(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 January 2019 (17.01.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/014458 A1

(51) International Patent Classification:
G01N 27/30 (2006.01) *H03M 1/12* (2006.01)
G01N 33/543 (2006.01)

(21) International Application Number: PCT/US2018/041841

(22) International Filing Date: 12 July 2018 (12.07.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/531,458 12 July 2017 (12.07.2017) US

(71) Applicant: MAXIM INTEGRATED PRODUCTS, INC. [US/US]; 160 Rio Robles, San Jose, CA 95134 (US).

(72) Inventors: **YANG, Yaohua**; 2412 Remington Drive, West Linn, OR 97068 (US). **MCCARROLL, Benjamin, J.**; 1736 Nw Andrew Place, Portland, OR 97229 (US). **CAHILL, Sean**; 2120 Hanover Street, Palo Alto, CA 94306 (US). **YIN, Ruming**; 12697 Nw Avignon Lane, Portland, OR 97229 (US). **KOO, Ronald, B.**; 655 Rivera Drive, Los Altos, CA 94024 (US).

(74) Agent: **CHAKRABARTI, Manisha**; Advent, LLP, The Advent Building, 17838 Burke Street, Suite 200, Omaha, NE 68118 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

(54) Title: MOBILE SENSOR SYSTEM FOR ANALYZING FLUID SAMPLES

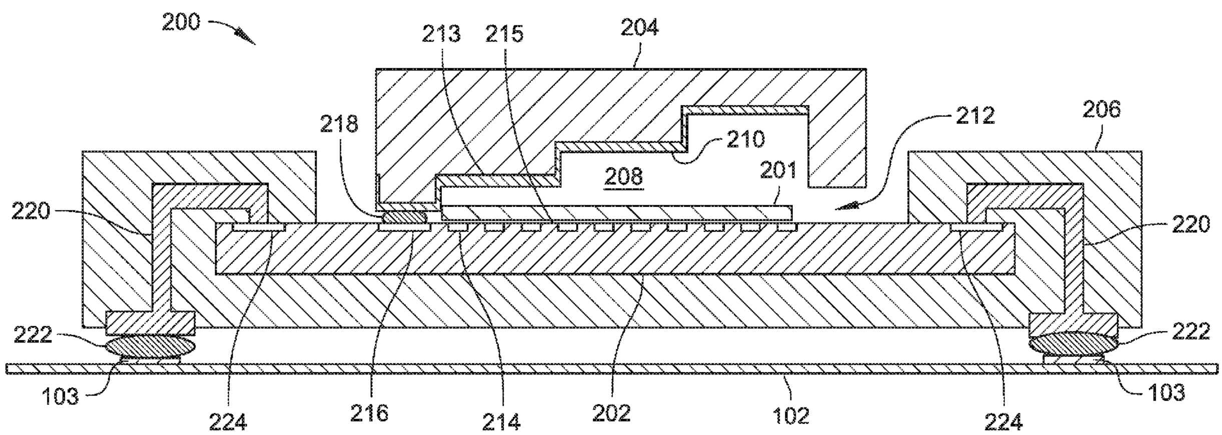

FIG. 2A

(57) Abstract: A sensor system includes an array of conductive elements, an electrode proximate to the array, column selection circuitry, a plurality of readout circuits and a plurality of analog-to-digital converters. The electrode and the array of conductive elements define a cavity configured to receive a fluid sample. The electrode is configured to transmit at least one electrical signal through the fluid sample. The column selection circuitry is configured to select a column of conductive elements from the array. The readout circuits are coupled to respective ones of M rows of conductive elements in the array and are configured to receive signals from respective conductive elements of a selected column of conductive elements. The readout circuits are further configured to generate readout signals based on the signals received from the respective conductive elements. The analog-to-digital converters are configured to convert the readout signals into digital signals.

WO 2019/014458 A1

[Continued on next page]

EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

MOBILE SENSOR SYSTEM FOR ANALYZING FLUID SAMPLES

BACKGROUND

[0001] The analysis of components in biological fluids (e.g., blood, urine, saliva, etc.) and other fluids (e.g., liquid or gas samples, etc.) is continuing to increase in importance. Biological fluid tests can be used in a health care environment to determine physiological and/or biochemical states, such as disease, mineral content, pharmaceutical drug effectiveness, and/or organ function. For example, it may be desirable to determine an analyte concentration within an individual's blood to manage a health condition, such as diabetes. Consequently, the individual may be required to go to a diagnostic laboratory or medical facility to have blood drawn and then wait (often for an extended period) for analysis results. The individual typically schedules a follow-up visit with a healthcare provider to review the analysis results, which can also add cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] The detailed description is described with reference to the accompanying figures. The use of the same reference numbers in different instances in the description and the figures may indicate similar or identical items. Various embodiments or examples ("examples") of the present disclosure are disclosed in the following detailed description and the accompanying drawings. The drawings are not necessarily to scale. In general, operations of disclosed processes may be performed in an arbitrary order, unless otherwise provided in the claims.

[0003] FIG. 1A is a block diagram representation of an example of a test device including an embodiment of a sensor system for analyzing a fluid sample;

[0004] FIG. 1B is a block diagram representation of an example of a controller configured to communicate with an embodiment of a sensor system;

[0005] FIG. 2A is a diagrammatic partial cross-sectional side elevation view of an embodiment of sensor system configured as a sensor package;

[0006] FIG. 2B is a diagrammatic partial cross-sectional side elevation view of an embodiment of a sensor system configured as a sensor package;

[0007] FIG. 3 is a schematic view of an electronics configuration of an embodiment of a sensor system;

[0008] FIG. 4 is a partial schematic view of an electronics configuration of an embodiment of a sensor system;

[0009] FIG. 5 is a partial perspective view of a configuration of an embodiment of a sensor system;

[0010] FIG. 6 is a partial schematic view of an electronics configuration of an example of a sense path of an embodiment of a sensor system;

[0011] FIG. 7A is a diagrammatic representation of a sensor system including multiple arrays of conductive elements;

[0012] FIG. 7B is a diagrammatic representation of a sensor system including multiple arrays of conductive elements;

[0013] FIG. 7C is a diagrammatic representation of a sensor system including multiple arrays of conductive elements;

[0014] FIG. 8 is a flow diagram representation of an example of a process for analyzing a fluid sample using an embodiment of a sensor system.

DETAILED DESCRIPTION

Overview

[0015] Sensor systems that allow for onsite analysis of fluid samples (e.g., biological fluids or other liquid or gas samples) are increasing in importance. For example, onsite sensor systems can be used to analyze freshly collected fluid samples rather than having to preserve the fluid samples for transport to a remotely located lab for analysis. Onsite sensor systems can also be used to obtain faster results for analyzed fluid samples, to perform analysis of fluid samples in remote areas where transportation and/or access to test equipment is limited, to perform self-tests for patients who need to have one or more of their biological samples (e.g., blood, saliva, urine, etc.) analyzed frequently (rather than having to go to a healthcare facility each time a test is needed), and so forth.

[0016] A mobile sensor system and process for analyzing a fluid sample are disclosed. The sensor system includes at least one array of conductive elements forming an MxN matrix, where M is a number of rows of conductive elements and N is a number of columns of conductive elements. The sensor system further includes an electrode proximate to the array of conductive elements. The electrode and the array of conductive elements define a cavity that is configured to receive a fluid sample. The electrode is configured to transmit at least one electrical signal through the fluid sample. The sensor system also includes column selection circuitry (e.g., electronic switches) configured to select a column of the N columns of conductive elements. A plurality of readout circuits are coupled to respective ones of the M rows of conductive elements. The plurality of readout circuits are configured to receive signals from respective conductive elements of a selected column of conductive elements. The signals correspond to the electrical signal or signals transmitted through the fluid sample. For example, a readout circuit can be configured to receive a signal from a respective one of the conductive elements, where the signal is affected by changes in impedance resulting from particles (e.g., cells, biological structures, beads, microparticles, etc.) in the fluid sample between the electrode and the respective one of the conductive elements. The plurality of readout circuits are further configured to generate readout signals based on the signals received from the respective conductive elements. In this manner, the sensor system scans a sample space defined by the array of conductive elements and generates informational signals (i.e., readout signals) associated with characteristics of the fluid sample, such as its particle content, particle morphology, particle density, particle distribution, presence/absence of an analyte, analyte concentration, and so forth. The sensor system also includes a plurality of analog-to-digital convertors coupled to respective ones of the plurality of readout circuits. The plurality of analog-to-digital convertors are configured to convert the readout signals from the plurality of readout circuits into digital signals.

[0017] The sensor system may be implemented in a sensor package. For example, the sensor system can be implemented in a sensor package (e.g., a chip) that is mounted to or embedded in a test device (e.g., test strip) or another device (e.g., a mobile device, analysis instrument, fluid collection device (e.g., syringe, intravenous blood drawing device, or a push button blood collection device that employs microneedles to draw blood through a skin surface, such as the TAP device manufactured by Seventh Sense

Biosystems, Inc.), or fluid container (e.g., microfluidic cassette, test tube, petri dish, etc.)). In some embodiments, the digital signals output by the analog-to-digital converters are processed (e.g., filtered, amplified, phase and/or frequency shifted, modulated, or the like) by digital processing circuitry coupled to the analog-to-digital converters. The digital processing circuitry can be configured to transmit the processed digital signals to a controller (e.g., a controller of a test device, a mobile device controller, or the like). The controller can then provide analytical results based on the digital signals or may be configured to transmit information associated with the digital signals (or results based on the digital signals) to another device or system that is configured to store and/or analyze the information.

Example Implementations

[0018] Referring to FIG. 1A, an example of a test device 100 including an embodiment of a sensor system 200 is shown. Examples of a test devices 100 include, but are not limited to, a test strip, a mobile device, a computer device, an analysis instrument, a fluid collection device, and a fluid container. Examples of mobile devices include, but are not limited to, a smartphone, a wearable device, a tablet, a digital camera, a notebook computer, a media player, and a portable gaming device. Examples of fluid collection devices include, but are not limited to, a syringe, an intravenous blood drawing device, and a push button blood collection device that employs a microneedle to draw blood through a skin surface. An example of a push button blood collection device is a TAP device manufactured by Seventh Sense Biosystems, Inc. Examples of fluid containers include, but are not limited to, a microfluidic cassette, a test tube, and a petri dish.

[0019] In an embodiment, the test device 100 includes a controller 108, a sensor system 200, a transceiver 106, a battery 110, and an antenna 104. The controller 108 is communicatively coupled to the sensor system 200 and the transceiver 106. The transceiver 106 is communicatively coupled to the antenna 104. The battery 110 is electrically coupled to the sensor system 200.

[0020] The sensor system 200 is configured to receive a fluid sample and scan the received fluid sample to detect one or more analytes in the fluid sample. In an embodiment, the sensor system 200 is configured to analyze a fluid sample by scanning the fluid sample to determine at least one characteristic of particles that may be present in the fluid sample. Examples of particles include, but are not limited to cells, biological structures, beads, and microparticles. Examples of characteristic of the particles include, but are not limited to an amount of a particle within the fluid sample, a spatial distribution of the particles within the fluid sample, dimensions of the particles within the fluid sample, and a concentration of particles within the fluid sample.

[0021] In an embodiment, the sensor system 200 is be configured to perform an assay. An assay is a test that is performed by adding one or more reagents to a fluid sample and analyzing the manner in which the fluid sample and/or the reagents are consequently affected. For example, functionalized beads may agglutinate or agglomerate when a certain analyte is present in the fluid sample. Functional beads typically comprise one or more reagents or are coated with one or more reagents. Examples of assays include, but are not limited to, agglutination assays, agglomeration assays, immunoassays, kinetic agglutination assays, agglomeration-of-beads assays, kinetic agglomeration-of-beads assays, coagulation assays, kinetic coagulation assays, surface antigen assays, receptor assays from biopsy procedures, circulating blood cells assays, and circulating nucleic acid assays.

[0022] In an embodiment, the sensor system 200 is a component of the test device 100. In an alternative embodiment, the sensor system 200 may be coupled to a test device 100. In an embodiment, the sensor system 200 may be embedded within the test device 100.

[0023] The controller 108 is configured to receive fluid sample data from the sensor system 200. In an embodiment, the controller 108 is configured to communicate fluid sample data received from the sensor system 200 to an external device 101 via the transceiver 106 and antenna 104. Examples of external devices 101 include, but are not limited to, a mobile device, a computer, and an analysis instrument. In an embodiment, the controller 108 is a component of the sensor system 200. In an alternative embodiment, the controller 108 is a component of an external device 101 communicatively coupled to the test device 100.

[0024] Examples of transceivers 106 include, but are not limited to, a near-field communication (NFC) transceiver or other short range transceivers. The transceiver

106 is communicatively coupled to the antenna 104 to enable the transmission of information from the test device 100 and the receiving of information at the test device 100. In an embodiment, the transceiver 106 is configured to communicatively couple the test device 100 to an external device 101. The antenna 104 is configured to transmit information sent by the controller 108 to the external device 101. For example, the controller 108 can be configured to send information received from the sensor system 200 to the external device 101 via the transceiver 106 and the antenna 104. In an embodiment, the external device 101 may be configured to receive information from the controller 108 via a direct (e.g., wired) connection. In an embodiment, the controller 108 is configured to receive information from the external device 101 via the transceiver 106 using a direct (e.g., wired) connection).

