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(54) **METHOD AND APPARATUS TO CALIBRATE ULTRASOUND TRANSDUCERS**

(71) Applicant: **Butterfly Network, Inc.**, Guilford, CT (US)

(72) Inventors: **Sarp Satir**, San Francisco, CA (US); **Jaime Scott Zahorian**, Guilford, CT (US)

(73) Assignee: **Butterfly Network, Inc.**, Guilford, CT (US)

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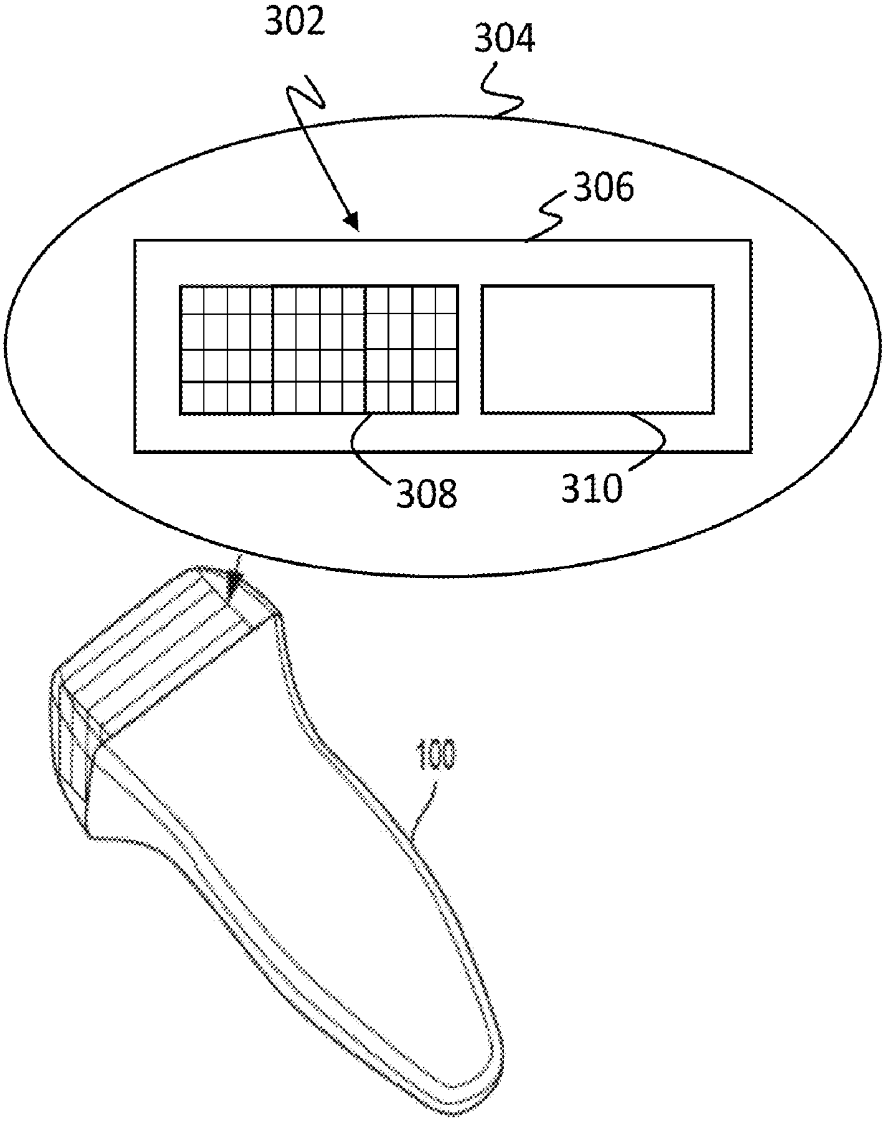
(57) **ABSTRACT**

The disclosed embodiments relate to a capacitive micromachined transducers for ultrasound imaging having pressure calibrator to compensate for ultrasound image distortions caused by environmental pressure changes. In one embodiment, the disclosure relates to a method to calibrate a first ultrasound transducer of an array of ultrasound transducers for ambient pressure variation. The method includes the steps of detecting a real-time ambient pressure value; determining a pressure difference value between the detected ambient pressure value and a predetermined pressure value; and calibrating the first ultrasound transducers to compensate for the determined pressure difference.



