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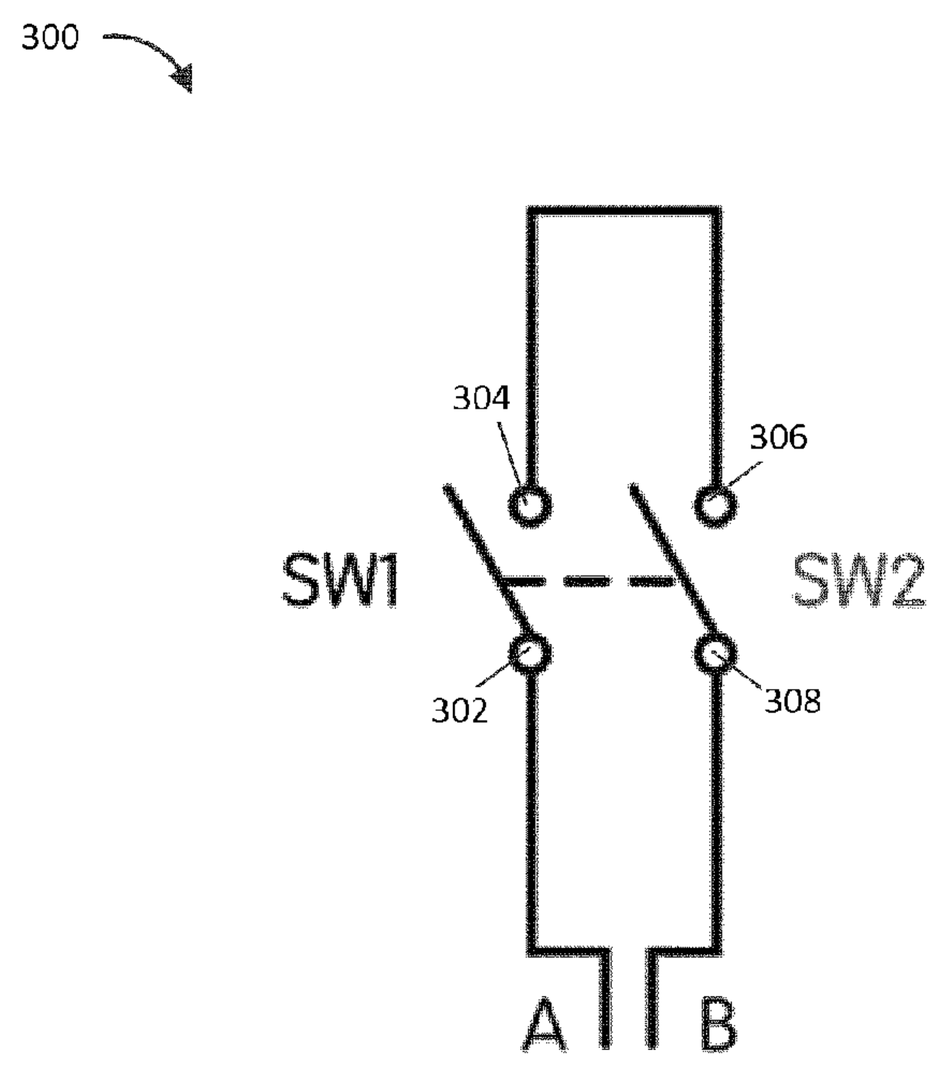

FIG. 3A

(57) Abrégé/Abstract:
Embodiments of negative pressure wound therapy systems and methods are disclosed. In one embodiment, a system includes a wound dressing, negative pressure source, switch, and control circuitry. The switch can include an actuator that toggles states of first and second pairs of contacts in response to a user input. The control circuitry can supply negative pressure with the negative pressure source when the state of the first pair of contacts is a first state and the state of the second pair of contacts is a second state, and the control circuitry can disable supply of negative pressure with the negative pressure source when the state of the first pair of contacts is not the first state or the state of the second pair of contacts is not the second state.

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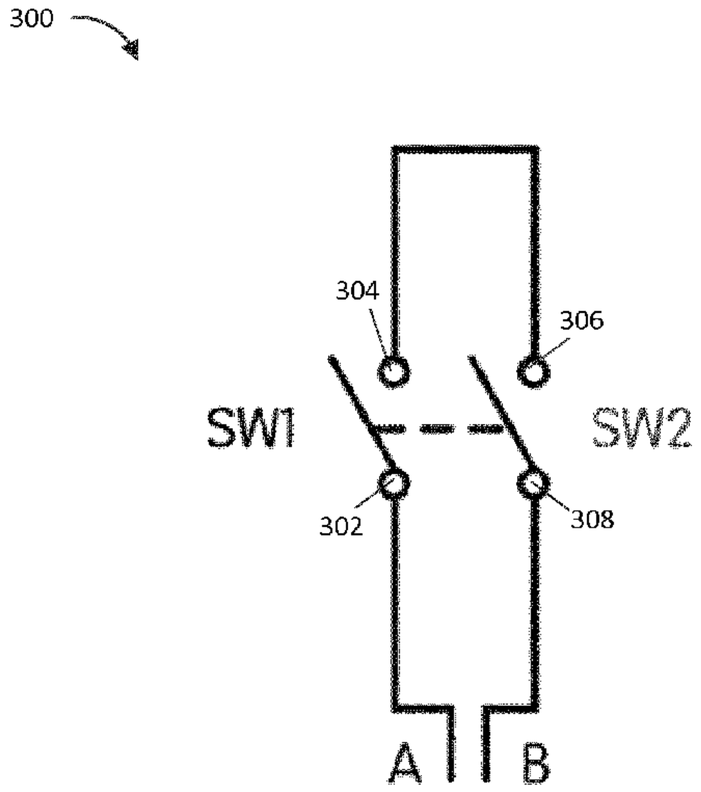

FIG. 3A

(57) Abstract: Embodiments of negative pressure wound therapy systems and methods are disclosed. In one embodiment, a system includes a wound dressing, negative pressure source, switch, and control circuitry. The switch can include an actuator that toggles states of first and second pairs of contacts in response to a user input. The control circuitry can supply negative pressure with the negative pressure source when the state of the first pair of contacts is a first state and the state of the second pair of contacts is a second state, and the control circuitry can disable supply of negative pressure with the negative pressure source when the state of the first pair of contacts is not the first state or the state of the second pair of contacts is not the second state.

[Continued on next page]

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REDUNDANT CONTROLS FOR NEGATIVE PRESSURE WOUND THERAPY SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/503,697, filed May 9, 2017; the disclosure of which is hereby incorporated by reference in its entirety.

BACKGROUND

[0002] Embodiments of the present disclosure relate to methods and apparatuses for dressing and treating a wound with negative or reduced pressure therapy or topical negative pressure (TNP) therapy. In particular, but without limitation, embodiments disclosed herein relate to negative pressure therapy devices, methods for controlling the operation of TNP systems, and methods of using TNP systems.

SUMMARY

[0003] In some embodiments, an apparatus for applying negative pressure to a wound is disclosed. The apparatus can include: a negative pressure source configured to provide negative pressure to a wound dressing via a fluid flow path; a switch including an actuator configured to toggle a state of a first pair of electrical contacts and a state of a second pair of electrical contacts in response to a user input; and control circuitry configured to: supply negative pressure with the negative pressure source in response to the first pair of electrical contacts being in an electrically connected state and the second pair of electrical contacts being in the electrically connected state, and disable supply of negative pressure with the negative pressure source in response to the first pair of electrical contacts being in an electrically disconnected state or the second pair of electrical contacts being in the electrically disconnected state.

[0004] The apparatus of the preceding paragraph can include one or more of the following features: The control circuitry is configured to disable supply of negative pressure with the negative pressure source in response to the first pair of electrical contacts being in the electrically connected state and the second pair of electrical contacts being in the electrically disconnected state. The actuator is configured to simultaneously toggle the state of the first pair of electrical contacts and the state of the second pair of electrical contacts in response to the user input. The control circuitry is configured to supply negative pressure with the negative pressure source in response to no user inputs other than the user input to the switch. When the actuator is broken and no longer able to toggle the state of the first pair of electrical contacts or the state of the second pair of electrical contacts, the control circuitry is further configured to no longer supply negative pressure with the negative pressure source. The control circuitry is further configured to detect a switch fault in response to the state of the first pair of electrical contacts not toggling within a threshold period of time subsequent to toggling of the state of the second pair of electrical contacts. The threshold period of time is 0.5 seconds, 1 second, 2 seconds, 3 second, or 5 seconds. The control circuitry is further configured to output a switch fault indication in response to detection of the switch fault. The first pair of electrical contacts includes a plurality of first traces and the second pair of electrical contacts includes a plurality of second traces, and the actuator is configured to short the plurality of first traces to one another and short the plurality of second traces to one another in response to the user input. The negative pressure source is disposed on or within the wound dressing. The control circuitry is configured to disable supply of negative pressure with the negative pressure source by deactivation of operation of the negative pressure source, opening of a vent positioned in the fluid flow path, or closing of a valve positioned in the fluid flow path. The switch is configured to receive the user input as a depression of the switch.

[0005] In some embodiments, a method for controlling application of negative pressure to a wound is disclosed. The method includes: using an actuator

of a switch, toggling a state of a first pair of contacts and a state of a second pair of contacts in response to receipt of a user input to the switch; supplying negative pressure with a negative pressure source to a wound dressing via a fluid flow path in response to the state of the first pair of contacts being a first state and the state of the second pair of contacts being a second state; and disabling supply of negative pressure with the negative pressure source in response to the state of the first pair of contacts not being the first state or the state of the second pair of contacts not being the second state, wherein the state of the first pair of contacts is the first state and the state of the second pair of contacts is the second state at a first time, and the state of the first pair of contacts is not the first state and the state of the second pair of contacts is not the second state at a second time.

[0006] The method of the preceding paragraph can include one or more of the following features: The first and second states correspond to forming an electrical connection. At a third time, the state of the first pair of contacts is the first state and the state of the second pair of contacts is not the second state. The toggling includes simultaneously toggling the state of the first pair of contacts and the state of the second pair of contacts in response to receipt of the user input to the switch. The method further includes detecting a switch fault in response to the state of the first pair of contacts not toggling within a threshold period of time subsequent to toggling of the state of the second pair of contacts. The threshold period of time is between 0.5 seconds and 5 seconds. The method further includes outputting a switch fault indication for presentation to a user in response to the detecting. The disabling includes disabling supply of negative pressure with the negative pressure source by deactivation of operation of the negative pressure source, opening of a vent positioned in the fluid flow path, or closing of a valve positioned in the fluid flow path.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Features and advantages of the present disclosure will be apparent from the following detailed description, taken in conjunction with the accompanying drawings of which:

[0008] FIG. 1 illustrates a negative pressure therapy system according to some embodiments.

[0009] FIGS. 2A and 2B respectively illustrate a side view and top view of a negative pressure therapy system, such as the negative pressure therapy system of FIG. 1, according to some embodiments.

[0010] FIG. 3A illustrates a circuit schematic for a switch of a negative pressure therapy system, such as the negative pressure therapy system of FIG. 1, according to some embodiments.

[0011] FIG. 3B is a logical truth table for the circuit schematic of FIG. 3A according to some embodiments.

[0012] FIGS. 4A, 4B, 5A, 5B, 6A, and 6B illustrate implementations of the circuit schematic of FIG. 3A according to some embodiments.

[0013] FIG. 7 illustrates a therapy control process usable to control delivery of negative pressure therapy in a negative pressure therapy system, such as the negative pressure therapy system of FIG. 1, according to some embodiments.

[0014] FIG. 8 illustrates a switch fault detection process usable to detect a switch fault in a negative pressure therapy system, such as the negative pressure therapy system of FIG. 1, according to some embodiments.

DETAILED DESCRIPTION

[0015] The present disclosure relates to methods and apparatuses for dressing and treating a wound with reduced pressure therapy or topical negative pressure (TNP) therapy. In particular, but without limitation, embodiments of this disclosure relate to negative pressure therapy apparatuses, methods for controlling the operation of TNP systems, and methods of using TNP systems. The methods and apparatuses can incorporate or implement any combination of the features

described below. In certain embodiments, the features of this disclosure can advantageously increase the safety of a patient when using a TNP apparatus.