[0025] The battery 110 is configured to power one or more components of the test device 100. In an embodiment, the battery 110 is electrically coupled to the sensor system 200, the controller 108, and the transceiver 106. In an embodiment, the battery is directly electrically coupled to one or more of the sensor system 200, the controller 108 and the transceiver 106. In an embodiment, the battery 110 is indirectly coupled to one or more of the sensor system 200, the controller 108, and the transceiver 106. In an embodiment, the battery is configured to be inductively charged via the antenna 104. In an embodiment, an energy harvesting circuit can be electrically coupled to the antenna 104.

[0026] Referring 1B, an example of a controller 108 configured to communicate with the sensor system 200 is shown. A sensor controller 234 has a configuration similar to that of the controller 108. The controller 108 includes a processor 112, a memory 114, and a communications interface 116. The processor 112 provides processing functionality for at least the controller 108. The processor can include any number of microprocessors, digital signal processors, micro-controllers, circuitry, field programmable gate array (FPGA) or other processing systems, and resident or external memory for storing data, executable code, and other information accessed or generated by the controller 108/sensor system 200. The processor 112 can execute one or more software programs embodied in a non-transitory computer readable medium that implement techniques described herein. The processor 112 is not limited by the materials from which it is formed or the processing mechanisms employed therein and, as such, can be implemented via semiconductor(s) and/or transistors (e.g., using electronic integrated circuit (IC) components), and so forth.

[0027] The memory 114 can be an example of tangible, computer-readable storage medium that provides storage functionality to store various data and or program code associated with operation of the controller 108/sensor system 200, such as software programs and/or code segments, or other data to instruct the processor 112, and possibly other components of the controller 108/sensor system 200, to perform the functionality described herein. Thus, the memory 114 can store data, such as a program of instructions for operating the controller 108/sensor system 200 (including its components), and so forth. It should be noted that while a single memory 114 is described, a wide variety of types and combinations of memory (e.g., tangible, non-transitory memory) can be employed. The memory 114 can be integral with the processor 112, can comprise stand-alone memory, or can be a combination of both.

[0028] Some examples of the memory 114 can include removable and non-removable memory components, such as random-access memory (RAM), read-only memory (ROM), flash memory (e.g., a secure digital (SD) memory card, a mini-SD memory card, and/or a micro-SD memory card), magnetic memory, optical memory, universal serial bus (USB) memory devices, hard disk memory, external memory, and so forth. In implementations, the controller 108/sensor system 200 and/or the memory 114 can include removable integrated circuit card (ICC) memory, such as memory provided by a subscriber identity module (SIM) card, a universal subscriber identity module (USIM) card, a universal integrated circuit card (UICC), and so on.

[0029] The communications interface 116 can be operatively configured to communicate with components of the sensor system 200 and/or transceiver 106. For example, the communications interface 116 can be configured to retrieve data from storage in the sensor system 200, transmit data for storage in the sensor system 200, and so forth. The communications interface 116 can also be communicatively coupled with the processor 112 to facilitate data transfer between components of the sensor system 200 and the processor 112. It should be noted that while the communications interface 116 is described as a component of a controller 108/sensor system 200, one or more components of the communications interface 116 can be implemented as external components communicatively coupled to the sensor system 200 via a wired and/or wireless connection. The sensor system 200 can also be configured to connect to one or more input/output (I/O) devices (e.g., via the communications interface 116). For example, an I/O device can include, but is not limited to, a display, a mouse, a touchpad, a touchscreen, a keyboard, a microphone (e.g., for voice commands), any combination of thereof, and the like.

[0030] The communications interface 116 and/or the processor 112 can be configured to communicate with a variety of different networks, such as near-field communication (NFC) networks, a wide-area cellular telephone network, such as a cellular network, a 3G cellular network, a 4G cellular network, or a global system for mobile communications (GSM) network; a wireless computer communications network, such as a WiFi network (e.g., a wireless local area network (WLAN) operated using IEEE 802.11 network standards); an ad-hoc wireless network, an internet; the Internet; a wide area network (WAN); a local area network (LAN); a personal area network (PAN) (e.g., a wireless personal area network (WPAN) operated using IEEE 802.15 network standards); a public telephone network; an extranet; an intranet; and so on. However, this list is provided by way of example only and is not meant to limit the present disclosure. Further, the communications interface 116 can be configured to communicate with a single network or multiple networks across different access points. In an embodiment, a communications interface 116 can transmit information from the controller 108 to an external device (e.g., mobile device, a computer connected to a network, cloud storage, etc.). In another embodiment, a communications interface 116 can receive information from an external device (e.g., a mobile device, a computer connected to a network, cloud storage, etc.).

[0031] Referring to FIG. 2A, an example of a packaged configuration of an embodiment of a sensor system 200 disposed on a test device substrate 102 is shown. An embodiment of the sensor system 200 includes a sensor platform substrate 202, a cap structure 204, a base substrate 206, an electrode structure 210 and a plurality of conductive elements 214.

[0032] The plurality of conductive elements 214 are embedded within the sensor platform substrate 202. For example the plurality of conductive elements 214 may be formed within one or more layers of the sensor platform substrate 202. Examples of conductive elements 214 include, but are not limited to metal panels, metal pillars, panels formed from conductive materials, pillars formed from conductive materials, panels formed from semi-conductive materials, and pillars formed from semi-conductive materials. Indium tin oxide (ITO) may be disposed upon the sensor platform substrate 202 to reduce electrochemical effects. In an embodiment, the plurality of conductive elements 214 are uniformly arranged in a planar configuration.

[0033] In embodiment, an electrical insulator and/or protective layer is disposed upon the conductive elements 214 such that the electrical insulator and/or protective layer at least partially covers the conductive elements 214.

[0034] In an embodiment, one or more of the conductive elements 214 are prepared for performing an assay. In an embodiment, one or more of the conductive elements 214 are coated with dry chemistry. Examples of dry chemistry include, but are not limited to, dry chemical reagents, microparticles, and microbeads. In an alternative embodiment, one or more of the conductive elements 214 are coated with a gel or slurry in which chemical reagents and/or microparticles are suspended. In an embodiment, the electrical insulator and/or protective layer is coated with dry chemistry. In an embodiment, the electrical insulator and/or protective layer is coated with a gel or slurry in which chemical reagents and/or microparticles are suspended.

[0035] The sensor platform substrate 202 is disposed upon the base substrate 206. In an embodiment, the sensor platform substrate 202 is at least partially embedded within the base substrate 206. In an embodiment, the sensor platform substrate 202 defines a portion of an integrated circuit, such as for example, an application specific integrated circuit (ASIC), that is disposed upon and/or at least partially embedded within the base substrate 206. In an embodiment, the sensor platform substrate 202 and the base substrate 206 are portions of a single substrate.

[0036] The sensor system 200 includes a cap structure 204. In an embodiment, the cap structure 204 is disposed upon the sensor platform substrate 202. In an embodiment, the cap structure 204 is disposed upon the base substrate 206. The cap structure 204 is disposed in relative proximity to the conductive elements 214. In an embodiment, the cap structure 204 includes a cap substrate that is mounted or otherwise coupled to the sensor platform substrate 202. In an embodiment, the cap structure 204 includes a cap substrate that is mounted on or otherwise coupled to the base substrate 206. In an embodiment, the cap structure 204 and sensor platform substrate 202 are portions of a single substrate. In an embodiment, the cap structure 204, the sensor platform substrate 202 and the base substrate 206 are portions of a single substrate.

[0037] The cap structure 204 has an inner surface 213. The electrode structure 210 is coupled to or embedded within the inner surface 213 of the cap structure 204 such that the electrode structure 210 faces the plurality of conductive elements 214 disposed within the sensor platform substrate 202. In an embodiment, an electrical insulator and/or protective layer is disposed over the electrode structure 210 such that the electrical insulator and/or protective layer at least partially covers the electrode structure 210. In an embodiment, the electrode structure 210 is prepared for performing an assay. In an embodiment, the electrode structure 210 is coated with dry chemistry. Examples of dry chemistry include, but are not limited to, dry chemical reagents, microparticles, and microbeads. In an alternative embodiment, the electrode structure 210 is coated with a gel or slurry in which chemical reagents and/or microparticles are suspended. In an embodiment, the electrical insulator and/or protective layer is coated with dry chemistry. In an embodiment, the electrical insulator and/or protective layer is coated with a gel or slurry in which chemical reagents and/or microparticles are suspended.

[0038] In an embodiment, the electrode structure 210 includes a single electrode with multiple surfaces having different distances from the inner surface 215 of the sensor platform substrate 202. The multiple surfaces allow for different sensitivities and/or can be used to filter the fluid sample 201 such each portion of the sensor area below the multi-level electrode 210 is sensitive to a different range of particle sizes. In an embodiment, the electrode structure 210 includes multiple electrodes disposed on the inner surface 213 of the cap structure 204 opposite the plurality of conductive elements 214. In an embodiment, the surfaces of each of the multiple electrodes of the electrode structure 210 has a different distance from the inner surface 215 of the sensor platform substrate 202.

[0039] In an embodiment, the cap structure 204 and the sensor platform substrate 202 define a cavity 208. In an embodiment, the cap structure 204, the sensor platform substrate 202 and the base substrate 206 define a cavity 208. The fluid sample 201 is deposited within the cavity 208 for testing. In an embodiment, the fluid sample 201 is deposited within the cavity 208 via capillary action. In an embodiment, the fluid sample 201 is disposed within the cavity with the assistance of a syringe or a pump. An example of a pump is a microfluidic pump.

[0040] The cavity 208 is disposed between the electrode structure 210 and the conductive elements 214. As described above, the electrode structure 210 is disposed upon the inner surface 213 of the cap structure 204, and the plurality of conductive elements 214 are arranged upon the inner surface 215 of the sensor platform substrate 202 that is opposite the inner surface 213 of the cap structure 204. The electrode structure 210 is configured to transmit at least one electrical test signal through the fluid sample 201 in the direction of the plurality of conductive elements 214 thereby generating a vertical electric field relative to the planar arrangement of the plurality of conductive elements 214. In other words, the generated electric field is substantially perpendicular to the inner surface 215 of the sensor platform substrate 202.

[0041] In an alternative embodiment, the plurality of conductive elements 214 are configured to transmit electrical test signals that can be received by other ones of the conductive elements 214 in order to generate horizontal electric fields relative to the receiving ones of the conductive elements 214. In other words, an electric field that is substantially parallel to the inner surface 215 of the sensor platform substrate 202 is generated.

[0042] The electrical test signal(s) generated by the electrode structure 210 passes through the fluid sample 201 disposed within the cavity 208 and at least a portion of the electrical test signal(s) is detected by the plurality of the conductive elements 214. The plurality of conductive elements 214 are configured to generate sense signals corresponding to the detected portion of electrical test signal (s).

[0043] The sensor system 200 includes one or more electrical paths 220 that enable electrical coupling between electrical components disposed on/or coupled to the sensor platform substrate 202 to other components of the test device 100. Examples of the electrical paths 220 include, but are not limited to, through-silicon vias (TSVs) and conductive traces.

[0044] The sensor platform substrate 202 includes a sensor platform connector 224. Examples of sensor platform connectors 224 include, but are not limited to, input/output (I/O) pads, I/O pins, and I/O sockets. The sensor platform connectors 224 enable electrical coupling with electronic components disposed on the sensor platform substrate 202, such as for example the conductive elements 214, via the electrical pathway 220.

[0045] The test device substrate 102 includes one or more test device connectors 103. Examples of test device connectors 224 include, but are not limited to, input/output (I/O) pads, I/O pins, and I/O sockets. Electrical coupling is provided between electrical components disposed on the sensor platform substrate 202 and the test device 100 via the sensor platform connector 224, the electrical pathway 220, the solder bump 222 and the test device connector 103.

[0046] In an embodiment, the electrode structure 210 is electrically coupled to an electrode connector 216 disposed on the sensor platform substrate 202 via a solder bump 218. Examples of the electrode connectors 216 include, but are not limited to input/output (I/O) pads, I/O pins, and I/O sockets. The electrode connector 216 is coupled to and/or defines a portion of an electrical path on sensor platform substrate 202 for electrically coupling the electrode structure 210 to other components of the sensor system 200 and/or test device 100. An example of such a component is an electrode driver circuitry configured to drive the electrode structure 210. An example of electrode driver circuitry is a digital-to-analog converter (DAC). In embodiments, where sensor platform substrate 202 and the cap structure 204 are portions of a common structure, the electrode structure 210 can be electrically coupled to the electrode driver circuitry that drives the electrode structure 210 by at least one electrical path defined on or through at least a portion of the common structure.

[0047] Referring to FIG. 2B, an example of a packaged configuration of an alternative embodiment of a sensor system 200 disposed on a test device substrate 201 is shown. The electrode structure 210 has a substantially flat or planar configuration. The substantially flat electrode structure 210 is disposed on the inner surface 213 of the cap structure 204 and the plurality or conductive elements are disposed opposite the substantially flat electrode structure 210. In other embodiments, the electrode structure

210 may be disposed on an inner sidewall of the cavity 208 with the conductive elements being disposed on an opposing inner sidewall of the cavity 208.