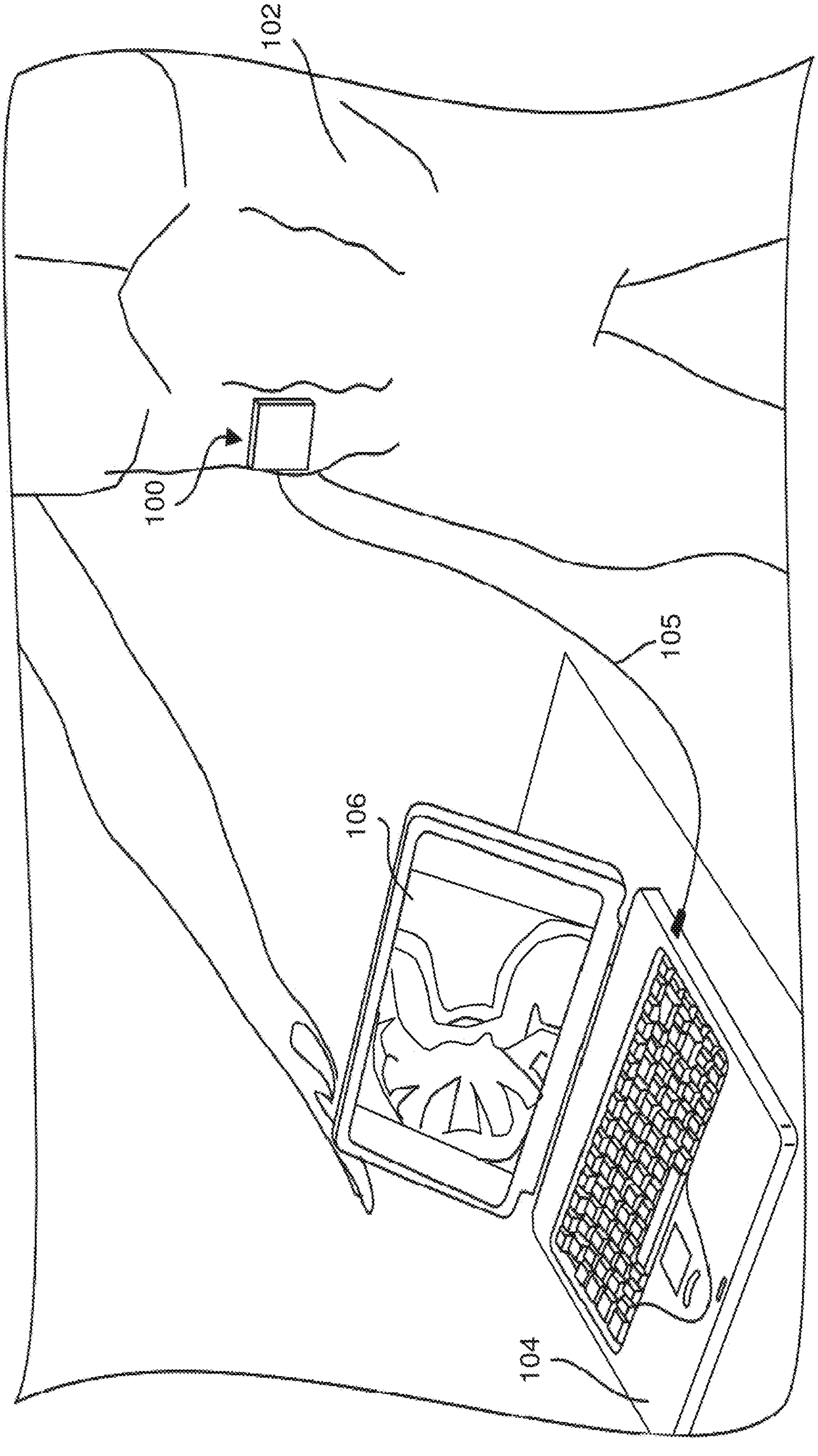


Fig. 1

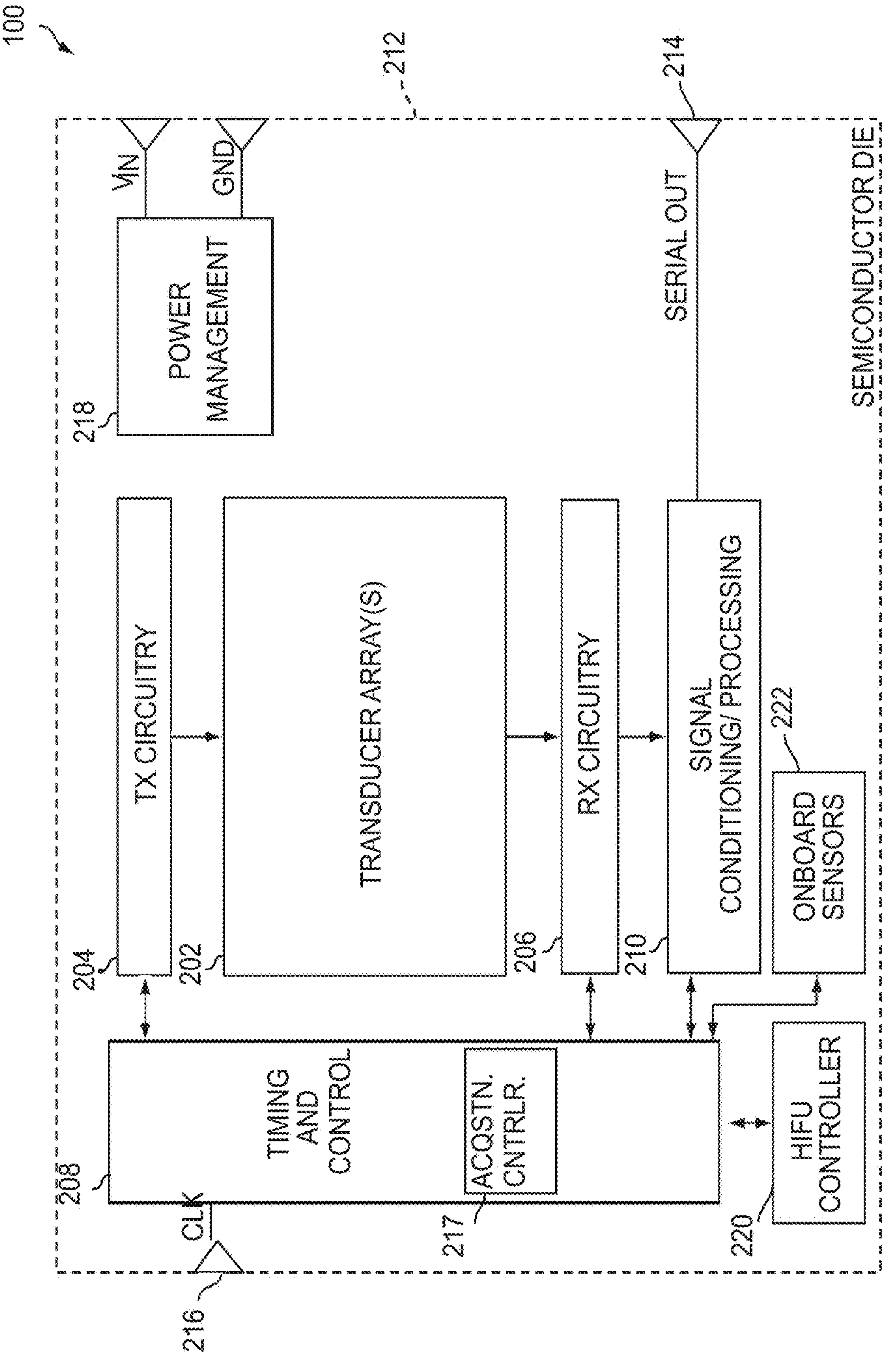

100
212
214
VIN
GND
POWER MANAGEMENT
218
SERIAL OUT
SEMICONDUCTOR DIE
TX CIRCUITRY
TRANSDUCER ARRAY(S)
RX CIRCUITRY
SIGNAL CONDITIONING/ PROCESSING
204
202
206
210
222
ONBOARD SENSORS
208
TIMING AND CONTROL
ACQSTN. CNTRLR.
217
CLK
216
220
HIFU CONTROLLER