[0016] Many different types of wound dressings are known for aiding in the healing process of a human or animal. These different types of wound dressings include many different types of materials and layers, for example, gauze, pads, foam pads or multi-layer wound dressings. TNP therapy, sometimes referred to as vacuum assisted closure, negative pressure wound therapy, or reduced pressure wound therapy, can be a beneficial mechanism for improving the healing rate of a wound. Such therapy is applicable to a broad range of wounds such as incisional wounds, open wounds and abdominal wounds or the like.

[0017] TNP therapy can assist in the closure and healing of wounds by reducing tissue oedema, encouraging blood flow, stimulating the formation of granulation tissue, removing excess exudates, and reducing bacterial load and thus, infection to the wound. Furthermore, TNP therapy can permit less outside disturbance of the wound and promote more rapid healing.

[0018] As is used herein, reduced or negative pressure levels, such as –X mmHg, represent pressure levels that are below atmospheric pressure, which typically corresponds to 760 mmHg (or 1 atm, 29.93 inHg, 101.325 kPa, 14.696 psi, etc.). Accordingly, a negative pressure value of –X mmHg reflects pressure that is X mmHg below atmospheric pressure, such as a pressure of (760–X) mmHg. In addition, negative pressure that is “less” or “smaller” than –X mmHg corresponds to pressure that is closer to atmospheric pressure (e.g., –40 mmHg is less than –60 mmHg). Negative pressure that is “more” or “greater” than –X mmHg corresponds to pressure that is further from atmospheric pressure (e.g., –80 mmHg is more than –60 mmHg).

Overview

[0019] The user interfaces of some TNP apparatuses may have a limited elements through which a user can provide user input. In some instances, particular user interfaces may include just a single element usable by the user to

stop and start operation of the TNP apparatus, such as the delivery of negative pressure, and the user may not be able to replace or interchange the functionality of the single element with that of another element. These particular user interfaces can desirably be easier to construct and operate than more complicated user interfaces having numerous elements. However, the particular user interfaces may present a problem if the single element experiences a fault (for example, a failure) and is no longer able to function as expected. The user of the particular user interfaces may, for example, undesirably be unable to pause or stop delivery of negative pressure if negative pressure is being provided by the TNP apparatus.

[0020] The situation of a user being unable to stop delivery of negative pressure can additionally introduce risks to the healing of a wound of a patient or to the patient's health. If the patient experiences discomfort from the wound dressing during delivery of negative pressure and the single element fails such that it is no longer able to function to receive user input, the patient may be forced to either continue application of negative pressure therapy despite the dangers or remove the wound dressing, cut or sever one of the tubes or lumens (which may not be possible when a source of negative pressure is integrated in a wound dressing), break the TNP apparatus (for example, by pulling out electronics if possible), remove the power source (if accessible), or the like to terminate delivery of negative pressure. These actions (for example, removal of the wound dressing) can damage the wound of the patient and hinder any healing trajectory that was already progressed, as well as expose the wound to external contaminants due to a loss of protection from the wound dressing.

[0021] To help prevent the situation of the user being unable to stop delivery of negative pressure when it is necessary to do so, a TNP apparatus with the single element usable by the user to stop and start delivery of negative pressure can include redundant activation or deactivation controls or mechanisms within the single element. In one example, the single element can be a switch that includes an actuator configured to toggle a state of a first pair of contacts and a state of a second pair of contacts. If the state of either or both of the first or second pair of

contacts is toggled during delivery of negative pressure therapy, the TNP apparatus is caused to disable delivery of negative pressure therapy. Accordingly, in the event that the actuator may be broken and only able to toggle the state of one of the first and second pair of contacts, the actuator may nonetheless be usable to stop delivery of negative pressure with the TNP apparatus.

Reduced Pressure Therapy Systems and Methods

[0022] FIG. 1 illustrates a negative pressure therapy system 100 that includes a TNP apparatus 11 and a wound 14. The TNP apparatus 11 can be used to treat the wound 14. The TNP apparatus 11 can include control circuitry 12A, memory 12B, a negative pressure source 12C, a user interface 12D, a power source 12E, a first pressure sensor 12F, a second pressure sensor 12G (which may be optional), and a skin detector 12H that are configured to electrically communicate with one another. In addition, the TNP apparatus 11 can include a wound dressing 13. The power source 12E can provide power to one or more components of the TNP apparatus 11.

[0023] One or more of the control circuitry 12A, memory device 12B, negative pressure source 12C, user interface 12D, power source 12E, first pressure sensor 12F, second pressure sensor 12G, and skin detector 12H can be integral with, incorporated as part of, attached to, or disposed in the wound dressing 13. The TNP apparatus 11 can accordingly be considered to have its control electronics and pump on-board the wound dressing 13 rather than separate from the wound dressing 13.

[0024] The control circuitry 12A can include one or more controllers, activation circuits, boost converters, current limiters, feedback conditioning circuits, and H-bridge inverters. The one or more controllers can control the operations of one or more other components of the TNP apparatus 11 according at least to instructions stored in the memory device 12B. The one or more controllers can, for instance, control operations of the negative pressure source 12C via a signal input (for example, a pulse width modulation of the signal) to the one or more H-bridge

inverters, which in turn drive power from the power source 12E to the negative pressure source 12C.

[0025] The negative pressure source 12C can include a pump, such as, without limitation, a rotary diaphragm pump or other diaphragm pump, a piezoelectric pump, a peristaltic pump, a piston pump, a rotary vane pump, a liquid ring pump, a scroll pump, a pump operated by a piezoelectric transducer, a voice coil pump, or any other suitable pump or micropump or any combinations of the foregoing.

[0026] The user interface 12D can include one or more elements that receive user inputs or provide user outputs to a patient or caregiver. The one or more elements that receive user inputs can include buttons, switches, dials, touch screens, or the like, and the one or more elements that provide user outputs can include activation of a light emitting diode (LED) or one or more pixels of the display or activation of a speaker or the like. In one example, the user interface 12D can include a switch to receive a first user input (for instance, a negative pressure activation or deactivation input) and two LEDs to indicate an operating status (for example, functioning normally, under fault condition, or awaiting user input) of the TNP apparatus 11.

[0027] The first pressure sensor 12F can be used to monitor pressure underneath the wound dressing 13, such as pressure in a fluid flow path connecting the negative pressure source 12C and the wound 14, pressure at the wound 14, or pressure in the negative pressure source 12C. The second pressure sensor 12G can be used to monitor pressure external to the wound dressing 13. The pressure external to the wound dressing can be atmospheric pressure; however, the atmospheric pressure can vary depending on, for instance, an altitude of use or pressurized environment in which the TNP apparatus 11 may be used.

[0028] The control circuitry 12A can control the supply of negative pressure by the negative pressure source 12C according at least to a comparison between the pressure monitored by the first pressure sensor 12F and the pressure

monitored by the second pressure sensor 12G. The control circuitry 12A can include a controller, such as a microcontroller or microprocessor.

[0029] The skin detector 12H can be used to determine if the wound dressing 13 has been placed over the wound 14. The skin detector 12H can, for example, detect skin of a patient. The detection by the skin detector 12H can confirm whether the wound dressing 13 is coupled to skin of the patient next to the wound 14. When skin is detected, this may indicate that activation of the TNP apparatus 11 is intentional rather than unintentional and can thus be used to prevent unintentional activation of the TNP apparatus 11 or an end-of-life timer of the TNP apparatus 11, such as during transportation or manufacture of the TNP apparatus 11. In one example, if the skin detector 12H indicates to the control circuitry 12A that skin is detected, the control circuitry 12A can activate the negative pressure source 12C to supply negative pressure in response to receiving an activation input via the user interface 12D. If the skin detector 12H, on the other hand, indicates to the control circuitry 12A that skin is not detected, the control circuitry 12A may not activate the negative pressure source 12C to supply negative pressure in response to receiving an activation input via the user interface 12D. The skin detector 12H can include one or more of a capacitive sensor, an impedance sensor, an optical sensor, a piezoresistive sensor, a piezoelectric sensor, an elastoresistive sensor, and an electrochemical sensor.

[0030] The wound dressing 13 can include a wound contact layer, a spacer layer, and an absorbent layer. The wound contact layer can be in contact with the wound 14. The wound contact layer can include an adhesive on the patient facing side for securing the dressing to the skin surrounding the wound 14 or on the top side for securing the wound contact layer to a cover layer or other layer of the wound dressing 13. In operation, the wound contact layer can provide unidirectional flow so as to facilitate removal of exudate from the wound while blocking or substantially preventing exudate from returning to the wound 14. The spacer layer can assist in distributing negative pressure over the wound site and facilitating transport of wound exudate and fluids into the wound dressing 13.

Further, the absorbent layer can absorb and retain exudate aspirated from the wound 14.

[0031] The control circuitry 12A can, in some instances, prevent supply of negative pressure with the negative pressure source 12C. For example, the control circuitry 12A can prevent supply of negative pressure by deactivating operation of the negative pressure source, opening a vent positioned in the fluid flow path, and closing a valve positioned in the fluid flow path.

[0032] The supply of negative pressure with the negative pressure source 12C can, in some instances, be disabled. For example, supply of negative pressure can be disabled by deactivating operation of the negative pressure source 12C or the control circuitry 12A, opening a vent positioned in the fluid flow path, and closing a valve positioned in the fluid flow path. In some implementations, deactivating operation of the negative pressure source 12C or the control circuitry 12A can be performed by disconnection of power to the negative pressure source 12C or the control circuitry 12A or withdrawal of an enable signal provided to the negative pressure source 12C or the control circuitry 12A.

[0033] The control circuitry 12A can monitor a duty cycle of the negative pressure source 12C. As is used herein, the “duty cycle” can reflect the amount of time the negative pressure source 12C is active or running over a period of time. In other words, the duty cycle can reflect time that the negative pressure source 12C is in an active state as a fraction of total time under consideration. Duty cycle measurements can reflect a level of activity of the negative pressure source 12C. For example, the duty cycle can indicate that the negative pressure source 12C is operating normally, working hard, working extremely hard, etc. Moreover, the duty cycle measurements, such as periodic duty cycle measurements, can reflect various operating conditions, such as presence or severity of leaks, rate of flow of fluid (for instance, air, liquid, or solid exudate, etc.) aspirated from a wound, or the like. Based on the duty cycle measurements, such as by comparing the measured duty cycle with a set of thresholds (for instance, determined in calibration), the controller can execute or be programmed to execute algorithms or logic that control the

operation of the system. For example, duty cycle measurements can indicate presence of a high leak, and the control circuitry 12A can be programmed to indicate this condition to a user (for instance, patient, caregiver, or physician) or temporarily suspend or pause operation of the source of negative pressure in order to conserve power.

[0034] When the TNP apparatus 11 may be used to treat the wound 14, the wound dressing 13 can create a substantially sealed or closed space around the wound 13 and under the wound dressing 13, and the first pressure sensor 12F can periodically or continuously measure or monitor a level of pressure in this space. The control circuitry 12A can control the level of pressure in the space between a first negative pressure set point limit and at least a second negative pressure set point limit. In some instances, the first set point limit can be approximately –70 mmHg, or from approximately –60 mmHg or less to approximately –80 mmHg or more. In some instances, the second set point limit can be approximately –90 mmHg, or from approximately –80 mmHg or less to approximately –100 mmHg or more.

[0035] FIG. 2A illustrates a side view of a negative pressure therapy system 200, and FIG. 2B illustrates a top view of the negative pressure therapy system 200. The negative pressure therapy system 200 can be an example implementation of the negative pressure therapy system 100.

[0036] In the negative pressure therapy system 200, the wound dressing 13 of the TNP apparatus 11 is shown as attached to the wound 14. Arrows depict the flow of air through the wound dressing 13 and wound exudate from the wound 14. The TNP apparatus 11 can include an air exhaust 26 and a component area 25, such as a components housing or storage area for components of the TNP apparatus 11 like one or more of the control circuitry 12A, memory device 12B, negative pressure source 12C, user interface 12D, power source 12E, first pressure sensor 12F, second pressure sensor 12G, and skin detector 12H.