[0048] In another embodiment, a first section of the cavity 208 may include a first electrode structure 210 disposed on an inner surface 213 of the cap structure 204 and a first plurality of conductive elements 214 disposed on an inner surface 215 of the sensor platform substrate 202 opposite the first electrode structure and a second section of the cavity 208 may include a second electrode structure 210 disposed on an inner surface 215 of the sensor platform substrate 202 and a second plurality of conductive elements 214 disposed on an inner surface 213 of the cap structure 204 opposite the second electrode structure 210. While a number of different configurations of the electrode structure 210 with respect to a plurality of conductive elements 214 have been described, alternative configurations may be used where one or more electrode structures 210 are disposed within an inner surface of the cavity 208 with one or more sets of a plurality of conductive elements 214 disposed on an opposing inner surface of the cavity 208 with respect to the electrode structures 210.

[0049] Referring to FIG. 3 a schematic representation of an electronic configuration of an embodiment of a sensor system 200 is shown. The sensor system 200 includes digital processing circuitry 232, an array 211 of a plurality of conductive elements 214, a fluid sample detector 217, a reference signal generator 228, a phase-locked loop circuit or a delay-locked loop circuit (PLL/DLL) 230, a digital to analog converter (DAC) 226, column selection circuitry 260, a plurality of readout circuits 244, and a power manager 258. The digital processing circuitry 232 is communicatively coupled to the controller 108.

[0050] In an embodiment, the conductive elements 214 are arranged in an array 211. In an embodiment, the array 211 of conductive elements 214 is formed in an MxN matrix, where M is a number of rows of conductive elements 214 and N is a number of columns of conductive elements 214. Although a rectangular arrangement of the conductive elements 214 is shown, in other embodiments, the array 211 of conductive elements 214 can have an alternative configuration (e.g., a non-rectangular geometric layout).

[0051] The fluid sample detector 217 is communicatively coupled to the digital processing circuitry 232. The fluid sample detector 217 is coupled to and/or disposed in proximity to the array 211 of conductive elements 214. In an embodiment, the array 211 of conductive elements 214 is configured to detect the presence of a fluid sample 201 within the cavity 208 of the sensor system 200 by detecting a change in conductivity or impedance within the cavity 208. Examples of fluid sample detectors 217 include, but are not limited to a resistance sensor, an optical sensor, an electric field sensor, a magnetic field sensor, a pressure/force sensor, a thermal sensor, and a moisture sensor. Examples of optical sensors include, but are not limited to a photodiode and a photoresistor. Examples of an electric field sensor include, but are not limited to, an impendence sensor and a capacitance sensor. Examples of magnetic field sensors include, but are not limited to, a magnetic coil and a Hall effect sensor.

[0052] In an embodiment, the conductive elements 214 and/or the fluid sample detector 217 are configured to detect the presence of a fluid sample 201 in the cavity 208 of the sensor system 200. In an embodiment, the fluid sample detector 217 detects the introduction of a fluid sample 201 into the cavity 208 to enable the determination of a starting time of a reaction between the fluid sample 201 and a reagent (e.g., chemical reagent) disposed within the cavity 208 and/or the beginning of an assay performed with the fluid sample 201. The digital processing circuitry 232 receives data regarding the detection of the presence and/or the introduction of a fluid sample 201 into the cavity 208 from the fluid sample detector 217.

[0053] As discussed above, the electrode structure 210 of the sensor system 200 is configured to transmit at least one electrical test signal through the fluid sample 201 disposed within the cavity 208. The electrical test signal (or signals) are based on a reference signal generated by a reference signal generator 228. Examples of reference signal generators 228 include, but are not limited to a crystal oscillator (XO) and temperature compensated crystal oscillator (TCXO). In an embodiment, the electrode structure 210 is driven directly by the reference signal.

[0054] In an embodiment, the reference signal generator 228 is communicatively coupled to the phase-locked loop or delay-lock loop (PLL/DLL) circuit 230. The PLL/DLL 230 is configured to control a phase of the reference signal generated by the reference signal generator 228 responsive to commands received from the phase controller 240 of the digital processing circuitry 232. In an embodiment, the reference signal generated by the reference signal generator 228 is one or more of delayed, shifted, modulate and attenuated to generate a modified reference signal.

[0055] In an embodiment, the digital processing circuitry 232 receives the reference signal from the reference signal generator 228 and digitizes and/or processes the received reference signal. The digital processing circuitry 232 is communicatively coupled to the DAC 226. The DAC 226 receives the digitized and/or processed reference signal from the digital processing circuitry 232 and generates an electrode driver signal. The DAC 226 is communicatively coupled to the electrode structure 210. The electrode driver signal generated by the DAC 226 is used to drive the electrode structure 210 thereby causing the electrode structure 210 to transmit at least one electrical test signal through the fluid sample 201 disposed within the cavity 208.

[0056] In an embodiment, the digital processing circuitry 232 receives the modified reference signal from the PLL/DLL 230 and digitizes and/or processes the received modified reference signal. The DAC 226 receives the digitized and/or processed modified reference signal from the digital processing circuitry 232 and generates an electrode driver signal. The electrode driver signal generated by the DAC 226 is used to drive the electrode structure 210 thereby causing the electrode structure 210 to transmit at least one electrical test signal through the fluid sample 201 disposed within the cavity 208.

[0057] The electrical test signal(s) transmitted by the electrode structure 210 pass through the fluid sample 201 disposed within the cavity 208 of the sensor system 200. The transmitted electrical signal(s) is/are affected by changes in impedance between the electrode structure 210 and a respective conductive element 214 resulting from the presence of particles 203 within the fluid sample 201 disposed within the cavity 208. The array 211 of conductive elements 214 are configured to detect the version of the electrical test signal(s) that have passed through the fluid sample 201. The conductive elements 214 generate sense signals corresponding to the version of the electrical test signal(s) that have passed through the fluid sample 201. The generated sense signals represent one or more characteristics of the fluid sample 201.

[0058] The column selection circuitry 260 is communicatively coupled to the digital processing circuitry 232 and to the array 211 of conductive elements 214. The column selection circuitry 260 includes one or more of switches and multiplexers. In an embodiment, the column selection circuitry 260 is configured to select individual columns of the N columns of conductive elements 214 one column at a time to read the sense signals from the conductive elements 214 in the selected column.

[0059] The plurality of readout circuits 226 are communicatively coupled to the digital processing circuitry 232 and to the array 211 of conductive elements 214. Each of the plurality of readout circuits 244 is placed in series with an associated row of conductive elements 214 and is configured to be selectively electrically coupled to a conductive element 214 in that row when a column corresponding to the conductive element 214 is selected by the column selection circuitry 260.

[0060] For example, in operation, responsive to commands received from the digital processing circuitry 232, the column selection circuitry 260 selects a first column of the N columns. The first column includes M conductive elements 214 where each of the M conductive elements 214 in the first column are disposed in one through M rows. The plurality of readout circuits 244 consist of M readout circuits, where each of the M readout circuit 244 is associated with a specific row of conductive elements 214. Each of the M readout circuits 244 receive the sense signals generated by the conductive element 214 in the row associated with the readout circuit 244 and in the selected column. All of the sense signals generated by the conductive elements 214 in a selected column are read in parallel at roughly the same time. In other words, the sense signals generated by the conductive elements 214 in a selected column are read substantially simultaneously by the associated readout circuits 244. The readout circuits 244 processe the received sense signals and generate readout signals that are transmitted to the digital processing circuitry 232.

[0061] The column selection circuitry 260 then selects a second column of the N columns. Each of the M readout circuits 244 receive the sense signals generated by the conductive element 214 in the row associated with the readout circuit 244 and in the second column. The readout circuit 244 processes the received sense signals and generates readout signals that are transmitted to the digital processing circuitry 232. This process is repeated as the column circuitry 260 successively selects each of the N columns and the readout circuits 244 receive the sense signals generated by each of the conductive elements in the selected column thereby collecting sense signals from each of the conductive elements 214 in the array 211. In an alternative embodiment, each of the conductive elements 214 in a selected column are read sequentially one at a time.

[0062] In an embodiment, each of the plurality of readout circuit 244 includes a multiplier 246 and an integrator 248. The multiplier 246 is coupled to the integrator 248. In an embodiment, the multiplier 246 is coupled in series with the integrator 248. The multiplier 246 is configured to multiply a sense signal received at the readout circuit 244 from a respective conductive element 214 by a second reference signal. The second reference signal is based upon the reference signal generated by the reference signal generator 228 that is used to drive the electrode structure 210. In an embodiment, the second reference signal is a copy of the reference signal generated by the reference signal generator 228. In an another embodiment, the second reference signal is copy of the modified reference signal generated by the PLL/DLL circuit 230.

[0063] In another embodiment, the digital processing circuitry 232 includes a phase controller 240. An example of a phase controller 240 is a PLL/DLL circuit. In an embodiment, the phase controller 240 is configured to adjust the phase of the reference signal by $\frac{\pi}{2}$ radians to generate the second reference signal. For example, the reference signal can comprise a sine wave and the second reference signal generated by the phase controller 240 can comprise a cosine wave, or vice versa. In another embodiment, the phase controller 240 is configured to adjust the phase of the modified reference signal by $\frac{\pi}{2}$ radians to generate the second reference signal.

[0064] The multiplied sense signal generated by the multiplier 246 is received at the integrator 248. The integrator 248 generates a readout signal based on the received multiplied sense signal.

[0065] In an embodiment, the digital processing circuitry 232 includes a frequency controller 238. The frequency controller 238 is configured to adjust a frequency of the reference signal and/or the second reference signal. The phase controller 240 and/or the frequency controller 238 can also be configured to control the phase or frequency parameters of digitized readout signals or fluid sample data signals output by the digital processing circuitry 232. The sensor system 200 also includes biasing circuitry 254 configured to generate reference currents, bandgap references, and so forth. For example, the biasing circuitry 254 can generate references for the DAC 226, ADCs 250, and/or other electronic components of the sensor system 200.

[0066] Each of the plurality of readout circuits 244 are coupled to an associated one of a plurality of analog-to-digital convertors (ADC) 250. Each ADC 250 is configured to receive the readout signal generated by the associated readout circuit 244. The readout signal received at the ADC 250 is an analog signal. The ADC is configured to convert the analog readout signal received from the associated readout circuit 244 into a digital readout signal. The digital processing circuitry 232 is coupled to the plurality of ADCs 250 and is configured to receive the digital readout signals for further processing.

[0067] In an embodiment, the digital processing circuitry 232 is configured to output a fluid sample data signal incorporating at least a portion of one or more of the digital readout signals received from the associated ADCs 250 to the controller 108. In an embodiment, the fluid sample data signal includes at least a portion of the readout digital signals, at least one signal based on filtering, phase shifting, modulating, and/or attenuating at least one of the readout digital signals, imaging data based on at least a portion of the readout digital signals, and/or data based on aggregating, averaging, and/or comparing at least a portion of the readout digital signals. In an embodiments, the digital processing circuitry 232 is configured to store the received digital readout signals and/or the generated fluid sample data signals in a memory 236 that is coupled to the sensor controller 234. For example, the sensor controller 234 can be configured to store the digital readout signals and/or fluid sample data signals based on the digital readout signals in the memory 236 prior to transmitting the fluid sample data signals to the controller 108. In an embodiment, the fluid sample data signal is transmitted to the external device 101.

[0068] In an embodiment, each of the plurality of the ADCs 250 is coupled to a common ramp generator 252. The ramp generator 252 is configured to supply a stepped up reference voltage (e.g., a ramp signal) to the ADCs 250.

[0069] In an embodiment, the sensor system 200 includes a power manager 256. In an embodiment, the power manager 256 is configured to receive a power signal (VBATT) from the battery 110 coupled to the sensor system 200. In another embodiment, the power manager 256 is configured to receive a power signal from an external source (e.g., from device 101) via a direct (e.g., wired) connection or a wireless (e.g., inductive charging) connection. The power manager 256 includes one or more voltage regulators 258 (e.g., low-dropout regulators (LDOs)) that are configured to step up or step down the voltage of the power signal to provide one or more output voltages (e.g., VOUT 1, VOUT 2, VOUT 3, etc.) for establishing reference signals and/or powering various components of the sensor system 200 and/or components coupled to the sensor system 200, such as controller 108, and transceiver 106.

[0070] Referring to FIG. 4, a partial schematic view of an electronics configuration of an embodiment of a sensor system 200 is shown. The sensor system 200 includes first and second arrays 211 of conductive elements 214. The first and second arrays 211 of conductive elements 214 share a common set of readout circuits 244. The sensor system 200 includes row selection circuitry 262. The row selection circuitry 262 includes one or more switches and/or one or more multiplexers between the common set of readout circuits 244 and the first and second arrays 211. The row selection circuitry 262 selectively couples each of the first and second arrays to the common set of readout circuits 244 one array at a time responsive to commands received from the digital processing circuitry 232.

[0071] Upon the coupling of the selected array 211 of conductive elements 214 with the common set of readout circuits 244, each of the plurality of readout circuits 244 is placed in series with an associated row of conductive elements 214 and is configured to be selectively electrically coupled to a conductive element 214 in that row when a column corresponding to the conductive element 214 is selected by the column selection circuitry 260.

[0072] For example, in operation, responsive to commands received from the digital processing circuitry 232, the column selection circuitry 260 selects a first column of the N columns. The first column includes M conductive elements 214 where each of the M conductive elements 214 in the first column are disposed in one through M rows. The common set of readout circuits 244 consist of M readout circuits, where each of the M readout circuit 244 is associated with a specific row of conductive elements 214. Each of the M readout circuits 244 receive the sense signals generated by the conductive element 214 in the row associated with the readout circuit 244 and in the selected column.