Fig. 2

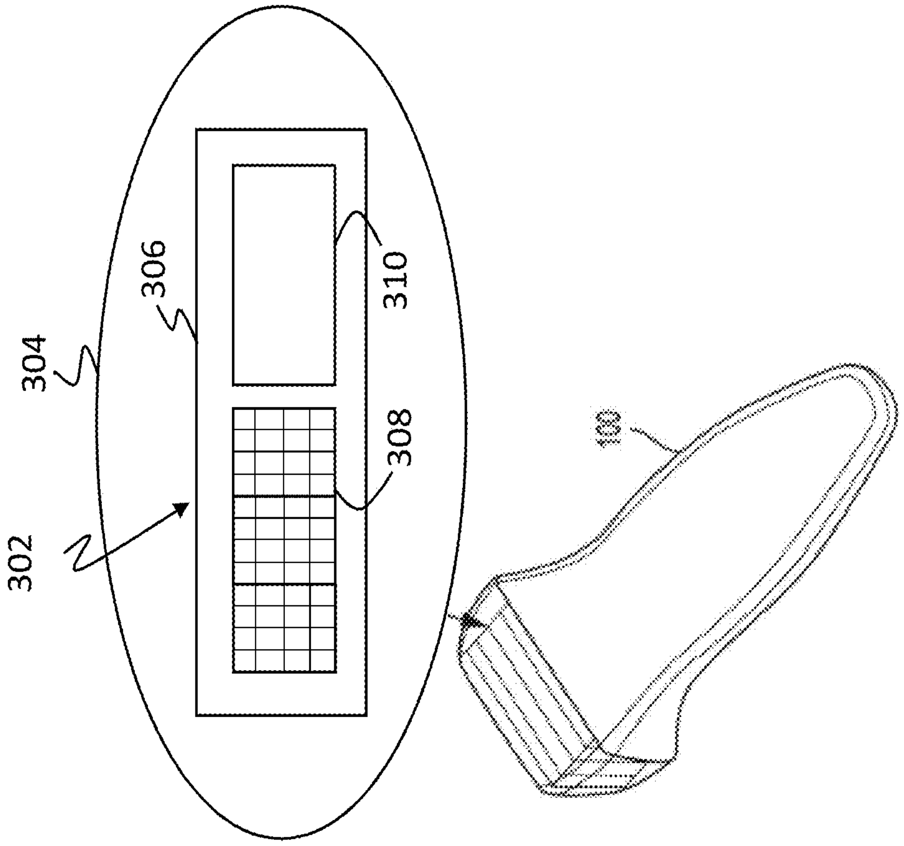


Fig. 3

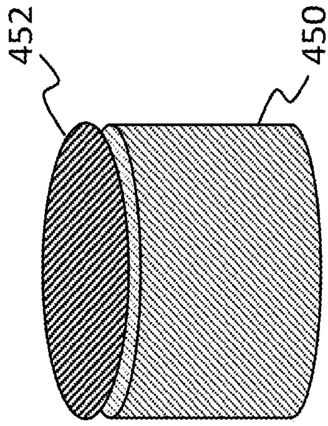


Fig. 4B

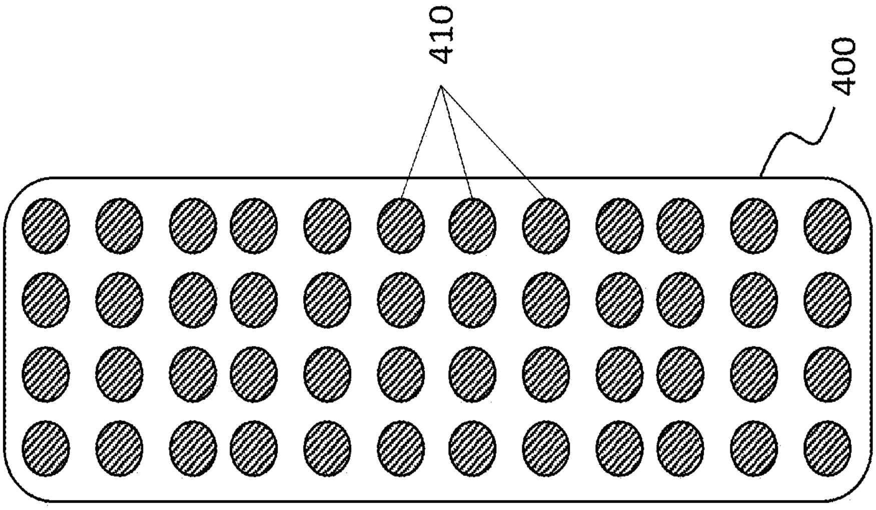


Fig. 4A

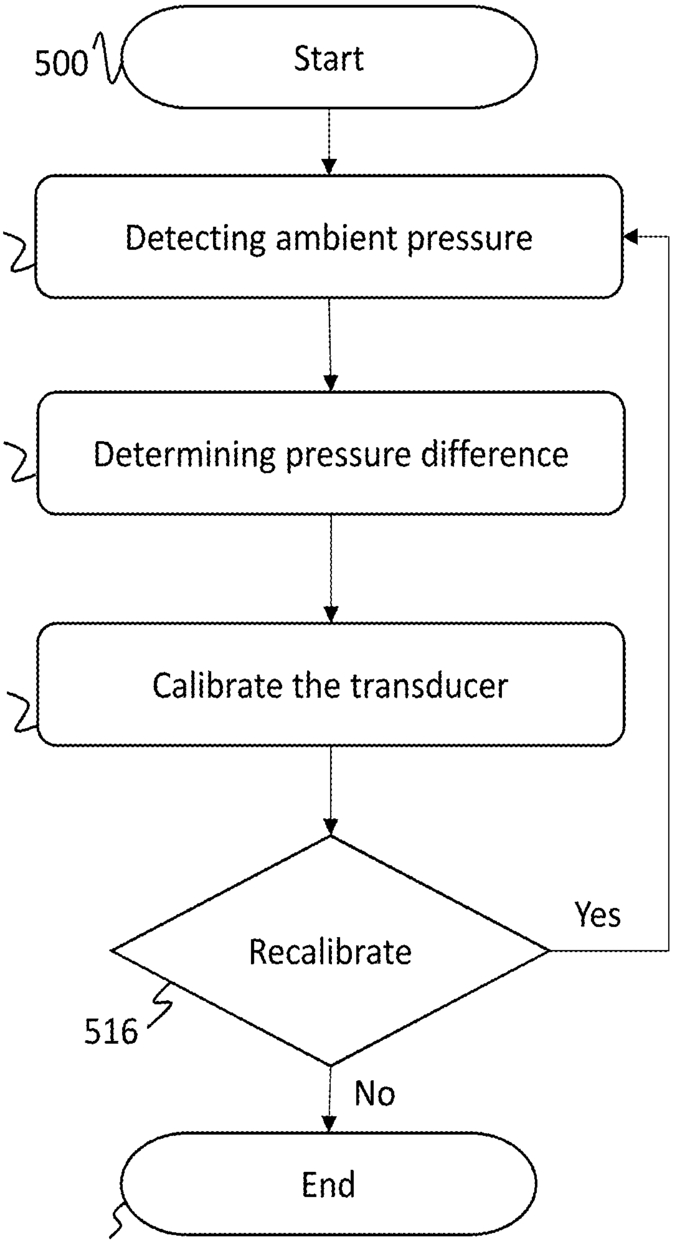

500
Start
510
Detecting ambient pressure
512
Determining pressure difference
514
Calibrate the transducer
Recalibrate
516
Yes
No
End
518