[0037] The user interface 12D of the negative pressure therapy system 200 can include a switch 21, a first indicator 23 (such as a first LED), and a second

indicator 24 (such as a second LED). The switch 21 can receive a negative pressure activation or deactivation user input (for example, such as receiving the activation or deactivation user input in response to depression of the switch 21). The first indicator 23 and the second indicator 24 can indicate an operating status like functioning normally, under fault condition, or awaiting user input. In some implementations, the switch 21 can couple to a power supply connection of the negative pressure source 12C or the control circuitry 12A (such as a controller of the control circuitry 12A) or an enable signal of the negative pressure source 12C or the control circuitry 12A to activate or deactivate supply of negative pressure or disable supply of negative pressure. Moreover, the control circuitry 12A can monitor the user interface 12D, such as the switch 21, the first indicator 23, or the second indicator 24, to detect issues like a fault and, responsive to the fault detection, output a fault indication via the user interface 12D or activate or deactivate supply of negative pressure or disable supply of negative pressure. In certain embodiments, the control circuitry 12A may supply negative pressure with the negative pressure source 12C in response to no user inputs other a user input to the switch 21.

[0038] Component parts of the wound dressing 13 of the negative pressure therapy system 200 are illustrated to include an airlock layer 27, an absorbing layer 28, and a contact layer 29. The airlock layer 27 can enable air flow. The absorbing layer 28 can absorb wound exudate. The contact layer 29 can be soft and include silicon and be used to couple the TNP apparatus 11 to the patient.

[0039] FIG. 3A illustrates a circuit schematic 300 for a switch like the switch 21, according to some embodiments. The switch can be a double pole, single throw switch and include an actuator that toggles states of multiple sets of contacts (for example, two, three, four, or more sets of contacts) in response to a user input, such as a depression of the switch. The actuator can simultaneously or in a staggered manner toggle the states of the multiple sets of contacts. As illustrated in FIG. 3A, the multiple sets of contacts include a first pair of contacts including contacts 302 and 304 (collectively with a first contact pad forming a first

switch, which can be referred to as SW1) and a second pair of contacts including contacts 306 and 308 (collectively with a first contact pad forming a second switch, which can be referred to as SW2). SW1 and SW2 can act as redundant switches. Although the schematic 300 illustrates two pairs of contacts, any of the switches described herein can include more than two pairs of contacts.

[0040] The contacts 302 and 304 are shown as open, and the contacts 306 and 308 are shown as open. The contacts 302 and 304 may be open because a contact pad of SW1 is not electrically connecting or shorting the contacts 302 and 304 together. When the contacts 302 and 304 are open, SW1 may also be considered to be open. Similarly, the contacts 306 and 308 may be open because a contact pad of SW2 is not electrically connecting or shorting the contacts 306 and 308 together. When the contacts 306 and 308 are open, SW2 may also be considered to be open.

[0041] The contacts 302 and 304 may be closed when the contact pad of SW1 electrically connects or shorts the contacts 302 and 304 together. When the contacts 302 and 304 are closed, SW1 may also be considered to be closed. The contacts 306 and 308 may be closed when the contact pad of SW2 electrically connects or shorts the contacts 306 and 308 together. When the contacts 306 and 308 are closed, SW2 may also be considered to be closed.

[0042] The switch can further include an input A and an output B. For example, the input A can be electrically coupled to either power (for example, the power source 12E) or ground of the TNP apparatus 11, and the output B can be electrically coupled to control operations of the TNP apparatus (or vice versa). When the switch is closed, an electrical connection to power or ground is formed thereby enabling the TNP apparatus 11 to operate or function to provide therapy. For instance, when the switch is closed, a signal may be provided or generated to the control circuitry 12A to activate the negative pressure source 12C or enable supply of power by the power source 12E to other components of the TNP apparatus 11.

[0043] In some implementations, when the switch is functioning properly, the states of the multiple sets of contacts may toggle only in response to the user input to switch. If switch is broken, however, and the actuator is no longer able to toggle one or more of the multiple sets of contacts, the switch may no longer toggle states of all of the multiple sets of contacts in response to the user input. Accordingly, if the actuator is no longer able to toggle one or more of the multiple sets of contacts, the control circuitry 12A may no longer be configured to supply negative pressure with the negative pressure source 12C.

[0044] FIG. 3B is a logical truth table 310 for the circuit schematic 300. As can be understood from the logical truth table 310, the electrical path from the input A to the output B can be considered to be formed or “on” if both SW1 and SW2 are closed, and the electrical path from the input A to the output B can be considered to be not formed or “off” if at least one of SW1 or SW2 is open.

[0045] In other implementations, a switch can be designed differently from the circuit schematic 300 and be made to function according to an alternative logical truth table different from the logical truth table 310. The alternative logical truth table can include multiple possible configurations and each configuration cause the electrical path from the input A to the output B to be either on or off. One or more of the multiple possible configurations of the alternative logical truth table can cause the electrical path from the input A to the output B to be on, and the one or more other of the multiple configurations of the alternative logical truth table can cause the electrical path from the input A to the output B being off. In certain embodiments, a total number of the multiple configurations which cause the electrical path from the input A to the output B to be on can be less than a total number of the multiple configurations which cause the electrical path from the input A to the output B to be off. This may advantageously result in a bias toward causing the electrical path from the input A to the output B to be off unless the switch is properly functioning. As a result, the switch may intelligently cause the negative pressure source 12C to operate when the switch is properly functioning but not when the switch is not properly functioning.

[0046] FIGS. 4A and 4B illustrate an implementation of the circuit schematic 300, according to some embodiments. Contacts 402, 404, 406, 408 can respectively be implementations of the contacts 302, 304, 306, 308. The SW1 contact pad 410 can be an implementation of the contact pad of SW1 of FIG. 3A, and the SW2 contact pad 412 can be an implementation of the contact pad of SW2 of FIG. 3A.

[0047] As illustrated, at least some of the contacts 402, 404, 406, 408 can each include a primary trace and multiple secondary traces extending from the primary trace. The multiple secondary traces can each extend perpendicular to the primary trace from which it extends. The primary traces can be curved as shown with respect to the contacts 402 and 408 or straight as shown with respect to the contacts 404 and 406. The primary and secondary traces of the contacts 402, 404, 406, 408 can be printed, for example, on a circuit board.

[0048] In FIG. 4A, the contacts 402 and 404 are shown as open, and the contacts 406 and 408 are shown as open. In FIG. 4B, the contacts 402 and 404 are shown as closed due to contact of the SW1 contact pad 410 with the contacts 402 and 404, and the contacts 406 and 408 are shown as closed due to contact of the SW2 contact pad 412 with the contacts 406 and 408. An electrical path is formed from the input A to the output B, for example, through the contact 402, contact pad 410, contact 404, contact 406, contact pad 412, and contact 408. The SW1 contact pad 410 and the SW2 contact pad 412 can be conductive plates. Contact pads 410 and 412 may be brought into contact with the contacts 402, 404, 406, 408 by an actuator (or actuators), which can be mechanically, pneumatically, electrically, or the like actuated by a user input, such as a depression of the switch.

[0049] FIGS. 5A and 5B illustrate another implementation of the circuit schematic 300, according to some embodiments. Contacts 502, 504, 506, 508 can respectively be implementations of the contacts 302, 304, 306, 308. The SW1 contact pad 510 can be an implementation of the contact pad of SW1 of FIG. 3A, and the SW2 contact pad 512 can be an implementation of the contact pad of SW2 of FIG. 3A.

[0050] As illustrated, at least some of the contacts 502, 504, 506, 508 can each include a primary trace and multiple secondary traces extending from the primary trace. The multiple secondary traces can each extend perpendicular to the primary trace from which it extends. The primary traces can be straight as shown. The primary and secondary traces of the contacts 502, 504, 506, 508 can be printed, for example, on a circuit board.

[0051] In FIG. 5A, the contacts 502 and 504 are shown as open, and the contacts 506 and 508 are shown as open. In FIG. 5B, the contacts 502 and 504 are shown as closed due to contact of the SW1 contact pad 510 with the contacts 502 and 504, and the contacts 506 and 508 are shown as closed due to contact of the SW2 contact pad 512 with the contacts 506 and 508. An electrical path is formed from the input A to the output B, for example, through the contact 502, contact pad 510, contact 504, contact 506, contact pad 512, and contact 508. The SW1 contact pad 510 and the SW2 contact pad 512 can be conductive plates. Contact pads 510 and 512 may be brought into contact with the contacts 502, 504, 506, 508 by an actuator (or actuators), which can be mechanically, pneumatically, electrically, or the like actuated by a user input like a depression of the switch.

[0052] FIGS. 6A and 6B illustrate another implementation of the circuit schematic 300, according to some embodiments. Contacts 502, 604, 606, 608 can respectively be implementations of the contacts 302, 304, 306, 308. The SW1 contact pad 610 can be an implementation of the contact pad of SW1 of FIG. 3A, and the SW2 contact pad 612 can be an implementation of the contact pad of SW2 of FIG. 3A.

[0053] As illustrated, at least some of the contacts 602, 604, 606, 608 can each include a perimeter trace that extends around a conductive area. The perimeter trace and the contact area of the contacts 602, 604, 606, 608 can be printed, for example, on a circuit board.

[0054] In FIG. 6A, the contacts 602 and 604 are shown as open, and the contacts 606 and 608 are shown as open. In FIG. 6B, the contacts 602 and 604 are shown as closed due to contact of the SW1 contact pad 610 with the contacts 602

and 604, and the contacts 606 and 608 are shown as closed due to contact of the SW2 contact pad 612 with the contacts 606 and 608. An electrical path is formed from the input A to the output B, for example, through the contact 602, contact pad 610, contact 604, contact 606, contact pad 612, and contact 608. The SW1 contact pad 610 and the SW2 contact pad 612 can be conductive plates. Contact pads 610 and 612 may be brought into contact with the contacts 602, 604, 606, 608 by an actuator (or actuators), which can be mechanically, pneumatically, electrically, or the like actuated by a user input like a depression of the switch.

[0055] FIG. 7 illustrates a therapy control process 700 usable to control delivery of negative pressure therapy by an apparatus, such as the TNP apparatus 11. For convenience, the therapy control process 700 is described in the context of the TNP apparatus 11, but may instead be implemented in other systems described herein or by other systems not shown. The therapy control process 700 can be performed, in some instances, by the control circuitry 12A alone or in combination with the user interface 12D of the TNP apparatus 11.

[0056] At block 702, the therapy control process 700 can receive a user input. The user input can be received, for instance, via the user interface 12D, such as by depression of the switch 21.

[0057] At block 704, the therapy control process 700 can attempt to toggle states of multiple sets of contacts (for example, close the contacts) in response to the user input. The switch 21 can, for example, include an actuator (or actuators) that can attempt to toggle the states of multiple pairs of contacts like the contacts 302 and 304 and the contacts 306 and 308. If the switch 21 is functioning properly, the switch 21 can toggle the states of the multiple pairs of contacts. For example, the state of the multiple pairs of contacts can each be toggled simultaneously (or substantially so) or one after another so that each of the multiple pairs of contacts is closed. If the switch 21 is not functioning properly, the switch 21 may not toggle the state of one or more of the multiple pairs of contacts.

[0058] At block 706, if the states of the multiple sets of contacts were not toggled, the therapy control process 700 can end. On the other hand, if the states

of the multiple sets of contacts were toggled, the therapy control process 700 can move to block 708 to supply negative pressure. The supply of negative pressure can be initiated by the control circuitry 12A and performed by the negative pressure source 12C, and the negative pressure can be supplied to the wound dressing 13 via the fluid flow path.