[0073] All of the sense signals generated by the conductive elements 214 in a selected column are read in parallel at roughly the same time. In other words, the sense signals generated by the conductive elements 214 in a selected column are read substantially simultaneously by the associated readout circuits 244. The readout circuit 244 processes the received sense signals to generate readout signals. The readout signals are transmitted to the digital processing circuitry 232.

[0074] The column selection circuitry 260 then selects a second column of the N columns. Each of the M readout circuits 244 receive the sense signals generated by the conductive element 214 in the row associated with the readout circuit 244 and in the second column. The readout circuit 244 processes the received sense signals to generate readout signals. The readout signals are transmitted to the digital processing circuitry 232. This process is repeated as the column circuitry 260 successively selects each of the N columns and the readout circuits 244 receive the sense signals generated by each of the conductive elements in the selected column thereby collecting sense signals from each of the conductive elements 214 in the array 211. In an alternative embodiment, each of the conductive elements 214 in a selected column are read sequentially one at a time. In this manner, the sensor system 200 can be configured to scan a selected array 211 of conductive elements 214, column-by-column. In an alternative embodiment, the sensor system 200 is configured to scan a selected array 211 of conductive elements 214 row-by-row in a similar manner with the row and column circuitry being reversed.

[0075] Referring to FIG. 5, a partial perspective view of a configuration of an embodiment of a sensor system 200 is shown. The electrode structure 210 is disposed proximate to the array 211 of conductive elements 214 with a fluid sample 201 disposed between the electrode structure 210 and the array 211 of conductive elements 214. The illustrated example of the fluid sample 201 includes a plurality of particles 203.

[0076] Responsive to an electrode driver signal received from the DAC 226, the electrode structure 210 transmits one or more electrical test signals through the fluid sample 201. The transmitted one or more electrical test signals are affected by changes in impedance between the electrode structure 210 and a respective conductive element

214 resulting from the presence of the particles 203 in the fluid sample 201. The array 211 of conductive elements 214 are configured to detect the version of the one or more electrical test signals that have passed through the fluid sample 201. The conductive elements 214 generate sense signals corresponding to the version of the one or more electrical test signals that have passed through the fluid sample 201. Each sense signal generated by each individual conductive element 214 in the array 211 represents changes in impedance between the electrode 210 and the respective conductive element 214 resulting from the presence of particles 203 in the fluid sample 201.

[0077] For example, a conductive element 214 positioned below a portion of the fluid sample 201 having a first concentration of particles 203 or a first sized particle 203 may produce a different (e.g., more or less powerful) sense signal than another conductive element 214 positioned below a portion of the fluid sample 201 having a second (different) concentration of particles 203, no particles, or a second (different) sized particle 203 as a result of differing impedance characteristics of the respective portion of the fluid sample 201.

[0078] The fluid sample is scanned by the array 211 of conductive elements 214 as sense signals are received from each of the conductive elements 214 in the array. In the case where the array 211 has N columns and M rows, the column selection circuitry 260 selects individual columns of the N columns, one column at a time. Each of the M readout circuit 244 is associated with one of the M rows of conductive elements 214. Upon the selection of a column by the column selection circuitry 260, each of the M readout circuits 244 receive the sense signals generated by the conductive element 214 in the row associated with the readout circuit 244 and in the selected column.

[0079] All of the sense signals generated by the conductive elements 214 in a selected column are read in parallel by the M readout circuits 244 at roughly the same time. In other words, the sense signals generated by the conductive elements 214 in a selected column are read substantially simultaneously by the associated readout circuits 244.

[0080] In this manner, the sensor system 200 can be configured to scan a selected array 211 of conductive elements 214, column-by-column. In an alternative embodiment, each of the conductive elements 214 in a selected column are read sequentially one at a time. In an alternative embodiment, the sensor system 200 is configured to scan a selected array 211 of conductive elements 214 row-by-row in a similar manner with the row and column circuitry being reversed.

[0081] Referring to FIG. 6 a partial schematic view of an electronics configuration of an example of a sense path of an embodiment of a sensor system 200 is shown. The sense path for sensing a signal from a respective conductive element 214 of the plurality of conductive elements 214 in an array 211 includes switches 261 and/or 263 (e.g., switches of the column selections circuitry 260 and/or the row selection circuitry 262) that are configured to place a respective readout circuit 244 in communication with the conductive element 214. The readout circuit 244 can be coupled to an ADC 250 including at least a first comparator 278 and a second comparator 288 in series with the first comparator 278. The first comparator 278 can be coupled to one or more biasing capacitors (e.g., capacitor 280 and/or capacitor 282) and switches 274 and 276 configured to selectively connect the first comparator 278 with the readout circuitry 244 to receive a first phase (Φ_1) (e.g., quadrature) component of a readout signal and a second phase (Φ_2) (e.g., in-phase) component of the readout signal. The second comparator 288 can be coupled to switches 284 and 286 configured to selectively connect the second comparator with a first ramp signal (e.g., for the first phase component) and/or a second ramp signal (e.g., for the second phase component) generated by a ramp generator 252. The ramp generator 252 is also coupled to a counter 290 configured to maintain a multi-bit count of the ramp signal steps (e.g., voltage increases) performed until the comparator 288 output signal toggles (e.g., from 1 to 0 or 0 to 1) for the first and second phase components. When the comparator 288 output signal toggles, sensor controller 234 is configured to store a respective count value (e.g., the digitized readout signals, sometimes referred to herein as "digital signals") for the first and second phase components of the readout signal in memory 236. The sensor controller 234 can be configured to store the digital signals output by each of the ADCs 250 for the respective conductive elements 214 being read from each of the rows in the array 211.

[0082] In FIGS. 7A through 7C embodiments of the sensor systems 200 including multiple arrays 211 of conductive elements 214 and multiple electrode structures 210 are shown. Referring to FIG 7A, an embodiment of the sensor system 200 includes first and second electrode structures 210, 264 and nine arrays 211 of conductive elements 214. The first electrode structures 210 is disposed in proximity to three arrays 211 of conductive elements 214 and the second electrode structure 264 is disposed in proximity to six arrays 211 of conductive elements 214. The first electrode structure 210 is driven by a first DAC 226 and the second electrode structure 264 is driven by a second DAC 266.

[0083] Referring to FIG. 7B, an embodiment of the sensor system 200 includes first, second, and third second electrode structures 210, 264, 268 and nine arrays 211 of conductive elements 214. The first electrode structures 210 is disposed in proximity to three arrays 211 of conductive elements 214, the second electrode structure 264 is disposed in proximity to three arrays 211 of conductive elements 214, and the third electrode structure 268 is disposed in proximity to three arrays 211 of conductive elements 214. The first electrode structure 210 is driven by a first DAC 226, the second electrode structure 264 is driven by a second DAC 266, and the third electrode structure 210 is driven by a third DAC 270.

[0084] Referring to FIG. 7C, an embodiment of the sensor system 200 includes first, second, and third second electrode structures 210, 264, 268 and nine arrays 211 of conductive elements 214. The first electrode structures 210 is disposed in proximity to three arrays 211 of conductive elements 214, the second electrode structure 264 is disposed in proximity to three arrays 211 of conductive elements 214, and the third electrode structure 268 is disposed in proximity to three arrays 211 of conductive elements 214. The first, second, and third electrode structures 210, 264, 268 is driven by a single DAC 226. The sense controller 234 manages the operation of a switch 272 (e.g., a one-to-two or one-to-many switch, a multiplexer, or the like) to selectively couple the DAC 226 to one of the first, second, and third electrode structures 210, 264, 268 when at least one array 211 associated with the selected electrode structure 210 is to be scanned by the sensor system 200.

[0085] In an embodiment, all of the arrays 211 can be configured to perform the same type of assay or test. In another embodiment, different arrays 211 can be configured to perform different types of assays or tests. For example, at least one of the arrays 211 can have a different chemistry (e.g., a different reagent coating) than another one of the arrays 211. In an alternative embodiment, at least one of the arrays 211 can be configured to detect a different range of concentrations of an analyte than another one of the arrays 211. The electrode structures (e.g., electrode structure 210, electrode structure 264 and/or electrode structure 268) may be configured to transmit electrical signals having the same or different parameters (e.g., different frequency, phase, or amplitude). The foregoing embodiments described and illustrated in FIGS. 7A through 7C are example implementations. However, the sensor system 200 can include any number of arrays and/or electrodes structures. In some embodiments, the arrays 211 are disposed upon a single substrate 202. For example, the arrays 211 can form a grid, such as the 3x3 grid shown in FIGS. 7A through 7C. In other embodiments, at least one array 211 can be disposed upon a substrate that is different from the substrate of another array 211 of the sensor system 200.

Example Process

[0086] Referring to FIG. 8 a flowchart representation of an example process 300 for analyzing a fluid sample 201 using an embodiment of a sensor system 200 is shown. In general, operations of disclosed processes (e.g., process 300) may be performed in an arbitrary order, unless otherwise provided in the claims.

[0087] The process 300 includes disposing a fluid sample within a cavity 208 defined between an array 211 of conductive elements 214 and an electrode 210 (block 302). In an implementation, the array 211 of conductive elements 214 forms an MxN matrix, where M is a number of rows of conductive elements 214 and N is a number of columns of conductive elements 214. The electrode structure 210 transmits at least one electrical signal through the fluid sample 201 (block 304). The conductive elements 214 receive at least a portion of the transmitted electrical signal(s) and generate sense signals as a result. The array 211 of conductive elements 214 is scanned on a column-by-column (and/or a row-by-row) basis. For example, at least one column of the N columns of conductive elements 214 is selected with column selection circuitry 260 (block 306). The column selection circuitry 260 can selectively connect readout circuits 244 with a selected column of conductive elements 214 to collect measurements from the selected column of conductive elements 214. The readout circuits 244 receive sense signals from respective conductive elements 214 of the selected column of conductive elements 214 and can generate corresponding readout signals (block 308). A plurality of ADCs 250 coupled to respective readout circuits 244 can then convert the readout signals generated by the readout circuits 244 into digital signals (block 310). The digital signals may be further processed (e.g., averaged, aggregated, filtered, or otherwise manipulated) and/or transmitted to an external device (e.g., device 101). For example, in some implementations, the digital signals are processed by digital processing circuitry 232 and/or controller 108. In some implementations, sensor controller 234 and/or controller 108 can transmit processed digital signals or data based upon the digital signals to the external device 101.

[0088] Generally, any of the functions described herein can be implemented using hardware (e.g., fixed logic circuitry such as integrated circuits), software, firmware, manual processing, or a combination thereof. Thus, the blocks discussed in the above disclosure generally represent hardware (e.g., fixed logic circuitry such as integrated circuits), software, firmware, or a combination thereof. In the instance of a hardware configuration, the various blocks discussed in the above disclosure may be implemented as integrated circuits along with other functionality. Such integrated circuits may include all of the functions of a given block, system, or circuit, or a portion of the functions of the block, system, or circuit. Further, elements of the blocks, systems, or circuits may be implemented across multiple integrated circuits. Such integrated circuits may comprise various integrated circuits, including, but not necessarily limited to: a monolithic integrated circuit, a flip chip integrated circuit, a multichip module integrated circuit, and/or a mixed signal integrated circuit. In the instance of a software implementation, the various blocks discussed in the above disclosure represent executable instructions (e.g., program code) that perform specified tasks when executed on a processor. These executable instructions can be stored in one or more tangible computer readable media. In some such instances, the entire system, block, or circuit may be implemented using its software or firmware equivalent. In other instances, one part of a given system, block, or circuit may be implemented in software or firmware, while other parts are implemented in hardware.

[0089] In an embodiment, a sensor system 200 includes a plurality of conductive elements 214 uniformly arranged in a planar configuration, an electrode structure 210 proximate to the plurality of conductive elements 214 and a cavity 208 configured to receive a fluid sample. The cavity 208 is disposed between the plurality of conductive elements 214 and the electrode structure 210. The electrode structure 210 is configured to transmit at least one electrical test signal through the fluid sample. The sensor system

200 also includes conductive element selection circuit 260, readout circuitry 244, and analog-to-digital convertor circuitry 226. The conductive element selection circuitry 260 is configured to select a different subset of the plurality of conductive elements 214 until every one of the plurality of conductive elements 214 has been selected. The readout circuitry 244 configured to receive sense signals generated by each of conductive elements 214 in the selected subset of the plurality of conductive elements 214 and generate readout signals based on the received sense signals. The analog-to-digital convertor circuitry 226 is configured to receive the generated readout signals from the readout circuitry and convert the received readout signals into digital signals.

[0090] It is to be understood that the present application is defined by the appended claims. Although embodiments of the present application have been illustrated and described herein, it is apparent that various modifications may be made by those skilled in the art without departing from the scope and spirit of this disclosure.