Fig. 5

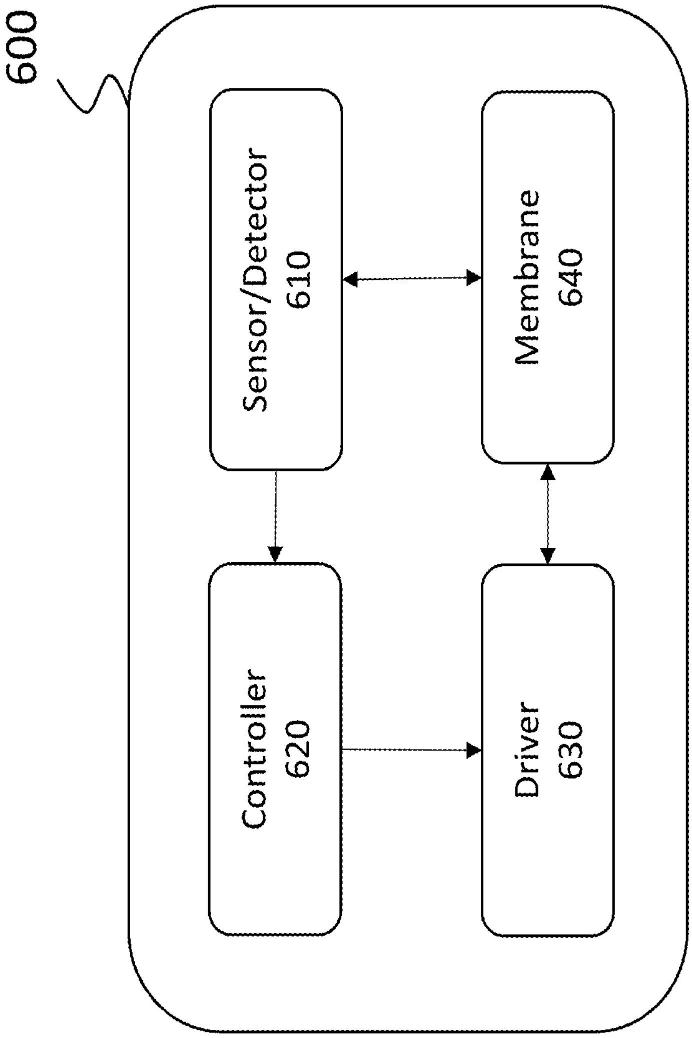

600
Sensor/Detector
610
Membrane
640
Controller
620
Driver
630

Fig. 6

METHOD AND APPARATUS TO CALIBRATE ULTRASOUND TRANSDUCERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Ser. No. 62/772,454, filed on Nov. 28, 2018 under Attorney Docket No. B1348.70104US00, and entitled "METHOD AND APPARATUS TO CALIBRATE ULTRASOUND TRANSDUCERS." which is hereby incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present application relates to ultrasound devices having a pressure sensor calibrator. Specifically, the disclosed embodiments relate to micromachined ultrasonic transducers for ultrasound imaging or therapy having pressure calibrator to compensate for ultrasound image distortions caused by environmental pressure changes.

RELATED ART

[0003] Ultrasound devices may be used to perform diagnostic imaging and/or treatment. Ultrasound imaging may be used to see internal soft tissue body structures. Ultrasound imaging may be used to find a source of a disease or to exclude any pathology. Ultrasound devices use sound waves with frequencies which are higher than those audible to humans. Ultrasonic images are made by sending pulses of ultrasound into tissue using a probe. The sound waves are reflected off the tissue, with different tissues reflecting varying degrees of sound. These reflected sound waves may be recorded and displayed as an image to the operator. The strength (amplitude) of the sound signal and the time it takes for the wave to travel through the body provide information used to produce an image.

[0004] Many different types of images can be formed using ultrasound devices. The images can be real-time images. For example, images can be generated that show two-dimensional cross-sections of tissue, blood flow, motion of tissue over time, the location of blood, the presence of specific molecules, the stiffness of tissue, or the anatomy of a three-dimensional region.

SUMMARY

[0005] In an exemplar embodiment, the disclosure relates to a method to calibrate a first ultrasound transducer of an array of ultrasound transducers for ambient pressure variation. An exemplary method includes the steps of: detecting a real-time ambient pressure; determining a pressure difference between the detected ambient pressure and a predetermined pressure; calibrating the first ultrasound transducers to compensate for the determined pressure difference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0007] FIG. **1** illustrates an example of an ultrasound probe configured to perform a sequence of acquisitions according to one embodiment of the disclosure.

[0008] FIG. **2** illustrates an ultrasound probe architecture according to some embodiments of the disclosure.

[0009] FIG. **3** illustrates an ultrasound probe for ultrasound imaging according to one embodiment of the disclosure.

[0010] FIG. **4**A schematically illustrates top view of an exemplary ultrasound probe head.

[0011] FIG. **4**B schematically illustrates an exemplary ultrasonic transducer.

[0012] FIG. **5** shows an exemplary flow-diagram for calibrating one or more transducers according to one embodiment of the disclosure.

[0013] FIG. **6** schematically shows a calibration apparatus according to one embodiment of the disclosure.

DETAILED DESCRIPTION

[0014] Various aspects and embodiments of the application will be described with reference to the following figures. It should be appreciated that the figures are not necessarily drawn to scale. Items appearing in multiple figures are indicated by the same reference number in all the figures in which they appear.

[0015] Ultrasound devices may be used to perform diagnostic imaging and/or treatment, using sound waves with frequencies that are higher than those audible to humans. Ultrasound imaging may be used to see internal soft tissue body structures, for example to find a source of disease or to exclude any pathology. When pulses of ultrasound are transmitted into tissue (e.g., by using a probe), sound waves are reflected off the tissue, with different tissues reflecting varying degrees of sound. These reflected sound waves may then be recorded and displayed as an ultrasound image to the operator. The strength (amplitude) of the sound signal and the time it takes for the wave to travel through the body provide information used to produce the ultrasound image. Many different types of images can be formed using ultrasound devices, including real-time images. For example, images can be generated that show two-dimensional cross-sections of tissue, blood flow, motion of tissue over time, the location of blood, the presence of specific molecules, the stiffness of tissue, or the anatomy of a three-dimensional region.

[0016] FIG. **1** illustrates an example of an ultrasound probe configured to perform a sequence of acquisitions in accordance with some embodiments of the technology described herein. Specifically, FIG. **1** illustrates an example of an ultrasound probe **100** configured to perform imaging in a desired imaging mode in response to receiving an indication to begin imaging in the desired imaging mode. The ultrasound probe **100** is shown for purposes of illustration as being used to investigate a subject **102**. As illustrated in the embodiment of FIG. **1**, ultrasound probe is coupled to host device **104** via a connection **105**. The host device **104** may provide an initiation command to the ultrasound probe **100** to begin imaging in a desired imaging mode (e.g., in any of the imaging modes described herein), and in response to receiving the initiation command, ultrasound probe **100** may commence imaging in the desired imaging mode using control data stored in the ultrasound probe's memory (not shown in FIG. **1**).