[0059] At block 710, if the states of the multiple sets of contacts remain unchanged, the therapy control process 700 can move again to block 708 and the supply of negative pressure can continue. On the other hand, at block 710, if the state of at least one of the multiple sets of contacts is changed (for example, opened), the therapy control process 700 can move to block 712. For example, a user input can be received via the user interface 12D, such as by depression of the switch 21, and may cause the state of one or more of the multiple pairs of contacts to toggle. If the switch 21 is functioning properly, the switch 21 can toggle the states of the multiple pairs of contacts. For example, the state of the multiple pairs of contacts can each be toggled simultaneously (or substantially so) or one after another so that each of the multiple pairs of contacts is opened. If the switch 21 is not functioning properly, the switch 21 may not toggle the state of one or more of the multiple pairs of contacts.

[0060] At block 712, the therapy control process 700 can disable supply of negative pressure. The supply of negative pressure can, for instance, be disabled by deactivation of operation of the negative pressure source 12C or the control circuitry 12A, opening of a vent positioned in the fluid flow path, and closing of a valve positioned in the fluid flow path. Because the toggling of fewer than all of the multiple sets of contacts at block 710 (for example, opening) may result in the therapy control process 700 moving from block 710 to block 712, the therapy control process 700 can advantageously, in certain embodiments, favor disabling or be biased to disable the supply of negative pressure in response to some indication to disable supply of negative pressure despite not receiving an expected indication to disable supply of negative pressure that may involve toggling of all of the multiple sets of contacts. After block 712, the therapy control process 700 can end. In some

embodiments, block 710 can be performed periodically or in response to a change in the state of one or more contacts (such as, as a result of an interrupt being generated when the state of one or more contacts is toggled). In certain implementations, block 710 can be performed while negative pressure is being supplied.

[0061] FIG. 8 illustrates a switch fault detection process 800 usable to detect a switch fault in an apparatus configured to delivery negative pressure wound therapy, such as the TNP apparatus 11. For convenience, the switch fault detection process 800 is described in the context of the TNP apparatus 11, but may instead be implemented in other systems described herein or by other systems not shown. The switch fault detection process 800 can be performed, for example, by the control circuitry 12A alone or in combination with the user interface 12D. The process 800 can be used to detect a fault in the user interface 12D. The switch fault detection process 800 may begin, in some instances, with the negative pressure source 12C turned off and not providing negative pressure.

[0062] At block 802, the switch fault detection process 800 can detect a toggle in a state of one of a set of contacts. For example, the control circuitry 12A can detect a toggle in the state of one of the pair of contacts of the switch 21, such as the contacts 302 and 304 shown in FIG. 3A. The toggle can be detected, for instance, from a change in an electrical characteristic (such as voltage or current), mechanical characteristic, pressure characteristic, or thermal characteristic of the one of the pair of contacts of the switch 21 and may be detected using a sensor.

[0063] At block 804, the switch fault detection process 800 can determine whether a state of another set of contacts is toggled. For example, the control circuitry 12A can detect, in response to a user input to the switch 21, a toggle in the state of another of the pair of contacts of the switch 21, such as the contacts 306 and 308 shown in FIG. 3A. The toggle can be detected, for instance, from a change in an electrical characteristic (such as voltage or current), mechanical characteristic, pressure characteristic, or thermal characteristic of the other of the pair of contacts of the switch 21 and may be detected using a sensor.

[0064] If the state of the another set of contacts is toggled, the switch fault detection process 800 can move to block 806 and supply negative pressure. The supply of negative pressure can be initiated by the control circuitry 12A and performed by the negative pressure source 12C, and the negative pressure can be supplied to the wound dressing 13 via the fluid flow path.

[0065] If the state of the another set of contacts is not toggled, the switch fault detection process 800 can move to block 808 and output a switch fault indication. The failure of the another set of contacts to toggle can be indicative of the another set of contacts failing to toggle as would be expected from a user input. For example, the control circuitry 12A detect a switch fault from the another set of contacts not toggling and thus output the switch fault indication, such as for presentation on the user interface 12D. The switch fault detection process 800 at block 804 may moreover monitor for the toggle of the another set of contacts for a time period, such as 0.5 seconds, 1 second, 2 seconds, 3 second, 5 seconds, or longer, before moving to block 808 and outputting the switch fault indication.

[0066] Although the processes in Figures 7 and 8 describe toggling one or more contacts to enable or disable supply of negative pressure, toggling one or more contacts can be used for controlling other functions of the TNP apparatus 11, such as for example initial activation of the TNP apparatus 11.

Other Variations

[0067] Although one of more examples in this disclosure describe that a negative pressure source, control circuitry, or other components can be part of an integrated unit, such as on-board a wound dressing, the one or more examples do not limit the scope of the disclosure to such an integrated unit. The features related to redundant activation or deactivation control can, for instance, be included as part of a TNP apparatus that is not integral or separate from a wound dressing or with any medical or electronic device.

[0068] Any value of a threshold, limit, duration, etc. provided herein is not intended to be absolute and, thereby, can be approximate. In addition, any

threshold, limit, duration, etc. provided herein can be fixed or varied either automatically or by a user. Furthermore, as is used herein relative terminology such as exceeds, greater than, less than, etc. in relation to a reference value is intended to also encompass being equal to the reference value. For example, exceeding a reference value that is positive can encompass being equal to or greater than the reference value. In addition, as is used herein relative terminology such as exceeds, greater than, less than, etc. in relation to a reference value is intended to also encompass an inverse of the disclosed relationship, such as below, less than, greater than, etc. in relations to the reference value. Moreover, although blocks of the various processes may be described in terms of determining whether a value meets or does not meet a particular threshold, the blocks can be similarly understood, for example, in terms of a value (i) being below or above a threshold or (ii) satisfying or not satisfying a threshold.

[0069] Features, materials, characteristics, or groups described in conjunction with a particular aspect, embodiment, or example are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract, and drawings), or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features or steps are mutually exclusive. The protection is not restricted to the details of any foregoing embodiments. The protection extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

[0070] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of protection. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms. Furthermore, various omissions, substitutions and changes in the form of the methods and systems

described herein may be made. Those skilled in the art will appreciate that in some embodiments, the actual steps taken in the processes illustrated or disclosed may differ from those shown in the figures. Depending on the embodiment, certain of the steps described above may be removed, others may be added. For example, the actual steps or order of steps taken in the disclosed processes may differ from those shown in the figure. Depending on the embodiment, certain of the steps described above may be removed, others may be added. For instance, the various components illustrated in the figures may be implemented as software or firmware on a processor, controller, ASIC, FPGA, or dedicated hardware. Hardware components, such as processors, ASICs, FPGAs, and the like, can include logic circuitry. Furthermore, the features and attributes of the specific embodiments disclosed above may be combined in different ways to form additional embodiments, all of which fall within the scope of the present disclosure.

[0071] User interface screens illustrated and described herein can include additional or alternative components. These components can include menus, lists, buttons, text boxes, labels, radio buttons, scroll bars, sliders, checkboxes, combo boxes, status bars, dialog boxes, windows, and the like. User interface screens can include additional or alternative information. Components can be arranged, grouped, displayed in any suitable order.

[0072] Although the present disclosure includes certain embodiments, examples and applications, it will be understood by those skilled in the art that the present disclosure extends beyond the specifically disclosed embodiments to other alternative embodiments or uses and obvious modifications and equivalents thereof, including embodiments which do not provide all of the features and advantages set forth herein. Accordingly, the scope of the present disclosure is not intended to be limited by the specific disclosures of preferred embodiments herein, and may be defined by claims as presented herein or as presented in the future.

[0073] Conditional language, such as “can,” “could,” “might,” or “may,” unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other

embodiments do not include, certain features, elements, or steps. Thus, such conditional language is not generally intended to imply that features, elements, or steps are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without user input or prompting, whether these features, elements, or steps are included or are to be performed in any particular embodiment. The terms “comprising,” “including,” “having,” and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term “or” is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term “or” means one, some, or all of the elements in the list. Further, the term “each,” as used herein, in addition to having its ordinary meaning, can mean any subset of a set of elements to which the term “each” is applied.

[0074] Conjunctive language such as the phrase “at least one of X, Y, and Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to convey that an item, term, etc. may be either X, Y, or Z. Thus, such conjunctive language is not generally intended to imply that certain embodiments require the presence of at least one of X, at least one of Y, and at least one of Z.

[0075] Language of degree used herein, such as the terms “approximately,” “about,” “generally,” and “substantially” as used herein represent a value, amount, or characteristic close to the stated value, amount, or characteristic that still performs a desired function or achieves a desired result. For example, the terms “approximately”, “about”, “generally,” and “substantially” may refer to an amount that is within less than 10% of, within less than 5% of, within less than 1% of, within less than 0.1% of, and within less than 0.01% of the stated amount. As another example, in certain embodiments, the terms “generally parallel” and “substantially parallel” refer to a value, amount, or characteristic that departs from exactly parallel by less than or equal to 15 degrees, 10 degrees, 5 degrees, 3 degrees, 1 degree, or 0.1 degree.

[0076] The scope of the present disclosure is not intended to be limited by the specific disclosures of preferred embodiments in this section or elsewhere in this specification, and may be defined by claims as presented in this section or elsewhere in this specification or as presented in the future. The language of the claims is to be interpreted broadly based on the language employed in the claims and not limited to the examples described in the present specification or during the prosecution of the application, which examples are to be construed as non-exclusive.

WHAT IS CLAIMED:

1. An apparatus for applying negative pressure to a wound, the apparatus comprising:

a negative pressure source configured to provide negative pressure to a wound dressing via a fluid flow path;

a switch comprising an actuator configured to toggle a state of a first pair of electrical contacts and a state of a second pair of electrical contacts in response to a user input; and

control circuitry configured to:

supply negative pressure with the negative pressure source in response to the first pair of electrical contacts being in an electrically connected state and the second pair of electrical contacts being in the electrically connected state, and

disable supply of negative pressure with the negative pressure source in response to the first pair of electrical contacts being in an electrically disconnected state or the second pair of electrical contacts being in the electrically disconnected state.

2. The apparatus of claim 1, wherein the control circuitry is configured to disable supply of negative pressure with the negative pressure source in response to the first pair of electrical contacts being in the electrically connected state and the second pair of electrical contacts being in the electrically disconnected state.

3. The apparatus of claim 1 or 2, wherein the actuator is configured to simultaneously toggle the state of the first pair of electrical contacts and the state of the second pair of electrical contacts in response to the user input.

4. The apparatus of any one or more of claims 1-3, wherein the control circuitry is configured to supply negative pressure with the negative pressure source in response to no user inputs other than the user input to the switch.

5. The apparatus of any one or more of claims 1-4, wherein when the actuator is broken and no longer able to toggle the state of the first pair of electrical contacts or the state of the second pair of electrical contacts, the control circuitry is further configured to no longer supply negative pressure with the negative pressure source.

6. The apparatus of any one or more of claims 1-5, wherein the control circuitry is further configured to detect a switch fault in response to the state of the first pair of electrical contacts not toggling within a threshold period of time subsequent to toggling of the state of the second pair of electrical contacts.

7. The apparatus of claim 6, wherein the threshold period of time is 0.5 seconds, 1 second, 2 seconds, 3 second, or 5 seconds.

8. The apparatus of claim 6 or 7, wherein the control circuitry is further configured to output a switch fault indication in response to detection of the switch fault.

9. The apparatus of any one or more of claims 1-8, wherein the first pair of electrical contacts comprises a plurality of first traces and the second pair of electrical contacts comprises a plurality of second traces, and the actuator is configured to short the plurality of first traces to one another and short the plurality of second traces to one another in response to the user input.

10. The apparatus of any one or more of claims 1-9, wherein the negative pressure source is disposed on or within the wound dressing.

11. The apparatus of any one or more of claims 1-10, wherein the control circuitry is configured to disable supply of negative pressure with the negative pressure source by deactivation of operation of the negative pressure source, opening of a vent positioned in the fluid flow path, or closing of a valve positioned in the fluid flow path.

12. The apparatus of any one or more of claims 1-11, wherein the switch is configured to receive the user input as a depression of the switch.