CLAIMS

What is claimed is:

1. A sensor system, comprising:

an array of conductive elements forming an MxN matrix, wherein M is a number of rows of conductive elements and N is a number of columns of conductive elements;

an electrode structure proximate to the array of conductive elements;

a cavity configured to receive a fluid sample, the cavity being disposed between the array of conductive elements and the electrode structure, the electrode structure being configured to transmits at least one electrical test signal through the fluid sample;

column selection circuitry configured to select each of the N columns of conductive elements;

M readout circuits, each of the M readout circuits being electrically coupled to an associated one of the M rows of conductive elements and configured to:

receive a sense signal from each of the conductive elements in the associated one of the M rows of conductive elements responsive to the selection of the column associated with the conductive element, the sense signal corresponding to the at least one electrical test signal transmitted through the fluid sample, and

generate a readout signal based on the received sense signal; and

M analog-to-digital convertors electrically coupled to an associated one of the M readout circuits and configured to convert the readout signals received from the associated one of the M readout circuits into digital signals.

2. The sensor system of claim 1, further comprising digital processing circuitry coupled to the M analog-to-digital convertors, the digital processing circuitry being configured to:

receive the digital signals from the M analog-to-digital converters;

generate fluid sample data based on the received digital signals; and

transmit the generated fluid sample data to a controller.

3. The sensor system of claim 1, further comprising a reference signal generator configured to generate a first reference signal, the at least one electrical test signal transmitted by the electrode structure being based on the first reference signal.

4. The sensor system of claim 3, wherein the reference signal generator comprises a crystal oscillator.

5. The sensor system of claim 3, wherein the reference signal generator is coupled to one of a phase-locked loop and a delay-locked loop configured to control a phase of the first reference signal.

6. The sensor system of claim 3, wherein each of the M readout circuits comprises:

a multiplier configured to multiply the received sense signal with a second reference signal, the second reference signal being based upon the first reference signal; and

an integrator coupled to an output of the multiplier.

7. The sensor system of claim 6, wherein the second reference signal is a phase shifted version of first reference signal.

8. The sensor system of claim 1, further comprising:

a first substrate, wherein the array of conductive elements is disposed upon the first substrate; and

a second substrate, wherein the electrode structure is disposed upon the second substrate, the cavity being defined between the first substrate and the second substrate.

9. A sensor system, comprising:

a plurality of conductive elements uniformly arranged in a planar configuration;

an electrode structure proximate to the plurality of conductive elements;

a cavity configured to receive a fluid sample and disposed between the plurality of conductive elements and the electrode structure, the electrode structure being configured to transmit at least one electrical test signal through the fluid sample;

conductive element selection circuitry configured to select a different subset of the plurality of conductive elements until every one of the plurality of conductive elements has been selected;

readout circuitry configured to receive sense signals generated by each of conductive elements in the selected subset of the plurality of conductive elements and generate readout signals based on the received sense signals; and

analog-to-digital convertor circuitry configured to receive the generated readout signals from the readout circuitry and convert the received readout signals into digital signals.

10. The sensor system of claim 9, wherein each of the different the subsets of the plurality of conductive elements comprises at least one conductive element.

11. The sensor system of claim 9, wherein the plurality of conductive elements are arranged in an MxN array, wherein M is a number of rows of conductive elements and N is a number of columns of conductive elements and the different subsets of the plurality of conductive elements comprise different columns of conductive elements.

12. The sensor system of claim 11, wherein the readout circuitry comprises M readout circuits, each of the M readout circuits being electrically coupled to an associated one of the M rows of conductive elements and configured to:

receive a sense signal from each of the conductive elements in the associated one of the M rows of conductive elements responsive to the selection of the column associated with the conductive element, the sense signal corresponding to the at least one electrical test signal transmitted through the fluid sample, and

generate a readout signal based on the received sense signal;

13. The sensor system of claim 12, further comprising a reference signal generator configured to generate a first reference signal, the at least one electrical test signal transmitted by the electrode structure being based on first the reference signal.

14. The sensor system of claim 13, wherein the reference signal generator is coupled to one of a phase-locked loop and a delay-locked loop configured to control a phase of the first reference signal.

15. The sensor system of claim 13, wherein each readout circuit comprises:

a multiplier configured to multiply a received sense signal with a second reference signal, the second reference signal being based upon the first reference signal; and

an integrator coupled to an output of the multiplier.

16. The sensor system of claim 9, further comprising:

a first substrate, wherein the plurality of conductive elements are disposed upon the first substrate; and

a second substrate, wherein the electrode structure is disposed upon the second substrate, the cavity being defined between the first substrate and the second substrate.

17. A method, comprising:

depositing a fluid sample within a cavity disposed between an array of conductive elements and an electrode structure, the array of conductive elements forming an MxN matrix, where M is a number of rows of conductive elements and N is a number of columns of conductive elements;

transmitting at least one electrical test signal through the fluid sample from the electrode structure;

selecting each of the columns of the N columns of conductive elements with column selection circuitry;

receiving a sense signal from each of the conductive elements in a selected column of conductive elements at M readout circuits, each of the M readout circuits being electrically coupled to an associated one of the M rows of conductive elements; and

generating a readout signal at each of the M readout circuits, each of the generated readout signals being based on the sense signal received at the readout circuit;

receiving the readout signal generated at each of the M readout circuits at an associated analog-to-digital converter; and

converting each of the received readout signals into digital signals at the analog-to-digital converters.

18. The sensor system of claim 17, further comprising a reference signal generator configured to generate a first reference signal, the at least one electrical test signal transmitted by the electrode structure being based on the first reference signal.

19. The sensor system of claim 18, wherein each of the M readout circuits comprises:

a multiplier configured to multiply the received sense signal with a second reference signal, the second reference signal being based upon the first reference signal; and

an integrator coupled to an output of the multiplier.

20. The sensor system of claim 1, further comprising:

a first substrate, wherein the array of conductive elements is disposed upon the first substrate; and

a second substrate, wherein the electrode structure is disposed upon the second substrate, the cavity being defined between the first substrate and the second substrate.

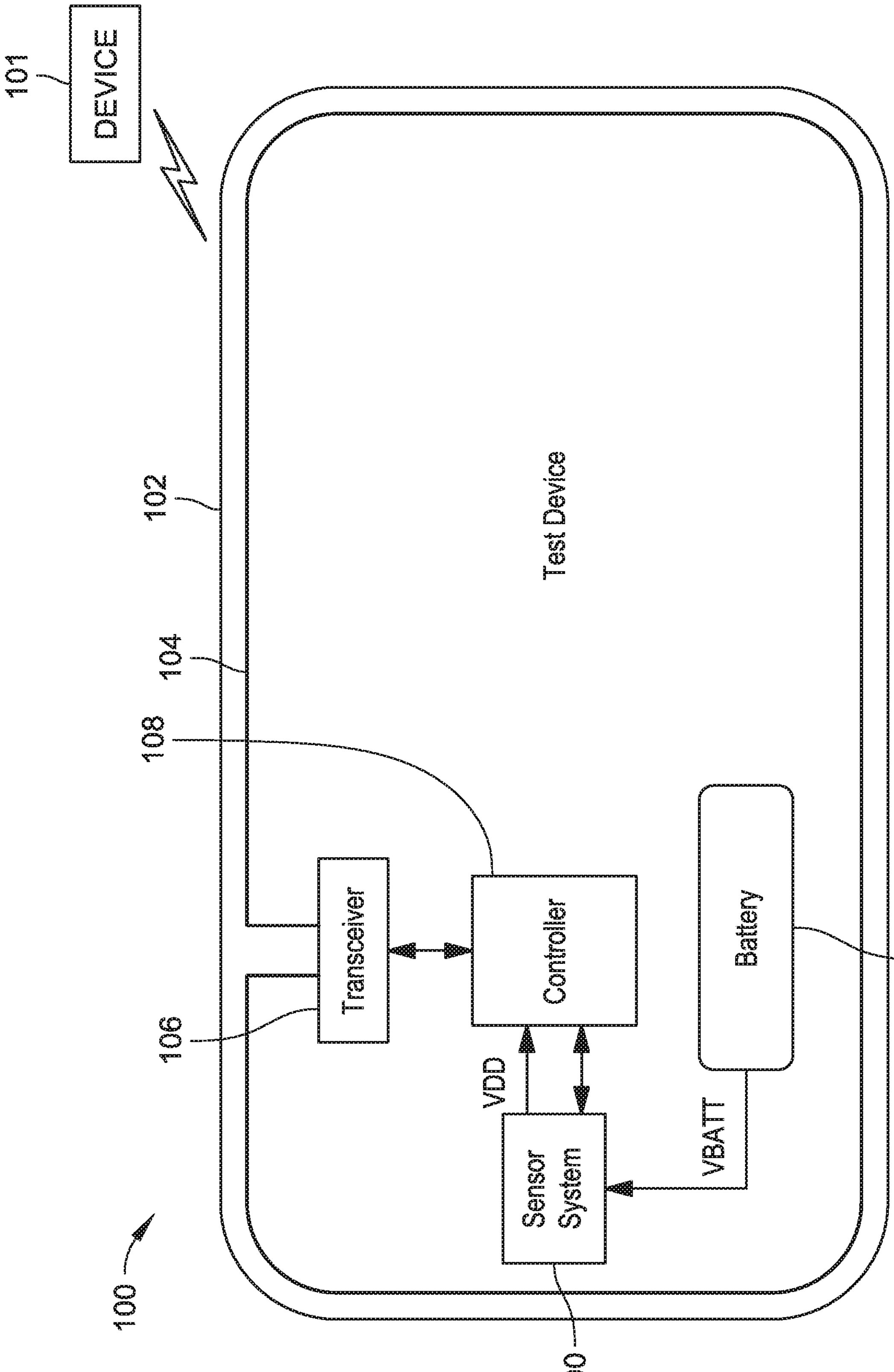
101
DEVICE
102
104
108
Test Device
Transceiver
Controller
Battery
106
110
VDD
VBATT
Sensor System
100
200

FIG. 1A

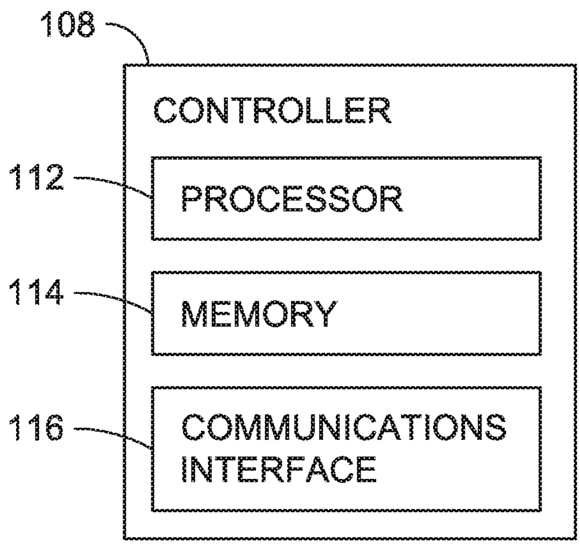
108
CONTROLLER
112
PROCESSOR
114
MEMORY
116
COMMUNICATIONS
INTERFACE

FIG. 1B

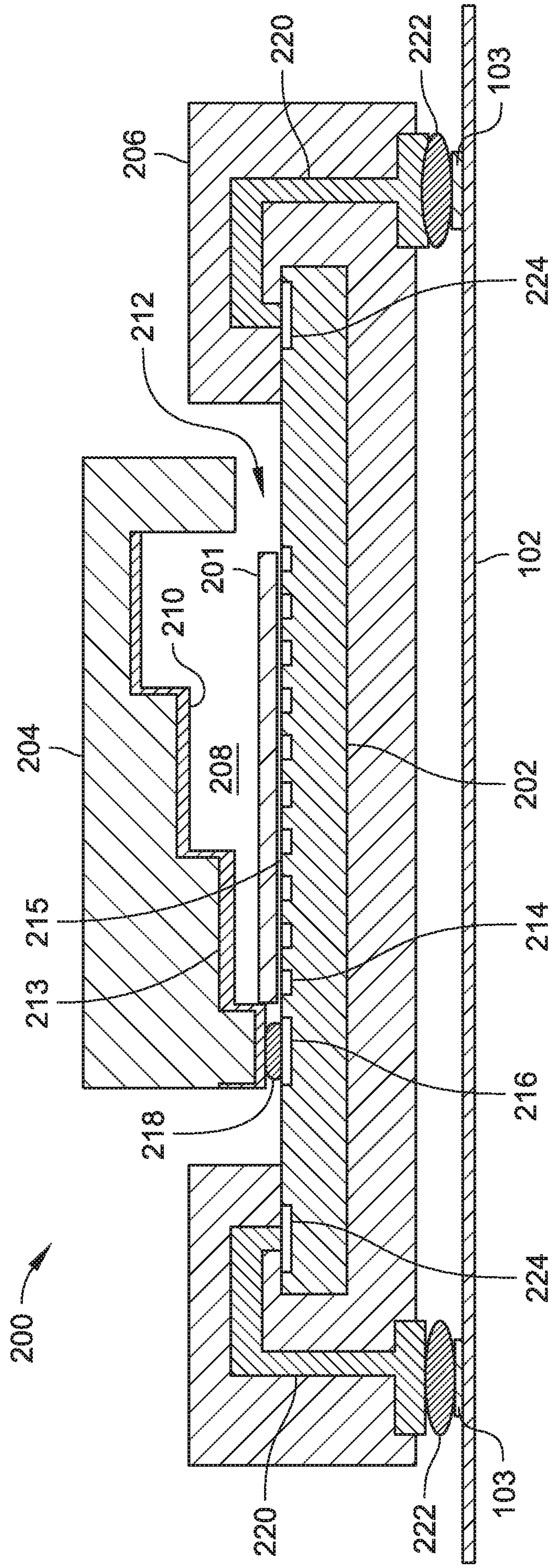
200
204
206
212
220
222
103
224
201
210
208
215
213
218
216
214
202
102
224
220
222
103