[0017] Host device **104** may be any suitable computing device and may be a portable computing device (e.g., a laptop, smartphone, a tablet, a personal digital assistant, a computing device affixed to portable medical equipment, etc.) or a fixed computing device (e.g., a desktop computer, a rack mount computer, a computing device affixed to other fixed medical equipment, etc.). In the illustrated embodiment, host device **104** includes display screen **106** on which ultrasound images may be displayed in real time, substantially in real time as imaging is performed (e.g., within a threshold number of frames such as within one, five or ten frames, within a threshold amount of time such as within one, five, or ten seconds, etc.), or after imaging is performed, though in other embodiments host device **104** may not have a display screen.

[0018] In the embodiment of FIG. **1**, connection **105** is a wired connection, but may be a wireless connection (e.g., a Bluetooth® connection or near field communication (NFC)), as aspects of the technology described herein are not limited in this respect. The connection **105** may be a digital connection, for example being of a type commonly used with commercial digital electronics, such as a universal serial bus (USB) cable, Thunderbolt, or FireWire, Connection **105** may connect to the serial output port **314** and clock input port **316** of the ultrasound probe **100**.

[0019] FIG. **2** illustrates components of ultrasound probe **100**, in accordance with some embodiments of the technology described herein. The ultrasound probe **100** includes one or more transducer arrangements (e.g., arrays) **202** of ultrasonic transducers, transmit (TX) circuitry **204**, receive (RX) circuitry **206**, timing and control circuitry **208**, signal conditioning/processing circuitry **210**, and/or a power management circuit **218** receiving ground (GND) and voltage reference (VIN) signals. Transmit circuitry **204** may assume different embodiments without departing form the disclosed principles.

[0020] The ultrasound probe **100** may include acquisition controller **217**, which may be implemented as a processor, for controlling other circuitry of the ultrasound probe to perform a sequence of acquisitions governed by control data stored on the ultrasound probe. Acquisition controller **217** may be part of the timing and control circuitry **208**, or may be separate in other embodiments. In general, the timing and control circuitry **308** may include suitable circuitry for controlling operation of the transmit circuitry **204**, receive circuitry **206**, onboard sensors **222**, and/or any other suitable components of ultrasound probe **100**. Optionally, a high intensity focused ultrasound (HIFU) controller **220** may be included if the ultrasound probe **100** is to be used to provide HIFU.

[0021] The ultrasound probe **100** may include one or more onboard sensors **222**, which may sense data about the probe and/or its environment. Sensors **222** are "onboard" in the sense that they may be integrated with ultrasound probe **100**, which may be done in any suitable way. For example, onboard sensors **222** may be discrete components on ultrasound probe **100**, may be integrated with the ultrasound transducers on the same substrate, etc. Sensors **222** may include one or more non-acoustic sensors of any suitable type and, for example, may include one or more accelerometers, gyroscopes, or other sensors indicating movement of the probe, one or more temperature sensors indicating the temperature of the probe (e.g., the temperature of the probe's circuitry), one or more sensors indicating an amount of power used by the probe, one or more pressure sensors, and/or any other suitable type(s) of sensors.

[0022] The onboard sensors **222** may obtain data about the probe and/or its environment when the probe is performing imaging, and the probe (e.g., acquisition controller **217**) may adapt the way in which it performs the imaging, processes data acquired during imaging, and/or initiates imaging based at least in part on the data acquired by onboard sensors **222**. For example, onboard sensors **222** may obtain data indicating that the probe has moved (e.g., a handheld probe may be moved inadvertently due to movement of the user's hand) and the probe may use the obtained data to adjust the way in which it performs imaging to account for the motion (e.g., by using beam steering or other techniques to continue imaging the same portion of the subject as was being imaged prior to the motion or by suitably post-processing the acquired data to account for the motion). As another example, onboard sensors **222** may obtain data indicating that the temperature of at least one component of the probe (e.g., the probe's circuitry) has exceeded a desired threshold and the probe may adjust the way in which it performs imaging to reduce the probe's temperature (e.g., by reducing the power of the transmitted pulses, by reducing the frequency at which the probe emits pulses, by performing less processing of the acquired data, etc.). As yet another example, onboard sensors **222** may obtain data indicating that the power used by the probe has exceeded a desired threshold and the probe may adjust the way in which it performs imaging to reduce the amount of power utilized by the probe (e.g., by reducing the power of the transmitted pulses, by reducing the frequency at which the probe emits pulses, by reducing the number of ultrasonic elements used to transmit and/or receive data, etc.) relative to the amount of power that would have been used by the probe if it continued to perform imaging without adjustment. It should be appreciated that the onboard sensors **222** may also collect data when the probe is not performing imaging and the collected data may be used to control the manner in which imaging is subsequently performed and/or the way data acquired as a result of imaging is processed.

[0023] In some embodiments, ultrasound probe **100** may receive an indication to perform an acquisition task (e.g., from host device **104**), receive non-acoustic data obtained by one or more of the onboard sensors **222**, and control, based on the non-acoustic data and control data for the acquisition task stored on the ultrasound probe **100**, the ultrasound probe **100** to obtain acoustic data for the acquisition task. This may be done in any suitable way. For example, in some embodiments, the control data may comprise multiple parameters governing performance of the acquisition task and one or more of the multiple parameters may be selected, based on the non-acoustic data, and used for controlling the ultrasound probe **100** to obtain acoustic data for the acquisition task. In some embodiments, the control data may comprise multiple parameters governing performance of the acquisition task and the value(s) of one or more of the multiple parameters may be adjusted, based on the non-acoustic data, to obtain parameter values to be used in controlling the ultrasound probe **100** to obtain acoustic data for the acquisition task.

[0024] Any suitable component(s) of ultrasound probe **100** may be controlled based, at least in part, on the non-acoustic data including, but not limited to, ultrasonic transducer arrangements **202**, transmit circuitry **204**, and receive circuitry **206**.

[0025] In the embodiment shown in FIG. **2**, all of the illustrated components are formed on a single semiconductor die (or substrate or chip) **212**, and thus the illustrated embodiment is an example of an ultrasound on a chip device. However, not all embodiments are limited in this respect. In addition, although the illustrated example shows both TX circuitry **204** and RX circuitry **206**, in alternative embodiments only TX circuitry or only RX circuitry may be employed. For example, such embodiments may be employed in a circumstance in which the ultrasound probe is operated as a transmission-only device to transmit acoustic signals or a reception-only device used to receive acoustic signals that have been transmitted through or reflected by a subject being ultrasonically imaged, respectively.

[0026] The ultrasound probe **100** further includes a serial output port **214** to output data serially to a host (e.g., serial output port **214** may be used to output data to a host device). The ultrasound probe **100** may also include a clock input port **216** to receive a clock signal (e.g., from a host device such as device **104**) and provide the received clock signal CLK to the timing and control circuit **208**.