13. An method for controlling application of negative pressure to a wound, the method comprising:

using an actuator of a switch, toggling a state of a first pair of contacts and a state of a second pair of contacts in response to receipt of a user input to the switch;

supplying negative pressure with a negative pressure source to a wound dressing via a fluid flow path in response to the state of the first pair of contacts being a first state and the state of the second pair of contacts being a second state; and

disabling supply of negative pressure with the negative pressure source in response to the state of the first pair of contacts not being the first state or the state of the second pair of contacts not being the second state,

wherein the state of the first pair of contacts is the first state and the state of the second pair of contacts is the second state at a first time, and the state of the first pair of contacts is not the first state and the state of the second pair of contacts is not the second state at a second time.

14. The method of claim 13, wherein the first and second states correspond to forming an electrical connection.

15. The method of claim 13 or 14, wherein at a third time, the state of the first pair of contacts is the first state and the state of the second pair of contacts is not the second state.

16. The method of any one or more of claims 13-15, wherein said toggling comprises simultaneously toggling the state of the first pair of contacts and the state of the second pair of contacts in response to receipt of the user input to the switch.

17. The method of any one or more of claims 13-16, further comprising detecting a switch fault in response to the state of the first pair of contacts not toggling within a threshold period of time subsequent to toggling of the state of the second pair of contacts.

18. The method of claim 17, wherein the threshold period of time is between 0.5 seconds and 5 seconds.

19. The method of claim 17 or 18, further comprising outputting a switch fault indication for presentation to a user in response to said detecting.

20. The method of any one or more of claims 13-19, wherein said disabling comprises disabling supply of negative pressure with the negative pressure source by deactivation of operation of the negative pressure source, opening of a vent positioned in the fluid flow path, or closing of a valve positioned in the fluid flow path.

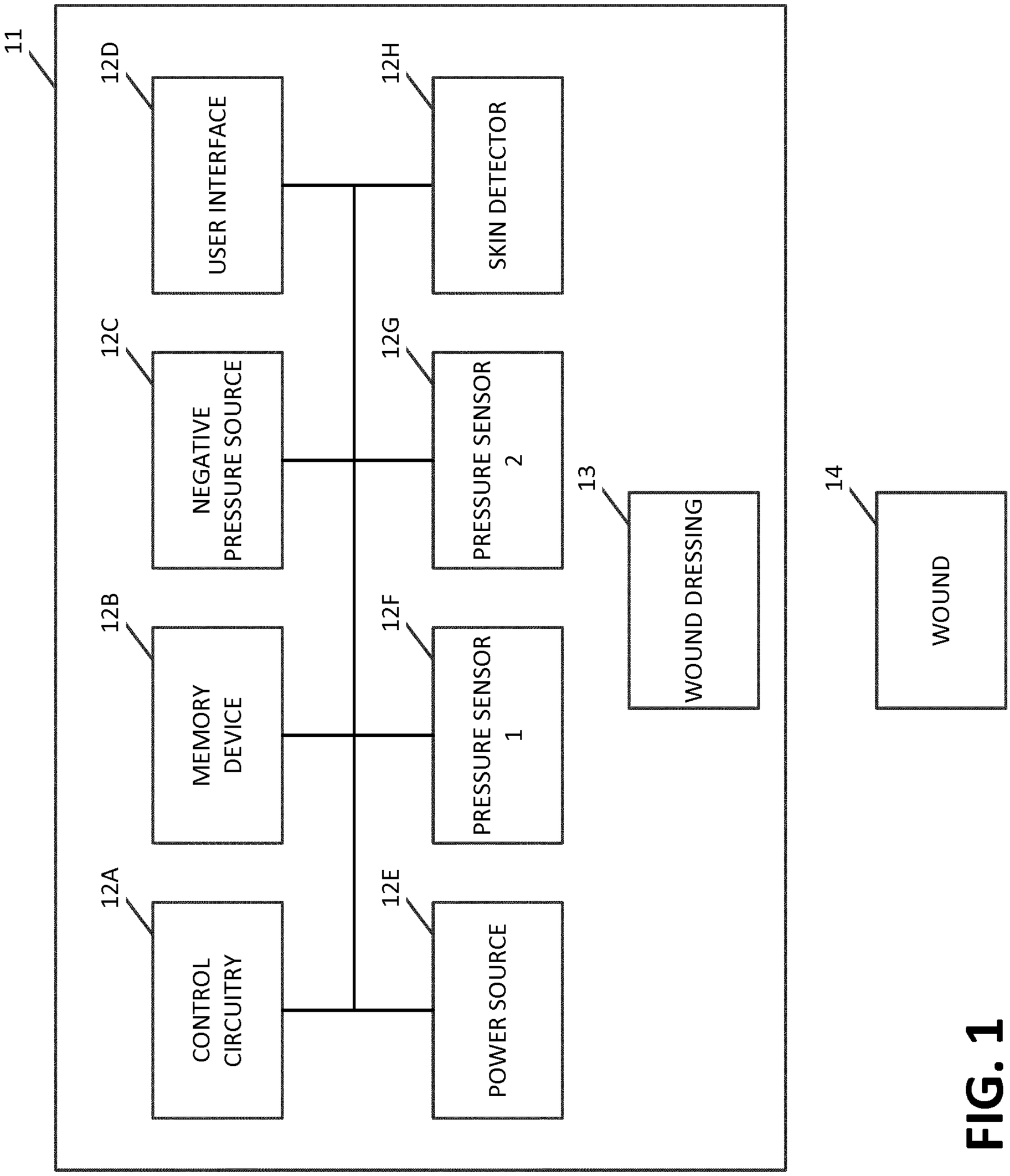
100
11
12A
CONTROL CIRCUITRY
12B
MEMORY DEVICE
12C
NEGATIVE PRESSURE SOURCE
12D
USER INTERFACE
12E
POWER SOURCE
12F
PRESSURE SENSOR 1
12G
PRESSURE SENSOR 2
12H
SKIN DETECTOR
13
WOUND DRESSING
14
WOUND

FIG. 1

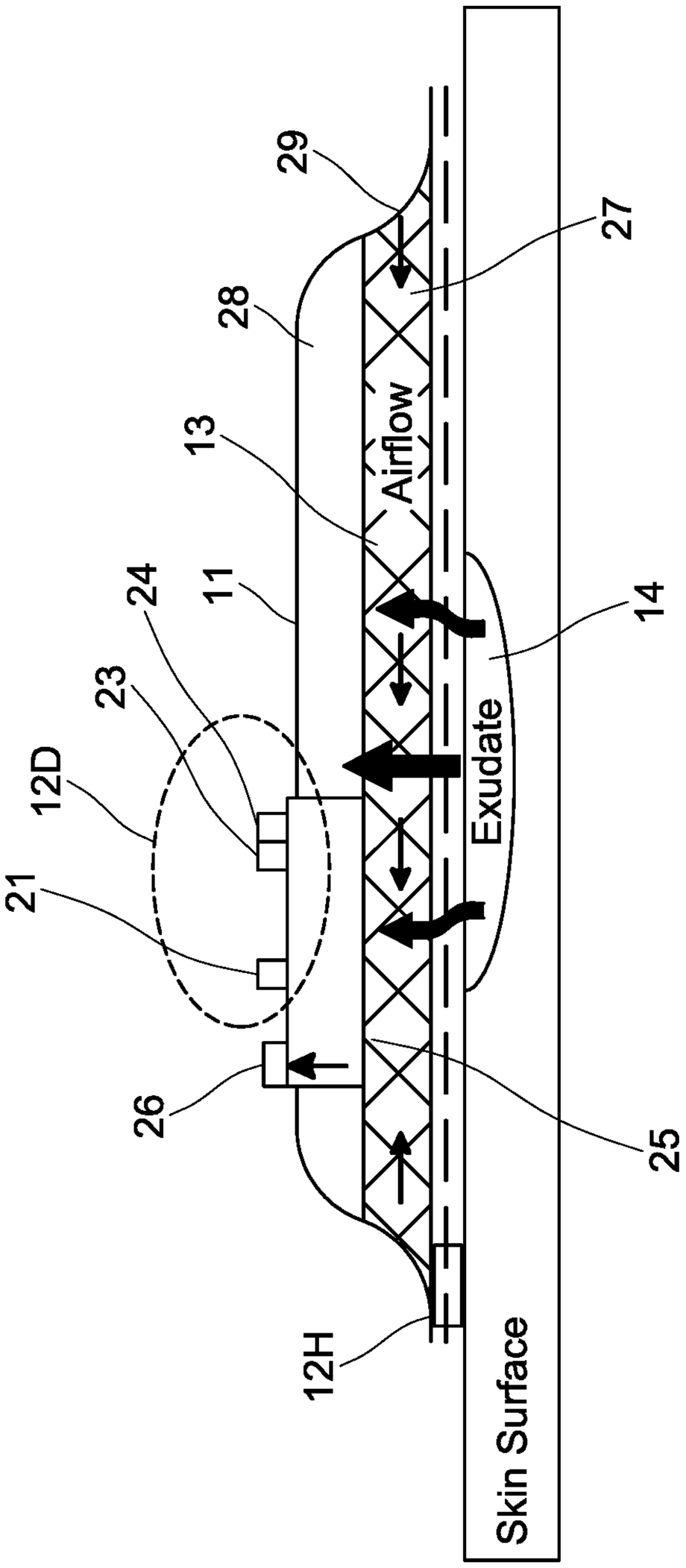
200
Skin Surface
12H
21
12D
23
24
11
13
29
28
Airflow
27
14
Exudate
25
26