FIG. 2A

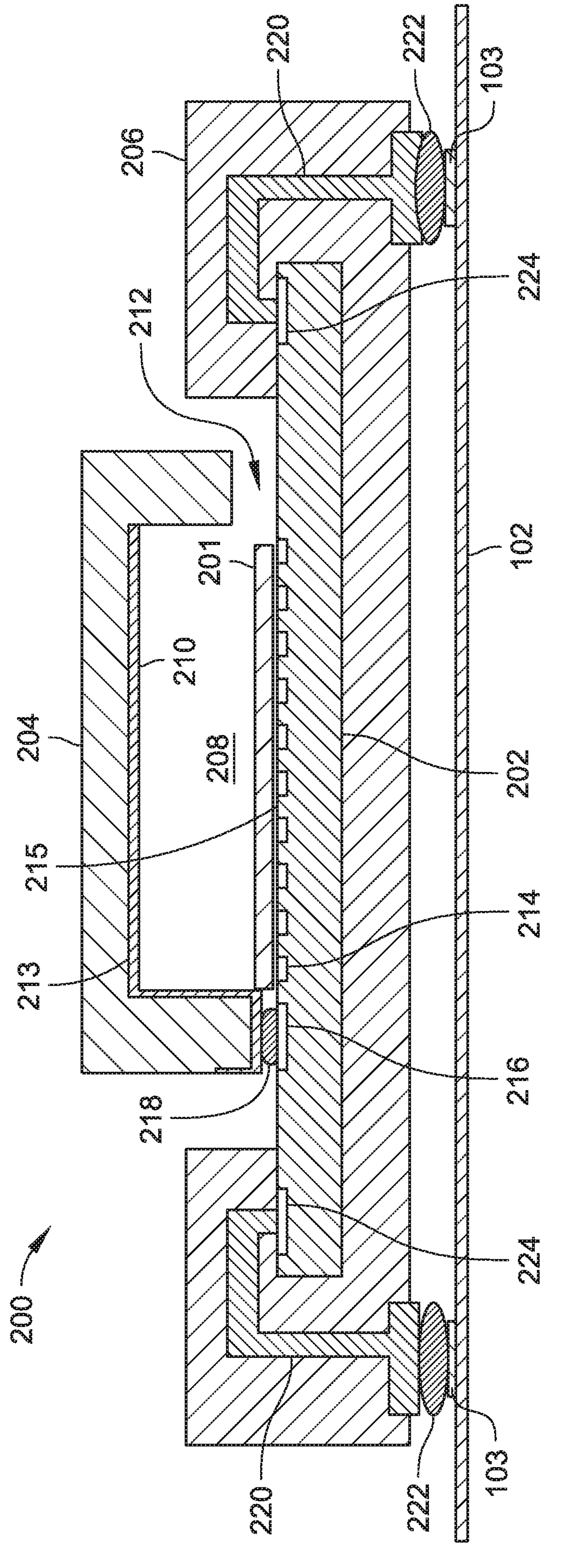
200
204
206
208
210
201
212
213
215
218
220
222
103
224
214
216
202
102

FIG. 2B

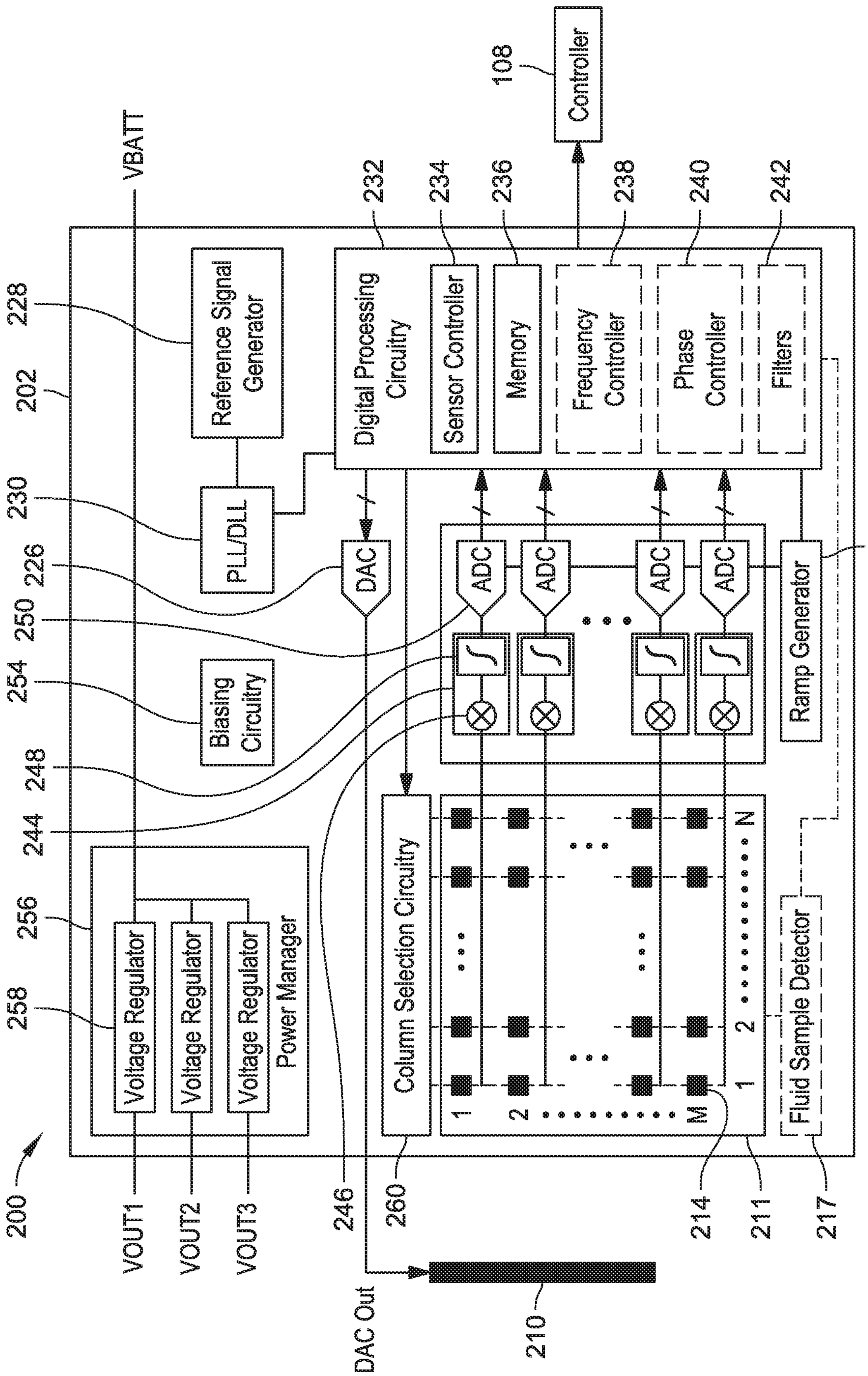
200
202
228
230
226
250
254
248
244
256
258
VBATT
Reference Signal Generator
PLL/DLL
DAC
Biasing Circuitry
Voltage Regulator
Voltage Regulator
Voltage Regulator
Power Manager
VOUT1
VOUT2
VOUT3
246
DAC Out
210
260
Column Selection Circuitry
232
234
236
238
240
242
Digital Processing Circuitry
Sensor Controller
Memory
Frequency Controller
Phase Controller
Filters
108
Controller
ADC
ADC
ADC
ADC
Ramp Generator
252
1
2
M
N
Fluid Sample Detector
214
211
217

FIG. 3

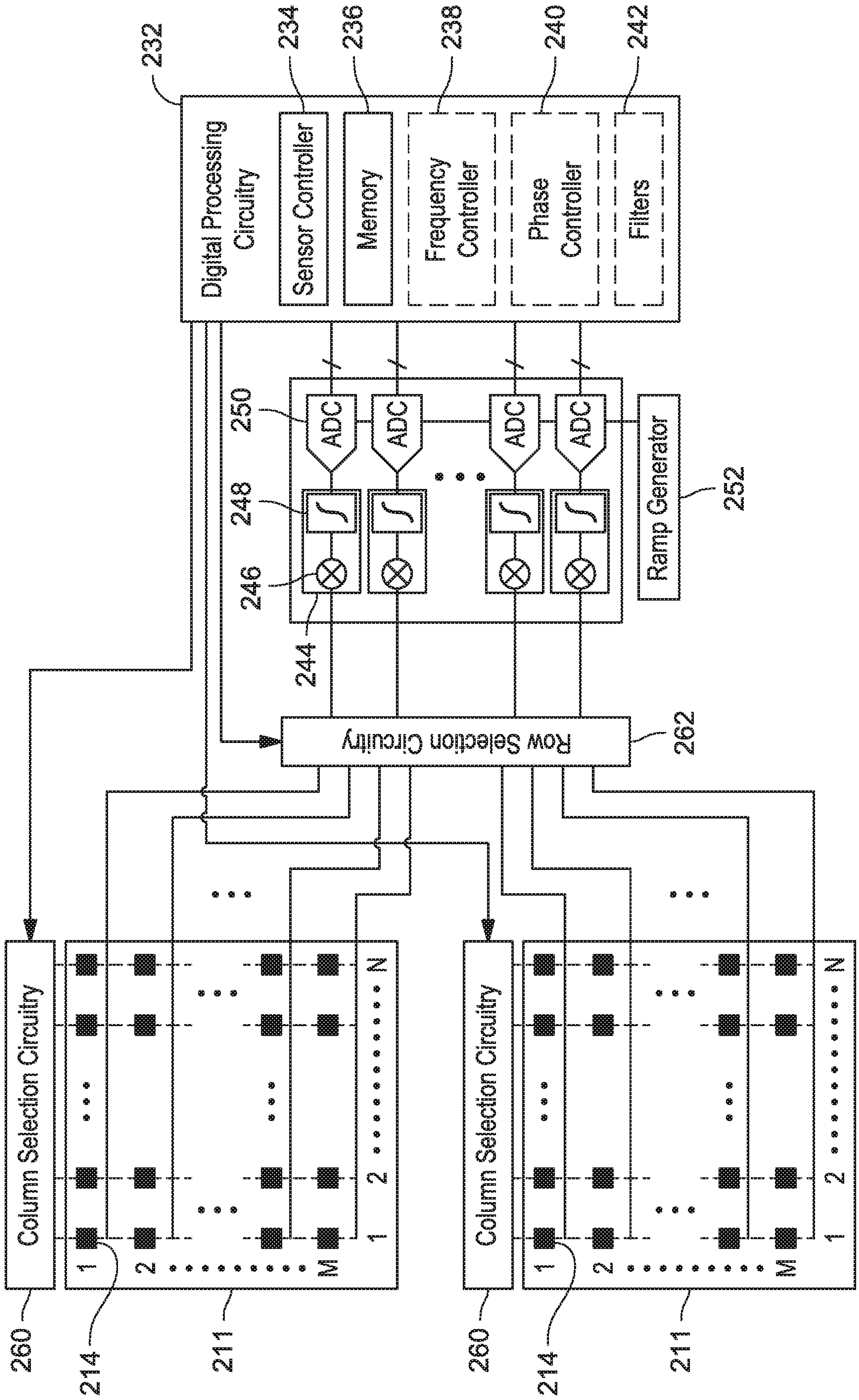
232
Digital Processing Circuitry
234
Sensor Controller
236
Memory
238
Frequency Controller
240
Phase Controller
242
Filters
250
ADC
248
246
244
Ramp Generator
252
Row Selection Circuitry
262
Column Selection Circuitry
260
214
211
1
2
M
N