[0027] FIG. **3** illustrates an ultrasound probe with a simplified schematic of an ultrasound-on-a-chip device that may be used in the probe. Probe **300** may be a handheld probe configured to plug into a computer, smartphone, tablet, or other external device, or to communicate wirelessly with such a device. The probe **300** may include an ultrasound-on-a-chip device **302**, shown in the call-out view **304**. The ultrasound-on-a-chip device **302** may include a substrate **306** with integrated ultrasonic transducers **308** and circuitry **310**. For ease of illustration, the schematic view of FIG. **3** shows the ultrasonic transducers **308** and circuitry **310** as simplified blocks in a side-by-side configuration. As is illustrated in subsequent figures, and described further below, the physical implementation may have the ultrasonic transducers and circuitry in a stacked configuration. Substrate **306** may be a semiconductor substrate, such as a silicon or silicon-on-insulator (SOI) substrate, and in some embodiments is a complementary metal oxide semiconductor (CMOS) substrate. Ultrasonic transducers **308** may be capacitive micromachined ultrasonic transducers (CMUTs) and the circuitry **310** may be integrated circuitry, such as silicon circuitry.

[0028] In the simplified representation of call-out view **304**, the ultrasonic transducers **308** and circuitry **310** are schematically depicted as being side-by-side for purposes of illustration. In practice, such a side-by-side configuration is physically possible on a substrate, but so are alternatives. In certain embodiments, substrate **306** is formed by bonding an engineered substrate having ultrasonic transducers with a substrate having an IC (or other electrical substrates, such as silicon interposers or other types of interposers, or printed circuit boards), such that the ultrasonic transducers and IC may be in a stacked configuration. In another embodiment, substrate **306** may comprise one or more sensors (e.g., pressure sensor) to detect ambient information. Such ambient information may include, for example, ambient temperature and pressure.

[0029] FIG. **4**A schematically illustrates top view of an exemplary ultrasound probe head. Specifically, FIG. **4**A shows the tops of ultrasound transducers **410** arranged on substrate **400**. Each instance of **410** may depict a membrane associated with a respective ultrasound cavity. Substrate **400** may comprise additional components, such as integrated circuitry (not shown) and sensors (not shown).

[0030] FIG. **4**B schematically illustrates an exemplary ultrasonic transducer. In FIG. **4**B, transducer **450** may be formed in a bulk silicon substrate (e.g., substrate **400**). Transducer **450** may be formed as a cylindrical cavity in a bulk silicon substrate (not shown). Transducer **450** may also include one or more electrodes (not shown). The electrode (not shown) may form a capacitive coupling with membrane **452**. Membrane **452** is configured to vibrate in order to generate and transmit ultrasound waves (i.e., transmit mode). Membrane **452** is also configured to detect and receive incoming (or rebound) ultrasound wave forms. In an exemplary embodiment, each transducer **450** comprises a membrane **452**.

[0031] Positioning of membrane **452** over the cavity of a transducer **450** is critical in that anomalies or variations in the membrane's position can have significant implications for the received signal. For example, if the membrane is not properly disposed over the cavity of the transducer, the received signal may distort the ultrasound image. In another example, if the membrane subsides or bulges (downward or upward) the ultrasound image may be distorted.

[0032] One such distortion is caused by external (e.g., ambient) pressure. When the external pressure is higher than the pressure inside the transducer cavity, the membrane (or portions thereof) may concave towards the transducer cavity. Alternatively, when the external pressure is lower than the pressure inside the transducer cavity, the membrane may bulge outwardly or form a convex surface relative to the substrate.

[0033] To address this and other deficiencies, an embodiment of the disclosure provides a method, system and apparatus to identify a relative pressure (or relative vacuum) and calibrate the ultrasound signals from the membrane accordingly. In one embodiment, an external sensor is used to detect ambient pressure and determine whether the ambient pressure is significant enough to calibrate the output signal of an affected transducer membrane.

[0034] FIG. **5** shows an exemplary flow-diagram for calibrating one or more transducers according to one embodiment of the disclosure. The flow-diagram of FIG. **5** may be implemented by processor circuitry. Memory circuitry may store instructions for executing a method as illustrated in the flow-diagram of FIG. **5**.

[0035] The process of FIG. **5** starts at step **500**. In one embodiment, step **500** is triggered by an external event. For example, step **500** may be triggered when the probe (e.g., probe **100**, FIG. **1**) is turned on. In another embodiment, step **500** is triggered during certain time intervals, for example, after every 3 minutes of probe operation. In still another embodiment, step **500** is triggered upon a probe operator's request.

[0036] At step **510**, external pressure is detected. The external pressure may be detected using one or more sensors. The detected pressure may denote real-time ambient pressure in the environment where the probe is operating. For example, if the probe is used inside a pressure chamber, the detected ambient pressure would denote the pressure inside the chamber. The sensors may be pressure sensors to measure ambient pressure at the environment where the ultrasound probe is used. The one or more sensors may be integrated in the probe. In one embodiment, the sensors are integrated in the circuitry that houses the ultrasound chip. For example, the one or more pressure sensors may be integrated with circuitry **310** of FIG. **3**.

[0037] In certain embodiments of the disclosure, ambient pressure is estimated as a function of the capacitive baseline measurements. The capacitive baseline measurement can be used and correlate to the detected ambient pressure. In an exemplary application, a baseline noise level output for a capacitive transducer can be measured. The baseline may define deflection in the transducer membrane in the absence of any input signal to the transducer or to the membrane. In some embodiments, the baseline deflection can be measured by the transducer output noise. Thus, any initial deflection (i.e., noise) in the membrane may be used to correlate noise to ambient pressure. In another embodiment, the deflection can define the pressure change from the base line or from a previous deflection level.

[0038] In an exemplary embodiment, the baseline noise level of one or more transducers is measured and used as an indication of an initial deflection in the membrane. A lookup table correlating membrane deflection to ambient pressure may be apriori stored at an accessible database. The detected initial deflection (i.e., baseline noise) can be correlated to an ambient pressure based on the information considered in the lookup table.

[0039] At step **512**, the pressure difference value is determined. The pressure difference value may be determined as a difference between the value detected in step **510** (e.g., pressure detected by a sensor or pressure detected based on baseline noise) and a predefined pressure. The predefined pressure may be an arbitrary pressure value. For example, the predetermined pressure value may be atmospheric pressure at sea level.

[0040] At step **514**, the transducer is calibrated to compensate for the determined pressure difference. The difference between real-time and the predetermined pressure can be used to calibrate any reading from the transducer. In other words, the difference between a real-time deflection in the transducer membrane and the expected deflection in the transducer membrane can be used to calibrate the transducer. The calibration value may be used to compensate an ultrasound image obtained from the transducer.

[0041] At step **516**, recalibration determination is made. If additional calibration is deemed appropriate, the process reverts back to step **510**. If additional calibration is not required, the process ends at step **518**.