FIG. 2A

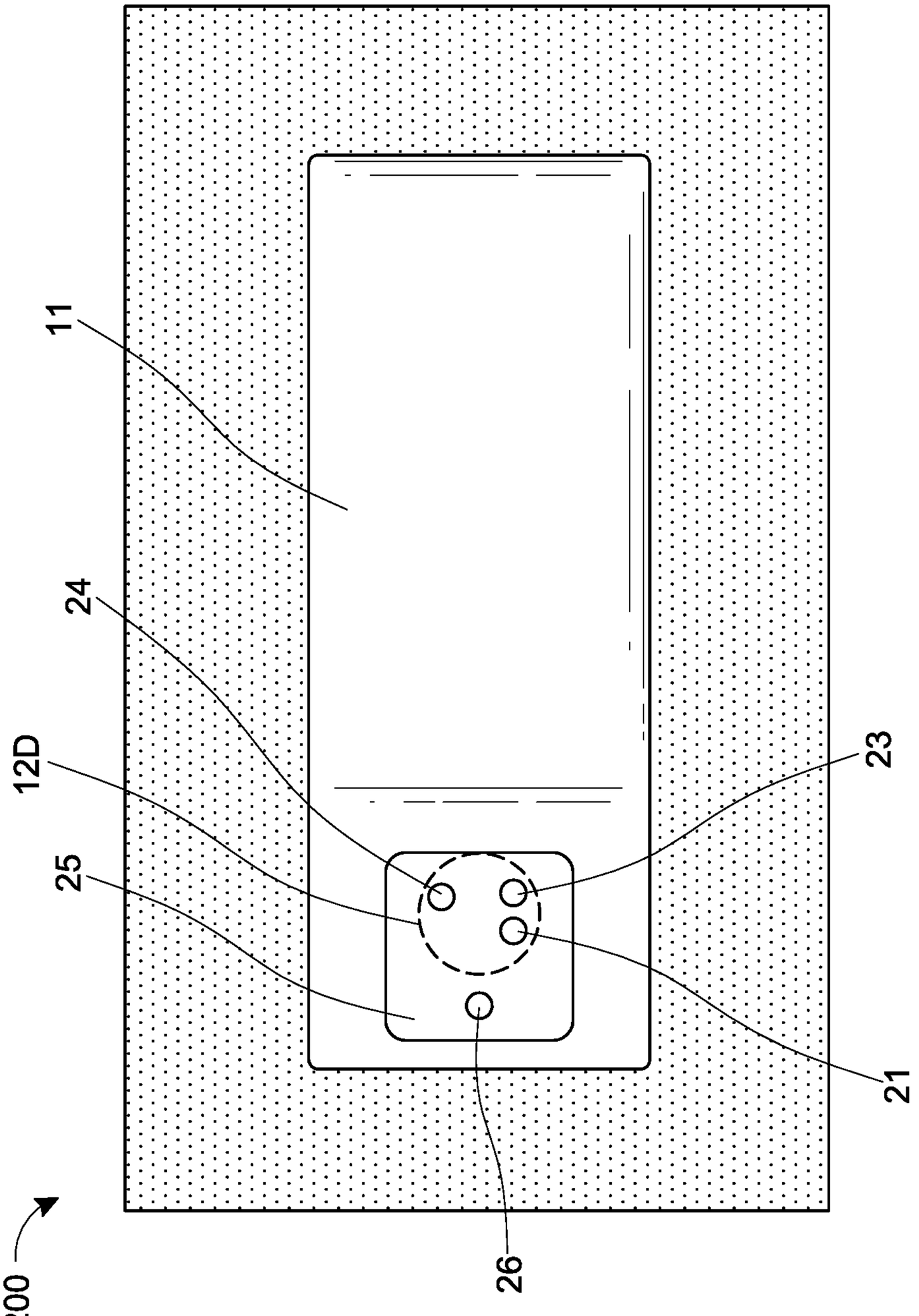

FIG. 2B

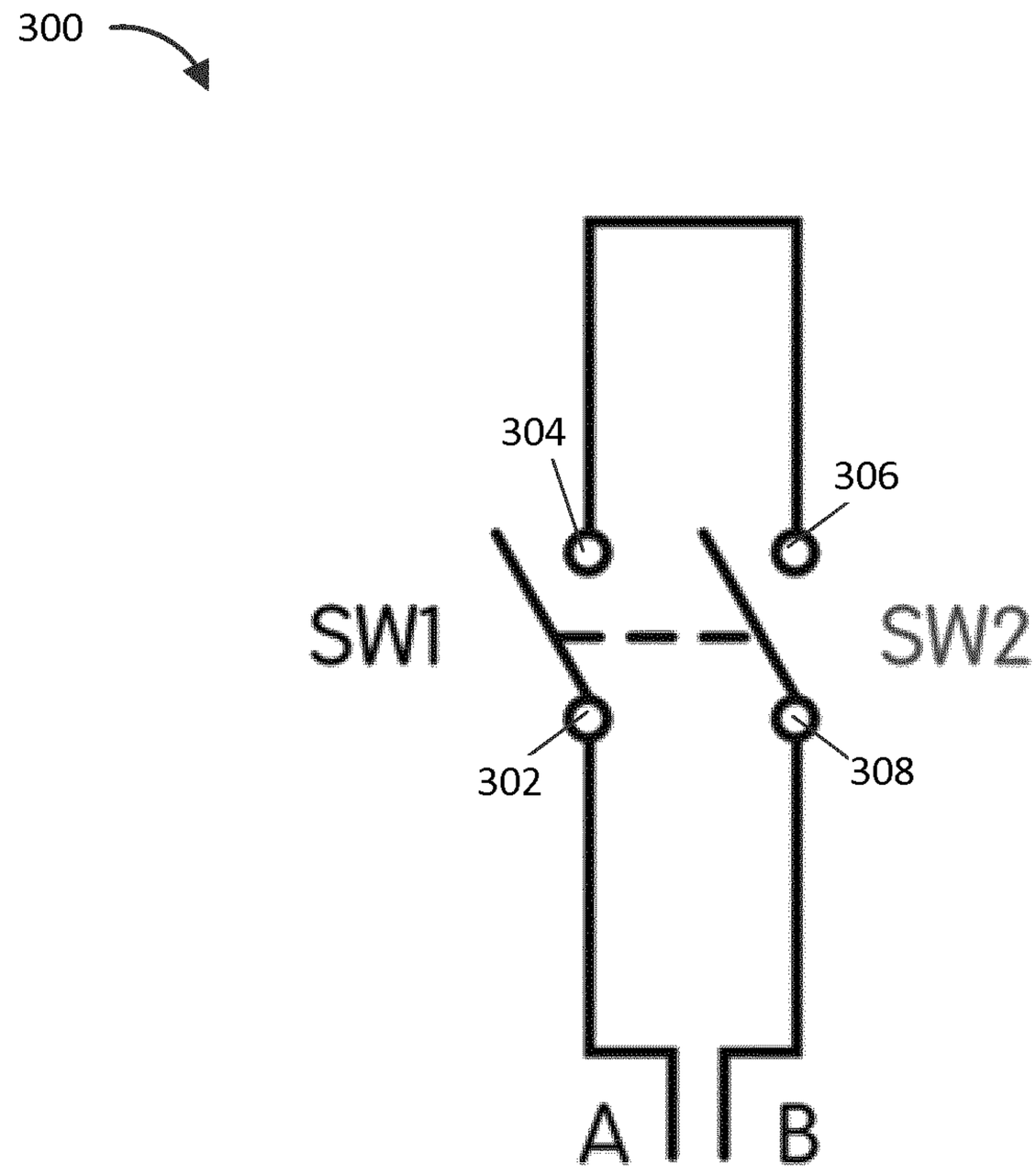

FIG. 3A

310

A&B On/Off	State of SW1	State of SW2
On	Closed	Closed
Off	Open	Closed
Off	Closed	Open
Off	Open	Open

FIG. 3B

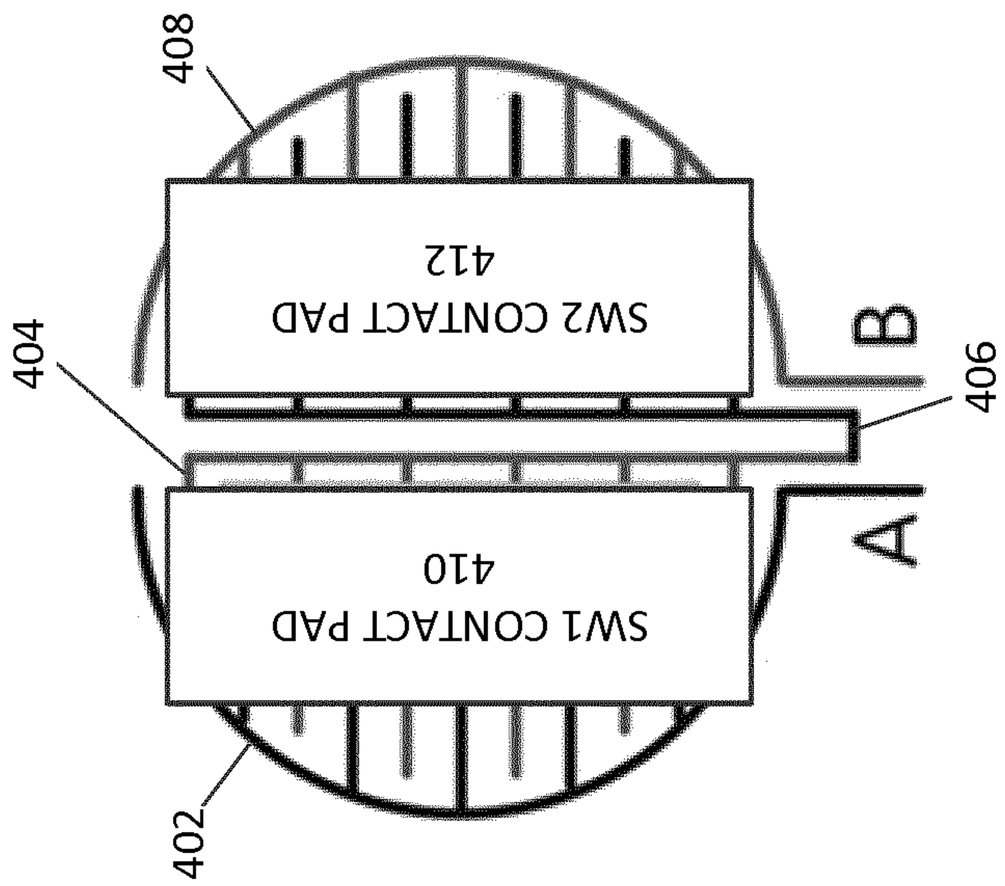
408
SW2 CONTACT PAD
412
404
B
406
A
SW1 CONTACT PAD
410
402