FIG. 4

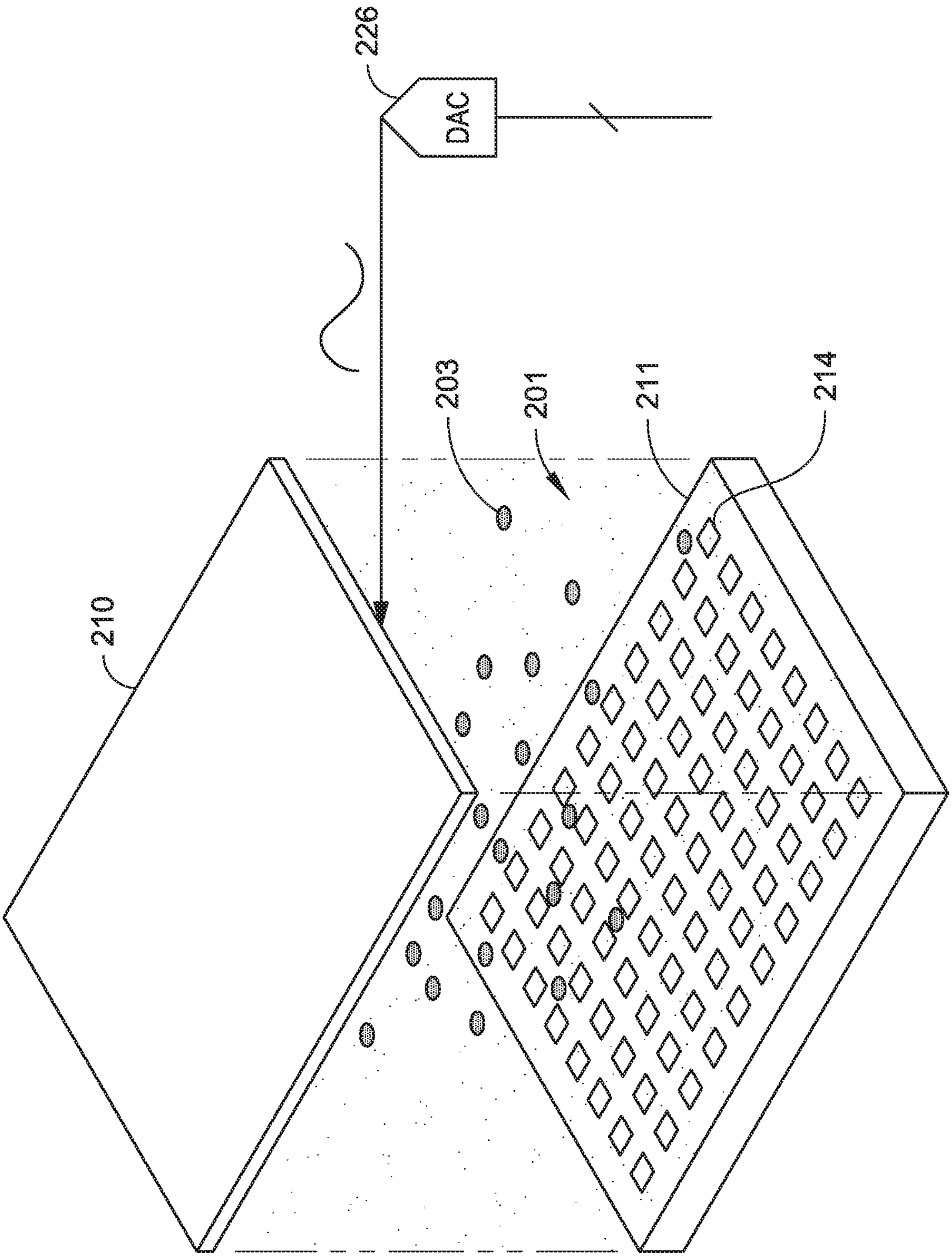

FIG. 5

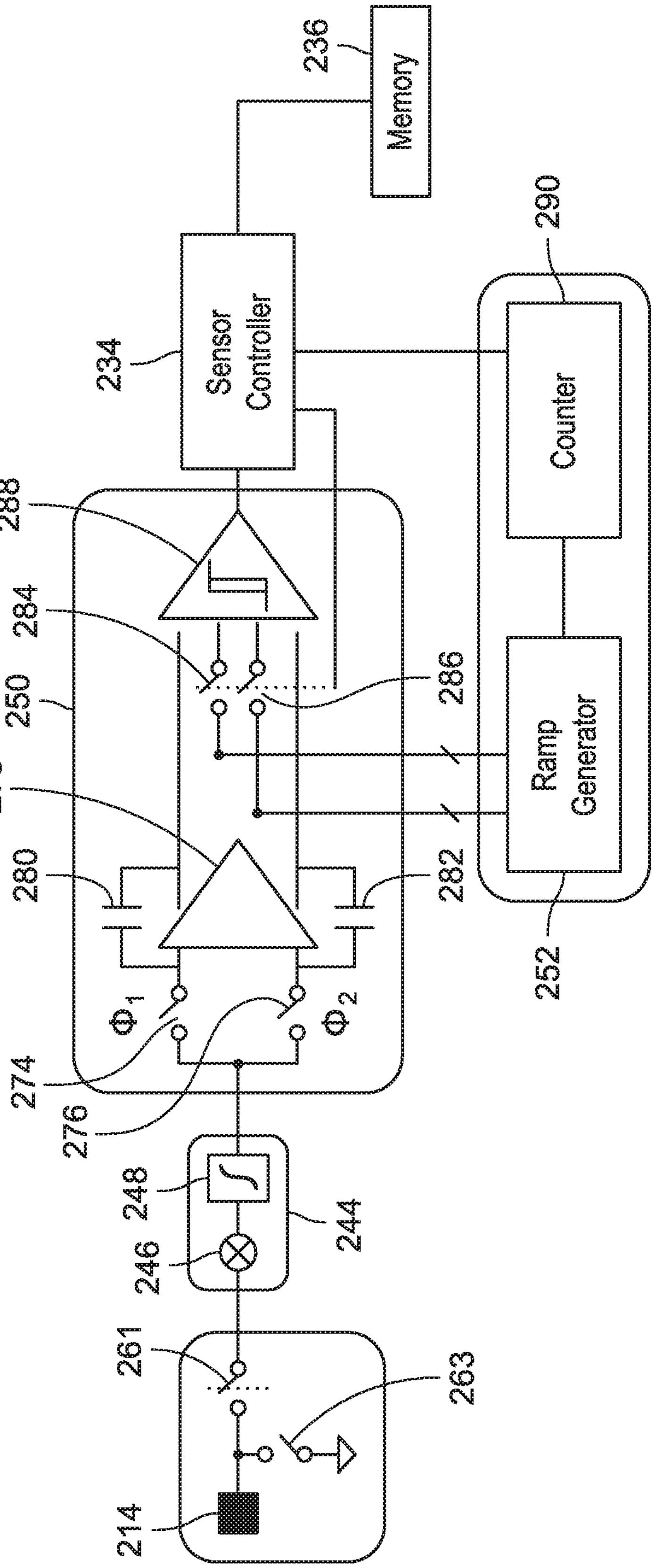
236
Memory
234
Sensor Controller
290
Counter
288
284
250
286
278
280
282
Ramp Generator
252
Φ1
Φ2
274
276
248
244
246
261
263
214

FIG. 6

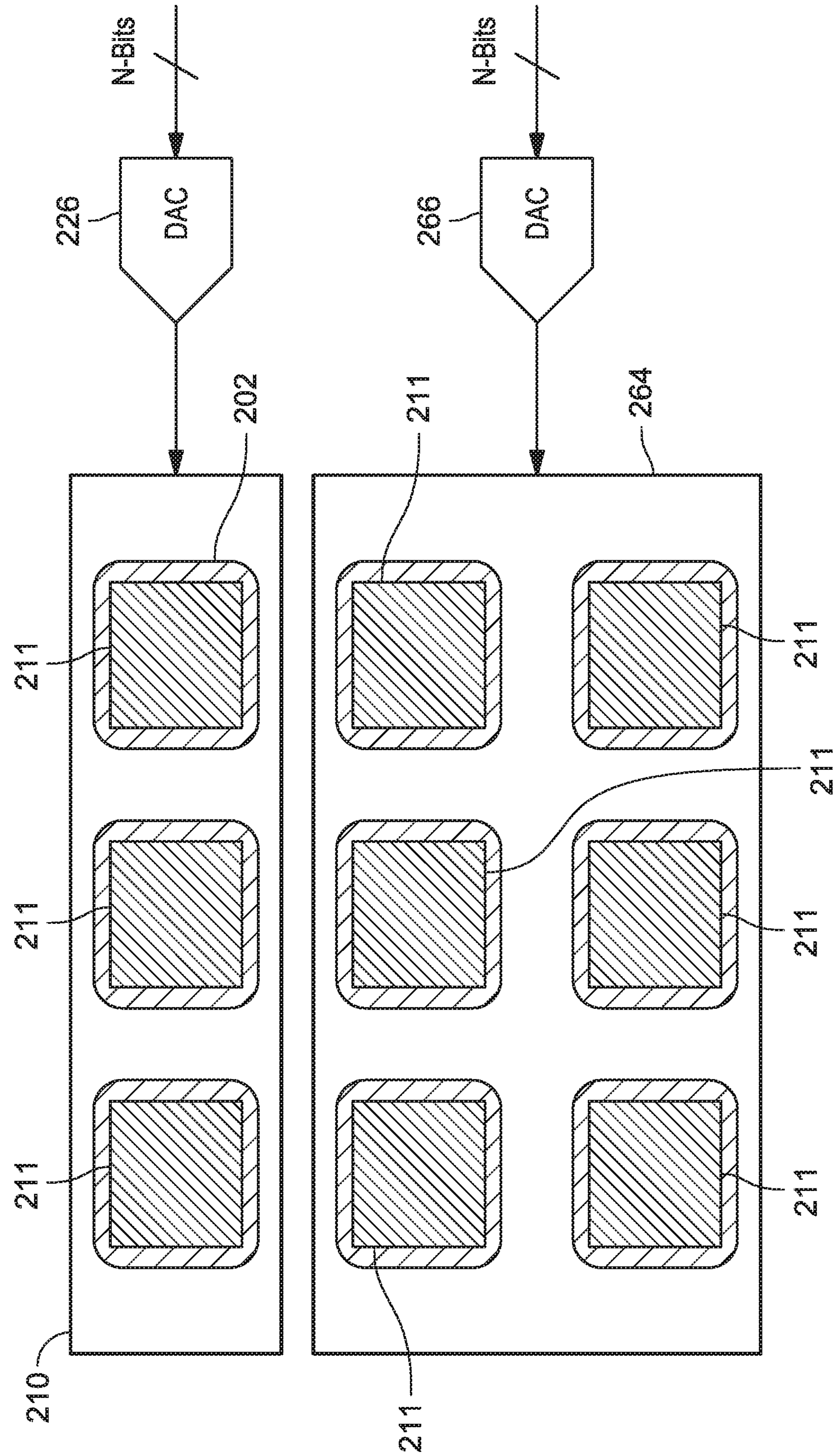
N-Bits
N-Bits
226
DAC
266
DAC
202
211
264
211
211
211
211
211
211
211
211
210
211