[0042] FIG. **6** schematically shows a calibration apparatus according to one embodiment of the disclosure. Apparatus **600** of FIG. **6** includes sensor (interchangeably, detector) **610**, controller **620**, driver **630** and membrane **640**. Apparatus **600** may be implemented in hardware or a combination of hardware and software (e.g., firmware). Apparatus **600** may be incorporated into an ultrasound probe. In one embodiment, apparatus **600** is integrated with a circuitry configured to operate the ultrasound probe. The ultrasound probe can be handheld, portable, ultrasound probe as disclosed herein. In certain embodiments, apparatus **600** may be implemented as an independent chipset. In other embodiments, apparatus **600** may be integrated with an existing semi-conductor die (e.g., semiconductor die **100** of FIG. **2**).

[0043] Sensor **610** may define a conventional pressure sensor or any device that can detect a pressure change. In one embodiment, sensor **610** comprises a transducer configured to detect pressure change.

[0044] In certain embodiments, sensor **610** comprises a detector configured to communicate with membrane **640** and detect a deflection in the membrane. The membrane deflection may be determined as any deflection (e.g., sagging or bowing) in the membrane as compared to a predefined level. For example, a membrane may be deflected inwardly (i.e., sagging) due to increased ambient pressure). Detector **610** may detect, identify and register the deflection as compared with the predefined, normal, level. Membrane **640** can be associated with a transducer cavity (not shown). Sensor **610** may comprise a sensor and/or detector (e.g., hardware and software) in communication with membrane **640** and configured to detect any deflection or inflation of membrane **640**; the results of which may be correlated to an external pressure estimate.

[0045] Sensor/Detector **610** may communicate the detected deflection to Controller **620**. Controller **620** may comprise hardware, software or a combination of hardware and software (e.g., firmware). Controller **620** may comprise one or more processors circuitry (not shown) in communication with one or more memory circuitry (not shown) to receive input signal from Sensor/Detector **610**. Controller **620** may comprise, or communicate with, a memory (e.g., database or a table) circuitry. The memory circuitry may include a database correlating membrane deflection with ambient pressure. For example, the database may include a table correlating each additional pressure points with a corresponding deflection (or inflation) of the membrane as measured from a baseline. Controller **620** may compare information from the input signal to determine whether sensor calibration is required.

[0046] In one embodiment, when controller **620** determines that sensor calibration is required, the controller signals driver **630** to adjust bias signal to membrane **640**. The adjusted bias signals to the sensor can cause membrane **640** to move to a baseline position. Thereafter, the membrane movements will be calibrated by the additional bias to compensate for the detected pressure difference. Driver **630** may comprise hardware and/or software required to drive membrane **640**. In certain embodiments, controller **620** may engage driver **630** to thereby cause membrane **640** to deflect in a predetermined amount consistent with available information and the estimated ambient pressure. By way of example, controller **620** may determine that membrane **640** is deflected in response to external pressure by a determined amount. Controller may then determine (e.g., using a look up table stored in the memory) that the membrane deflection is due to a known amount of external pressure. Controller **620** may then direct driver **630** to deflect membrane **640** by an amount required to bring membrane **640** to a substantially flat (or predetermined baseline) level. In one example, driver **630** may comprise a voltage regulator to bias membrane **640** to a base level. Thereafter, any additional pressure sensed by membrane **640** can be used to measure ultrasound wave without ambient pressure distortion.

[0047] In FIG. **6**, membrane **640** may represent a membrane from a single transducer. Alternatively, membrane **640** in FIG. **6** may represent a plurality (e.g., a group) of membranes of a CMUT chip. In an exemplary embodiment, the signal may be an averaged value from a group of membranes **640** to represent an average deflection in a group of membranes. For example, a group of membranes in the array of membranes may be selected and an average deflection value may be assessed on the group of membranes.

[0048] In an alternative embodiment, when sensor calibration is required, the controller may use the offset information to calibrate any signal coming from membrane **640**. Here, an external calibration is not made to the transducer's membrane; instead, the signal coming from the transducer is adjusted to account for any pressure calibration offset.

[0049] The disclosed embodiments may be used with a CMUT-type transducers. The disclosed embodiments may be equally applied to piezoelectric-type transducers. For example, the disclosed embodiments may be applied to one or more transducers having piezoelectric membranes. Using the disclosed principles, membrane deflection due to external factors (e.g., pressure or temperature) can be determined and the transducer membrane(s) may be calibrated accordingly.

[0050] The following non-limiting example are provided to illustrate different embodiments consistent with the disclosed principles.

[0051] Example 1 is directed to an ultrasound device, comprising an ultrasound-on-a-chip device comprising an array of ultrasonic transducers; and a pressure sensor configured to detect pressure applied to an ultrasonic transducer of the array.

[0052] Example 2 is directed to the ultrasound device of example 1, wherein the pressure sensor is integrated with the ultrasound on-a-chip device.

[0053] Example 3 is directed to a method to calibrate a first ultrasound transducer of an array of ultrasound transducers for ambient pressure variation, the method comprising: detecting a real-time ambient pressure value; determining a pressure difference value between the detected ambient pressure value and a predetermined pressure value; and calibrating the first ultrasound transducers to compensate for the determined pressure difference.

[0054] Example 4 is directed to the method of example 3, wherein detecting a real-time ambient pressure further comprises measuring the ambient pressure with a pressure sensor.

[0055] Example 5 is directed to the method of example 3, wherein detecting a real-time ambient pressure further comprises measuring a noise level output of the first ultrasound transducer and correlating the noise level output to ambient pressure and wherein the noise level output defines the noise output of the first ultrasound transducer absent an input signal to the first transducer.

[0056] Example 6 is directed to the method of example 3, wherein detecting a real-time ambient pressure further comprises measuring an average noise level output per transducer for the array of ultrasonic transducers and correlating the average noise level output to ambient pressure and wherein the average noise level output defines the averaged noise output of the array of ultrasound transducers absent an input signal to the array.

[0057] Example 7 is directed to the method of example 5, wherein measuring a noise level output of at least one of the ultrasonic transducers further comprises detecting background noise of a first transducer by measuring the first transducer's noise output in the absence of an input signal to the first transducer.

[0058] Example 8 is directed to the method of example 3, wherein determining a pressure difference further comprises comparing the real-time ambient pressure value with a predefined pressure value.

[0059] Example 9 is directed to the method of example 3, wherein the step of calibrating the first ultrasound transducers further comprises biasing the first ultrasound transducer to a first bias value to cause a predetermined deflection in a membrane of the first ultrasound transducer.

[0060] Example 10 is directed to the method of example 3, wherein the step of calibrating the first ultrasound transducers further comprises adjusting the image quality of a received signal from the first ultrasound transducer to compensate for the pressure difference.

[0061] Example 11 is directed to the method of example 10, further comprising dynamically changing an image parameter to compensate for the pressure difference.