FIG. 4B

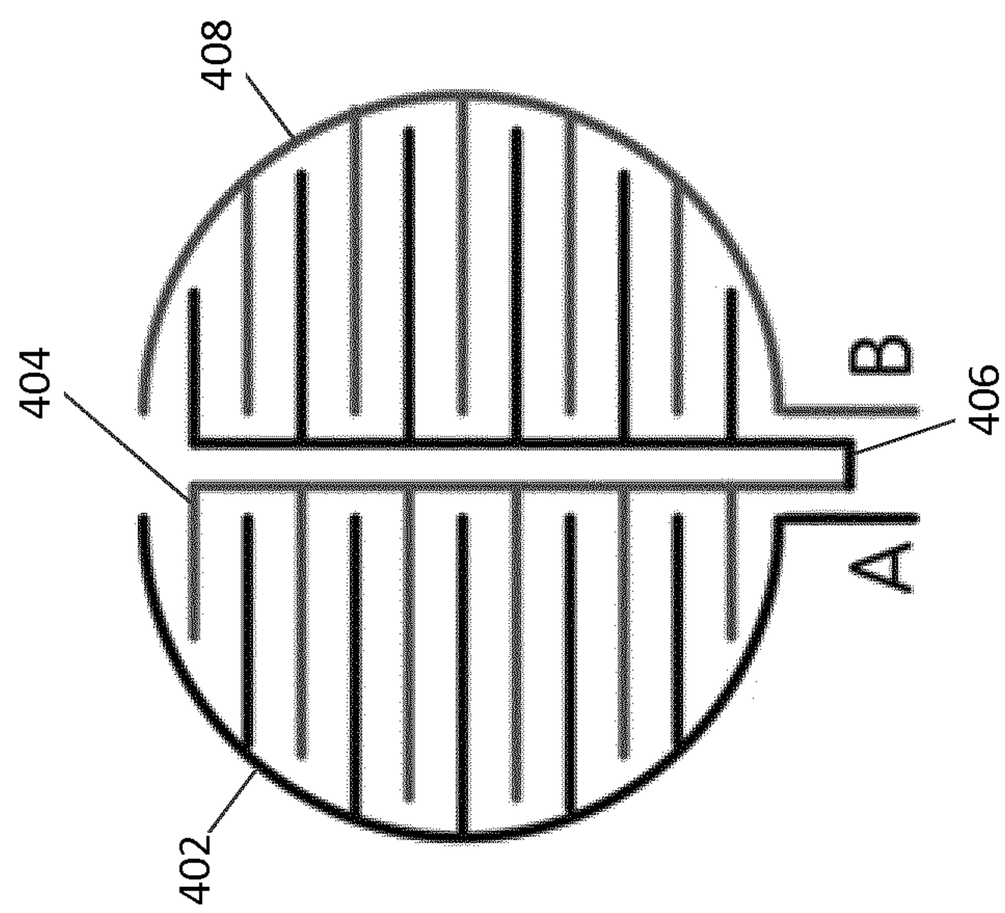
408
404
B
406
A
402

FIG. 4A

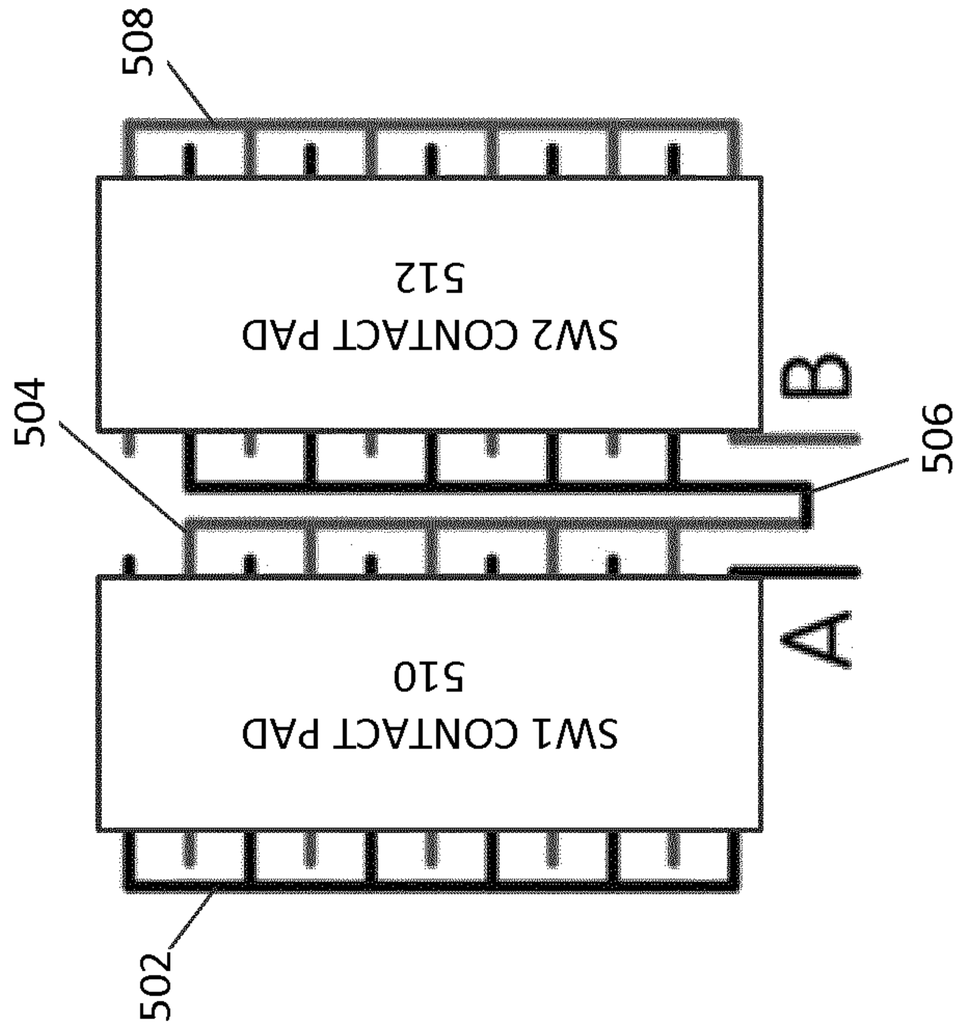
508
512
SW2 CONTACT PAD
B
504
506
A
510
SW1 CONTACT PAD
502

FIG. 5B

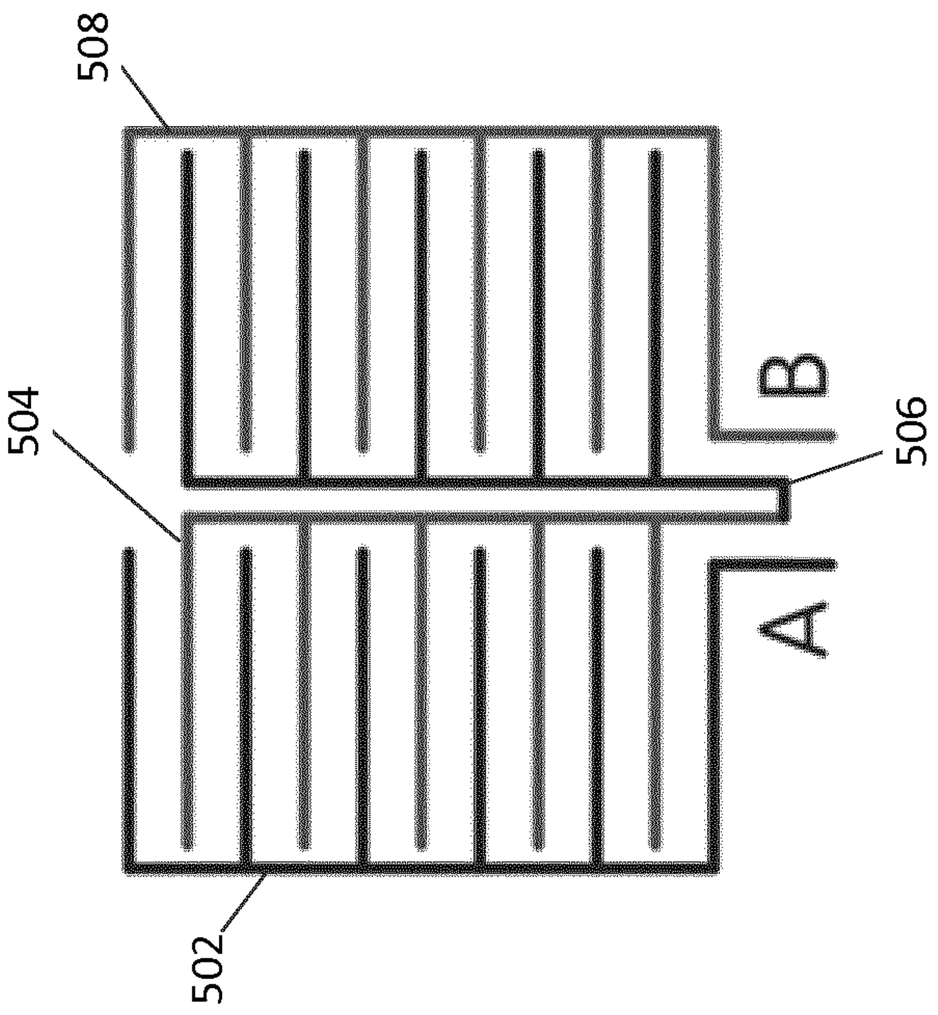
508
B
504
506
A
502

FIG. 5A

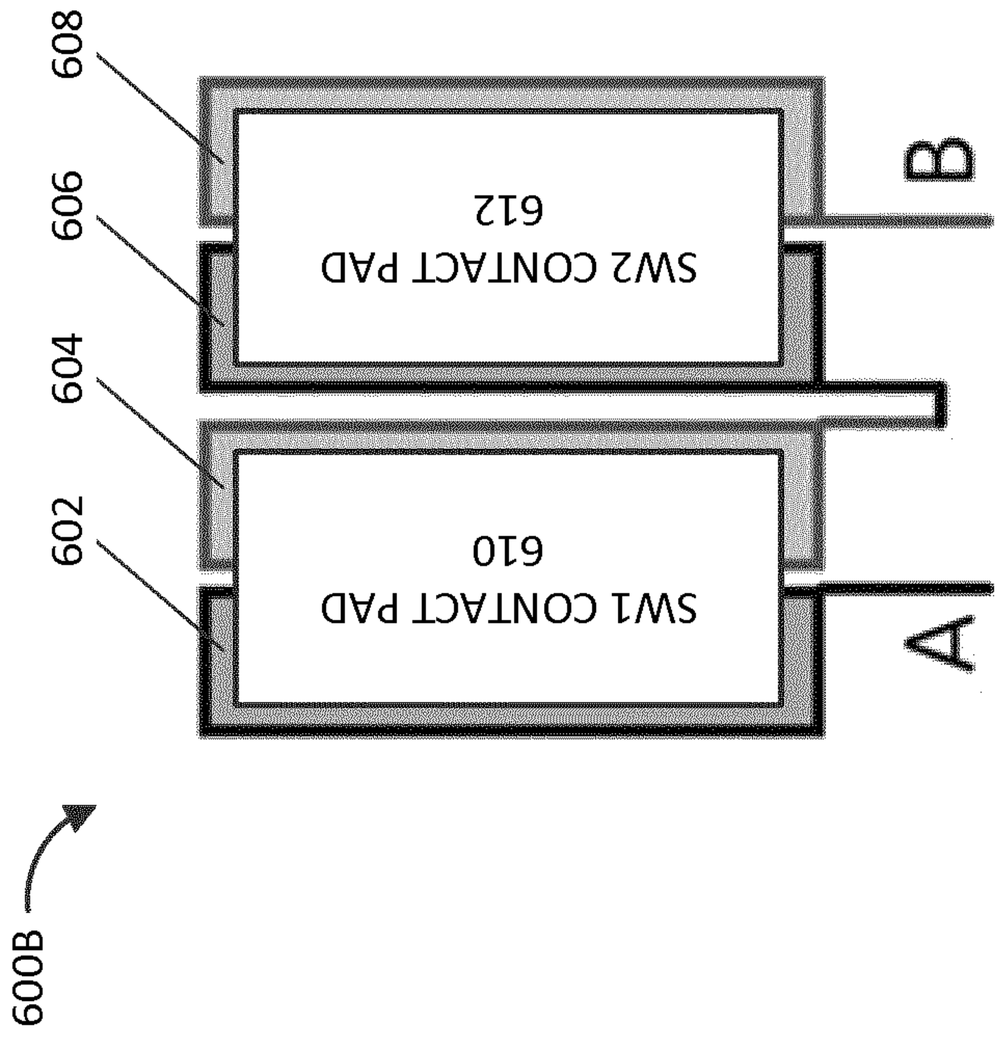
608
606
604
602
612
SW2 CONTACT PAD
610
SW1 CONTACT PAD
B
A
600B