FIG. 7A

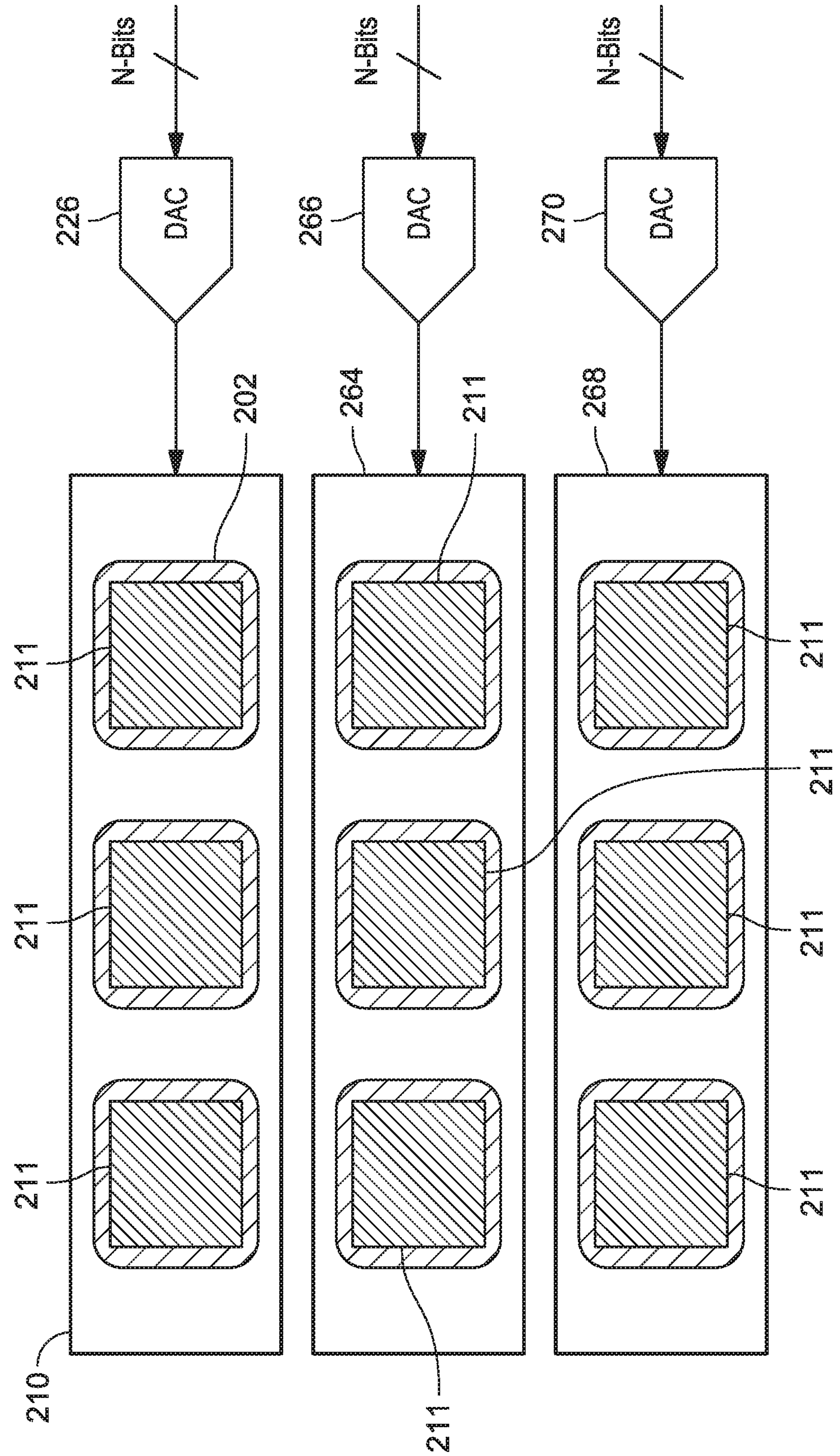

FIG. 7B

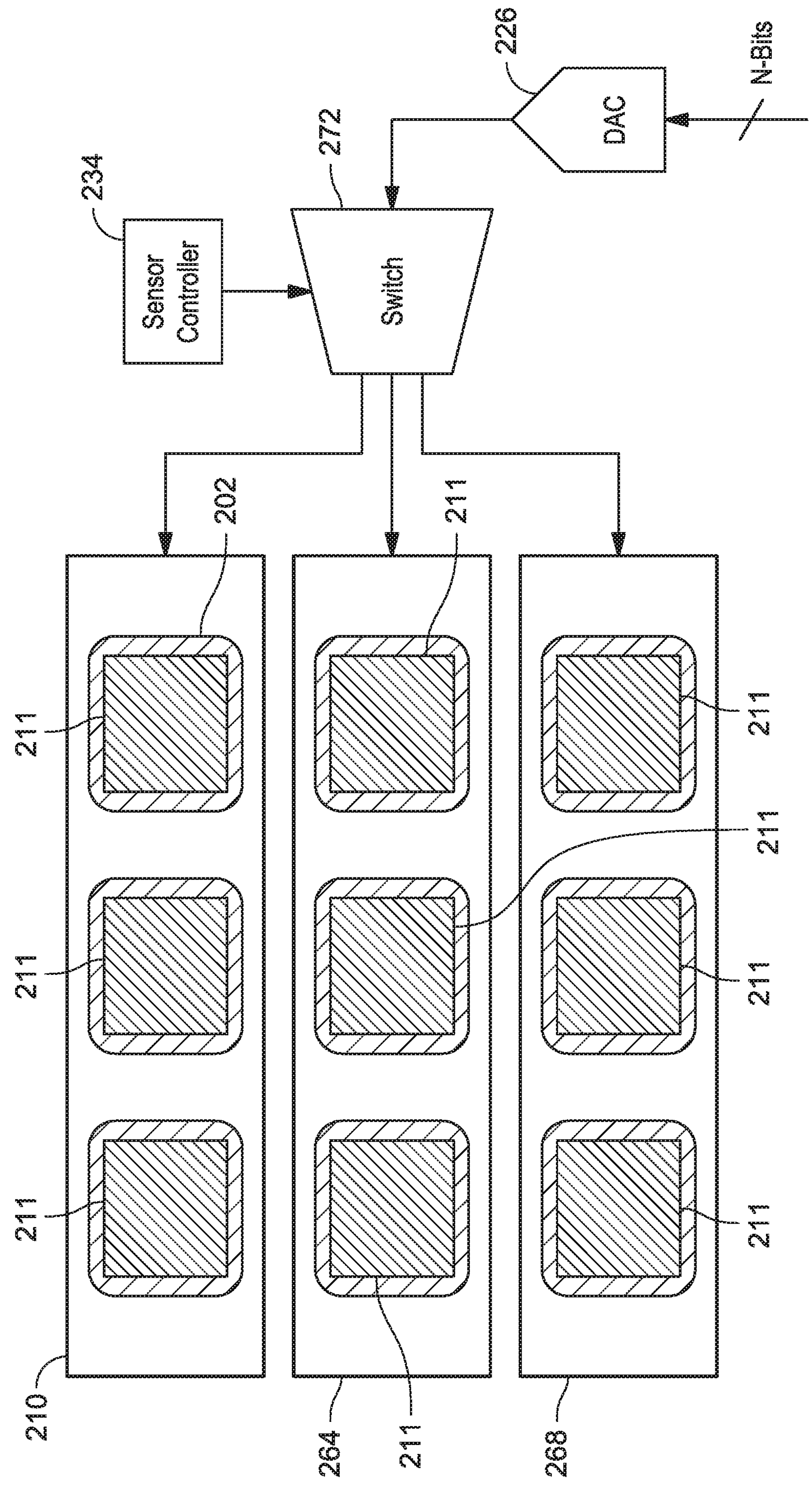
226
N-Bits
DAC
272
234
Sensor Controller
Switch
202
211
211
211
211
211
211
211
211
211
211
210
264
268

FIG. 7C

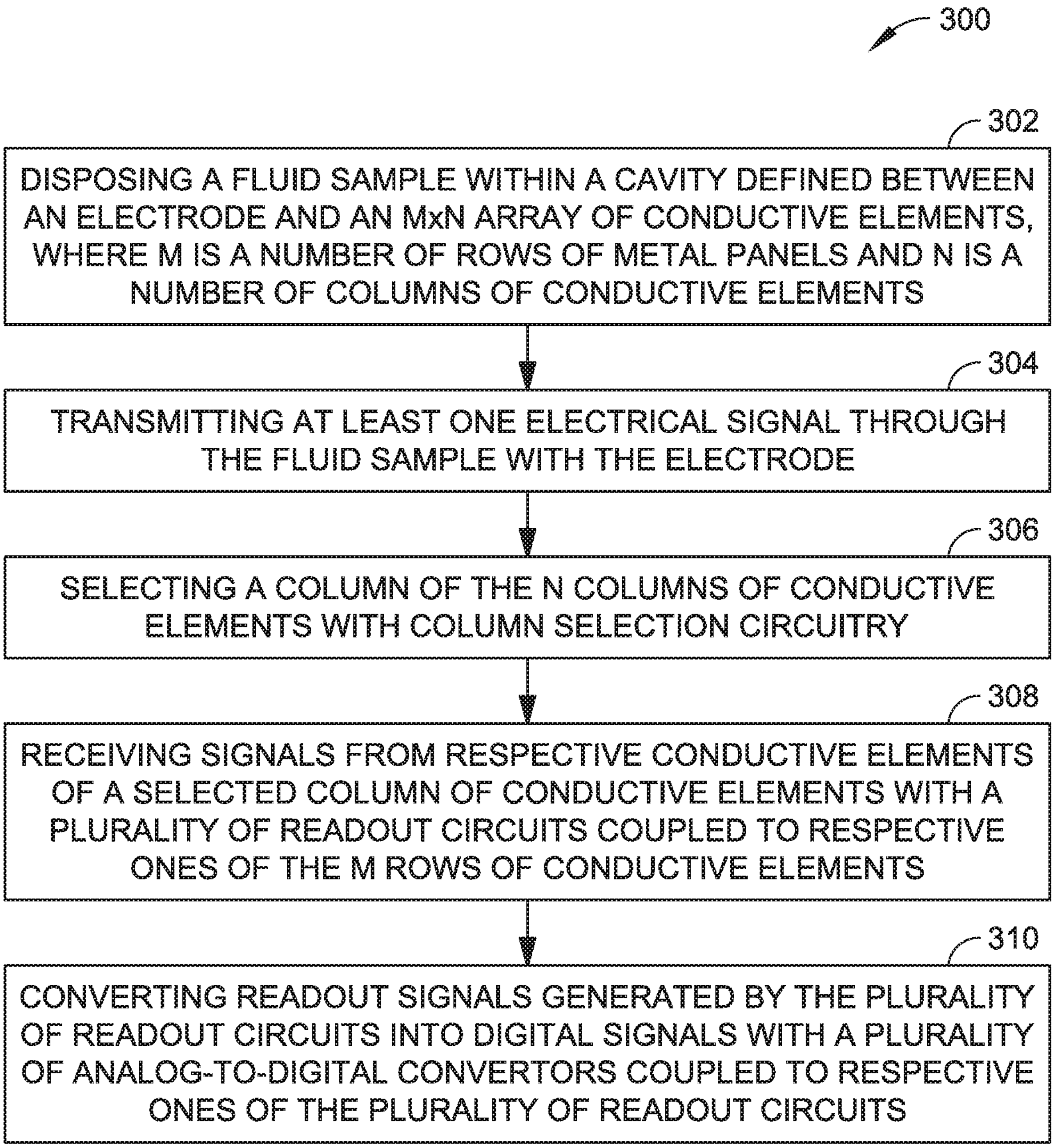
300
302
DISPOSING A FLUID SAMPLE WITHIN A CAVITY DEFINED BETWEEN AN ELECTRODE AND AN MxN ARRAY OF CONDUCTIVE ELEMENTS, WHERE M IS A NUMBER OF ROWS OF METAL PANELS AND N IS A NUMBER OF COLUMNS OF CONDUCTIVE ELEMENTS
304
TRANSMITTING AT LEAST ONE ELECTRICAL SIGNAL THROUGH THE FLUID SAMPLE WITH THE ELECTRODE
306
SELECTING A COLUMN OF THE N COLUMNS OF CONDUCTIVE ELEMENTS WITH COLUMN SELECTION CIRCUITRY
308
RECEIVING SIGNALS FROM RESPECTIVE CONDUCTIVE ELEMENTS OF A SELECTED COLUMN OF CONDUCTIVE ELEMENTS WITH A PLURALITY OF READOUT CIRCUITS COUPLED TO RESPECTIVE ONES OF THE M ROWS OF CONDUCTIVE ELEMENTS
310
CONVERTING READOUT SIGNALS GENERATED BY THE PLURALITY OF READOUT CIRCUITS INTO DIGITAL SIGNALS WITH A PLURALITY OF ANALOG-TO-DIGITAL CONVERTORS COUPLED TO RESPECTIVE ONES OF THE PLURALITY OF READOUT CIRCUITS

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/041841

A. CLASSIFICATION OF SUBJECT MATTER

G01N 27/30(2006.01)i, G01N 33/543(2006.01)i, H03M 1/12(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)
G01N 27/30; C12M 1/34; C12Q 1/68; C40B 30/02; G01N 27/02; G01N 27/12; G01N 27/406; G01N 33/00; G01N 33/53; H05K 3/42; G01N 33/543; H03M 1/12

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) & keywords: biosensor, conductive element, matrix, electrode, cavity, circuit, analog to digital converter, fluid sample

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2016-0327500 A1 (MAXIM INTEGRATED PRODUCTS, INC.) 10 November 2016 See paragraphs [0016]-[0030] and figures 1, 3-5.	1,2,8-12,16,17,20
A		3-7,13-15,18,19
Y	WO 2008-108872 A2 (BIOWARN LLC. et al.) 12 September 2008 See page 51, 52 and figures 13A.	1,2,8-12,16,17,20
A	US 2006-0115828 A1 (PALMIERI et al.) 01 June 2006 See paragraphs [0032]-[0046], [0053]-[0058] and figures 1-4, 13, 15.	1-20
A	EP 1019715 B1 (CALIFORNIA INSTITUTE OF TECHNOLOGY et al.) 26 January 2005 See paragraphs [0043]-[0047], [0110]-[0115] and figures 1-2B, 16, 17.	1-20
A	US 2016-0047774 A1 (STMICROELECTRONICS PTE LTD.) 18 February 2016 See paragraphs [0044]-[0052] and figures 7-10.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"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
28 November 2018 (28.11.2018)

Date of mailing of the international search report
28 November 2018 (28.11.2018)

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
LEE, Hun Gil
Telephone No. +82-42-481-8525

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016-0327500 A1	10/11/2016	DE 102016108413 A1	10/11/2016
		DE 102016116264 A1	02/03/2017
		US 2016-0363550 A1	15/12/2016
		US 2018-0059098 A1	01/03/2018
		US 9753028 B2	05/09/2017
WO 2008-108872 A2	12/09/2008	WO 2008-108872 A3	20/11/2008
US 2006-0115828 A1	01/06/2006	EP 1618955 A1	25/01/2006
		EP 1618955 A9	26/04/2006
		EP 1618955 B1	22/12/2010
		US 2012-0071365 A1	22/03/2012
		US 8083916 B2	27/12/2011
EP 1019715 B1	26/01/2005	AT 288079 T	15/02/2005
		AT 435422 T	15/07/2009
		AU 1998-88256 A	01/03/1999
		AU 1999-37427 A	01/11/1999
		AU 747878 B2	30/05/2002
		AU 754648 B2	21/11/2002
		CA 2310622 A1	18/02/1999
		CA 2325886 A1	21/10/1999
		CA 2325886 C	21/07/2009
		DE 69828803 T2	05/01/2006
		EA 002902 B1	31/10/2002
		EA 200000457 A1	23/04/2001
		EP 1019715 A1	19/07/2000
		EP 1070244 A2	24/01/2001
		EP 1555527 A1	20/07/2005
		EP 1555527 B1	01/07/2009
		IL 136607 A	20/03/2005
		JP 2002-511579 A	16/04/2002
		JP 4482228 B2	16/06/2010
		NZ 504675 A	19/12/2003
		US 2002-0005580 A1	17/01/2002
		US 2002-0098119 A1	25/07/2002
		US 2003-0136960 A1	24/07/2003
		US 2006-0208254 A1	21/09/2006
		US 2009-0309614 A1	17/12/2009
		US 6495892 B2	17/12/2002
		US 6627154 B1	30/09/2003
		US 6746960 B2	08/06/2004
		US 7061061 B2	13/06/2006
		US 7550310 B2	23/06/2009
		WO 99-08105 A1	18/02/1999
		WO 99-08105 A9	06/05/1999
		WO 99-53287 A2	21/10/1999
		WO 99-53287 A3	02/12/1999

International application No.
PCT/US2018/041841

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016-0047774 A1	18/02/2016	US 2018-0067074 A1	08/03/2018
		US 9851328 B2	26/12/2017