[0062] Example 12 is directed to an ultrasound transducer device, comprising: an array of ultrasound transducers including a first transducer in the array, wherein the first transducer further comprises a first capacitive micromachined transducer (CMUT) with a first membrane; a detector in communication with the first transducer, the detector configured to detect a deflection value in the first membrane; and a controller in communication with the CMUT, the controller configured to receive the deflection value from the detector, determine a pressure difference value between the detected ambient pressure and a predetermined pressure and compensate for the determined pressure difference value.

[0063] Example 13 is directed to the ultrasound device of example 12, wherein the detector is an ambient pressure sensor.

[0064] Example 14 is directed to the ultrasound device of example 12, wherein the detector is configured to measure a noise level output of the first ultrasound transducer and correlate the noise level output to ambient pressure and wherein the noise level output defines the noise output of the first ultrasound transducer absent an input signal to the first transducer.

[0065] Example 15 is directed to the ultrasound device of example 12, wherein the detector is configured to correlate the first membrane's deflection in the absence of an input signal as a measure of ambient pressure.

[0066] Example 16 is directed to the ultrasound device of example 12, wherein the detector is configured to detect an average noise level output per transducer for the array of ultrasonic transducers and to correlate the average noise level output from the array of ultrasound transducers.

[0067] Example 17 is directed to the ultrasound device of example 12, wherein the detector is configured to measure a noise level output of the first transducer by measuring the first transducer's noise output in the absence of an input signal.

[0068] Example 18 is directed to the ultrasound device of example 12, wherein the controller compensates for the determined pressure difference value by biasing the first membrane.

[0069] Example 19 is directed to the ultrasound device of example 12, wherein the controller compensates for the determined pressure difference value by biasing a respective membrane associated with each transducer in the array.

[0070] Example 20 is directed to the ultrasound device of example 12, wherein the controller compensates for the determined pressure difference by adjusting an image quality of a received signal from the array of transducers.

[0071] Example 21 is directed to the ultrasound device of example 12, wherein the array of ultrasound transducers, the detector and the controller are integrated in a solid-state device.

[0072] Example 22 is directed to the ultrasound device of example 12, wherein the array of ultrasound transducers, the detector and the controller are integrated to form a chipset.

[0073] While the principles of the disclosure have been illustrated in relation to the exemplary embodiments shown herein, the principles of the disclosure are not limited thereto and include any modification, variation or permutation thereof.

What is claimed is:

1. An ultrasound device, comprising:

an ultrasound-on-a-chip device comprising an array of ultrasonic transducers; and

a pressure sensor configured to detect pressure applied to an ultrasonic transducer of the array.

2. The ultrasound device of claim **1**, wherein the pressure sensor is integrated with the ultrasound on-a-chip device.

3. A method to calibrate a first ultrasound transducer of an array of ultrasound transducers for ambient pressure variation, the method comprising:

detecting a real-time ambient pressure value;

determining a pressure difference value between the detected ambient pressure value and a predetermined pressure value; and

calibrating the first ultrasound transducer to compensate for the determined pressure difference.

4. The method of claim **1**, wherein detecting a real-time ambient pressure further comprises measuring the ambient pressure with a pressure sensor.

5. The method of claim **3**, wherein detecting a real-time ambient pressure further comprises measuring a noise level output of the first ultrasound transducer and correlating the noise level output to ambient pressure and wherein the noise level output defines the noise output of the first ultrasound transducer absent an input signal to the first transducer.

6. The method of claim **3**, wherein detecting a real-time ambient pressure further comprises measuring an average noise level output per transducer for the array of ultrasonic transducers and correlating the average noise level output to ambient pressure and wherein the average noise level output defines the averaged noise output of the array of ultrasound transducers absent an input signal to the array.

7. The method of claim **5**, wherein measuring a noise level output of at least one of the ultrasonic transducers further comprises detecting background noise of a first transducer by measuring the first transducer's noise output in the absence of an input signal to the first transducer.

8. The method of claim **3**, wherein determining a pressure difference further comprises comparing the real-time ambient pressure value with a predefined pressure value.

9. The method of claim **3**, wherein the step of calibrating the first ultrasound transducer further comprises biasing the first ultrasound transducer to a first bias value to cause a predetermined deflection in a membrane of the first ultrasound transducer.

10. The method of claim **3**, wherein the step of calibrating the first ultrasound transducers further comprises adjusting the image quality of a received signal from the first ultrasound transducer to compensate for the pressure difference.

11. The method of claim **10**, further comprising dynamically changing an image parameter to compensate for the pressure difference.

12. An ultrasound transducer device, comprising:

an array of ultrasound transducers including a first transducer in the array, wherein the first transducer further comprises a first capacitive micromachined transducer (CMUT) with a first membrane;

a detector in communication with the first transducer, the detector configured to detect a deflection value in the first membrane; and

a controller in communication with the CMUT, the controller configured to receive the deflection value from the detector, determine a pressure difference value between the detected ambient pressure and a predetermined pressure and compensate for the determined pressure difference value.

13. The ultrasound device of claim **12**, wherein the detector is an ambient pressure sensor.

14. The ultrasound device of claim **12**, wherein the detector is configured to measure a noise level output of the first ultrasound transducer and correlate the noise level output to ambient pressure and wherein the noise level output defines the noise output of the first ultrasound transducer absent an input signal to the first transducer.

15. The ultrasound device of claim **12**, wherein the detector is configured to correlate the first membrane's deflection in the absence of an input signal as a measure of ambient pressure.

16. The ultrasound device of claim **12**, wherein the detector is configured to detect an average noise level output per transducer for the array of ultrasonic transducers and to correlate the average noise level output from the array of ultrasound transducers.

17. The ultrasound device of claim **12**, wherein the detector is configured to measure a noise level output of the first transducer by measuring the first transducer's noise output in the absence of an input signal.

18. The ultrasound device of claim **12**, wherein the controller compensates for the determined pressure difference value by biasing the first membrane.

19. The ultrasound device of claim **12**, wherein the controller compensates for the determined pressure difference value by biasing a respective membrane associated with each transducer in the array.

20. The ultrasound device of claim **12**, wherein the controller compensates for the determined pressure difference by adjusting an image quality of a received signal from the array of transducers.

21. The ultrasound device of claim **12**, wherein the array of ultrasound transducers, the detector and the controller are integrated in a solid-state device.

22. The ultrasound device of claim **12**, wherein the array of ultrasound transducers, the detector and the controller are integrated to form a chipset.

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专利名称(译)	校准超声换能器的方法和设备		
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[标]发明人	SATIR SARP ZAHORIAN JAIME SCOTT		
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摘要(译)

所公开的实施例涉及一种用于超声成像的电容性微机械换能器，其具有压力校准器以补偿由环境压力变化引起的超声图像失真。 在一个实施例中，本公开涉及一种用于针对环境压力变化来校准超声换能器阵列中的第一超声换能器的方法。 该方法包括检测实时环境压力值的步骤。 确定检测到的环境压力值与预定压力值之间的压力差值； 校准第一超声换能器以补偿确定的压差。