FIG. 6B

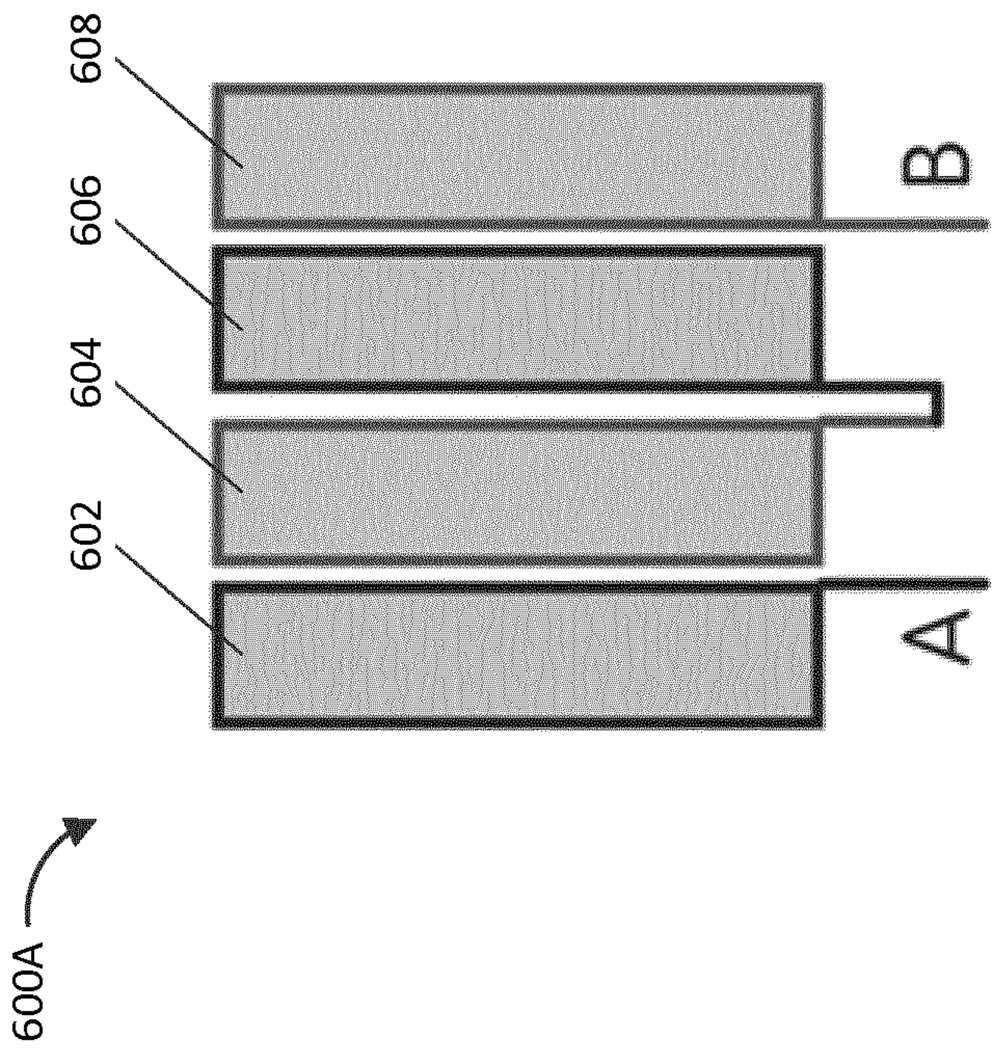
608
606
604
602
B
A
600A

FIG. 6A

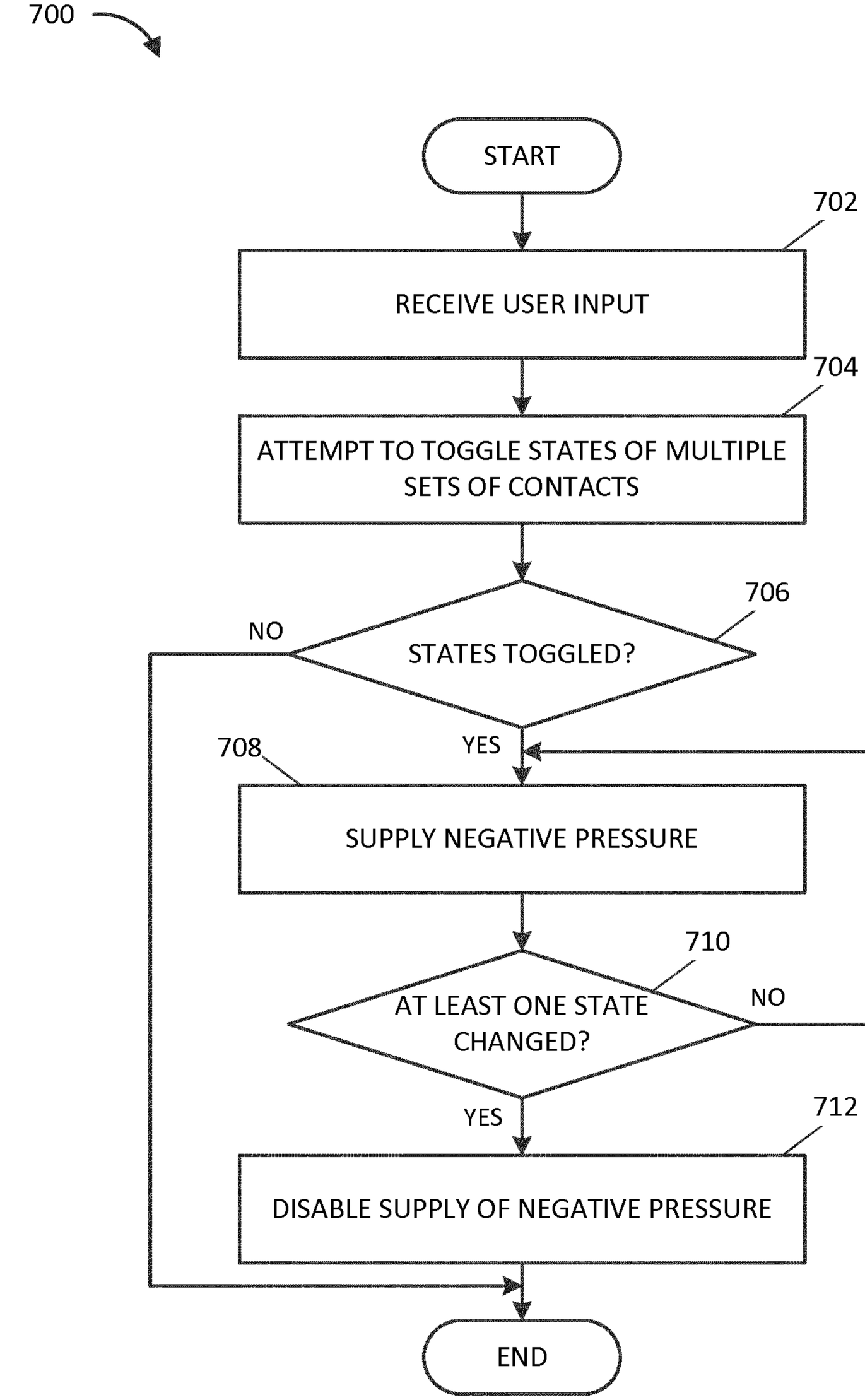
THERAPY CONTROL PROCESS
700
START
702
RECEIVE USER INPUT
704
ATTEMPT TO TOGGLE STATES OF MULTIPLE SETS OF CONTACTS
706
STATES TOGGLED?
NO
YES
708
SUPPLY NEGATIVE PRESSURE
710
AT LEAST ONE STATE CHANGED?
NO
YES
712
DISABLE SUPPLY OF NEGATIVE PRESSURE
END

FIG. 7

SWITCH FAULT DETECTION PROCESS

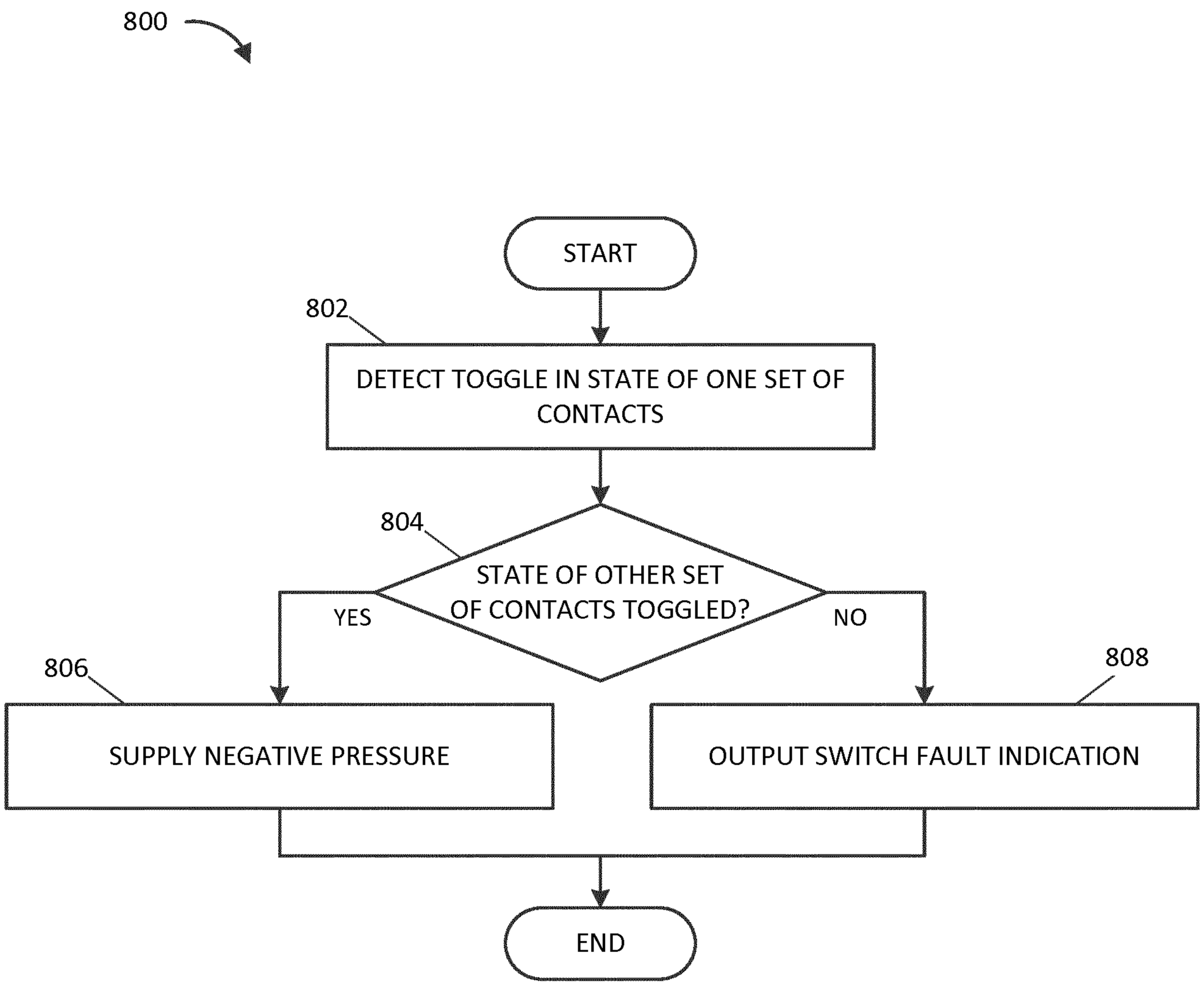

FIG. 8

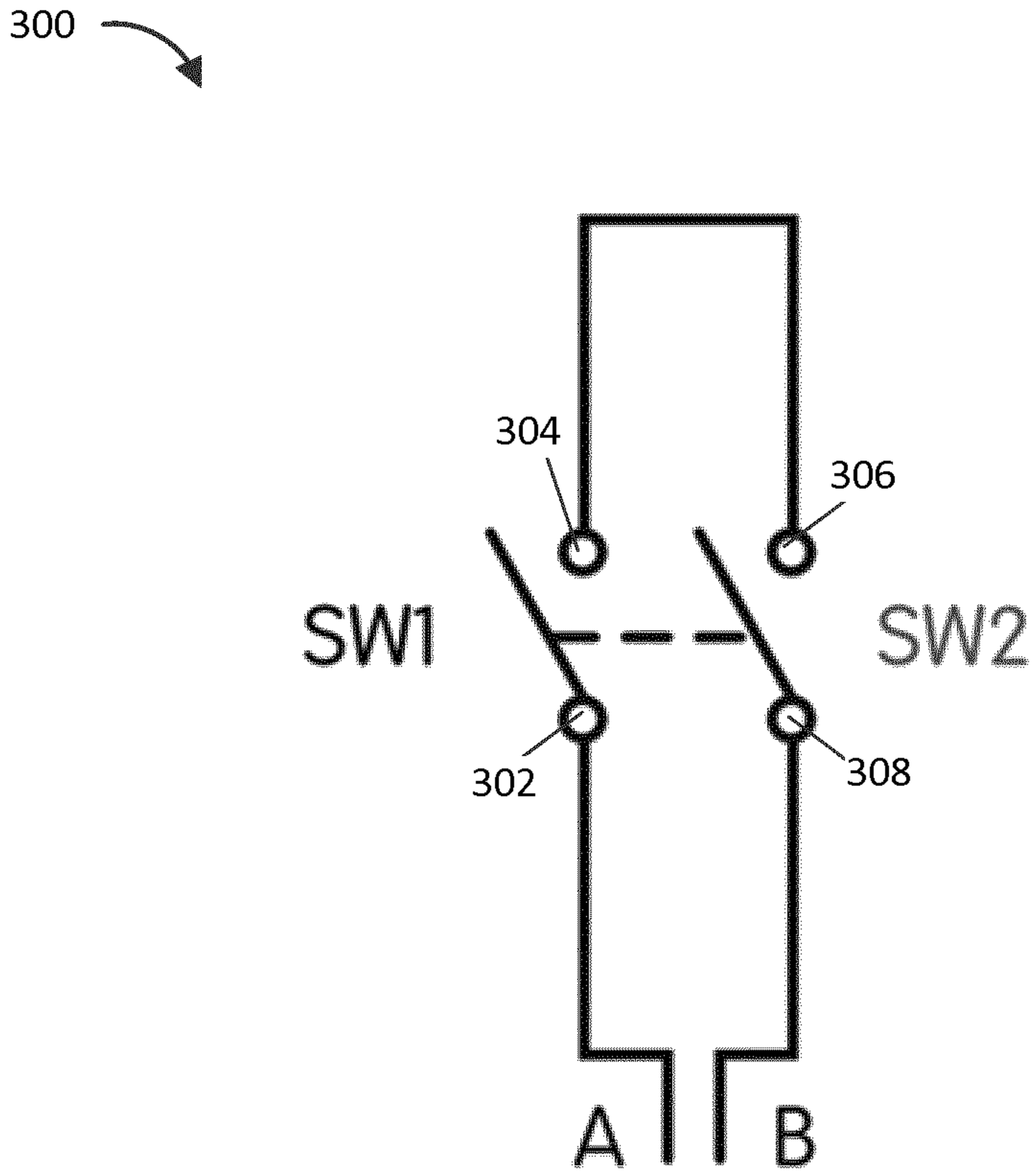

FIG. 3A