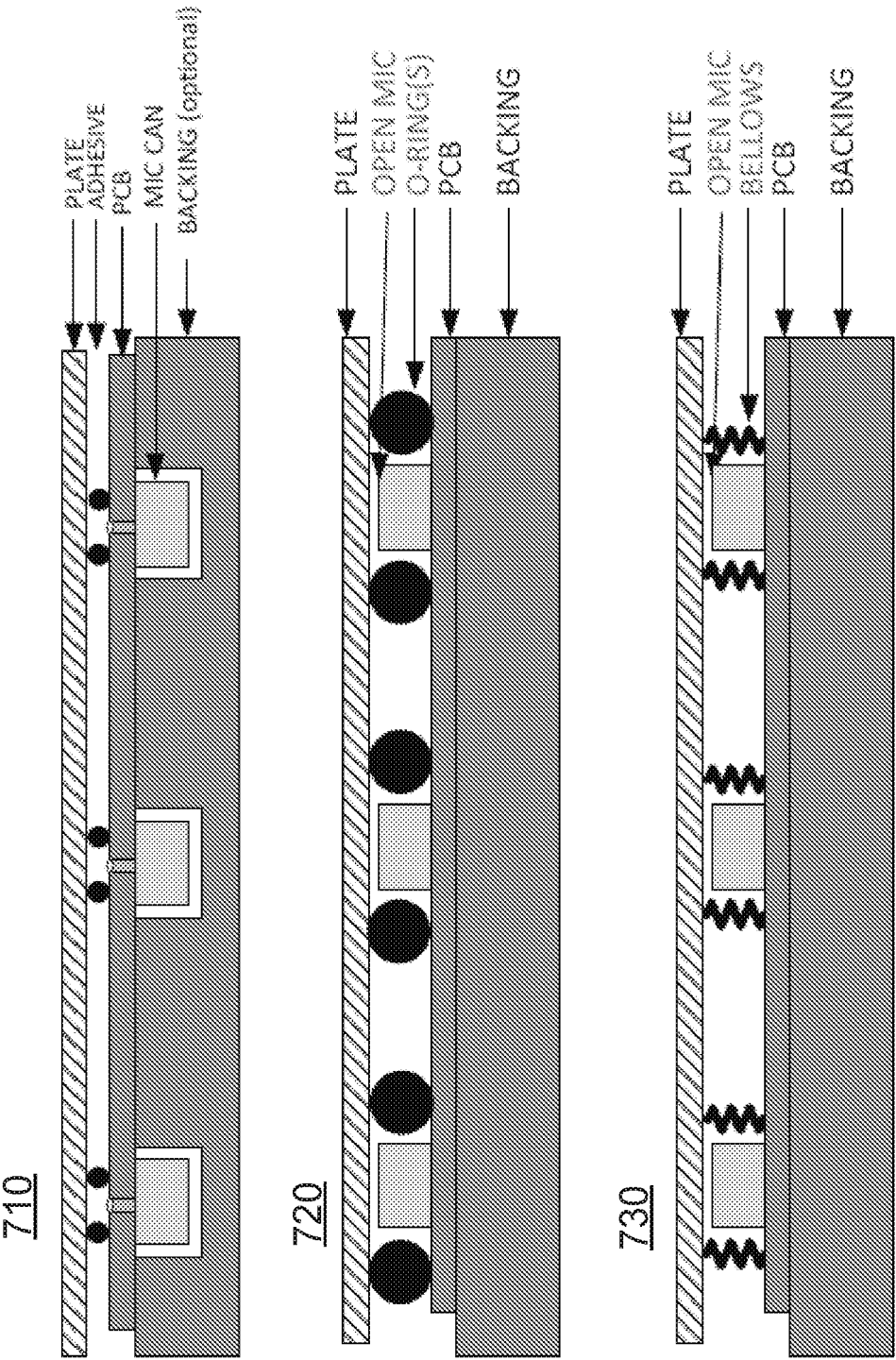


FIG. 7

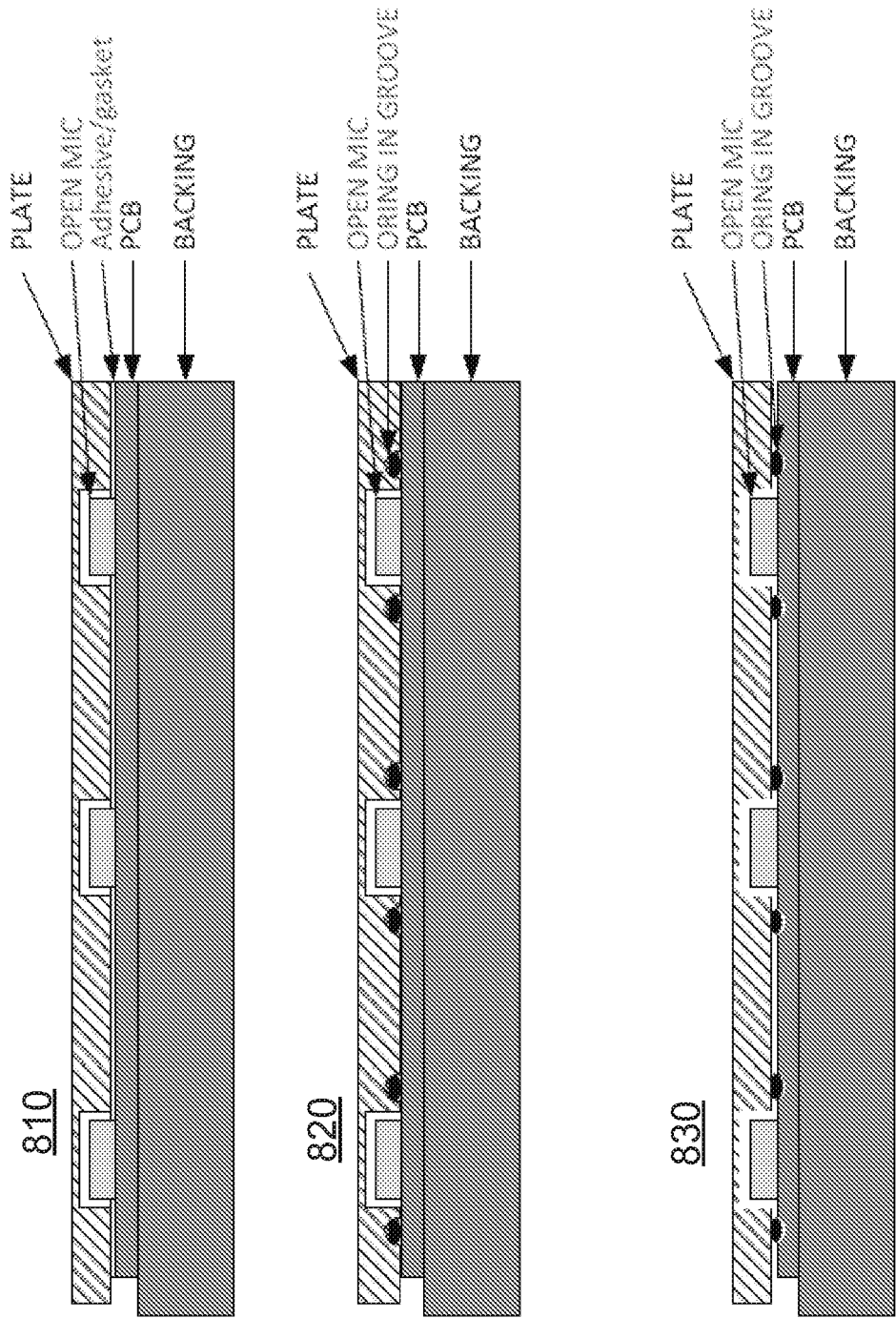


FIG. 8

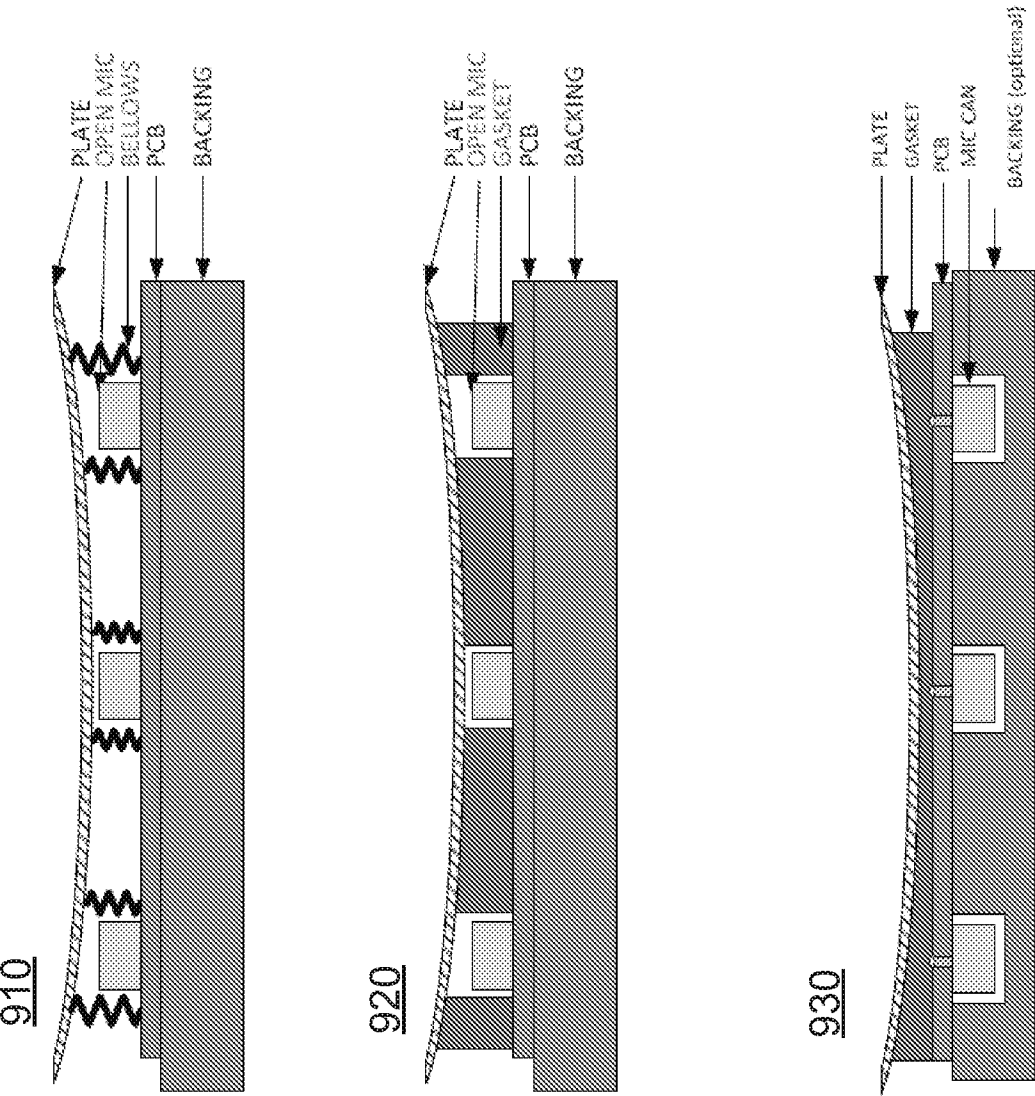


FIG. 9

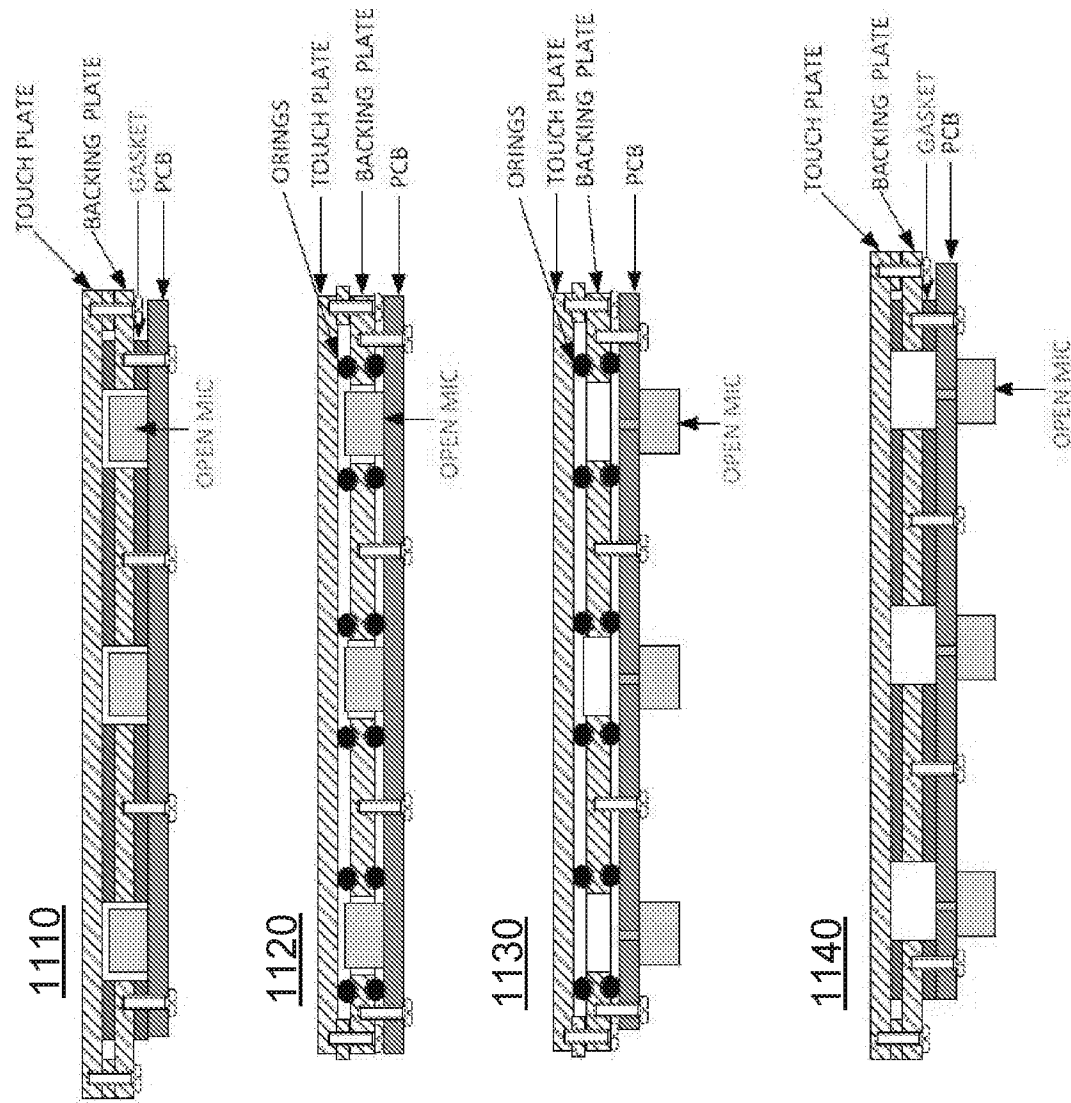


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/047450

A. CLASSIFICATION OF SUBJECT MATTER

INV. G06F3/041 G06F3/043
ADD.

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 H03K

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

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

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017/240418 A1 (QUTUB SARMAD [US] ET AL) 24 August 2017 (2017-08-24) cited in the application abstract; figures 1,2A,5,6 paragraph [0002] paragraph [0021] paragraph [0035] - paragraph [0038] -----	1-20
A	US 2008/260181 A1 (BOWEN JAMES SAMUEL [US]) 23 October 2008 (2008-10-23) abstract; figure 8 paragraph [0044] -----	3,9-12
A	US 2012/042735 A1 (MEI JIA-XIN [CN] ET AL) 23 February 2012 (2012-02-23) abstract; figure 14 paragraph [0038] ----- -/-	3



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

23 October 2018

Date of mailing of the international search report

30/10/2018

Name and mailing address of the ISA/

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Authorized officer

Dhondt, Erik

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2018/047450

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/242527 A1 (ALI A; CRADOCK S; DEKTOR S; HAMEL M; QUTUB S; VOLK M) 24 August 2017 (2017-08-24) cited in the application abstract; figures 5B,5C -----	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/047450

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US 2017242527 A1	24-08-2017	US 2017242527 A1 WO 2017142976 A1	24-08-2017 24-08-2017